

International Conference on GMS 2020: Balancing Economic Growth and Environmental Sustainability

Focusing on Food - Water - Energy Nexus

20 - 21 February 2012

Royal Orchid Sheraton Hotel and Towers

Bangkok, Thailand

Conference Proceedings



GREATER MEKONG
SUBREGION
CORE ENVIRONMENT
PROGRAM

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Edited by
Hasan Moinuddin and Jay Maclean



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**International Conference on GMS 2020:
Balancing Economic Growth and Environmental Sustainability,
Focusing on Food-Water-Energy Nexus**

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FOREWORD

The Asian Development Bank (ADB) has been assisting the Greater Mekong Subregion (GMS) Economic Cooperation Program since 1992. The program has accomplished a lot because of proactive cooperation of its six member countries—Cambodia, the People’s Republic of China, the Lao People’s Democratic Republic, Myanmar, Thailand, and Viet Nam. The progress is reflected in terms of improvements in infrastructure connectivity, promotion of trade and investment, stimulation of economic growth, and reduction of poverty. However, such progress has not been without some adverse impacts on the environment. Based on such recognition, the countries adopted a 10-year strategic framework in 2002 to address the growing environmental degradation. The framework noted that “environmental considerations must be at the forefront of all decision-making regarding development projects.”

The GMS 2020 International Conference – Balancing Economic Growth and Environmental Sustainability – provided the setting to review progress under the 2002-2011 strategic framework, and to consider the subregion’s potential and challenges in the coming decade and beyond. The conference was highly successful, mainly because of valuable contributions from nearly 240 participants representing several stakeholder groups including the GMS governments, the private sector, development partners, academia, and civil society.

The central theme of the conference – food-water-energy nexus, which is already at the forefront of political and scientific debate in the GMS – attracted most attention from participants. A nexus approach can enhance water, energy and food security by increasing efficiency, reducing trade-offs, and building synergies across sectors. Many presentations, therefore, focused on deepening the awareness and understanding of the nexus as a basis for transition to climate resilient and green economic pathways of development. Several presenters stressed that vision and courage to transcend conventional sectoral approaches and silo thinking is crucial to advance the pursuit of sustainability in the subregion.

The GMS is poised to grow at 7.5% annually, doubling its economic output by 2020. However, increasing resource constraints, in particular finite land and water resources (though renewable), suggest that innovative ways of achieving higher resource efficiency will be vital to support future development. In addition, institutional innovations including effective governance structures supported by both private and public sector investments are essential to facilitate the integrated management of energy, water, and agriculture systems in the GMS. ADB is committed to play its part in assisting countries in the subregion to achieve this goal by mobilizing additional financial resources and developing new knowledge products.

It is hoped that this publication will promote a more positive image of the GMS and contribute to the development of policies and measures necessary for the subregion to improve its economic competitiveness while protecting environmental integrity.



Kunio Senga,
Director General, Southeast Asia Regional Department (SERD)
Asian Development Bank

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ABBREVIATIONS

ADB	Asian Development Bank
AOX	adsorbable organic halides
APERC	Asia Pacific Energy Research Centre
BKPM	bleached kraft pulp mill
BOD	biochemical oxygen demand
CCGT	combined cycle gas turbine
CEP-BCI	Core Environment Program and Biodiversity Conservation Corridors Initiative
COD	chemical oxygen demand
DEQ	Department of Environmental Quality
EAPP	East African Power Pool
ECP	Economic Cooperation Program
EDC	Electricité du Cambodge
EdI	Electricité du Laos
EGAT	Electricity Generating Authority of Thailand
EIU	Economist Intelligence Unit
EOC	Environment Operations Center
EPF	Energy Power Forum
EU	European Union
EVN	Electricity of Viet Nam
FAO	Food and Agriculture Organization of the United Nations
FDI	foreign direct investment
FIPI	Forest Inventory and Planning Institute, MARD, Viet Nam
GDP	gross domestic product
GHG	greenhouse gas
GMS	Greater Mekong Subregion
GNI	gross national income
GZAR	Guangxi Zhuang Autonomous Region
HIV/AIDS	human immunodeficiency virus / acquired immunodeficiency syndrome
IEA	International Energy Agency
IGA	intergovernmental agreement
IPCC	Intergovernmental Panel on Climate Change
Lao PDR	Lao People's Democratic Republic
M&I	municipal and industrial

MARD	Ministry of Agriculture and Rural Development, Viet Nam
MDGs	Millennium Development Goals
MEP	Ministry of Electric Power
MONRE	Ministry of Natural Resources and Environment, Viet Nam
MRB	Mekong River Basin
MRC	Mekong River Commission.
NGOs	nongovernment organization
ODA	official development assistance
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of Petroleum Exporting Countries,
PCB	polychlorinated biphenyl
PCC	power control center
PPP	purchasing power parity
PRC	People's Republic of China
REF	Rural Electricity Fund
RIMPPI	Regional Indicative Master Plan on Power Interconnection
RPT	regional power trade
RPTCC	Regional Power Trade Coordination Committee
RPTOA	Regional Power Trade Operating Agreement
SIEPAC	Central American Electrical Interconnection System
TCF	totally chlorine free
TPES	total primary energy supply
UN	United Nations
UNDP	United Nations Development Programme
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
US EPA	United States Environmental Protection Agency
VND	Vietnamese dong
WAPP	West African Power Pool
WDI	world development indicators
WHO	World Health Organization
WSS	water supply and sanitation
WTO	World Trade Organization

Conference Inauguration

Welcome Remarks

Craig Steffensen, Country Director, ADB Thailand Resident Mission

Official Inauguration

*Mingquan Wichayarangsaridh, Deputy Permanent Secretary,
Ministry of Natural Resources and Environment, Thailand*

Opening Remarks

Stephen Groff, Vice President, ADB

WELCOME REMARKS

by

Craig Steffensen,
Country Director,
ADB Thailand Resident Mission
at the

GMS 2020 International Conference: Balancing Economic Growth with Environmental Sustainability 20 February 2012

Swasdee Khrap, Good Morning!

I am Craig Steffensen, Country Director for the Asian Development Bank based here in Bangkok.

And welcome to this 2-day gathering to discuss the Food-Water-Energy nexus.

Nowhere was this nexus so clear as in Thailand recently. Exceptionally heavy rains in August and September 2011, accompanied by four tropical storms caused Thailand's worst flooding since 1942.

The death toll exceeded 700 persons and 4 million households or about 13 million people in 64 of Thailand's 77 provinces were affected by flood waters, with widespread damage and loss to homes, factories, businesses, transport and energy infrastructure, social service facilities, and crops and livestock.

The total economic damages and losses caused by the floods are estimated at about \$45 billion, which, I think, makes it the fifth most costly national disaster on record. It is probably not an exaggeration to say that those who were affected by the floods, myself included, know first hand the interrelationship between food, water and energy. Bangkok, and most parts of Thailand, faced severe shortages of all three for months on end due to factory and business closures and supply chains being cut off by flood waters and energy outages. I think all of us remember the days when it was pretty hard to find a bottle of water or our favorite orange juice on supermarket shelves. Thailand's agriculture took a big hit in 2011 because so much farmland was affected.

So perhaps, the most important take away message from the 2011 flood is the importance of inter-sectoral coordination to mitigate future disasters. Water management, in particular, requires a sound understanding of the big picture – requirements for hydropower, agriculture, industry and domestic consumption and the need to maintain the integrity of natural systems that buffer the extreme effects of fluctuating weather patterns are critical.

The theme of this Conference: Balancing Economic Growth with Environmental Sustainability is very pertinent therefore to Thailand and to the Greater Mekong Subregion.

With these words, Welcome!

I would now like to call upon the Deputy Permanent Secretary of the Ministry on Natural Resources and Environment, Khun Mingquan Wichayarangsaridh, to inaugurate the GMS 2020 Conference.

Thank you very much.

INAUGURAL SPEECH

by

Mrs Mingquan Wichayarangsaridh

Deputy Permanent Secretary

Ministry of Natural Resources and Environment,

Thailand

at

**GMS 2020 International Conference: Balancing
Economic Growth and Environmental Sustainability**

20 February 2012

Royal Orchid Sheraton Hotel & Tower, Bangkok

Swasdee Kha,

Honorable Vice Minister Dr Parisak of Lao PDR,

Your Excellencies from Cambodia, People's Republic of
China, Lao PDR, Myanmar and Viet Nam,

Mr Stephen Groff, Vice President of the Asian Development
Bank, distinguished guests, ladies and gentlemen.

It gives me a great pleasure today to inaugurate the
International Conference of the Greater Mekong Subregion
– GMS 2020 on behalf of the Minister of Natural Resources
and Environment who is now on other mission. Although he
is unable to attend this conference, he sends his warmest
greetings to us all and wishes this Conference a success.

The timing of the GMS 2020 International Conference is
indeed very appropriate after Thailand recovers from the
devastating floods of 2011. The theme of the Conference
“Food-Water-Energy nexus” is highly relevant and critically
important at this juncture of development and growth in the
countries of the GMS.

Excellencies,

Ladies and gentlemen,

Most developing countries enjoyed a relatively high level of
economic growth over the last three decades accompanied
by rapid industrialization, urbanization, and agricultural
intensification. This growth relied extensively on the
country's abundant and diverse natural resources. It has
led to the degradation of land and water quality, caused the
loss of natural habitats, and generated increasing levels
of air and water pollution.

The current trends of natural resources declining and
environmental degradation show that there are persistent
implementation gaps, according to the commitments of
the landmark Conference of 1972, the Earth Summit in

1992 and the World Summit on Sustainable Development
in 2002. Many commitments made by the international
community have not been fully met at the time when
the world is still suffering from the repercussion of
multiple crises. The GMS is more or less threaten by the
aforementioned crises.

However, since 1992, the six GMS countries; Cambodia,
People's Republic of China, Lao PDR, Myanmar, Thailand,
and Viet Nam have agreed to work together on development
of linked system of infrastructure and trade designed to
support economic development goals. Moreover, the GMS
countries have a Strategic Development Framework (SDF)
to cooperate in major areas, one of which is to protect
the environment and promote sustainable use of shared
natural resources.

Excellencies,

Ladies and gentlemen,

In Thailand, more than three hundred villages face high
flood risk each year; droughts, which occur annually can
cause great damage to agriculture and industry. Nearly
one third of the country's land area is classified as medium
or high risk from drought. Of particular concern is water
scarcity, which occurs against a backdrop of low availability,
high pollution, and increased per capita consumption.

Thailand has 25 river basins with 254 sub-basins.
Rainwater is one of the most important sources of water.
Data, however, suggests that Thailand's per capita water
resource is less than other countries in the region and
one third of it flows into the Mekong. The West basins
have the largest storage capacity with the smallest total
irrigation area. Existing water storage is about 37 percent
of the annual runoff, on average, but in fact useable water
is less. There is tremendous pressure on Thailand's water
resources.

Excellencies,

Ladies and gentlemen,

Economic and population growth does not only increase
demand for water but also induces water pollution. Water
demand is expected to increase by 35% over the next
two decades. It is estimated that an increase in Thailand's
population from 62 million in 2004 to 73 million by 2024
would lead to an increase in average water demand from
the present 57,000 million cubic meters to 77,000 million
cubic meters over the next two decades.

The meeting of increased future water needs will require effective management and cooperation of stakeholders, development of additional water storage capacities, increasing efficiencies in water use, reducing waste and system losses as well as establishing legal and regulatory aspects that enjoy wide acceptance and compliance by water users.

We also wish to avoid the future disproportionately negative impacts from man made or natural disasters. Construction of uncontrolled settlements in low lying areas, conversion of wetlands and riverine areas previously used as a natural flood water sinks, weak drainage control and flood water management in the peak rainy season, and incidence of heavy rainfall led to the most terrible flood disaster that ever happened throughout Thailand in the last fifty years. It affected around 13 million people across 64 provinces and is estimated at the cost of 45 billion US\$.

Moreover, rapid industrial expansion and population growth as well as the linkage between food-water-energy nexus becomes even critical resulting in a need to re-assess our development paradigms. Industrialization also brings with it sharply increasing pollution levels (e.g. solid and hazardous waste, air, noise, and water), which can cause major health impacts.

Excellencies,
Ladies and gentlemen,
Thailand has recognized the potential of economic development of the adverse social and environmental effects both of which are avoidable. In response, the Government and the Thai people have launched new initiatives to improve air and water quality, reforest degraded land, adopt energy efficient technologies, invest in pollution abatement schemes, and reduce Greenhouse Gas emissions to work towards global targets of climate change mitigation.

In addition, Thailand sincerely believes that unsustainable development could be reversed in the future by taking actions on green growth. We have included the environmental issue into the National Economic and Social Development Plan since 1997. The Tenth National Economic and Social Development Plan (2007 – 2011) pursued the royal direction of His Majesty the King's Sufficiency Economy Philosophy. The philosophy emphasizes the balance between the limitations of natural resources and environment, which should be conserved and used safely and wisely without adversely affecting the

needs of the present and future generations. The Eleventh National Economic and Social Development Plan, which begins in 2012 highlights the importance of green economy, whereby setting ambitious goals and targets to decouple economic growth from environmental degradation in every sector of this national development plan.

Excellencies,
Ladies and gentlemen,
As you may know that the United Nations Conference on Sustainable Development or "RIO+20" will be held in Rio de Janeiro, Brazil, on June 20-22, 2012. We wish this meeting an important stepping stone to echo our regional needs and means of implementation to the international community. We support a "green economy" as well as encourage cooperation under the "green economy" issue, such as information or knowledge sharing, technology transfer, and human resource development in the subregion.

Let me conclude, it is important that the sustainable development is for the future of sustainability of natural resources and environment as well as the people's livelihood and well-being in the subregion. In the midst of threat of climate change and uncertain economy, we must have faith and confidence in ourselves and in our destiny. Our subregion, linked by the mighty flow of the Mekong River, is richly endowed with natural resources and economic potential. Thailand is delighted to strengthen the cooperation and to work with you all, with ADB, development partners and other organizations, to achieve our common vision; that is, to free people from poverty and provide sustainable development opportunities for all.

Excellencies,
Ladies and gentlemen,
Thailand welcomes the GMS 2020 - balancing economic growth with environmental sustainability and appreciates this big gathering of GMS country representatives, experts and specialists in food, water, climate change and energy, development partners, civil societies, academia, and development partners. The Conference gives planners and policymakers an opportunity to listen attentively and act on the recommendations speedily to meet the challenges of this decade and beyond.

I wish you all a very successful Conference and hope that all of you take this opportunity to enjoy staying in Bangkok. With these words, I now declare the Conference open.

Thank you.

OPENING REMARKS

by

Stephen P. Groff,
Vice President (Operations 2),
Asian Development Bank

GMS 2020: Balancing Economic Growth and Environmental Sustainability International Conference

Honorable Vice Minister(s),
Your excellencies, distinguished guests, colleagues, ladies
and gentlemen.

Good morning to you all.

Let me start by first thanking our host country Thailand, and particularly Khun Mingquan Wichayarangsaridh of the Ministry of Natural Resources and Environment for joining me in inaugurating this conference, which assumes special significance in the wake of the unfortunate natural resource disasters Thailand and many GMS countries faced during 2011.

Ladies and gentlemen, I am honored to join, and speak to, this distinguished gathering of Greater Mekong Subregion (GMS) policy makers, sustainable development researchers, practitioners and development partners. We have gathered here to take an objective look at the impressive economic prosperity of GMS over the last decade. More importantly, we are here to deliberate upon the economic development and environmental sustainability challenges GMS countries will face during the coming decade. I believe this GMS2020 conference addresses a critical question confronting not just the Asian but the global development community, namely, how best to bring about a balanced convergence between economic growth and environmental sustainability?

Equally important and opportune is the timing of this conference. GMS leaders at the December 2011 Summit in Myanmar endorsed the GMS Strategic Framework for 2012-2022. This will guide ADB's regional economic cooperation and integration agenda in the GMS for the next decade, but its effective implementation requires state-of-the-art developmental knowledge and know-how. This has to be done as part of the global economic dynamic involving a restructuring and rebalancing of the global economy— indeed, robust growth and increasing economic

sophistication in Asia has shifted the axis on which the global economy turns – deeper regional trade and economic and political relationships can unlock the most severe constraints to growth and can help leverage the construction of a more sustainable and inclusive pattern of development. GMS is strategically placed to capture these economic development opportunities. It is in this context I see the conference deliberations and outcomes to be of special relevance as it should enable us to design and deploy knowledge based development strategies and investments.

Let me briefly refresh our memories of what the GMS countries have achieved so far. It is an impressive story. Guided by the now famous GMS brand, articulated through the 3C's - enhancing 'connectivity', increasing 'competitiveness', and achieving a greater sense of 'community,' the GMS has enjoyed a period of sustained and buoyant economic growth over the last decade averaging 6.5% GDP growth, and as illustrated by the countries' resilience during the recent financial and economic crisis, this growth is based on strong foundations - whether expressed in terms of income, consumption or through composite measures such as the UN's Human Development Index (HDI). In my view, this level of growth and prosperity would not have materialized independent of the GMS economic cooperation program launched by farsighted leaders of the subregion in 1992. Over the last decade, the GMS economic cooperation program has mobilized over \$14 billion in completed and planned investments. It has facilitated and delivered multi-modal transport systems, anchored through transport/economic corridors, energy interconnections, and investments in the information superhighway laying the basis for expanded physical connectivity, enhanced production and employment opportunities, and improved livelihoods.

The new GMS Strategic Framework (2012-2022) focuses on developing "software" to complement the "hardware" achievements. Future development of these economic corridors will depend on deepening and widening of these geographic pathways to align them to the changes in technology demands and trade flows within the region. These "second generation" investments will need to be informed by sound assessment of environmental and natural resources. Optimal and efficient use of environmental and natural resources will ultimately underpin the "competitiveness" of the economic corridors.

All countries in the GMS now face increased competition for resources and rising costs. Growing resource demands worldwide as well as in the GMS are encountering a

growing set of material and ecological constraints – recent volatility in commodity markets and “spikes” in food and energy prices indicates what the future might hold.

Food demand from the Mekong River Basin, for instance, is projected to increase by 20 to 50 percent by 2030. Demands on use of water for food and energy production, domestic and industrial use, is exponentially increasing while ground and surface water sources are depleting and degrading. The management of the food-water-energy nexus will be the most critical challenge of this decade. The challenges are not only technical in nature, but will also call into question the adequacy of our current resource governance, management and fiscal regimes. Climate change only adds to this already complex and complicated policy and practice conundrum.

Sustainability in the 21st century requires investments in smart development – getting more food and industrial output from the same amount of material and energy inputs. It makes business and ecological sense. Stimulating growth through green technology and investments can provide the financing, innovation platform and political attention to begin the process of effecting this transformation – with the emphasis on making growth processes resource-efficient, cleaner, and more resilient without necessarily slowing them. There are existing technologies and practices which need to be scaled up and deployed at a larger scale. For example, precision agriculture, efficient water supply and re-use, and clean (renewable) energy generation fuels and other frontier technologies are already part of the “green” growth agenda in the region awaiting appropriate policy signals and regulatory incentives for “take-off.”

Improvement of fuel efficiency in freight fleets moving across the region would help reduce the cost of logistics, simultaneously reducing carbon intensity of regional and global supply chains and increasing their business performance; in the energy sector, shifting to renewable energy and demand side management, including improving the efficiency of electricity generation and distribution, will help reduce the vulnerability of the region to fuel price fluctuations; in the agriculture sector, the focus could be on moving to less water intensive crops, improved use of biotechnology with lower agro-chemical dependence, and intensification rather than expansion. Urban centers need to be made cleaner and safer by adopting resource saving measures such as rain water harvesting, energy efficiency of buildings, and reducing, reusing and recycling wastes.

It is worth noting here that People’s Republic of China

(PRC) is already “walking the talk” in the region - the PRC’s fast-growing labor force in renewable-energy generation, is currently estimated at more than 1.1 million based on investments of over \$17 billion - part of a \$468 billion investment in greening key sectors by 2015. ADB has also initiated ambitious, catalytic interventions to promote transformational change in clean energy, sustainable energy, integrated natural and water resource management, sustainable transport and climate resilient urban development. Environmentally sustainable growth is a key development agenda - in 2010, for example, ADB approved 50 projects with environmental sustainability, totaling about \$4.8 billion – representing a 52% increase over 2009 in the number of projects.

As I mentioned earlier, this Conference gives us an opportunity to deliberate upon how the food-water-energy nexus should and can drive future economic growth in the GMS – which is inclusive and does not compromise our ecological infrastructure for current and future growth. The Conference provides us a unique opportunity to take stock of the developmental achievements of the past decade focusing on what lessons of success as well as failure we can learn from this journey. I believe our deliberations will bring out how critical water has been and will be to our food, energy and environmental security; we will notice that economic prosperity of the past decade has come at a high environmental cost, and this growth pathway is not sustainable. Over the next two days you will collectively take a hard look at our current food, water and energy situation and recommend actions for the future. I am also particularly pleased that we have private sector representatives to showcase technologies and innovations that are environmentally friendly and promote resource efficiencies and reduce wastage. Without private sector participation our assessments and agenda for the future will not be realized.

We need to chart a pro-poor pro-environment roadmap to 2020. The challenge is to increase efficiencies in resource use, restore and recapitalize the natural resource base, safeguard environmental quality while creating jobs and sustaining economic growth. ADB stands ready to work with GMS countries and development partners to shape a roadmap catalyzing investments for a “greener” development trajectory in the GMS.

I am confident that this conference will provide us insights, and actionable evidence and knowledge for mapping a sustainable and resilient economic future for the GMS.

I wish you all a very successful conference. Thank you.

**Session 1: Decade of Development, Growth, and Impacts
2001 - 2010 in the GMS**

DYNAMICS OF ECONOMIC GROWTH IN THE GMS: A RETROSPECTIVE VIEW 2000 - 2010

Arkhom Termittayapaisith¹ and Ladawan Kumpa²

Excellency, Distinguished Guests, Ladies and Gentlemen,

It is my great pleasure as a representative of the National Economic and Social Development Board to deliver this presentation. The group of countries making up the GMS-5³ had an average GDP growth rate of about 6.1% in 2000-2008. This was about 1% point higher than ASEAN-5⁴ but slower than that of the Peoples' Republic of China (PRC). The GMS-5 slowed down sharply in 2009, in the aftermath of the global financial crisis of 2008, but staged a sharp recovery in 2010 (Table 1).

The GDP per capita (in 2005 PPP\$) increased in all countries during 1993-2010, especially during the 2000s. In terms of GDP per capita, Thailand has consistently shown the best performance since 1993, although the PRC is rapidly closing the gap; Cambodia, Lao PDR, and Viet Nam are also improving though at a slower rate.

The structure of economic activities in the GMS is diverse; the PRC, Thailand, and Viet Nam have a greater share of manufacturing than Cambodia, Lao PDR, and

Myanmar, which are more reliant on primary sectors and agriculture. This difference in economic structure is reflected in the sector contributions to economic growth (Figure 1).

GMS countries have grown rapidly in the last decade, fueled partly by rapid integration with the global economy through both the trade and investment channels. Greater outward orientation and increased economic integration with the global economy have been a key pillar of the development plans of the GMS countries. The share in intra-GMS-5 exports grew slightly from 3.4% in 2000 to 6.4% in 2009; but in the same period the share of exports by the PRC jumped from 6.3% to 14%. The data show that exports of GMS-5 to PRC increased about 21% faster than among the GMS-5 and at the same time share of trade of intra-GMS-5 with the rest of the world declined (Table 2). The PRC and Thailand account for most of the intra-GMS trade.

GMS countries are increasingly linked with the global economy through both trade and FDI. Trade to GDP of the GMS countries has increased over the last two decades (Figure 2), while the outstanding stock of foreign direct investment (FDI) increased manifold between 1993 and 2010 (Figure 3).

Table 1: GMS Economic Growth during 2000-2010

GDP Growth (%)	2000-2008	2009	2010
Cambodia	9.2	0.1	6.3
Guangxi Zhuang Autonomous Region, PRC	11.5	13.9	14.2
Yunnan, PRC	9.6	12.1	12.3
Lao PDR	6.9	7.3	7.5
Myanmar	11.8	5.1	5.3
Thailand	4.8	-2.3	7.8
Viet Nam	7.5	5.3	6.8
PRC	10.4	9.2	10.3
GMS-5	6.1	0.7	7.3
ASEAN-5	5.2	2.0	7.7

Figure 1: Share of Major Sectors in GDP (%), 2007-2009

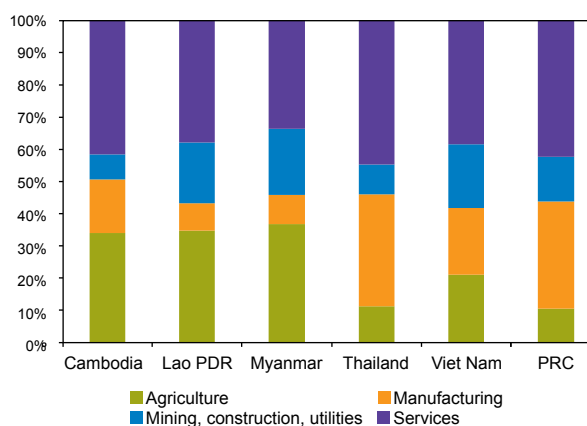


Table 2: Growing Regional Focus of GMS-5 Trade

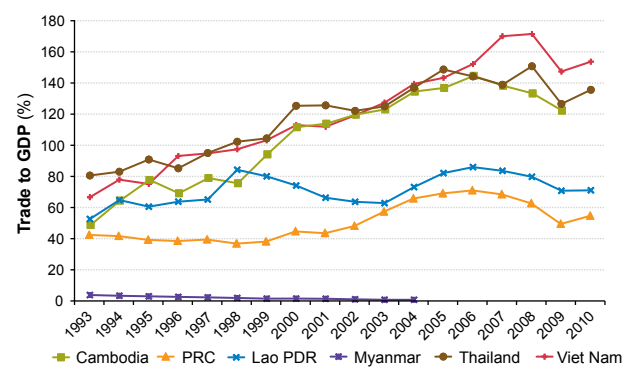
	Intra GMS-5	PRC	ASEAN-5	Rest of World
Share in Total GMS-5 Exports in %				
2000	3.4	6.3	15.1	75.2
2009	6.4	14.0	13.6	66.0
Average Annual Growth of GMS-5 Exports, 2000-2009				
	19.1%	21.2%	9.7%	9.3%

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² Deputy Secretary General, Office of the National Economic and Social Development Board (NESDB), Thailand

³ GMS-5 comprises Cambodia, Lao PDR, Myanmar, Thailand, and Viet Nam

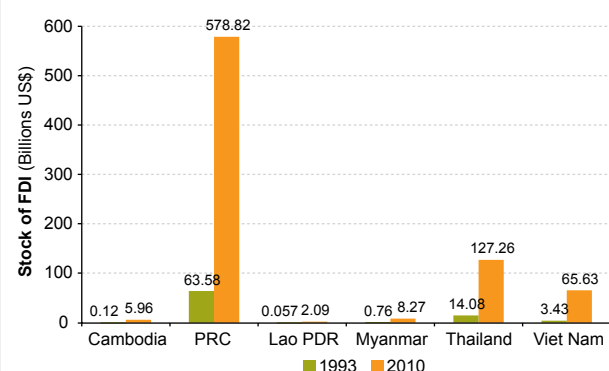
⁴ ASEAN-5 comprises Brunei Darussalam, Indonesia, Malaysia, Philippines, and Singapore (i.e. non-GMS ASEAN countries)

Figure 2: Trade as Percentage of GDP in GMS Countries, 1993-2010

products still have the larger share in exports of GMS-5 to both the PRC and rest of the world (Table 3).

Although the share of total FDI originating from within the subregion has increased, it still remains very small. FDI inflows from the rest of the world to the GMS-5 make up the majority. ASEAN-5 accounted for about a fifth of the cumulative FDI inflows. The share of FDI inflows originating in other GMS-5 countries and the PRC doubled during the past decade. Most of the intra-GMS FDI inflow in Cambodia, Lao PDR, and Myanmar is from the PRC and Thailand. Viet Nam is also a major source of FDI for Cambodia.

The GMS countries are expected to maintain growth in the short run, although there are risks to their growth prospects and the development challenges that each face are somewhat different. However, trade rebalancing toward regional markets can promote resilience to the economic downturn presently seen in Europe and the United States. In this regard, the GMS program has sought to integrate countries in the subregion through both hard (i.e., roads) and soft (i.e., trade facilitation measures to ensure smooth movement of trucks and goods) infrastructure measures. Growth will also be assisted by the increasing intra-GMS FDI, which will be a key driver of intra-GMS trade in the future.

Figure 3: Foreign Direct Investment Stocks in GMS Countries, 1993 and 2010

GMS exports increased rapidly during the 2000s. The magnitude of PRC exports is much greater than the combined exports of the GMS-5 and has grown much more rapidly (19.1% per year for PRC vs. 10.9% for GMS-5).

The composition of GMS-5 exports, however, varies by destination: two thirds of GMS-5 exports are from manufacturing, with primary commodities making up the remaining third. But composition varies by direction of trade. The share of primary commodities in intra-GMS trade increased in the past decade but manufacturing

Table 3: Share in Exports of the GMS-5 Countries (%)

Destination	2000		2009	
	Primary	Manufacturing	Primary	Manufacturing
GMS-5 Exports to PRC	41.1	59.0	28.3	71.7
Intra-GMS-5 Exports	40.4	59.6	51.3	48.7
GMS-5 Exports to rest of the world	26.6	73.4	32.4	67.6
Total GMS-5 Exports	27.9	72.1	33.0	67.0

GROWTH IN THE GREATER MEKONG SUBREGION IN 2000 - 2010 AND FUTURE PROSPECTS

Utsav Kumar and Pradeep Srivastava¹

1. Introduction

The Greater Mekong Subregion (GMS) comprises Cambodia, Guangxi Zhuang Autonomous Region and Yunnan Province of the People's Republic of China (PRC), the Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, and Viet Nam. The GMS countries have grown rapidly since the establishment of the GMS economic cooperation program in 1992. GMS countries other than the PRC (referred to as GMS5 in this paper) have grown at an average annual rate of 5.3% during 1992-2010, over the same period PRC grew by 10.3% per annum. The rapid growth in the GMS5 countries was punctuated twice during this period—first by the Asian financial crisis in 1997-1998 and then a second time by the global financial crisis of 2008-2009. Both the times output growth decelerated sharply and output contracted in Thailand, the largest economy among the GMS5. In both instances, the GMS5 staged a V-shaped recovery.

This paper discusses the growth dynamics in the GMS during the 2000s, the structure of economic activity, sectoral contributions to growth, and also examines the patterns in welfare outcomes. While many factors have contributed to the rapid growth in the GMS during the 2000s, a key contributing factor is the continued outward orientation towards regional and global markets. Growing integration with the global economy has been on account of both increase in trade and increase in foreign direct investment (FDI). The paper looks at some of the key trends and patterns in trade and FDI in the region during the 2000s.

The low-income GMS countries have grown at a brisk pace during the 2000s. However, their per capita incomes remain far below that of Thailand which continues to have the highest per capita income in the region. One exception to this is the PRC which has closed the gap with the Thailand the most—from having 30% of Thailand's GDP per capita (in 2005 PPP terms) in 1992 to being at 90%

of Thailand's GDP per capita in 2010. Rapid growth in the GMS has been accompanied by decline in poverty levels and improvements in human development (as measured by United Nations' Human Development Index). However, inequality has edged up across the region showing that though many were pulled out of poverty in the last two decades, gains were unequally distributed.

The structure of the economic activity across the GMS countries is varied with Cambodia, Lao PDR, and Myanmar (CLM) more dependent on primary sectors—agriculture and mining—than the other three countries. With the exception of Cambodia, this is also reflected in the trading patterns of the six countries with each other and with the rest of the world—CLM countries export primary products to and import manufactured goods from other countries in the region and the outside the world. In the case of Cambodia, while intra-GMS exports are largely in primary commodities, its garments exports to the rest of the world dominate its export basket. Similarly, the share of cumulative FDI inflows in the CLM countries going to primary sectors is greater than the share of FDI going to primary sectors in Thailand and Viet Nam. The latter two, on the other hand, attract more FDI in the manufacturing sector.

The direction of GMS5 trade has changed somewhat during the last decade. The share of the GMS5 trade with PRC and other GMS5 countries has almost doubled during 2000s. PRC's share of total GMS5 exports increased from 6.3% in 2000 to 14% in 2010 and the share of intra-GMS5 exports in the total exports of GMS5 increased from 3.4% in 2000 to 6.4% in 2010. Thus, there seems to have been some rebalancing towards regional markets in the last decade. Likewise, the share of cumulative FDI coming from other GMS5 countries doubled to 2.1% and that from PRC doubled to 2.9% during 2005-2009 compared with 2000-2004. But these shares are very small and a large chunk of FDI still comes from outside the region.

To the extent that exports to markets, and FDI from, outside the GMS continues to account for a lion's share, vulnerability to developments in those markets remains. In addition, with the growing dependence on the PRC as a market for exports and for FDI, the GMS5 countries can be impacted by economic events in the PRC as well. The long-term challenges facing the GMS countries are somewhat different.

CLM countries need to diversify their economic base away from primary and low-value added goods and move up the value chain. Lao PDR and Myanmar also need to tackle

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the macroeconomic challenges arising out of resource revenues. PRC, Thailand, and Viet Nam are at varied levels of per capita income and though not yet stuck in the middle-income trap, need to move up the value chain further from product assembly to product development. This will require a stable macroeconomic environment to encourage investment, strengthening of institutional and legal frameworks to encourage research and development, and further improvements in trade facilitation so that some of the low-value added tasks can be done in countries which are further down the value chain.

The rest of the paper is organized as follows. Section 2 discusses growth dynamics in the GMS in the 2000s. Sections 3 and 4 discuss trade and FDI in the GMS, respectively. Section 5 closes the paper with a discussion of growth prospects and key challenges facing the GMS countries.

2. Growth in the GMS in 2000s

Among the six GMS member countries, PRC accounts for a lion's share of the subregion's size, in terms of both GDP and population (Tables 1 and 2). For the purposes of this paper and to avoid aggregate statistics for GMS,

as a group, being driven by PRC, GMS5 countries, i.e., GMS countries excluding PRC, are considered separately. Among the GMS5 economies, Thailand is the largest economy in terms of GDP. It accounted for the largest share (61%) in terms of GDP (measured in PPP terms) followed by Viet Nam (27%). In terms of population, however, Viet Nam is the largest country in the GMS5 with 38.6% of the total GMS5 population while Thailand accounted for 31%. Among the GMS5, Lao PDR's share in GDP and population is the smallest.

GMS5 grew at an average annual rate of 6.1% during 2000-2008 (Figure 1).² This was about 2 percentage points slower than the average growth rate of 8.1% in the period immediately preceding the Asian financial crisis, 1993-1996. The slowdown in the overall GMS5 growth rate was largely due to a sharp slowdown in Thailand, the largest economy in GMS5 in terms of GDP, from 8.1% during 1993-1996 to 4.8% during 2000-2008 (Table 3). Growth in the GMS5 during 2000-2008 was comparable to that of ASEAN5 but slower than that of PRC.³ GMS5 slowed down sharply in 2009, in the aftermath of the global financial crisis of 2008, growing at only 0.6% in 2009. GMS5, like other countries in the region, staged a V-shaped recovery registering a 7.3% growth in 2010.

Table 1: Selected indicators in GMS economies

	Population in 2010 (in millions)	GDP in 2010, current US\$ (in billions)	GDP per capita in 2000, current US\$	GDP per capita in 2010, current US\$
Cambodia	14.1	11.6	293.6	821.0
PRC	1,338.3	6,031.8	949.2	4,507.0
Guangxi Zhuang, AR, PRC	46.0	141.4	559.7	3,071.1
Yunnan province, PRC	46.0	106.7	566.6	2,321.4
Lao PDR	6.2	7.3	326.3	1,175.7
Myanmar	61.2	45.4	177.6	742.4
Thailand	69.1	318.8	1,943.2	4,610.0
Viet Nam	86.9	103.6	401.5	1,191.4

Source: World Economic Outlook database (September 2011), Asian Development Outlook Update (2011), World Bank (East Asia and Pacific Economic Update, November 2011), CEIC for data on Guangxi Zhuang autonomous region and Yunnan province of PRC, and authors' estimates.

Table 2: Share in GMS population and GDP (%), 2006-2010

	Including PRC		Excluding PRC	
	Share in GDP	Share in Population	Share in GDP	Share in Population
Cambodia	0.3	0.9	3.1	6.3
PRC	90.1	85.7		
Lao PDR	0.1	0.4	1.5	2.7
Myanmar	0.7	3.1	7.6	21.4
Thailand	6.0	4.4	60.8	31.0
Viet Nam	2.7	5.5	27.0	38.6

Source: World Development Indicators and authors' estimates. Note: Share of each country in GMS5 (or GMS6) total population and GDP is the average share during 2006-2010. Share in GDP shown is for GDP measured in PPP terms.

² GMS5 comprises Cambodia, Lao PDR, Myanmar, Thailand, and Viet Nam.

³ ASEAN5 comprises Brunei Darussalam, Indonesia, Malaysia, Philippines, and Singapore.

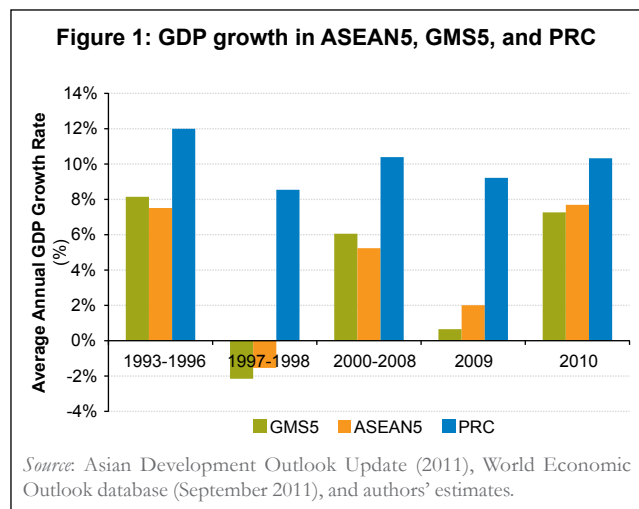


Table 3 shows the growth rate of the GMS5 member countries. Also shown in the table are the growth rates of PRC and the two provinces of PRC that comprise the Greater Mekong Subregion. Cambodia and Myanmar grew faster during 2000-2008 than they did immediately preceding the Asian financial crisis, i.e., during 1993-1996, Lao PDR grew at a similar pace during the two periods while Thailand and Viet Nam grew at a slower pace in the latter period than before the Asian financial crisis. All the economies in the GMS, except Lao PDR and Guangxi Zhuang autonomous region of and Yunnan province of PRC, slowed down in the aftermath of the global financial crisis during 2009. Cambodia and Thailand staged a V-shaped recovery in 2010 while growth accelerated in the other economies.

Thailand contributed almost three-fourth of the overall GMS5 growth in the pre-Asian financial crisis period during 1993-1996, accounting for 6 percentage points of the GMS5 growth (Figure 2). However, it contributed only 49% of the GMS growth during 2000-2008. Correspondingly, the contribution of all the other GMS5 countries to the overall GMS5 growth increased during 2000-2008 compared with 1993-1996.

GMS5 GDP per capita (weighted by population and measured in 2005 PPP constant international dollars) increased by 1.5 times from \$3,100 in 2000 to \$4,666 in 2010 (Figure 3). This increase was slightly higher than the increase in ASEAN5 GDP per capita from \$3,689 to \$5,180, an increase of 1.4 times. GDP per capita of PRC increased the most, by 2.5 times from \$2,667 to \$6,810. Using GDP

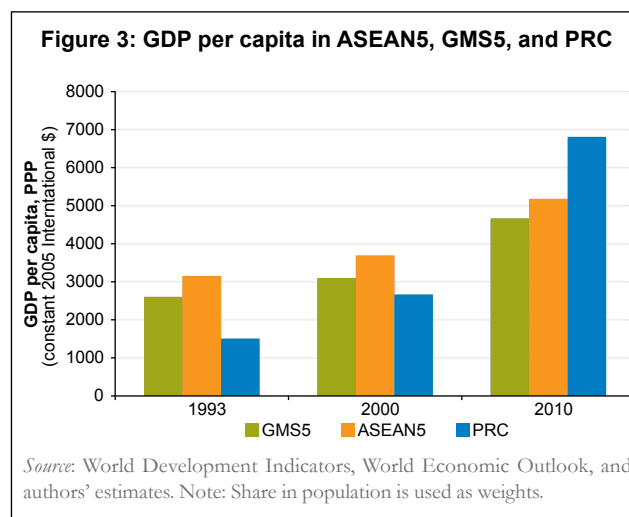
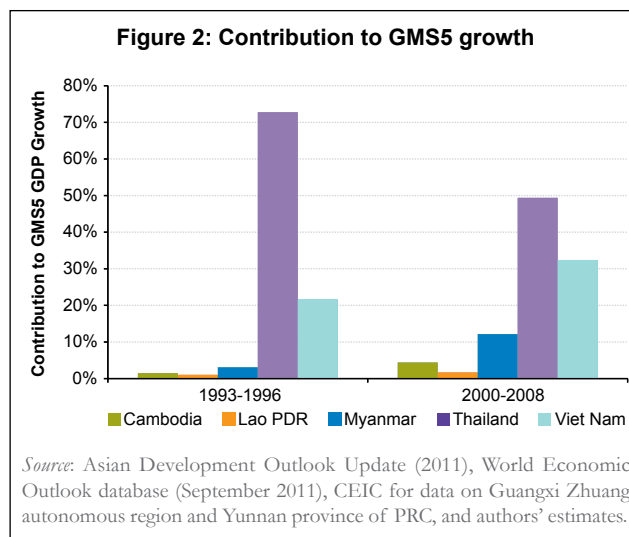


Table 3: Average annual GDP growth rates (%) in the GMS economies

	1993-1996	1997-1998	2000-2008	2009	2010
Cambodia	6.0	5.3	9.2	0.1	6.3
PRC	12.0	8.5	10.4	9.2	10.3
Guangxi Zhuang, AR, PRC	13.4	8.6	11.5	13.9	14.2
Yunnan, PRC	11.0	8.7	9.6	12.1	12.3
Lao PDR	7.0	5.6	6.9	7.3	7.5
Myanmar	6.6	5.8	11.8	5.1	5.3
Thailand	8.1	-6.1	4.8	-2.3	7.8
Viet Nam	8.9	7.0	7.5	5.3	6.8
GMS5	8.1	-2.2	6.1	0.7	7.3
ASEAN5	7.5	-1.5	5.2	2.0	7.7

Source: Asian Development Outlook Update (2011), World Economic Outlook Database (September 2011), CEIC for data on Guangxi Zhuang autonomous region and Yunnan province of PRC, and authors' estimates.

weights, however, shows a much higher GDP per capita in the ASEAN5 countries. Using GDP weights, the GDP per capita of ASEAN5 increased from \$9,299 in 2000 to \$12,331 in 2010.⁴ GDP per capita of the GMS5 increased from \$4,336 in 2000 to \$5,931 in 2010.

During the seventeen year period, 1993-2010, GDP per capita (measured in PPP terms) increased in all the GMS countries as shown by the upward movement of the dots representing the various countries in Figure 4. The GDP per capita of all the GMS countries was less than that of Thailand in 1993 and continued to be so in 2010, though PRC has caught up rapidly during this period (Figure 4 and 5). GDP per capita of the GMS countries in 1993 was 30%

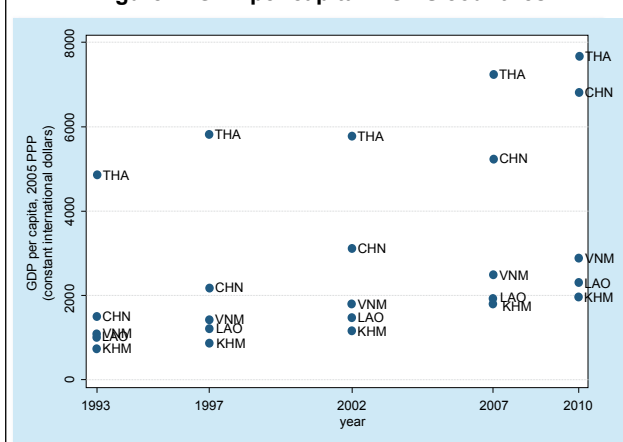
or less than that of Thailand (Figure 5). In other words, the gap of the various GMS countries with Thailand was 70% or more. Over the next two decades, 1993-2010, all the countries managed to reduce the gap with Thailand though to a different extent. PRC succeeded in reducing the gap by the most. PRC's gap with Thailand in 1993 was 70%, i.e., PRC's GDP per capita was 30% that of Thailand's. By 2010, PRC's GDP per capita was 90% that of Thailand's, i.e., the gap was reduced to 10%. Cambodia, Lao PDR and Viet Nam also closed the gap with Thailand though their per capita incomes continued to be less than 40% that of Thailand's in 2010.

With the exception of Lao PDR and Myanmar, the structure of economic activity in each GMS country has remained more or less the same during 2000-2010 (Figure 6). In Lao PDR, the share of mining etc. and services in GDP increased while that of agriculture and manufacturing declined. In Myanmar, on the other hand, an increase in the share of mining etc. was accompanied by a commensurate decline in the share of the agricultural sector.

However, the structure of economic activity is different across the GMS countries (Figure 6). PRC, Thailand, and Viet Nam have a greater share of manufacturing than Cambodia, Lao PDR, and Myanmar. The latter three, on the other hand, have a greater share of agriculture in economic activity than the former three countries. For the latest period, 2007-2009, the share of mining etc. in GDP in Myanmar and Lao PDR was higher than the share of manufacturing. Cambodia, Lao PDR, and Myanmar are, thus, relatively more dependent on primary sectors. Thailand, Viet Nam, and PRC, on the other hand, have relied more on manufacturing as an engine of growth.

The difference in the economic structure is also reflected in the sectoral contributions to growth (Figure 7). In general, growth in services contributed the most to GDP growth in the GMS countries, except in Lao PDR where growth in mining etc. and in Thailand where manufacturing growth contributed the most to GDP growth. In Cambodia, manufacturing and services contributed the most to GDP growth during the two periods. However, the contribution of agriculture and manufacturing to GDP growth in Cambodia was lower in 2000-2008 than during 1993-2000, while that of services and mining etc. increased. The sectoral contributions to GDP growth changed the most in Lao PDR. The contribution of agricultural growth halved from 43% during 1993-2000 to 22% of the GDP growth during 2000-2008 and that of manufacturing growth also declined from 24% in 1993-2000 to 1% in 2000-2008. On the other

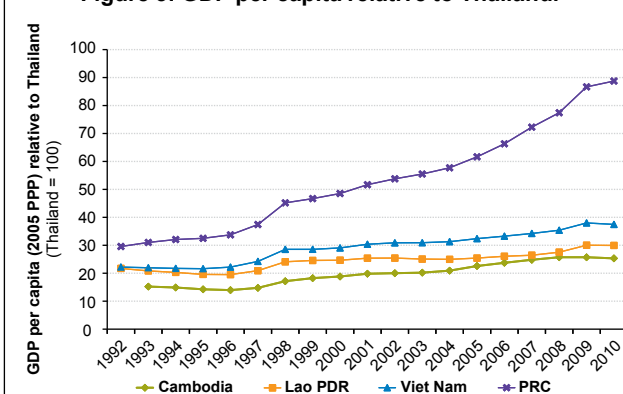
Figure 4: GDP per capita in GMS countries



Notes: CHN=People's Republic of China, KHM=Cambodia, LAO=Lao PDR, THA=Thailand, and VNM=Viet Nam

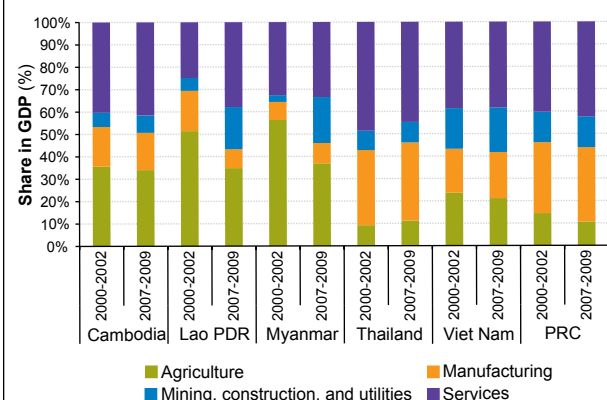
Source: World Development Indicators and authors' estimates.

Figure 5: GDP per capita relative to Thailand.



Source: World Development Indicators and authors' estimates.

⁴ The difference in the GDP per capita of ASEAN5 when weighted by population compared with the GDP per capita when weighted by GDP is due to the smaller share of Singapore when using population weights (1.3%) as compared to its weight in GDP terms which is about 13%.

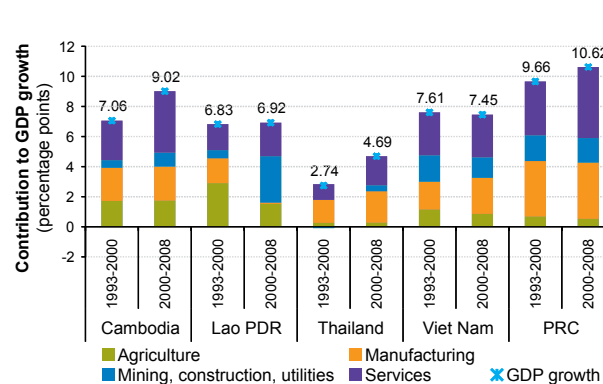
Figure 6: Structure of economic activity in GMS countries

Source: Asian Development Bank Key Indicators, World Development Indicators, and authors' estimates.

hand, the share of mining etc. in GDP growth increased from 8% during 1993-2000 to 44.7% during 2000-2008 and the contribution of services to the GDP growth also increased.

In Thailand, manufacturing growth continued to contribute the highest share to the GDP growth. In the wake of the Asian financial crisis, the mining, construction, and utilities contracted sharply and pulled back GDP growth for 1993-2000. The sector contributed positively to the GDP growth during 2000-2008 and largely accounted for the 11 percentage point decline in the contribution of manufacturing growth to GDP growth. In Viet Nam, the contribution of manufacturing growth to GDP growth increased by almost 8 percentage points, from 24% during 1993-2000 to 32% during 2000-2008, while the combined contribution of agriculture and mining etc. to GDP growth declined. In PRC, the contribution of services to GDP growth increased from 37% to 44.5% and this increase came at the expense of decline in the contribution of all the other sectors.

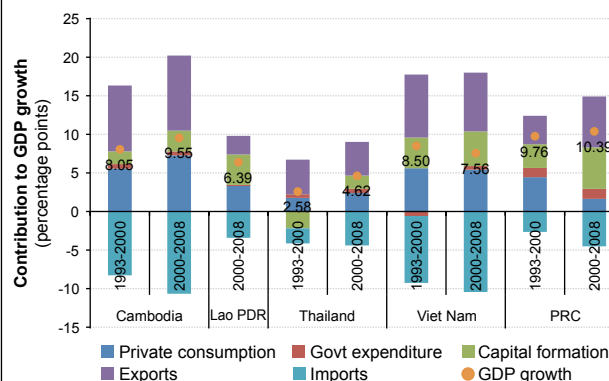
Enhanced integration with the global economy and promotion of exports have been central to the development strategy of the GMS countries in the last two decades. Contribution to GDP growth from the expenditure side shows that exports have contributed handsomely to the GDP growth in all the GMS countries (Figure 8). Shown in Figure 8 are the percentage point contributions to the overall GDP growth. So, for example, in the case of Thailand during 2000-2008, export growth contributed 4.4 percentage points of the total GDP growth of 4.62% which amounts to 95% of the overall GDP growth. Similarly in PRC during 2000-2008, export growth contributed 6.6 percentage points of the total GDP growth of 10.4%, i.e.,

Figure 7: Sectoral contribution to GDP growth

Source: Asian Development Bank Key Indicators, World Development Indicators, and authors' estimates.

export growth accounted for 63% of the total growth. Note that the export contribution to growth in itself is high and in some cases more than 100% (for example, Thailand during 1993-2000). At the same time, however, import growth, which has an offsetting impact in terms of contribution to GDP, is also very high. Only in PRC is the impact of export growth not fully offset by import growth.

Along with rapid growth and increase in per capita incomes, GMS countries have also seen a decline in poverty. Poverty, as measured by the headcount ratio, i.e., the share of the population below the national poverty line (Figure 9) or by the share of population living on less than \$2 (PPP) a day (Figure 10) fell during the 2000s. On the basis of the national poverty line, the sharpest decline amongst the GMS countries was seen in Viet Nam where poverty rate declined from 37.4% in 1998 to 14.5% in 2008. Poverty in rural and urban areas, based on the respective national rural and urban poverty lines, declined in all the GMS countries.

Figure 8: Contribution to GDP growth, expenditure side

Source: World Development Indicators and authors' estimates.

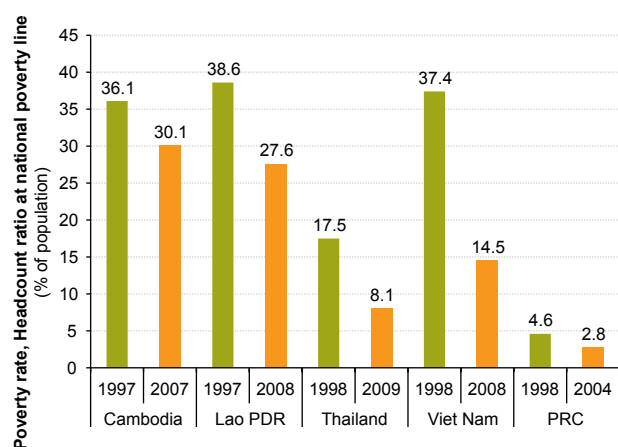
The headcount ratio shown above gives only the share of the population below the poverty line. However, it does not say anything how poor the individuals are. Figure 11 shows the poverty gap index based on the \$2 a day (PPP) poverty line. It measures the extent to which individuals are below the poverty line and is expressed as a percentage of the poverty line. Poverty gap declined across the GMS countries during the 2000s indicating that not only were there less poor (as shown by the decline in headcount ratio, Figure 10) but also the poor were, on average, less poor than they were in 1990s.

Though the continued growth in the 2000s lifted many out of poverty, it, however, did not lift all the boats equally. In other words, gains from rapid growth in the region were distributed unequally and the already rich benefited more. The ratio of income earned by the highest 20% to the

income earned by the lowest 20% (Figure 12) as well as Gini Coefficient (Figure 13) increased during the 2000s in all the GMS countries except Thailand. Thus, while growth has been inclusive to the extent that it has helped lift people out of poverty it has not been equitable as the gains in income of the richest have exceeded those of the poorest.

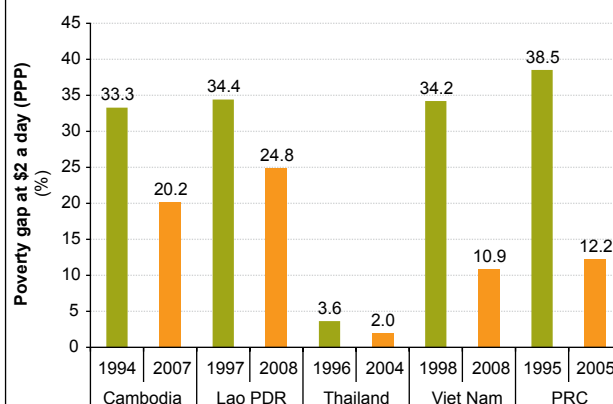
The United Nations' Human Development Index (HDI), a composite index of human development which measures achievements in health, education, and income, shows an improvement in all the GMS countries during the 2000s (Figure 14). However, all the countries in the GMS region rank low and are either in the "medium" human development or "low" human development categories (Human Development Report 2011). The rank of the GMS countries in 2011 out of 187 countries is shown next to the respective country on the horizontal axis in Figure 14.

Figure 9: Poverty rate based on national poverty line



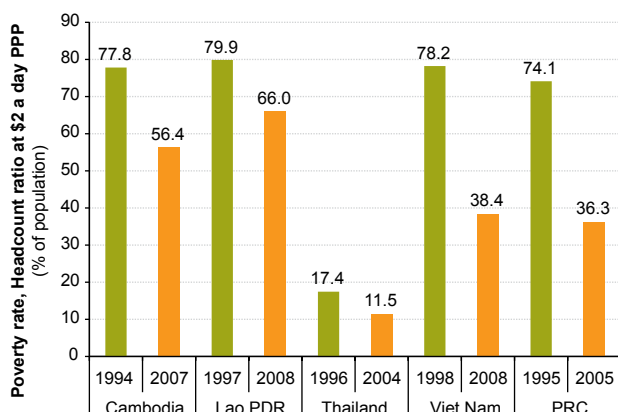
Source: Asian Development Bank Key Indicators and World Development Indicators.

Figure 11: Poverty gap



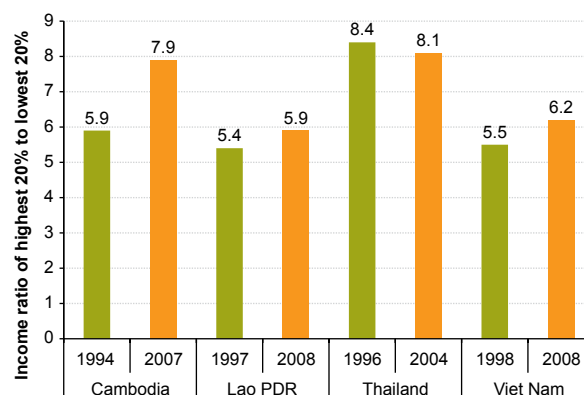
Source: Asian Development Bank Key Indicators and World Development Indicators.

Figure 10: Poverty rate based on \$2 (PPP) a day

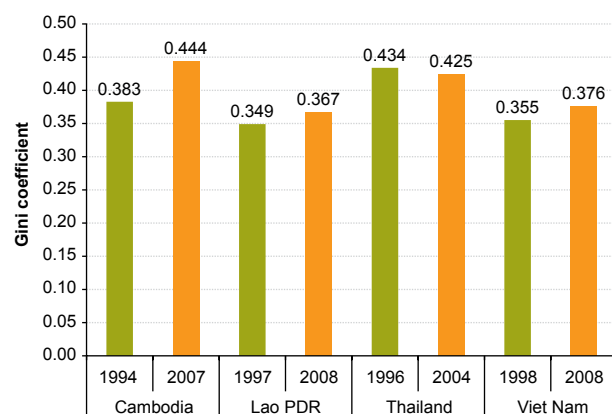


Source: Asian Development Bank Key Indicators and World Development Indicators.

Figure 12: Income ratio of highest 20% to lowest 20%



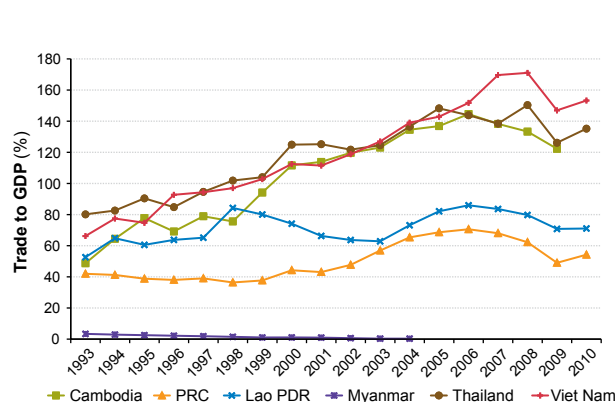
Source: World Development Indicators.

Figure 13: Gini Coefficient

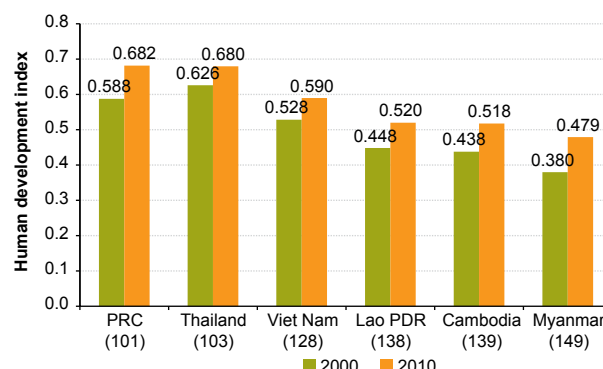
Source: World Development Indicators.

Thus, while the GMS countries have registered progress in the basic dimensions of human development, as measured by the HDI, there remains scope for improving health and education both of which contribute to human capital and therefore higher productivity, which is the key to improving living standards.

Rapid growth in the GMS countries has partly been fueled by greater integration with the rest of the world. In fact, greater outward orientation and increased economic integration with the global economy have been key pillars of the development plans of the GMS5 countries. For example, medium-term development of Cambodia, Lao PDR, and Viet Nam for 2006-2010 emphasized the role of trade in achieving various developmental goals (ADB 2008). Over the period 1993-2010, the GMS5 countries, in general, show greater integration with external markets through both the trade and the investment channels.

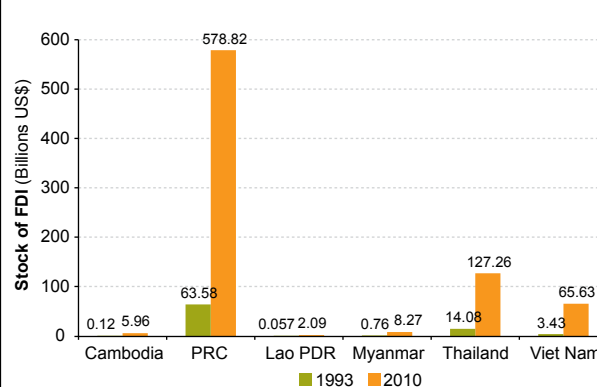
Figure 15: Trade-to-GDP ratio

Source: World Development Indicators.

Figure 14: Human Development Index (HDI)

Source: United Nations Human Development Report (2011).

Openness as measured by the ratio of the sum of exports and imports of goods and services to GDP (trade-to-GDP ratio) increased in all the GMS countries except Myanmar during the last two decades (Figure 15). Cambodia's trade-to-GDP ratio increased from 48.7% in 1993 to 122.3% in 2009, PRC's increased from 42.0% in 1993 to 54.2% in 2010, from 52.6% in 1993 to 71.1% in 2010 in Lao PDR, Thailand's trade-to-GDP ratio increased from 80.2% in 1993 to 135.2% in 2010, and that of Viet Nam increased from 66.2% in 1993 to 153.3% in 2010. Myanmar's trade-to-GDP ratio declined from 3.4% in 1993 to 0.3% in 2004.⁵ Various studies have shown that, after taking into account the possibility that countries with higher incomes may trade more, countries that trade more have a higher income, i.e., higher trade *causes* higher income (for example, Frankel and Romer (1999) and Ferrarini (2010)). Thus, policies to promote trade, by reducing trade barriers or improving trade facilitation, can have a positive impact on growth and can also make a dent on poverty.

Figure 16: Stock of FDI

Source: UNCTAD.

⁵ Source: World Development Indicators (2011), World Bank.

The stock of FDI in the GMS countries increased manifold between 1993 and 2010 (Figure 16). The stock of FDI in Cambodia in 2010 amounted to \$5.96 billion (an increase of 47.7 times since 1993), in Lao PDR the stock of FDI in 2010 was \$2.10 billion (36.5 times more than it was in 1993), in Myanmar the stock of FDI increased by 10.9 times from 1993 and stood at \$8.3 billion in 2010, Thailand's stock of FDI in 2010 was \$127.26 billion representing a nine-fold increase since 1993, and that of Viet Nam soared by 19 times to \$65.63 billion in 2010. In PRC the stock of FDI increased by 9.1 times during 1993-2010, from \$63.58 billion to \$578.82 billion.⁶

The next two sections examine the pattern of trade and FDI in the GMS5 countries in greater detail.

3. Pattern of trade in the GMS countries^{7,8}

Total exports (including to each other) of the GMS6 countries (GMS5 plus PRC) grew at an average annual pace of 17.4%, from \$336.2 billion in 2000 to \$1,423.5 in 2009 (Figure 17).⁹ Total imports (including from each other) of the GMS6 increased from \$307.1 billion to \$1,222.8 in 2009, an average annual growth rate of 16.6%. The dip in exports and imports in 2009 is a reflection of the collapse in trade in the aftermath of the global financial crisis in late 2008 and its impact on the real economy. Of the total exports of GMS6 to the world only 15.6% originated in the GMS5 in 2009. Similarly, GMS5 accounted for only 17.7% of the total GMS6 imports in 2009. It is, therefore, important to look at the trade patterns of GMS5 countries separately from the PRC so that inferences about GMS trade are not dominated by the trade flows of PRC.

⁶ Source: UNCTAD.

⁷ This section draws freely from a companion paper, Srivastava and Kumar (2011).

⁸ The main source for all the trade data used in this section is the United Nations' Commodity Trade (UNCOMTRADE) database. Data for the years 2000–2009 at the SITC (Rev. 2) 2-digit level is used. For the purposes of this report, following the approach of Feenstra *et al.* (2005), import side data is taken as the base data. In other words, imports of Thailand from PRC are used as exports of PRC to Thailand. In case of missing import values, export side data is used to obtain the value of the bilateral trade flow at the 2-digit level. Thus, a single series of trade values is used. It is used as exports from country A to country B if looking at exports and the same series is used as imports of country B from country A when examining the imports. Total exports to and total imports from the world are taken as reported in the UNCOMTRADE database except for Cambodia, Lao PDR, and Myanmar. For the latter three countries, data for trade with the world, at the SITC (Rev. 2) 2-digit level, was obtained by aggregating trade with individual countries. For ease of presentation of composition of trade, SITC (Rev. 2) 2-digit products were combined into a smaller number of groups. Appendix 1 shows the 2-digit SITC products that comprise each group.

⁹ Some other recent papers that examine GMS trade flows are ADB (2008), Duval (2008), Banik (2011), and Menon and Melendez (2011).

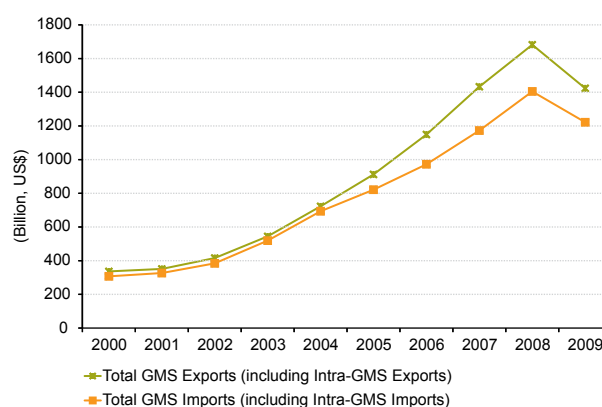
GMS5 total exports and imports. Figures 18A and 18B show the trend in GMS5 exports and imports, respectively. GMS5 exports and imports grew slower than the respective GMS6 flows indicating that the growth rates noted above were dominated by growth in the trade flows of PRC. Total exports of the GMS5 countries increased from \$87.2 billion to \$251.3 billion in 2008 before declining to \$221.7 in 2009, an average annual increase of 10.9% during 2000-2009. Total imports of the GMS5 economies grew at 11.4% during 2000-2009, and increased from \$82.0 billion in 2000 to \$272.1 billion in 2008 and declined to \$216.2 billion in 2009.

In general, greater outward orientation in the GMS countries, through both the trade and investment channels, fueled integration with the global economy (Figures 15 and 16). Lowering of own trade barriers as well as those by the importing countries such as the phasing out of the Multi-Fiber Agreement further aided integration with the global economy.

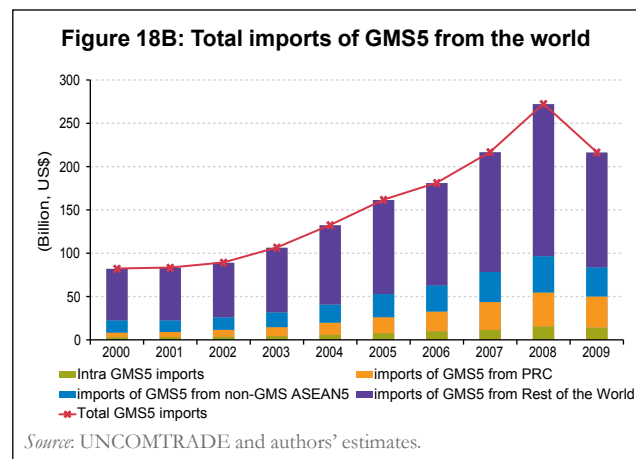
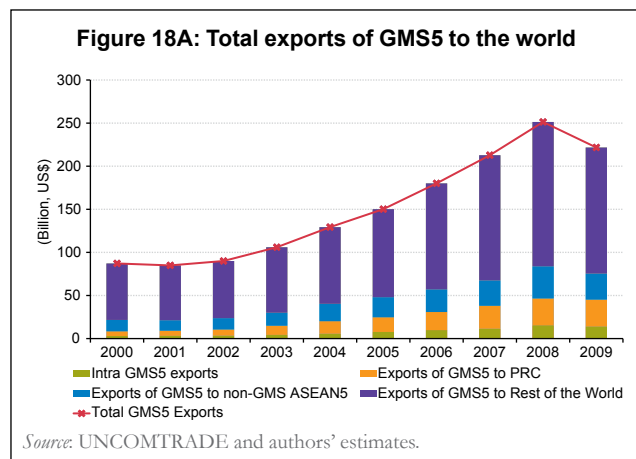
Easing of restrictions on foreign direct investment (FDI) provided an impetus to trade and growth. For example, removal of barriers to FDI and foreign ownership have resulted in relocation of garment factories from Republic of Korea, Taipei, China, and PRC to Cambodia. This has helped stimulate garment exports from Cambodia (ADB 2008). Similarly, FDI projects in agriculture and forestry and in mining have helped export growth in Lao PDR (ADB 2008).

Among other reasons that contributed to the increase in trade during the 2000s are: fragmentation of production processes across borders which was further aided by advances in transportation and communication—for

Figure 17: Total exports and imports of GMS6



Source: UNCOMTRADE and authors' estimates.



example, Viet Nam has benefited from setting up of regional production networks; easy access to finance for trade and consumption; a relatively benign global environment in the 2000s; and emergence of PRC as a key market and source for imports. Greater regional integration within the GMS has been facilitated through setting up of hard infrastructure and complementary trade facilitation measures as well as through ASEAN (five of the six GMS countries are also members of ASEAN) initiatives such as the ASEAN Free Trade Area (AFTA).

Among the GMS5 countries, Thailand accounted for 68.7% of the total exports from GMS5 countries in 2009, down by 10 percentage points compared with 2000 (Figure 19A). Table 4 shows the size of GMS countries' trade with the world. Viet Nam's share increased by 9 percentage points over 2000-2009 and the combined share of Cambodia, Lao PDR, and Myanmar (CLM) by 1 percentage point. Similarly, Thailand continues to account for a major share of imports of the GMS5 countries though its share has declined over time. During the same period, Viet Nam's share of total imports of GMS5 countries increased by 13 percentage points. The combined share of CLM countries

continues to be small though it increased marginally during 2000-2009.

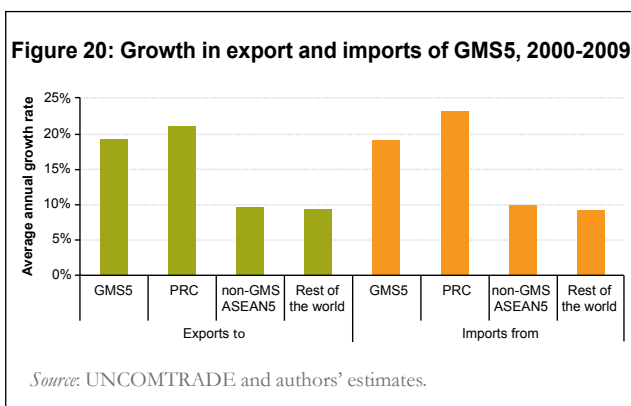
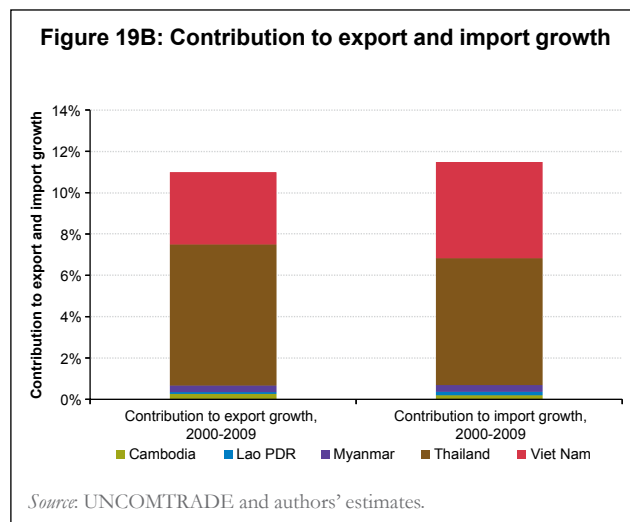
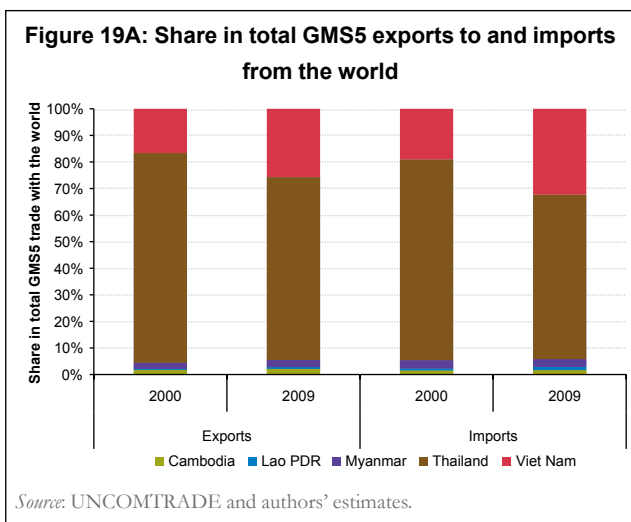
Of the 10.9% growth in the total exports of the GMS5 countries, 6.8 percentage points (i.e., 62% of the total export growth) is accounted for by Thailand and 3.4 percentage points by Viet Nam. CLM together accounted for less than 1 percentage point of the export growth of GMS5 countries (Figure 19B). Similarly, on the import side, Thailand and Viet Nam accounted for a bulk of the growth in GMS5 imports from the world.

Figures 18A, 18B, Figure 20, Figure 21 (Panel A and B) show GMS5 trade with PRC, intra-GMS5, non-GMS ASEAN5, and the rest of the world. A few things stand out. First, of the four destinations shown, GMS5 exports to and imports from PRC increased the fastest, growing at 21.2% and 23.4%, respectively, during 2000-2009 (Figure 20). This increase was faster than the increase in GMS5 exports to and imports from the world. Consequently, the share of PRC in the exports and imports of GMS5 increased. Share of exports to PRC in total GMS5 exports increased by 2.2 times—from 6.3% in 2000 to 14.0% in

Table 4: Total exports and imports of GMS countries

	Exports (US\$, billions)			Imports (US\$, billions)		
	2000	2008	2009	2000	2008	2009
GMS	336.37	1,682.03	1,423.37	307.07	1404.69	1221.8
of which						
PRC	249.2	1,430.69	1,201.65	225.09	1,132.56	1,005.56
GMS5	87.17	251.34	221.72	81.98	272.13	216.24
of which						
Cambodia	1.54	5	4.83	1.28	4.09	3.62
Lao PDR	0.35	1.39	1.34	0.6	2.52	2.6
Myanmar	1.98	6.35	5.95	2.54	6.2	6.3
Thailand	68.82	175.91	152.5	61.92	178.61	133.77
Viet Nam	14.48	62.69	57.1	15.64	80.71	69.95

Source: UNCOMTRADE and authors' estimates.



2009 (Figure 21A). Similarly, share of imports from PRC in total GMS5 imports went up from 6.6% to 16.6%, an increase of 2.5 times (Figure 21B).

Second, intra-GMS5 exports (and by definition imports) grew by 19.1%, from \$2.9 billion in 2000 to \$14.1 billion in 2009. Intra-GMS5 exports (imports) as share of total GMS5 exports (imports) almost doubled between 2000 and 2009. Intra-GMS5 exports as a share of total GMS5 exports increased from 3.4% in 2000 to 6.4% in 2009 and the share of intra-GMS5 imports in total GMS5 imports increased from 3.6% in 2000 to 6.5% in 2009.¹⁰

Third, commensurate with an increase in dependence on markets and suppliers within the GMS5 and PRC, share of rest of the world in GMS5 exports and imports declined. However, the share of exports to and imports from non-GMS ASEAN5 as a share of total GMS5 exports and imports declined only marginally. On the other hand, the

share of the rest of the world (i.e., excluding non-GMS ASEAN5) declined by about 10 percentage points.

Thus, there seems to have been a change in the direction of the trade during 2000-2009 and a “rebalancing” of sources of demand and supply away from the rest of the world towards other GMS trading partners.

The dependence of each of the GMS member countries on trade with different trading partners varies. Among the GMS countries, Lao PDR and Myanmar are the most dependent on trade with GMS followed by Cambodia.¹¹

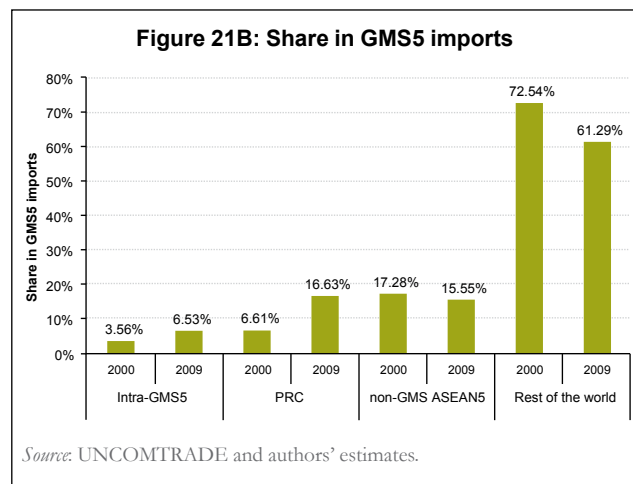
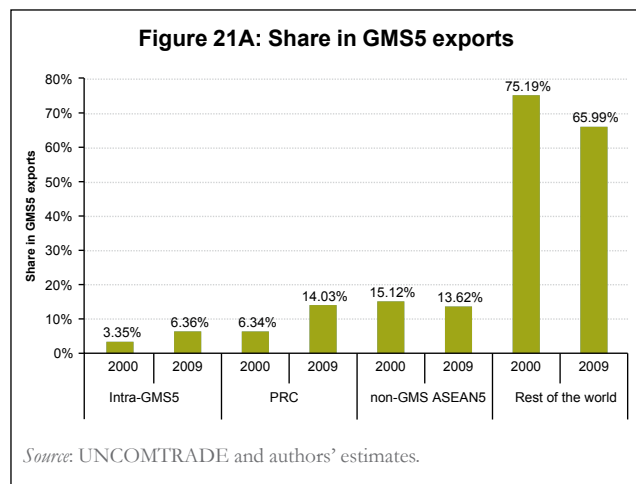
The size of intra-GMS (i.e., GMS5 and PRC taken together) trade increased from \$13.87 billion in 2000 to \$81.17 billion in 2009, an average annual growth rate of 21.7%.¹² PRC and Thailand account for the bulk of the intra-regional trade flows throughout the period 2000 to 2009.

Looking at shares from the export side, 39.1% of the intra-GMS exports in 2000, and 44.3% in 2009, originated from PRC (Figure 22, Panels A and B). These were headed to other GMS countries (i.e., GMS5 countries). Similarly on the import side, 39.9% of the intra-GMS imports in 2000, and 38.3% in 2009, were headed to PRC (Figure 22, Panels C and D). These trade flows originated in the GMS5 countries. Thus, GMS5 countries imported more from PRC than from each other and exported less to PRC and slightly more to each other in 2009 compared with what they did in 2000.

¹⁰ By definition, total intra-GMS5 exports are the same as intra-GMS5 imports. However, the shares are different because of different denominators, total GMS5 exports to the world vis-à-vis total GMS5 imports from the world.

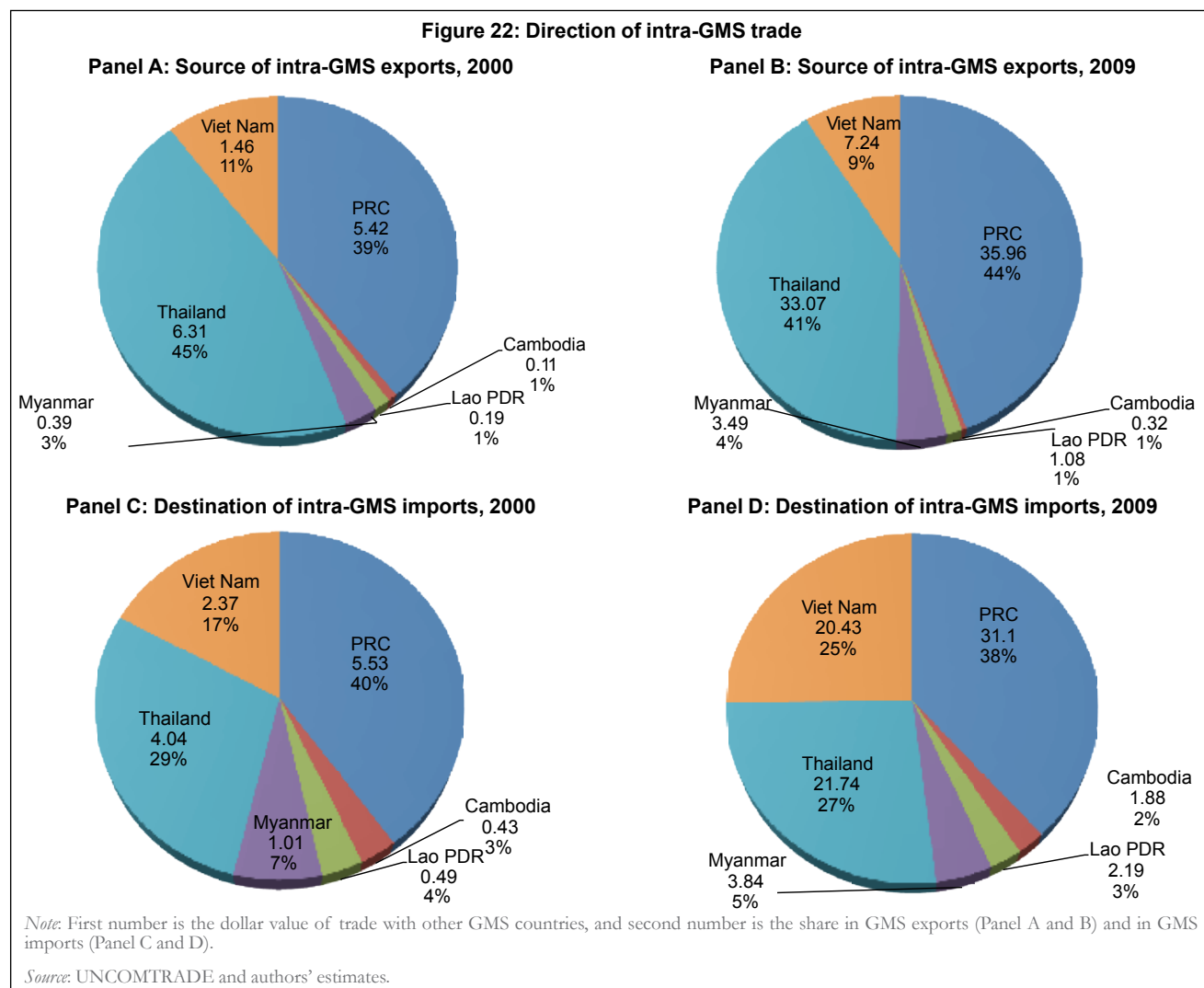
¹¹ Appendix Figure 1 (Panel A-L) shows the size and the direction of exports and imports of the individual GMS countries for the years 2000 to 2009.

¹² By definition, size of intra-GMS exports will equal intra-GMS imports.



In other words, 82% (44%+38%, Figure 22 Panel B and D) of the intra-GMS trade flows in 2009 (up from 79% in 2000) involved PRC, either as a market or a supplier for GMS5 countries. Only 18% of the intra-GMS trade in 2009 was among the GMS5 countries and did not involve PRC.

Thailand and Viet Nam are the other countries which account for a large share of trade flows within the GMS region. Thailand accounted for as much as 41% of the intra-GMS exports (note that this also includes exports to PRC as these are intra-GMS and not just intra-GMS5).



Viet Nam's share in the intra-GMS imports increased by 8 percentage points between 2000-2009.

CLM countries were the source for about 6% (including exports to PRC) of the intra-GMS exports in 2009 (compared with 5% in 2000). About 10% (including imports from PRC) of the intra-GMS imports were headed to CLM countries in 2009 (a decline of 4 percentage points compared with 2000). Thus, only 16% of the intra-GMS trade in 2009 involved CLM countries; the remaining 84% of the intra-GMS trade was among PRC, Thailand, and Viet Nam.

In terms of composition, 67% of the total exports of GMS5 countries is manufacturing and the rest, 33% is primary commodities. Similarly, on the import side, 70% of the total imports of GMS5 countries is manufacturing products and 30% is primary commodities (Figure 23A).¹³ During 2000-2009, the share of manufacturing in both total exports and imports declined by 5 and 7 percentage points, respectively. Of the 10.9% percent growth in exports during 2000-2009, 64% (i.e., 7 percentage points) came from growth in exports of manufacturing products and the rest 3.9 percentage points from primary export growth. Similarly on the import side, manufacturing accounted for two-thirds of the import growth and primary products for one-third of the total import growth of 11.4% during 2000-2009 (Figure 23B).

However, the composition varies by direction of trade as shown in Table 5. Intra-GMS5 trade (by definition export or import) is almost equally split between manufacturing and primary commodities. Further, the share of primary commodities in intra-GMS trade increased from 40.4% in

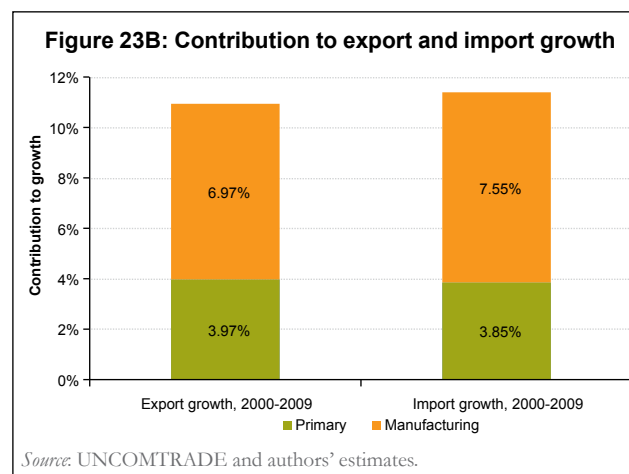
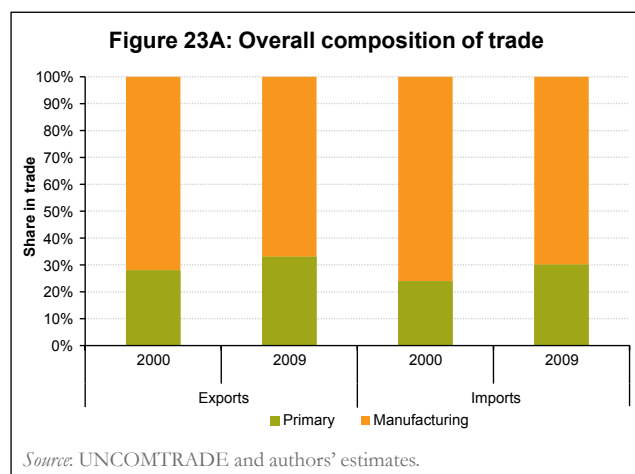
2000 to 51.3% in 2009. On the other hand, manufacturing products have the largest share in the exports of and imports of GMS5 from PRC and rest of the world and the share of manufacturing products increased during 2000-2009.

Figures 24 (Panel A-F) and 25 (Panel A-D) show a more disaggregated composition of exports and imports in 2000 and 2009, differentiating among the trading partners. The main export items (in 2009) for intra-GMS trade were fuel (32%); machinery and transport equipment (20%); food and beverages (11%); and chemicals (9%).

Almost half of exports to PRC in 2009 were machinery and transport equipment (49.7%). Other main export items to PRC include chemicals, fuel, and agricultural raw materials. In 2009, machinery and transport was the main export item to the rest of the world as well (29%), though its share declined from 37% in 2000, followed by food and beverages (18%) and textiles, apparels and travel goods (12%)

By definition of intra-regional trade, the composition of intra-GMS5 imports is the same as that of intra-GMS5 exports (Figure 24, Panel A and B). From PRC, machinery and transport equipment; chemicals; non-metallic minerals etc.; and textiles, apparels, and travel goods were the main import items of GMS5 in 2009 (Figure 25, Panel B). From rest of the world the main import were machinery and transport equipment; fuel; chemicals; and non-metallic minerals, metals, iron and steel.

The overall export structure of the GMS5 hides differences in the export structure across the GMS5 countries.



¹³ Primary commodities are defined to include SITC (Rev. 2) codes 0, 1, 2, 3, 4, 68, and 97. Manufacturing products comprise of SITC (Rev. 2) codes 5 to 9 except 68 and 97. See Appendix 1 for further details.

Table 5: Composition of trade (by direction)

Panel A: Share in exports of the GMS5 countries (%)				
Destination of exports	2000		2009	
	Primary	Manufacturing	Primary	Manufacturing
Exports to PRC	41.05	58.95	28.30	71.70
Intra-GMS5 Exports	40.41	59.59	51.31	48.69
Exports to rest of the world	26.56	73.44	32.42	67.58
Panel B: Share in imports of the GMS5 countries (%)				
Source of imports	2000		2009	
	Primary	Manufacturing	Primary	Manufacturing
Imports from PRC	13.33	86.67	11.91	88.09
Intra-GMS5 imports	40.41	59.59	51.31	48.69
Imports from rest of the world	24.07	75.93	32.22	67.78

Source: UNCOMTRADE and authors' estimates.

The composition of the imports of the individual GMS5 countries is, however, fairly similar. The share of primary and manufacturing commodity export and imports in each of the GMS member countries is shown in Figure 26 (Panels A and B). Appendix Figure 2 (Panels A-L) show a more disaggregated export and import structure of the GMS countries in 2000 and 2009 (by trading partners). A few observations stand out.

First, export baskets of Lao PDR and Myanmar comprise largely of primary products (Figure 26 Panel A). Viet Nam's export basket used to have a greater share of primary products (54%) in 2000, but the share of primary product declined to 40% by 2009. PRC's and Thailand's export basket continue to consist primarily of manufacturing products.

Second, Cambodia's overall export basket is dominated by manufacturing products, mainly garments. However, composition of Cambodia's export basket differs by destination (Appendix Figure 2, Panel C). While, Cambodia's exports to other GMS5 countries and PRC comprised largely of primary products—90% and 50%, respectively in 2009, primary products accounted for only 10% of the exports to the rest of the world. Since absolute export values for trade with the rest of the world are higher, they dominate the pattern for the overall exports shown in Figure 26 (Panel A). Further, while the structure of intra-GMS5 exports and those to the rest of the world has not changed much from 2000 to 2009, share of primary products in exports to PRC increased from 13.6% in 2000 to 47.6% in 2009.

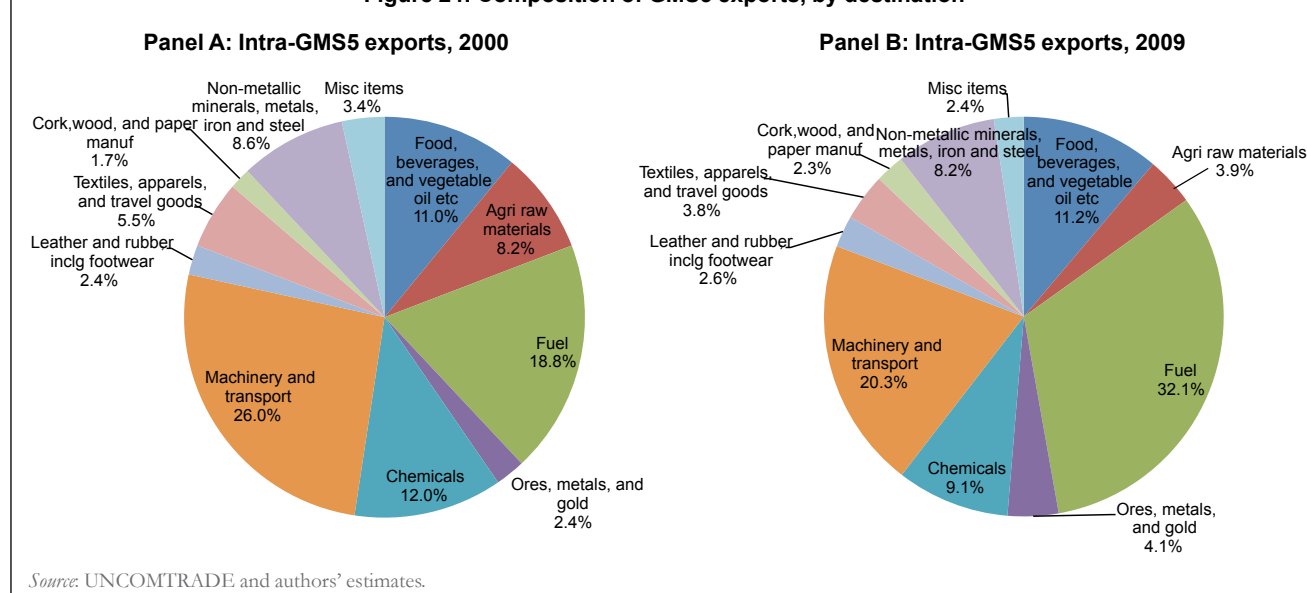
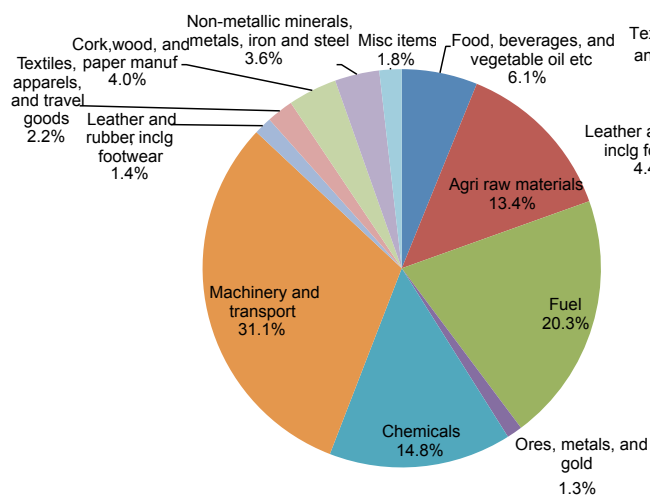
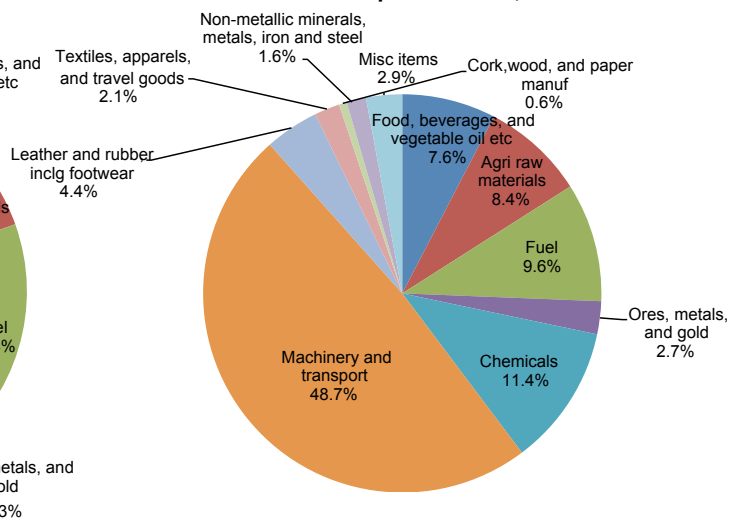
Figure 24: Composition of GMS5 exports, by destination

Figure 24: Composition of GMS5 exports, by destination (continued)

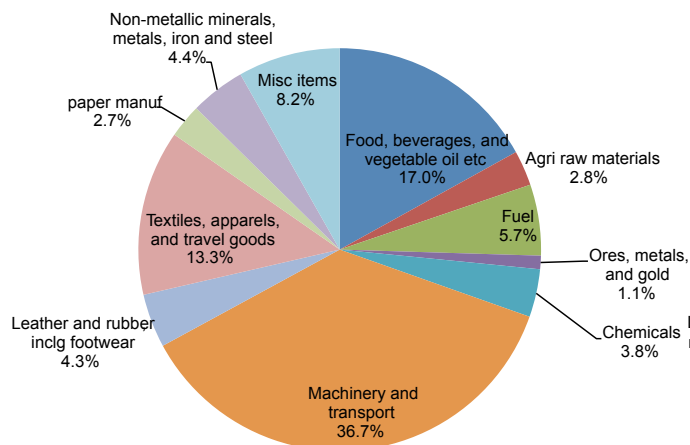
Panel C: Exports to PRC, 2000



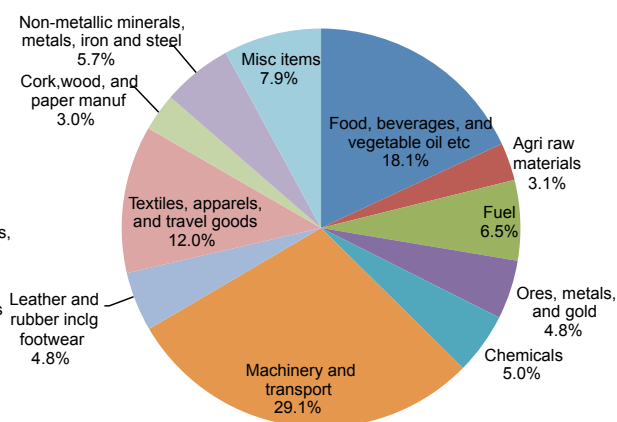
Panel D: Exports to PRC, 2009



Panel E: Exports to rest of the world, 2000



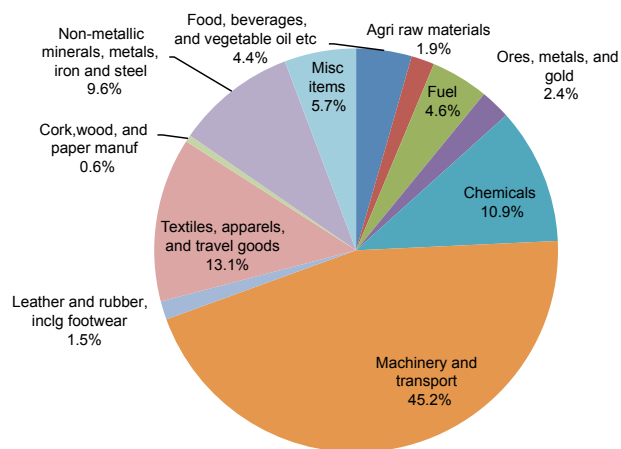
Panel F: Exports to rest of the world, 2009



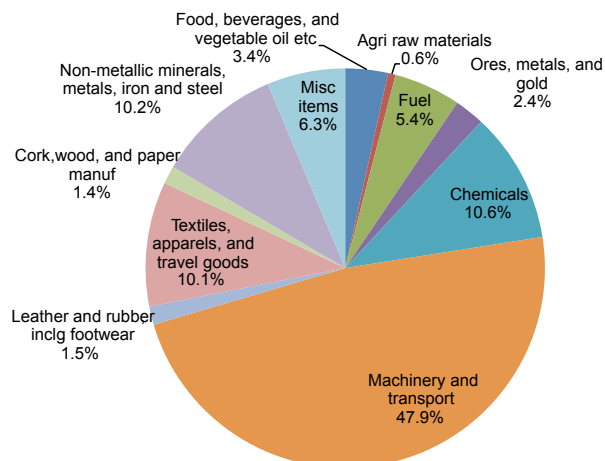
Source: UNCOMTRADE and authors' estimates.

Figure 25: Composition of GMS5 imports, by origin

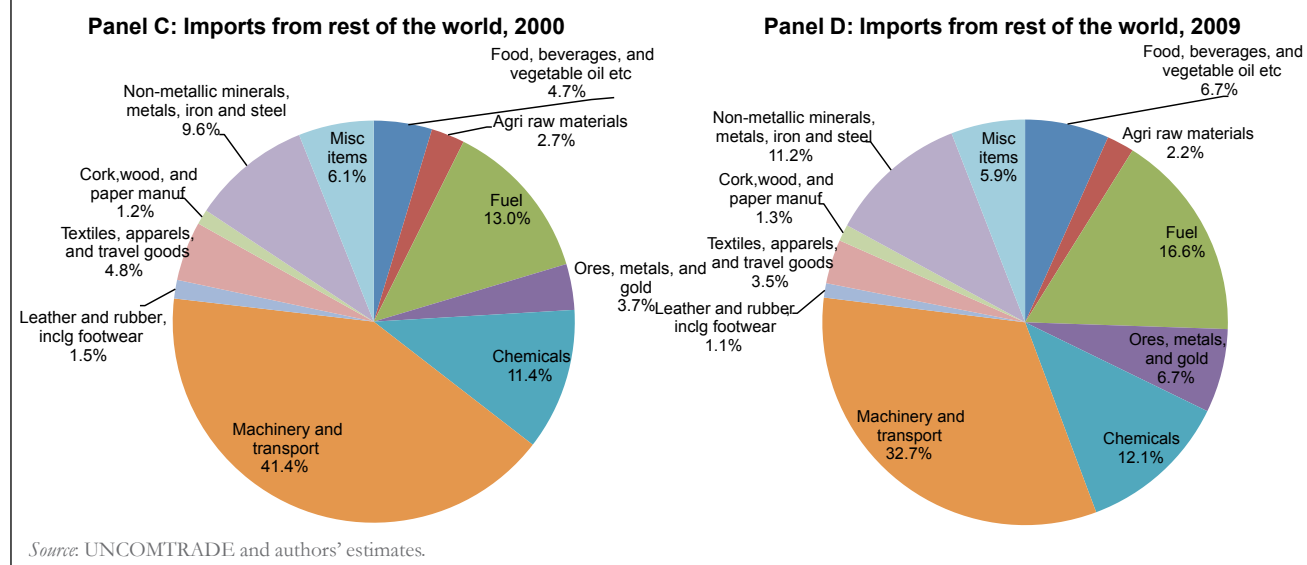
Panel A: Imports from PRC, 2000



Panel B: Imports from PRC, 2009



Source: UNCOMTRADE and authors' estimates.

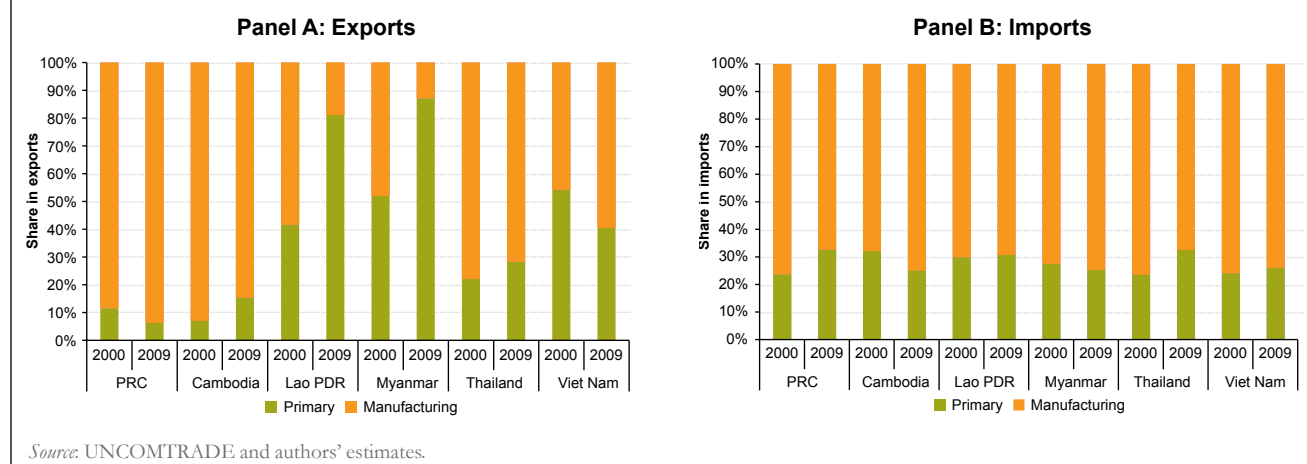
Figure 25: Composition of GMS5 imports, by origin (continued)

Third, similarly, there is a difference in export composition of Lao PDR, Myanmar, and Viet Nam to other GMS5 countries, their exports to PRC and to the rest of the world. In the case of Lao PDR, while intra-GMS5 exports and exports to PRC are largely primary in nature, exports to the rest of the world consist largely of textiles and garments (Appendix Figure 2, Panel E). Difference in Myanmar's export basket by destination is on account of the type of primary commodities exported to other GMS5 countries vis-à-vis PRC and the rest of the world (Appendix Figure 2, Panel G).

Fourth, as shown in Figure 24 (Panels A-F) exports of machinery and transport equipment account for roughly one-third of total GMS exports. However, machinery and transport figure prominently in the exports of only

two countries—Thailand and, more recently, Viet Nam (Appendix Figure 2, Panel I and Panel K). In other words, there is little export of machinery and transport equipment from the other GMS5 countries.

Fifth, there is little correlation in the exports of CLM countries, on one hand, and Thailand and Viet Nam, on the other hand, to other GMS5 countries and PRC (Appendix Figure 2). Similarly, exports of Thailand to the rest of the world are different from that of CLM countries and also from that of Viet Nam. Manufacturing exports from Viet Nam result in higher correlation between the exports baskets of Thailand and Viet Nam to the rest of the world. Because, Viet Nam's exports to the rest of the world also consist of primary products, its export basket to the rest of the world shows a high correlation with CLM countries.

Figure 26: Composition of trade of the GMS countries

Sixth, the import basket of all the GMS countries consists largely of manufacturing products (Figure 26, Panel B), with little difference across time or across trading partners (Appendix Figure 2). A few exceptions are noteworthy. Thailand's imports from other GMS5 countries have become more oriented towards primary products during 2000-2009 (Appendix Figure 2 Panel J). Share of primary products in Thailand's imports from GMS5 increased from 63% in 2000 to 81% in 2009. Also, imports from GMS5 are more of a primary nature than imports from PRC and rest of the world. 81% of the imports from GMS5 in 2009 were primary products, compared with 8% from PRC and 34% from rest of the world.

Finally, the structure of GMS5 exports to and imports from each of the three destinations/sources has more or less remained constant (as measured by high correlation) during 2000-2009. There are a few exceptions where the composition of export or the import basket has changed (shown in different panels of Appendix Figure 2). These include Cambodia's exports to PRC (Panel C), Lao PDR's exports to PRC and other GMS5 countries (Panel E), Myanmar's exports to the rest of the world (Panel G), and Thailand's imports from other GMS5 countries (Panel J).

4. Pattern of FDI in the GMS countries

The second channel through which the GMS countries have sought to integrate with the rest of the world is the foreign investment. Dunning's (1973) "OLI" framework categorizes the drivers of FDI into three groups: ownership (O)—why go abroad—these refer to firm specific advantages such as brand name, niche products, human capital etc.; location (L)—where to go—economic, cultural, historical factors; and internalization (I)—mode of entry—wholly owned subsidiary or a equity stake vis-à-vis other arrangements such as exports or licensing or franchising. Among these three drivers, while two are firm-specific (ownership and internalization), the third, location, which refers to host country characteristics is of greatest interest here.¹⁴

Economic characteristics driving FDI can be divided into three kinds—resource-seeking FDI, efficiency-seeking

FDI, and market-seeking FDI.¹⁵ Resource-seeking FDI is driven by the need to access particular resources in the host country. These resources could either be natural resources, raw materials, or even a large labor pool. Efficiency-seeking FDI, on the other hand, is motivated by the desire to look for efficient production centers. Factors determining this kind of FDI include productivity-adjusted labor costs, quality of skilled labor, macroeconomic environment, trade policy, and quality of hard infrastructure and soft infrastructure (for example, transport and trade facilitation). In recent years, with a fall in trade costs and advances in information and communication technologies, production processes have been fragmented to take advantage of the most efficient location for production. However, for cross-country supply chains to work, hard infrastructure and seamless movement of goods and trucks across borders are critical. Market-seeking FDI seeks to take advantage of the market size of the host country. Growth in the size of the home country markets, domestic investment regime, regional integration in the form of free trade areas which further expands the size of the market also play a role in determining the location of the market-seeking FDI.¹⁶

In some cases FDI may be driven exclusively by one of the three motives above. For example, FDI in resource-rich countries is guided by the availability of resources in host countries. However, more often than not, FDI in other cases is the interplay of all the three, i.e., its resource, efficiency, and market driven. For example, before PRC's accession to WTO, inward FDI was driven by its large labor pool (resource-driven), low labor costs after adjusting for productivity (efficiency-driven), and the size of the huge market which was protected behind tariff walls (market-driven).

The total stock of outstanding inward FDI stock in the world increased by approximately ten times from \$2.1 trillion in

¹⁴ While the discussion here has been compartmentalized to focus on host country characteristics, the decision of a firm to invest in a country is likely to be the result of interplay among the three categories. For example, decision on the mode of entry may depend among other things on the foreign investment regime of the host country, business facilitation services as well as the strength of its legal system which will be critical for a firm to safeguard its intellectual property.

¹⁵ Another type of distinction that is made in the theoretical literature is that between horizontal and vertical FDI. Vertical FDI involves fragmentation of the production process and relocation of certain stage of production to another country, and is likely to be guided by differences in relative factor endowments across countries (Helpman 1984). Horizontal FDI, on the other hand, involves operating a self-contained plant in the host country and is driven by market access and low fixed costs of setting up new plants (Markusen 1984). Markusen (2002) combines both the forms of FDI into a "knowledge-capital" model in which FDI is motivated by both market access and factor endowment differences.

¹⁶ With regard to FDI being attracted by the size of the integrated markets, not all countries in the regional integration may benefit as FDI may be concentrated in one or two countries. Also if the regional integration raises trade barriers for non-members, efficiency-seeking FDI may be undermined and this may offset some of the benefits of market-seeking FDI (Nunnenkamp 2001).

1990 to \$19.1 trillion in 2010. Of the total stock of inward FDI in 1990, 24.9% was accounted for by developing and transition economies and the rest by developed countries (Table 6). The share of developing economies in the stock of inward FDI increased to 34.7% in 2010 from 24.9% in 1990. Developing Asia accounted for 19.1% of the total FDI inward stock in 2010, up from 16.5% in 1990.

As shown in Table 6 (and later in Table 7 for outward FDI), PRC has attracted a lion's share of inward FDI and far exceeds the FDI attracted by the GMS5 countries. Among

the GMS countries, PRC had the highest share of world inward stock of FDI amounting to \$578.8 billion in 2010 (3% of the world total), up from 1% in 1990. Therefore, similar to the analysis of trade patterns above, GMS5 is discussed separately from PRC to avoid the patterns being dominated by FDI statistics for PRC. The stock of GMS5 countries in 1990 was \$10.2 billion (0.5% of the world stock of inward FDI). This increased by twenty times to \$209.2 billion (and amounted to 1.1% of the world stock of inward FDI) in 2010.

Table 6: Stock and flows of inward FDI (US\$ billions)

	Stock of inward FDI			Cumulative flow of inward FDI	
	1990	2000	2010	1990-1999	2000-2010
World	2,081.3 (100.0)	7,445.6 (100.0)	19,140.6 (100.0)	4,021.2 (100.0)	12,759.1 (100.0)
Developed economies	1,562.3 (75.1)	5,653.2 (75.9)	12,501.6 (65.3)	2,796.5 (69.5)	8,041.5 (63.0)
Developing and transition economies	519.0 (24.9)	1,792.4 (24.1)	6,639.0 (34.7)	1,224.7 (30.5)	4,717.6 (37.0)
Developing Asia	342.9 (16.5)	1,072.7 (14.4)	3,663.0 (19.1)	690.3 (17.2)	2,534.3 (19.9)
<i>of which</i>					
Cambodia	0.038 (0.002)	1.6 (0.02)	6.0 (0.03)	1.2 (0.03)	4.5 (0.04)
Lao PDR	0.013 (0.001)	0.6 (0.008)	2.1 (0.01)	0.5 (0.01)	1.5 (0.01)
Myanmar	0.28 (0.014)	3.2 (0.04)	8.3 (0.04)	3.6 (0.1)	4.8 (0.0)
Thailand	8.2 (0.40)	29.9 (0.4)	127.3 (0.7)	31.8 (0.8)	71.1 (0.6)
Viet Nam	1.6 (0.08)	20.6 (0.3)	65.6 (0.3)	13.3 (0.3)	43.4 (0.3)
GMS5	10.2 (0.49)	55.9 (0.8)	209.2 (1.1)	50.5 (1.3)	125.3 (1.0)
PRC	20.7 (0.99)	193.3 (2.6)	578.8 (3.0)	290.4 (7.2)	792.2 (6.2)
Total GMS	30.9 (1.5)	249.2 (3.3)	788.0 (4.1)	340.9 (8.5)	917.5 (7.2)
Brunei Darussalam	0.033 (0.002)	3.9 (0.1)	11.2 (0.06)	3.3 (0.1)	7.9 (0.1)
Indonesia			121.5 (0.6)		49.1 (0.38)
Malaysia	7.4 (0.35)	28.7 (0.4)	44.5 (0.2)	48.2 (1.2)	51.1 (0.4)
Philippines	1.8 (0.09)	10.1 (0.1)	15.0 (0.1)	11.9 (0.3)	18.1 (0.1)
Singapore	10.6 (0.51)	65.6 (0.9)	194.6 (1.0)	84.8 (2.1)	215.3 (1.7)
ASEAN5	19.9 (0.96)	108.4 (1.5)	386.8 (2.0)	148.2 (3.7)	341.4 (2.7)
Total ASEAN	30.1 (1.45)	164.3 (2.2)	596.0 (3.1)	198.6 (4.9)	466.7 (3.7)

Source: UNCTAD and authors' estimates. Note: Figures in brackets are percentages of world total.

Table 7: Stock and flows of outward FDI (US\$ billions)

	Stock of outward FDI			Cumulative flow of outward FDI	
	1990	2000	2010	1990-1999	2000-2010
World	2,094.2	7,962.2	20,408.3	4,183.6	12,892.6
	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)
Developed economies	1,948.1	7,083.5	16,803.5	3,727.4	10,613.6
	(93.0)	(89.0)	(82.3)	(89.1)	(82.3)
Developing and transition economies	145.5	878.7	3,604.7	456.2	2,279.0
	(6.9)	(11.0)	(17.7)	(10.9)	(17.7)
Developing Asia	67.6	608.4	2,276.2	326.2	1,426.2
	(3.2)	(7.6)	(11.2)	(7.8)	(11.1)
<i>of which</i>					
Cambodia		0.19	0.3	0.03	0.17
		(0.002)	(0.002)	(0.00)	(0.001)
Lao PDR	0.001	0.026		0.02	(0.02)
	(0.0000)	(0.0003)		(0.0004)	(-0.0001)
Myanmar					
Thailand	0.4	2.2	25.5	4.1	19.1
	(0.02)	(0.03)	(0.1)	(0.1)	(0.1)
Viet Nam					2.2
					(0.02)
GMS5	0.4	2.4	25.8	4.1	21.4
	(0.02)	(0.0)	(0.1)	(0.10)	(0.17)
PRC	4.5	27.8	297.6	23.2	251.2
	(0.21)	(0.3)	(1.5)	(0.6)	(1.9)
Total GMS	4.9	30.2	323.4	27.4	272.6
	(0.2)	(0.4)	(1.6)	(0.7)	(2.1)
Brunei Darussalam	0.0001	0.5	0.7	0.5	0.2
	(0.000)	(0.01)	(0.003)	(0.01)	(0.002)
Indonesia			1.7		24.9
			(0.01)		(0.2)
Malaysia	0.8	15.9	96.8	15.0	64.3
	(0.04)	(0.2)	(0.5)	(0.4)	(0.5)
Philippines	0.4	2.0	6.6	1.5	5.9
	(0.02)	(0.03)	(0.03)	(0.04)	(0.05)
Singapore	7.8	56.8	300.0	46.4	142.4
	(0.37)	(0.7)	(1.5)	(1.1)	(1.1)
ASEAN5	9.0	75.2	405.7	63.5	237.6
	(0.43)	(0.9)	(2.0)	(1.5)	(1.8)
Total ASEAN	9.4	77.6	431.5	67.6	259.0
	(0.45)	(1.0)	(2.1)	(1.6)	(2.0)

Source: UNCTAD and authors' estimates.

Note: Figures in brackets are percentages of world total.

In terms of flows, the total inward flow of FDI in the world (Table 6) during 2000-2010 (2000s) was \$12.8 trillion, up from \$4 trillion during 1990-1999 (1990s). The share of developing and transition economies in the cumulative flows increased from 30.5% in 1990s to 37.0% during 2000s. Developing Asia received one-fifth of the cumulative during 2000s, an increase of approximately 3 percentage points compared with the 1990s. Among the GMS countries, PRC received \$792.2 billion worth of FDI during 2000s (up from \$290.4 billion during 1990s). PRC's share in the world flows of FDI fell from 7.2% during 1990s

to 6.2% during 2000s. GMS5 received a total of \$125.3 billion worth of FDI during 2000s (0.98% of the world total) compared with \$50.5 billion during 1990s (1.26% of the world total).

In the last two decades, not only has the share of inward FDI to the developing countries increased but their share in outward FDI has also increased. The total stock of outward FDI in the world in 2010 was \$20.4 trillion (Table 7), ten times more than the stock of outward FDI in 1990 (\$2.1 trillion). In 1990, developing and transition economies

accounted for 6.9% of the total stock of outward FDI. This share more than doubled to 17.7% in 2010. Developing Asia's share of the total stock of outward FDI increased from 3.2% in 1990 to 11.2% in 2010. The share of outward stock of FDI from PRC (\$4.5 billion) increased from 0.2% of the world stock of FDI in 1990 to 1.5% in 2010 (amounting to \$297.6 billion).

The share of developing and transition economies in the cumulative flow of outward FDI in the world increased from 10.9% in 1990s to 17.7% during 2000s. Developing Asia's share in the cumulative outward flow of FDI increased from 7.8% of the world flows in 1990s to 11.1% in 2000s. Among the GMS countries, PRC's share in the world flows of outward FDI increased by three times from 0.56% in 1990s to 1.95% during 2000s.

In addition to the drivers of FDI mentioned above, outward FDI from developing countries is likely motivated by other factors. These include expanding beyond national markets to establish a presence in regional and global markets, desire to obtain access to advanced technology in developed countries through setting up of research and development centers, and the so-called "supplier following assembler" FDI where local suppliers in the host countries follow the assembler if the latter moves to a new location outside the country (Hiratsuka 2006).

A large share of outward FDI from developing economies is of the "south-south" kind, i.e., the FDI that is headed for other developing economies (UNCTAD 2006, pp. 117). Further, bulk of the south-south FDI is intra-regional. For example, intra-regional FDI flows in East, South, and Southeast Asia accounted for half of the FDI flows to the region during 2002-2004 (UNCTAD 2006, pp. 54), majority of which is between and within East and Southeast Asia.

The phenomenon of growing outward FDI from developing economies, especially that from developing Asia, has gathered attention in the literature on FDI. Recent studies such as Hattari and Rajan (2008), Hill and Jongwanich (2009), Hiratsuka (2006), Menon and Melendez (2011), Plummer and Cheong (2007), and UNCTAD (2006) have analyzed the pattern and drivers of outward FDI flow from developing economies, and in particular from developing Asia with a focus bilateral FDI flows within Asia and/or ASEAN.

Table 6 and 7 also show the inward and outward FDI stock and cumulative flow of each of the GMS5 member countries. Among the GMS5, Thailand is the major

recipient of FDI followed by Viet Nam. For outward FDI from GMS5, Thailand is a major source of outward FDI with a small amount originating in Viet Nam as well (Table 7).

For comparison with other countries in the region, also shown are the FDI statistics of the other ASEAN countries in Table 6 and 7. The inward FDI into ASEAN5 exceeds that of GMS5, however most of it is accounted for by Singapore. Among all the ASEAN countries, Thailand is the second largest recipient of FDI after Singapore. Similarly in terms of outward FDI, ASEAN5 exceeds GMS5 and Singapore is the largest source of FDI among all the ASEAN countries followed by Malaysia.

The analysis above examined the size of the overall inward and outward FDI of the GMS5 countries. Of particular interest is the source of inward FDI and direction of outward FDI of the GMS5 countries as well as the share of those flows originating from within the GMS and from non-GMS ASEAN5 countries. This is examined next for the period 2000-2008. The shorter time period is due to the lack of availability of consistent data for the entire ten year period, 2001-2010.

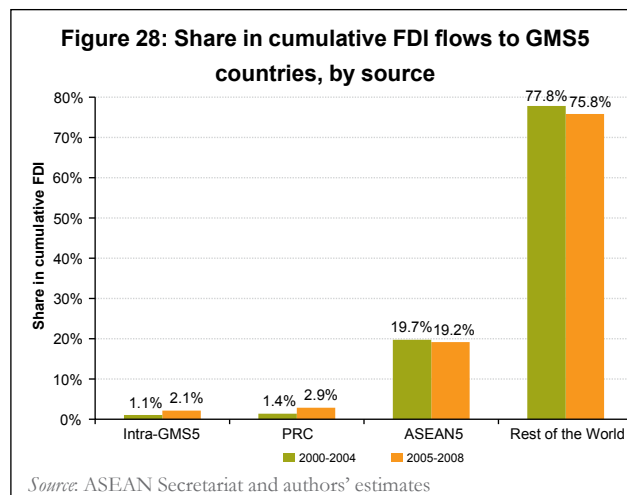
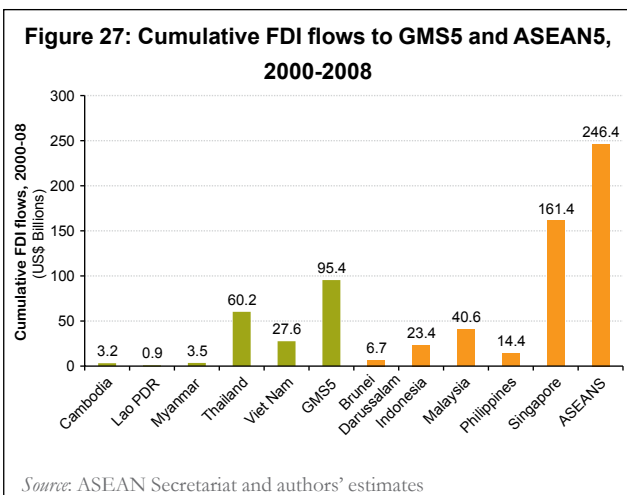
Over the period 2000-2008, total inward FDI flows into the GMS5 countries amounted to \$95.4 billion which was less than half of the cumulative FDI inflows in ASEAN5, \$246.4 billion, during the same period (Figure 27). Among the GMS5 countries, 63% of the total FDI inflow during 2000-2008 is accounted for by Thailand and 29% by Viet Nam. Lao PDR accounted for only 0.9% of the cumulative FDI in GMS5 during 2000-2009. The rest is distributed almost equally between Cambodia and Myanmar. Almost 65% of ASEAN5's cumulative FDI inflow during 2000-2008 is accounted for by Singapore.

Figure 28 shows the share of different sources in the cumulative FDI inflows to GMS5 countries during 2000-2004 and 2005-2008. FDI inflows from the rest of the world to GMS5, during both the sub-periods, accounted for the largest share of total cumulative FDI inflows and ASEAN5 accounted for about a fifth of the cumulative FDI inflows. PRC accounted for 1.4% during 2000-2004 and 2.9% during 2005-2008. Share of cumulative FDI inflow originating from within the GMS5 was 1.1% during 2000-2004 and it increased to 2.1% during 2005-2008. The share of the cumulative FDI inflows coming from the rest of the world declined marginally from 2000-2004 to 2005-2008. Commensurate with the decline in the share of FDI inflows from the rest of the world, share of FDI inflows originating in other GMS5 countries and PRC doubled.

Table 8: Cumulative inward FDI flows to GMS5 countries, by source (%)

Source→ Host	2000-2004				2005-2008			
	Intra-GMS5	PRC	ASEAN5	Rest of the World	Intra-GMS5	PRC	ASEAN5	Rest of the World
Cambodia	9.7	16.9	5.1	68.3	16.8	18.6	14.5	50.1
Lao PDR	18.4	20.1	7.0	54.5	20.1	7.1	1.5	71.3
Myanmar	1.8	10.0	15.8	72.4	11.9	29.8	1.2	57.2
Thailand	0.1	0.2	22.9	76.8	-0.1	0.4	23.4	76.2
Viet Nam	3.0	2.1	11.5	83.5	2.6	2.1	14.8	80.5

Source: ASEAN Secretariat-ASEAN FDI Database and authors' estimates.



However, the share of GMS5 and PRC in total FDI inflows into GMS5 remained low, at 2.1% and 2.9% respectively.

Table 8 shows the shares of cumulative FDI inflows for each of the GMS5 countries during 2000-2008. All the countries in the GMS5, get the bulk of their FDI inflows from outside the region (i.e., rest of the world not including GMS5, ASEAN5, and PRC) as shown in the last column under each sub-period.

Among the GMS5, Cambodia, Lao PDR, and Myanmar are relatively more dependent on FDI originating from other GMS5 countries and PRC (Table 8), though they still get most of their FDI from rest of the world. Viet Nam gets most

of its FDI from rest of the world and a small share from GMS5, which is largely from Thailand. (Table 9). Thailand, on the other hand, relies mostly on ASEAN5 and rest of the world for FDI inflows and GMS5 and PRC combined account for less than 1% of the FDI inflows into Thailand.

PRC's total FDI outflows to GMS5 countries during 2000-2008 amounted to US\$2,261 million. This was more than the total FDI outflows of any of the GMS5 countries to other GMS5 countries (Table 9, second-last row). For FDI flows originating within the GMS, Thailand is the second major source (after PRC) of FDI going to other GMS5 countries with Viet Nam a distant third. Of the total FDI inflows to GMS countries during 2000-2008 coming from PRC, the

Table 9: Bilateral cumulative FDI flows (in US\$ million), 2000-2008

	FDI Outward by						FDI inflow to GMS5				
	Cambodia	Lao PDR	Myanmar	Thailand	Viet Nam	PRC	From GMS5	From PRC	From ASEAN5	From Rest of the World	Total inward FDI
Cambodia		-	-	264	228	586	492	586	402	1,725	3,205
Lao PDR	0.03		0.45	152	24	79	176	79	20	612	886
Myanmar	-	-		295	5	815	300	815	206	2,167	3,488
Thailand	16	(36)	21		0.33	198	1	198	13,982	46,039	60,221
Viet Nam	2	25	-	705		584	732	584	3,854	22,419	27,588
Outward to GMS5	18	-11	21	1,417	257	2,261					
Total							1,702	2,261	18,463	72,962	95,388

Source: ASEAN Secretariat-ASEAN FDI Database and authors' estimates.

largest share, 36%, went to Myanmar. Intra-GMS FDI inflow in Cambodia, Lao PDR, and Myanmar is largely from PRC and Thailand. Viet Nam is also a major intra-regional source of FDI for Cambodia. Other than the FDI to Cambodia, Viet Nam is not a major source of FDI for other GMS5 countries. From among the GMS countries, FDI inflows to Viet Nam are largely from Thailand and PRC. FDI flows among Cambodia, Lao PDR, and Myanmar are minimal or none at all.

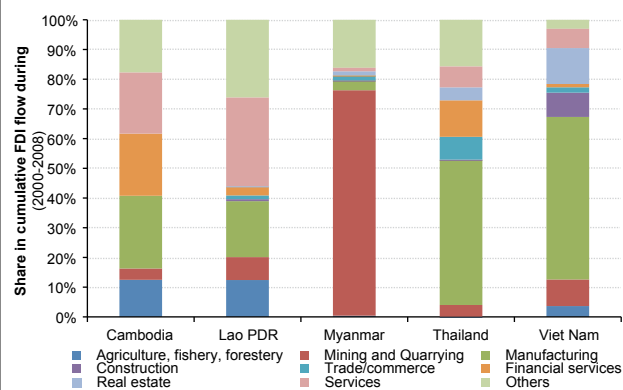
Figure 29 shows the sectoral distribution of the cumulative inward FDI flows in the GMS5 countries during 2000-2008. There are significant differences across the GMS5 countries. In Thailand and Viet Nam, manufacturing sector accounted for half, while in Myanmar mining and quarrying was the major recipient accounting for as much 75% of the total FDI flows during 2000-2008. In Thailand, apart from manufacturing sector, financial services also received significant FDI flows. Mining and quarrying, construction and real estate sectors also received significant FDI in Viet Nam, though their share remained below 10% compared with 55% share of manufacturing. In Cambodia, FDI was largely distributed across agriculture, manufacturing, financial services, and services. In Lao PDR the major recipients were agriculture, manufacturing, and services.

The distribution of FDI across sectors is largely in line with the share of sectors in exports. While exact comparison is not feasible due to lack of export data on similarly defined service sectors and lack of FDI data for disaggregated manufacturing sector, one can gauge the similarity of sectors receiving FDI and the key export sectors based on whether they are primary or secondary.

For example, Myanmar's exports of goods are largely primary in nature and the sector receiving the maximum share of FDI is mining and quarrying which is a primary sector. Similarly, in Thailand and Viet Nam, manufacturing products account for the largest share of exports and the manufacturing sector also is the major recipient of FDI. In Lao PDR and Cambodia, the export basket consists of both manufacturing and agricultural products and FDI inflows in both the countries is directed towards the two sectors along with FDI in service sectors.¹⁷

Since a large share of the FDI flowing into the GMS5 countries is of the resource-seeking type (for example in mining and quarrying sector in Cambodia, Lao PDR, and

Figure 29: Sectoral distribution of FDI inflows in GMS5 countries



Source: ASEAN Secretariat-ASEAN FDI database and authors' estimates.

Note: Sectoral distribution of FDI flows into Cambodia is for 2001-2008.

Myanmar) or efficiency-seeking (in manufacturing sectors in the GMS5 countries to take advantage to the most efficient location for production), the FDI inflows seem to be directed towards sectors of comparative advantage. At the same time, size of regional markets may also be determining FDI to take advantage of not only the domestic markets but also regional markets under the AFTA

5. Growth prospects of the GMS countries: 2010-2020

GMS5 economies are expected to maintain their growth over the next five years, 2011-2016. Table 10 shows the projected growth rates of the GMS countries for 2011, 2012, and average annual growth rates for 2013-2016.

Table 10: Projected GDP growth rates (%), 2011-2016

	2011	2012	2013-2016
Cambodia	6.8	6.5	7.4
PRC	9.3	9.1	9.5
Lao PDR	8.1	7.6	7.4
Myanmar	5.3	5.4	5.6
Thailand	4.0	4.5	4.9
Viet Nam	5.8	6.5	7.2

Source: Asian Development Outlook Update (September 2011) for 2011 and 2012, World Economic Outlook Database (September 2011) for 2013-2016, authors' estimates.

Cambodia, Lao PDR, and Myanmar are expected to maintain their pace of growth while the economies of PRC, Thailand, and Viet Nam are expected to slow down a bit. In PRC, weakened external environment and tightening monetary policy measures put in place to combat inflation are expected to contribute to a moderation in growth. In Thailand, slowdown in 2011 is expected on account of

¹⁷ Note that the discussion here is in terms of the share of primary and secondary sectors in total exports and total FDI.

earthquake in Japan earlier in the year and the associated disruption in supply chains, floods in Thailand later in the year which impacted key industrial zones, and on account of cautious consumer spending. Rehabilitation and reconstruction efforts later in the year and 2012 are likely to provide an impetus to growth. In Viet Nam, tightening fiscal, monetary, and credit policies put in place in the first quarter of 2011 to contain inflation are likely to slowdown growth in 2011.

However, there are some downside risks to the growth prospects of the GMS countries. They are likely to face a weak external environment on account of the sovereign debt crisis in the advanced economies. Any deterioration of the debt situation, especially in Europe, and its ensuing impact on the banking and the financial sector are likely to directly impact the GMS economies through both the trade channel, as demand will weaken further, and the finance channel as foreign investment flows dry up to meet obligations in the home country and to seek safer avenues. Lack of access to finance will also impact FDI flows.

Though there has been some rebalancing away from dependence on demand and finance from western economies, which can help soften the impact of weakening economic conditions, GMS5 are likely to see some indirect effects. There is a potential for a second round effect on the GMS5 economies as exports for final consumption from Japan and PRC are hit by weak external demand, which will trickle down the supply chain. Finally, a slowdown in PRC due to its own domestic measures and external conditions may also impact GMS5 economies as trade and investment ties with PRC have deepened in the 2000s.

In the long run, the development challenges that each of the GMS economies face are somewhat different. The resource-rich economies of Lao PDR and Myanmar need to tackle the challenges of macroeconomic management of resource revenues as well as generate sources of long-term and sustainable growth by diversifying their respective economic bases away from mining and agricultural sectors towards modern sectors. Similarly, Cambodia needs to diversify away from agricultural commodities and low-valued added manufacturing.

Myanmar needs to implement an ambitious and a wide-ranging reform agenda which includes liberalization of agriculture and trade, strengthening of macroeconomic management which is especially important in light of the stream of resource revenues expected from increased exports of natural gas, addressing weaknesses in

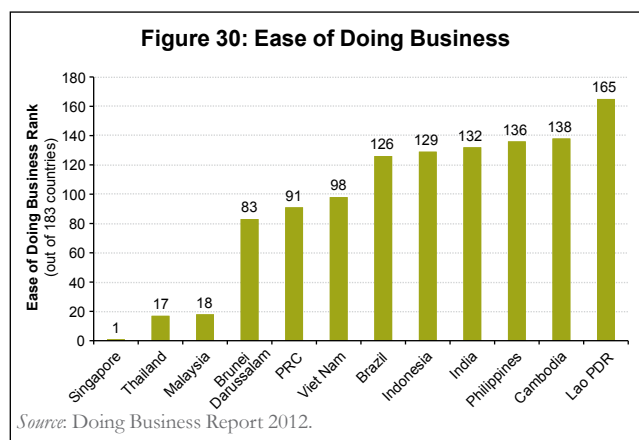
the financial sector, improving the business climate, generating fiscal resources to expand social and infrastructure spending, and reforming the tax system. Some steps have already been taken in this direction recently. These measures include (i) establishment of a new powerful Investment Commission and preparation of a new investment law to facilitate and attract FDI to non-natural resource based industries, (ii) privatization of state economic enterprises (SEEs) (60 of the 120 SEEs under the Ministry of Industry were privatized during 2011 and another 30 were expected to follow soon at the time of the writing of this paper), (iii) reduction of export taxes (from 10% to 2%) to promote exports, (iv) reducing the monetization of the deficit to fight inflation, and (v) allowing six private banks to open exchange rate windows and expanding credit for agriculture. Myanmar needs to balance its needs of using resource revenues in a way that meets the massive development needs of Myanmar without falling into the trap of “Dutch-disease”.

The long-term challenges in PRC, Thailand, and Viet Nam are somewhat different from the rest of the GMS economies. According to the World Bank’s classification, all the three countries are classified as middle-income countries. While the PRC and Thailand are in the upper-middle income category, Viet Nam is in the lower-middle income group. The challenge for PRC and Thailand is to avoid the middle-income trap, i.e., getting stuck in the middle-income category and not being able to transition to the high-income trap. In short, how do these countries keep growing? These countries not only need to continue moving up the value chain into higher value added products, away from simple assembly to product development but also implement other measures to support continued growth. These include strengthening of institutional and legal framework to encourage research and development, removing weaknesses in the financial sector, strengthening social safety nets, creating internal and regional sources of demand to reduce reliance on advanced economies which will ultimately help address the issue of global imbalances, investment in infrastructure, and a world class logistics sector, improving business climate, and promoting trade facilitation. The kind and depth of measures that will be needed across the three countries are likely to be very different. Of the various measures noted, trade facilitation is discussed in greater detail below.

As already noted, alongside pursuing policies at the regional level to further trade and investment in the GMS region, GMS member countries must improve their respective domestic business climate. The World Bank’s

Doing Business (DB) Report (2012) shows that the GMS countries have made improvements since 2005 and narrowed the gap with the best performers.¹⁸ Despite this narrowing, except Thailand which is ranked 17th (out of 183 countries), all the other GMS countries are in the bottom half of the ranking (Figure 30). Singapore, which continues to be the top performer, and Malaysia are the other ASEAN countries in the top twenty.

Countries that have implemented reforms covering multiple areas of the ease of doing business and have sustained such reforms for a long period are the ones that have narrowed the gap with the frontier the most (DB Report 2012). For example, Georgia was ranked similar to Viet Nam, 100th versus 99th respectively (out of 155 countries) in 2005 (DB Report 2006). Over the next six years, Georgia implemented reforms across multiple areas and almost closed the gap with the frontier in the areas of starting a business and registering property by 2011. Out of 174 countries, Georgia narrowed its gap to the frontier the most and by 2011 Georgia was ranked 16th (out of 183 countries) while Viet Nam was ranked 98th in 2011. Figure 31 shows the rank of GMS countries across the nine areas of doing business and compares it with that of Singapore which is the top performer in terms of the ease of doing business. GMS5 countries such as Cambodia, Lao PDR, and Viet Nam rank low across a number of areas of doing business and need to implement wide-ranging measures to reduce the cost of doing business as well as make such reforms an integral part of their respective long-term competitiveness strategy.



¹⁸ Best performer or “frontier” is defined as the most efficient performance by any economy since 2005, i.e., best performance across economies and across years from 2005 to 2011.

In addition to the ease of doing business, another area which can be a hurdle is the ease with which goods can be moved across borders. This is all the more important in today's time when production processes are fragmented across borders (as they are in the case of GMS countries), profit margins are razor thin and timely deliveries are critical to keep the supply chain fully functional and moving. Trade facilitation is, thus, critical to not only boosting trade but also to attracting FDI. Figures 32 and 33 provide a comparison of trade facilitation and logistics in the GMS countries with other countries from the Asia-Pacific region using World Bank's logistics performance index (LPI) and trading across borders. Singapore is the best performing country on LPI. Other than PRC and Thailand, all the GMS countries perform below the average for ASEAN5. Cambodia, Lao PDR, Myanmar, and Viet Nam (CLMV) all score low in various components of LPI (Table 11).

Another critical aspect is transport facilitation, i.e., the ease of moving vehicles carrying goods across borders smoothly. There are different aspects to transport facilitation such as traffic regulation, harmonization of vehicle standards, and backloading which depends on the structure of the domestic transport sector. Transport facilitation has been recognized as a critical binding constraint to the movement of goods across the GMS countries.

CLMV countries, which rank low on various measures of trade facilitation, need to implement further transport and trade facilitation measures across broad ranging areas from improving infrastructure to increasing the efficiency of customs administration to harmonizing traffic regulations for smooth movement of trucks. Improvements will not only help further trade but are also ultimately important to attract

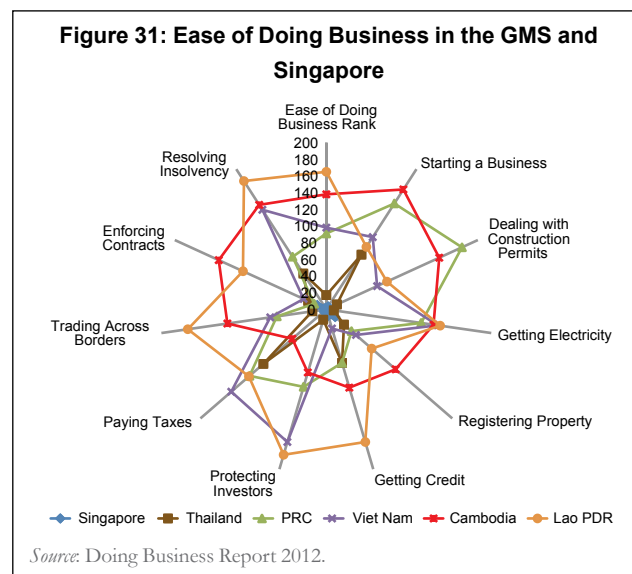
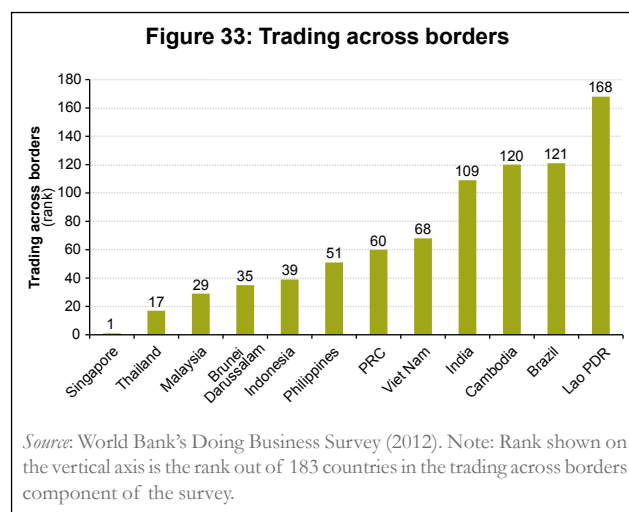
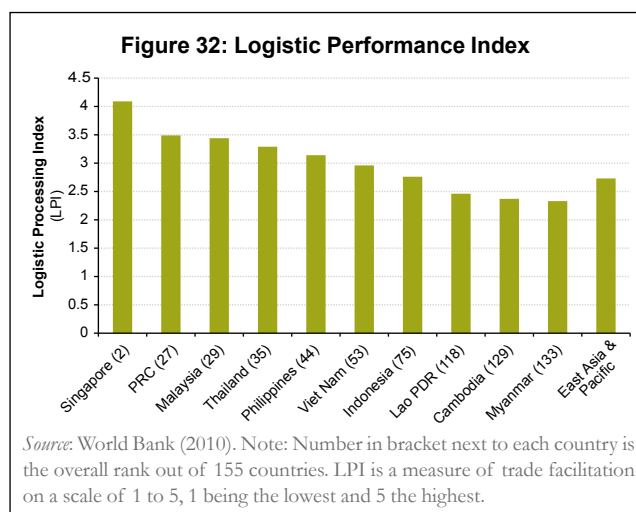


Table 11: LPI and its components, 2010

Rank	Country	LPI	Customs	Infrastructure	International shipments	Logistics competence	Tracking & tracing	Timeliness
2	Singapore	4.09	4.02	4.22	3.86	4.12	4.15	4.23
27	PRC	3.49	3.16	3.54	3.31	3.49	3.55	3.91
29	Malaysia	3.44	3.11	3.5	3.5	3.34	3.32	3.86
35	Thailand	3.29	3.02	3.16	3.27	3.16	3.41	3.73
44	Philippines	3.14	2.67	2.57	3.4	2.95	3.29	3.83
53	Viet Nam	2.96	2.68	2.56	3.04	2.89	3.1	3.44
75	Indonesia	2.76	2.43	2.54	2.82	2.47	2.77	3.46
118	Lao PDR	2.46	2.17	1.95	2.7	2.14	2.45	3.23
129	Cambodia	2.37	2.28	2.12	2.19	2.29	2.5	2.84
133	Myanmar	2.33	1.94	1.92	2.37	2.01	2.36	3.29
	GMS5 Average	2.68	2.42	2.34	2.71	2.50	2.76	3.31
	ASEAN5 Average	3.36	3.06	3.21	3.40	3.22	3.38	3.85
	ASEAN Average	2.98	2.70	2.73	3.02	2.82	3.04	3.55

Source: World Bank Logistic Processing Index (2010) and authors' estimates.



FDI, especially export-oriented FDI and FDI flowing in as a part of cross-border supply chain, as seamless movement of trucks and goods across borders and timely delivery are critical to the success of a fragmented production network.

The need for improved trade facilitation has been recognized at the highest level of the GMS leadership. Starting with the 13th GMS Ministerial Conference in December 2004, subsequent high-level GMS forums have emphasized the importance of transport and trade facilitation. At the 3rd GMS Summit in March 2008, the leaders of the GMS called for a greater focus on the “softer” aspects of regional cooperation in GMS, so as to build on the growing regional connectivity of hard infrastructure to enhance the competitiveness of the subregion. The 16th GMS Ministerial Conference in 2010 in Ha Noi approved an action plan for Transport and Trade Facilitation in the GMS.

GMS countries have made some progress in improving trade facilitation through various initiatives at various levels. For example, at the multilateral level the five ASEAN members of the GMS have signed a number of transport agreements such as the ASEAN Framework Agreement on the Facilitation of Goods in Transit, finalizing and signing of the Cross Border Transport Agreement (CBTA) annexes and protocols by all GMS countries and its ratification by most GMS countries. At the bilateral level, GMS countries have concluded bilateral road transport agreements involving nearly all neighboring countries in the subregion. GMS member countries have taken a variety of unilateral trade facilitation measures as well such as the E-Port in the PRC and One Stop Service Centers in Thailand, both of which are examples of customs electronic single-window projects. There is, however, a need to build on the past achievements in trade facilitation and accelerate the momentum going forward.

Recognizing the changes in the regional economic landscape and to keep up with the progress made in the first two decades of the GMS program which involved developing hard infrastructure to improve connectivity, the next phase of the GMS program, under the GMS Strategic Framework, 2012-2022 marks a major shift in the GMS program.¹⁹ This new GMS Strategic Framework marks a shift from improving regional connectivity to improving regional competitiveness which involves emphasis on soft infrastructure, i.e., policy and institutional reforms that will complement the improved physical connectivity.

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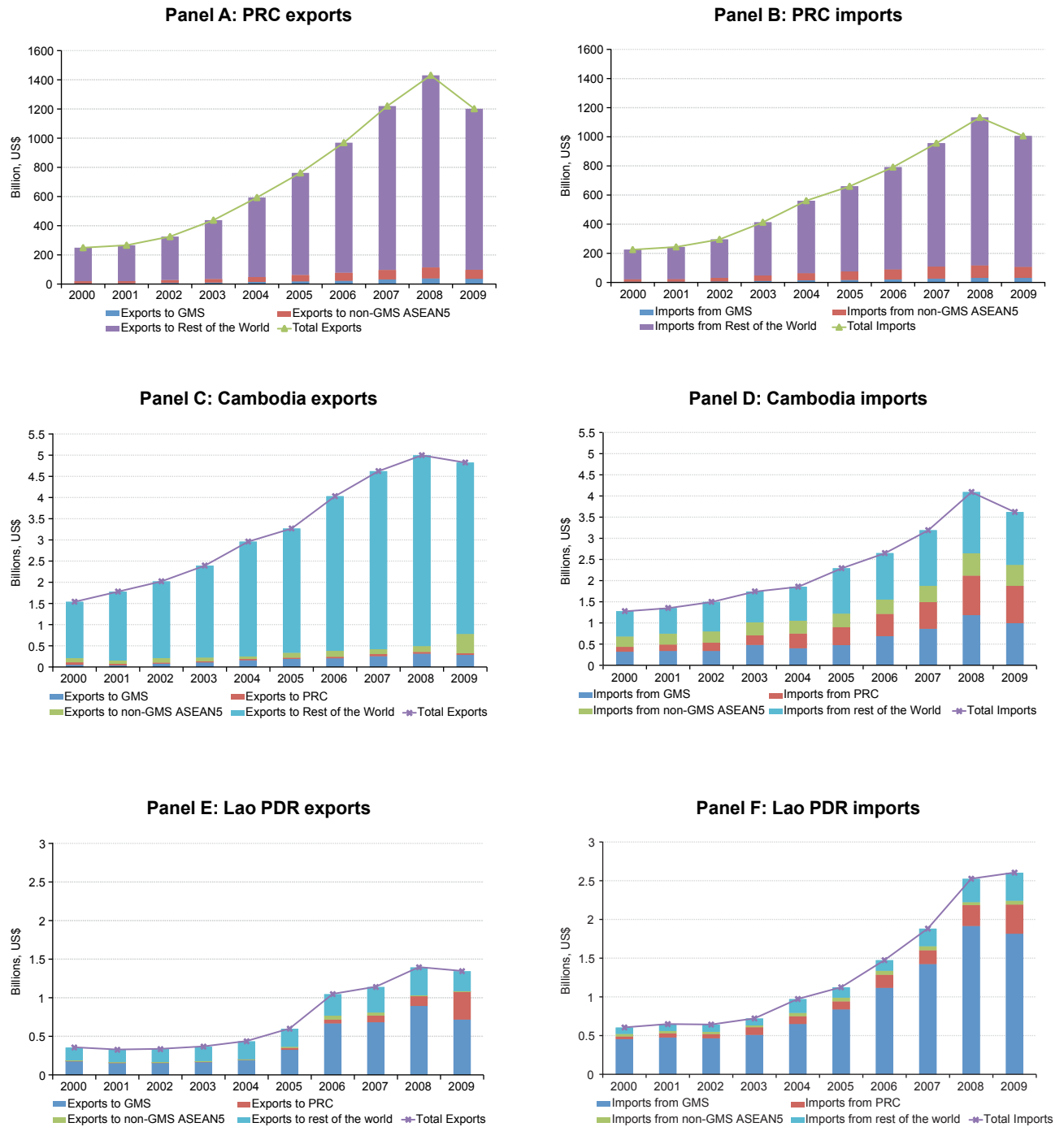
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¹⁹ GMS Strategic Framework 2012-2022 is available at: <http://beta.adb.org/sites/default/files/gms-ec-framework-2012-2022.pdf>

Appendix 1: SITC (Rev.2) 2-digit products and product categories used

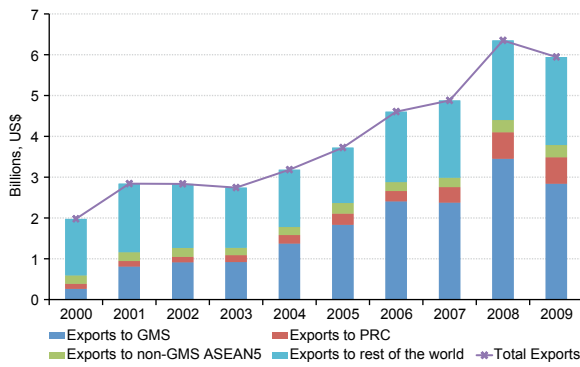
SITC (Rev. 2) 2-digit code	Product description	SITC (Rev. 2) 2-digit code	Product description
Primary Products		Manufacturing Products	
Food, beverages, and vegetable oil etc.		Chemicals	
00	Live animals chiefly for food	51	Organic chemicals
01	Meat and preparations	52	Inorganic chemicals
02	Dairy products and birds' eggs	53	Dyeing, tanning and colouring materials
03	Fish, crustacean and molluscs, and preparations thereof	54	Medicinal and pharmaceutical products
04	Cereals and cereal preparations	55	Oils and perfume materials; toilet and cleansing preparations
05	Vegetables and fruit	56	Fertilizers, manufactured
06	Sugar, sugar preparations and honey	57	Explosives and pyrotechnic products
07	Coffee, tea, cocoa, spices, and manufactures thereof	58	Artificial resins and plastic materials, and cellulose esters etc.
08	Feeding stuff for animals (not including unmilled cereals)	59	Chemical materials and products, nes
09	Miscellaneous edible products and preparations	Machinery and transport	
11	Beverages	71	Power generating machinery and equipment
12	Tobacco and tobacco manufactures	72	Machinery specialized for particular industries
22	Oil seeds and oleaginous fruit	73	Metalworking machinery
41	Animal oils and fats	74	General industrial machinery and equipment, nes, and parts of, nes
42	Fixed vegetable oils and fats	75	Office machines and automatic data processing equipment
43	Animal and vegetable oils and fats, processed, and waxes	76	Telecommunications, sound recording and reproducing equipment
Agricultural (agri) raw materials		77	Electric machinery, apparatus and appliances, nes, and parts, nes
21	Hides, skins and furskins, raw	78	Road vehicles
23	Crude rubber (including synthetic and reclaimed)	79	Other transport equipment
24	Cork and wood	Leather and rubber, inclg footwear	
25	Pulp and waste paper	61	Leather, leather manufactures, nes, and dressed furskins
26	Textile fibres (not wool tops) and their wastes (not in yarn)	62	Rubber manufactures, nes
29	Crude animal and vegetable materials, nes	85	Footwear
Fuel		Textiles, apparels, and travel goods	
32	Coal, coke and briquettes	65	Textile yarn, fabrics, made-up articles, nes, and related products
33	Petroleum, petroleum products and related materials	83	Travel goods, handbags and similar containers
34	Gas, natural and manufactured	84	Articles of apparel and clothing accessories
35	Electric current	Cork, wood, paper, and furniture	
Ores, metals, and gold		63	Cork and wood, cork manufactures
27	Crude fertilizer and crude minerals	64	Paper, paperboard, and articles of pulp, of paper or of paperboard
28	Metalliferous ores and metal scrap	82	Furniture and parts thereof
68	Non-ferrous metals	Non-metallic minerals, metals, iron and steel	
97	Gold, non-monetary (excluding gold ores and concentrates)	66	Non-metallic mineral manufactures, nes
		67	Iron and steel
		69	Manufactures of metals, nes
		Misc items	
		87	Professional, scientific, controlling instruments, apparatus, nes
		88	Photographic equipment and supplies, optical goods; watches, etc.
		81	Sanitary, plumbing, heating, lighting fixtures and fittings, nes
		89	Miscellaneous manufactured articles, nes
		91	Postal packages not classified according to kind
		93	Special transactions, commodity not classified according to class
		94	Animals, live, nes, (including zoo animals, pets, insects, etc.)
		95	Armoured fighting vehicles, war firearms, ammunition, parts, nes
		96	Coin (other than gold coin), not being legal tender

Appendix Figure 1: Direction of trade of GMS countries

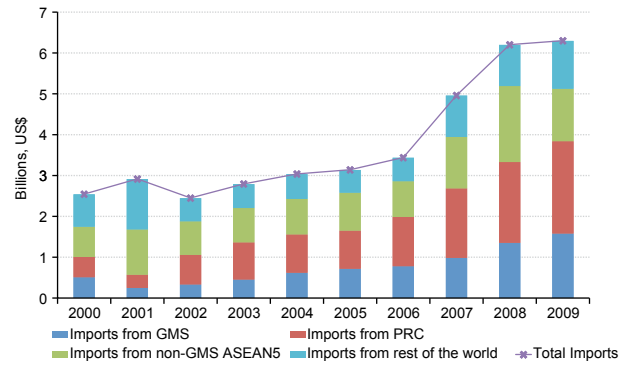


Appendix Figure 1: Direction of trade of GMS countries (continued)

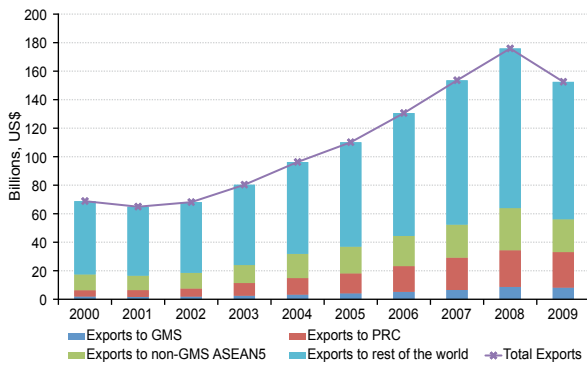
Panel G: Myanmar exports



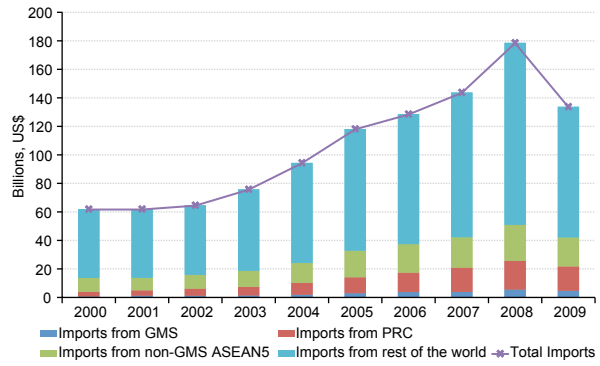
Panel H: Myanmar imports



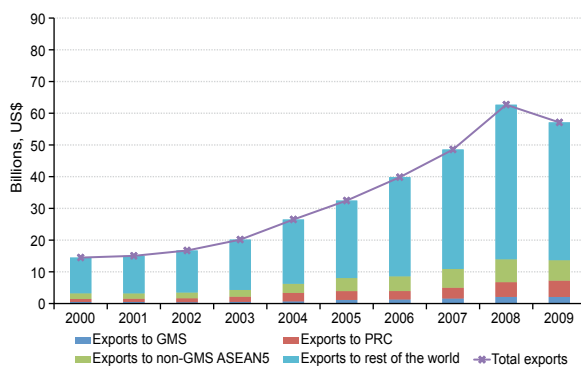
Panel I: Thailand exports



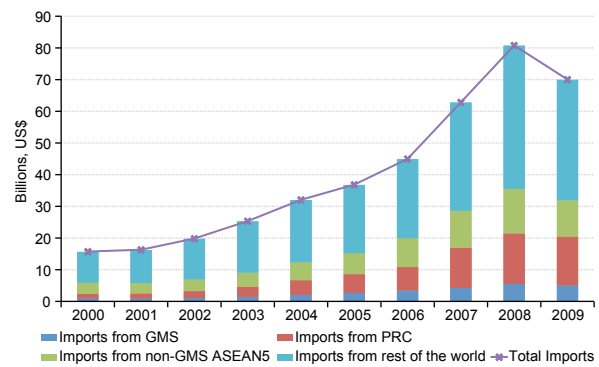
Panel J: Thailand imports



Panel K: Viet Nam exports

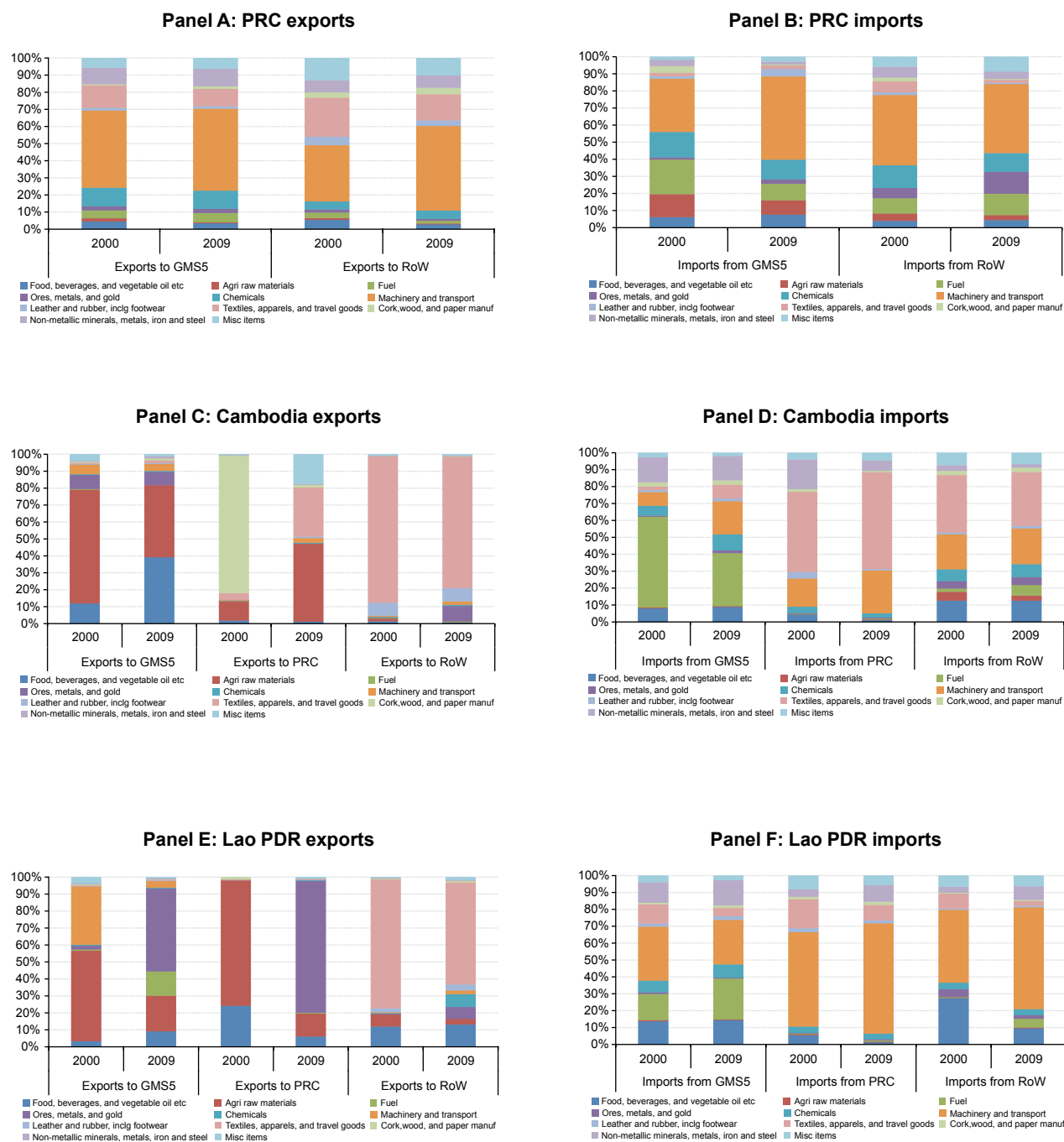


Panel L: Viet Nam imports



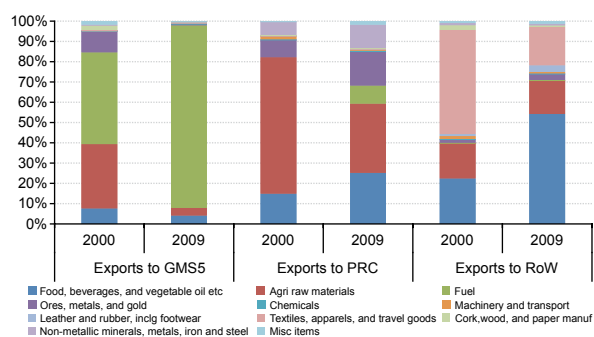
Source: UNCOMTRADE and authors' estimates.

Appendix Figure 2: Composition of trade of GMS countries

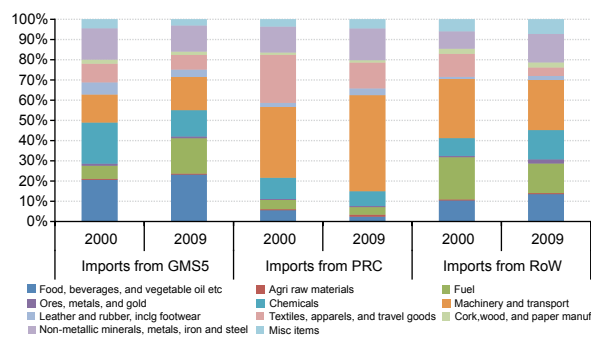


Appendix Figure 2: Composition of trade of GMS countries (continued)

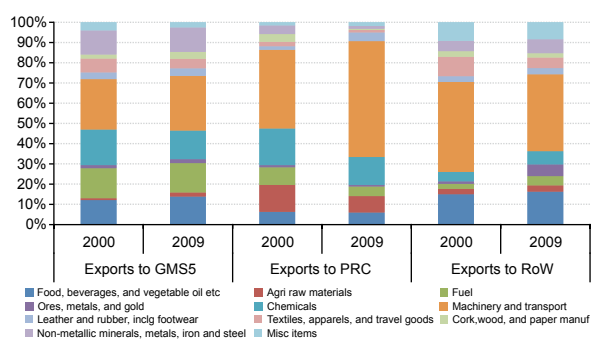
Panel G: Myanmar exports



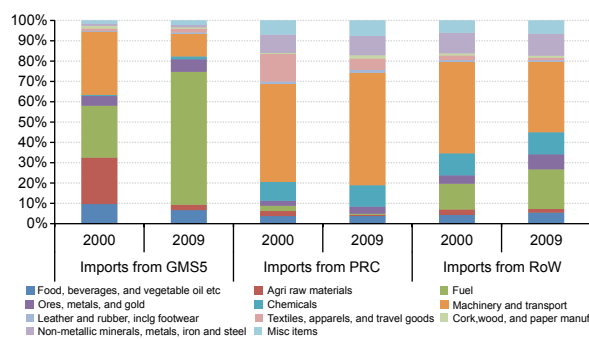
Panel H: Myanmar imports



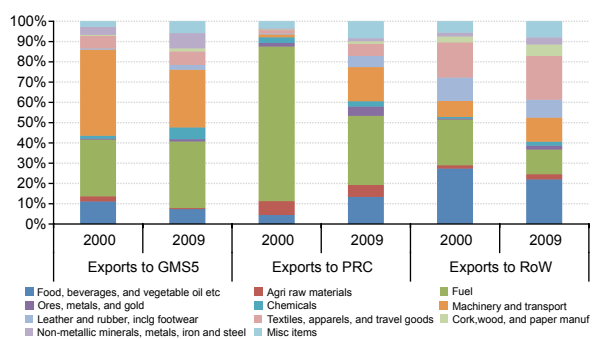
Panel I: Thailand exports



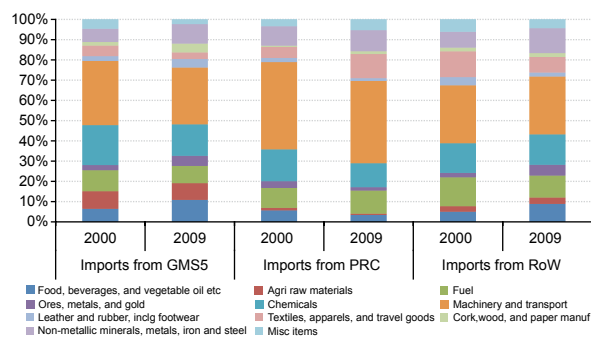
Panel J: Thailand imports



Panel K: Viet Nam exports



Panel L: Viet Nam imports



Source: UNCOMTRADE and authors' estimates.

ECONOMIC GROWTH AND DEVELOPMENT IN CAMBODIA, 2001 - 2010, AND STRATEGIES AND PLANS FOR 2011 - 2020

Hing Vutha¹

Abstract

Cambodia went through a remarkable period of rapid growth during 2001–2010 with an average economic growth rate of 8% per annum. This rapid growth raised per capita income from \$309 in 2001 to \$735 in 2010 and highlighted several main lessons for Cambodia. First, political stability and effective macroeconomic management together with a liberal trade and investment regime are key to sustaining high growth performance. Second, growth was very narrowly based and unlikely to be sustainable in its current form. Third, high growth has reduced poverty but increased inequality. The aspirations for Cambodia in 2020 should be for a country that is no longer aid-dependent, has graduated from least-developed-country status to lower-middle-income status, and has made significant progress in achieving sustainable socioeconomic development, poverty reduction, and more equitable distribution of national wealth. These will be achieved through, among other things, high levels of gross domestic product growth based on economic diversification and enhanced competitiveness; strategic integration of Cambodia's economy into subregional, regional, and global trading systems; investment in soft and hard infrastructure; improvement in quality of education and the labor force; and strengthening of democratic development and public institutions.

1. Economic Transition and Policy Priorities

Cambodia has undergone profound transformation from a centrally planned to a market-oriented economy over the last two decades. This economic transformation can be classified into three major phases. The first phase (1989–1993), involved a gradual departure from a planned economy. Policy reforms included (i) end of state interference in economic production and privatization of state-owned enterprises; (ii) private ownership of

agricultural land and unrestricted private crop sales; (iii) re-establishment of the national bank and transformation of the banking system into a two-tiered system; and (iv) restoration of macroeconomic stability. These policy reforms were aided by peace brought about by the Paris Peace Agreement in 1991, and by political stability resulting from establishment of the coalition Government in 1993.

The second phase (1994–1999) involved more widespread economic rehabilitation and reconstruction. Guided by the National Programme to Rehabilitate and Develop Cambodia (NPRD) and Socioeconomic Development Plan 1996-2000 (SEDP I), economic policies focused on (i) developing the productive base by increasing rice yields, promoting livestock production, and diversifying commercial agriculture; (ii) developing a strong private sector, including small and medium enterprises; (iii) promoting foreign direct investment; and (iv) reintegrating the Cambodian economy into regional and international economic systems. The trade regime gradually became more outward-looking and liberal, and development plans made trade a major development agenda. Trade restrictions were abolished and exports were heavily promoted through unilateral market access and regional trade agreements. Cambodia re-established normal trade relations with the United States (US) in 1996. This was followed by a series of bilateral trade agreements with the US and European Union (EU) on textile and apparels and membership of the Association of Southeast Asian Nations (ASEAN) in 1999.

The third phase began in 2000 and has been characterized by rapid economic growth, expanded trade, investment and private enterprise, and deeper integration into regional and international economies. The current policy objective is to ensure inclusive sustainable economic growth that can contribute to poverty reduction and social development. The policy priorities are to (i) create a favorable macroeconomic and financial environment; (ii) actively participate in subregional, regional, and global economic cooperation; (iii) foster economic and trade diversification and competitiveness; (iv) strengthen private sector participation; and (v) attract investment through a more conducive business and investment climate. Deeper economic integration has become a main pillar of Cambodia's economic strategy. Cambodia has been admitted to the World Trade Organization (WTO) in 2004 and actively participated in ASEAN and several ASEAN-initiated schemes, including the ASEAN Free Trade Agreement (FTA), the ASEAN-China FTA, the ASEAN-Republic of Korea FTA, and the ASEAN-Japan FTA. Cambodia has adopted reforms to ensure that its

¹ Cambodia Development Resource Institute (CDRI).

trade policy and practices are fair and nondiscriminatory, transparent, and predictable. With a view to increasing exports, trade policy focuses not only on finding export markets, but also on improving trade facilitation, export diversification, and competitiveness and trade finance.

2. Cambodia's Growth during 2001 - 2010

2.1 Growth Performance: High Growth with Structural Change

Cambodia has gone through a remarkable period of rapid growth over the last decade. During 2001–2010, growth has averaged 8% per annum and per capita income increased from \$309 to \$735. Growth was interrupted by the recent global financial crisis, which badly affected key sectors, including garment and footwear, construction and real estate business, tourism, and finance and banking. As a result, the economy contracted to record low rate of 0.1%. There is a sign of quick recovery indicated by recovery in garment production and exports, a resilient finance and banking sector, and impressive growth of the agriculture sector. The economy rebounded to 5% growth in 2010.

Industry is the fastest growing sector followed by services. They accounted for 10.2% and 8.6% contribution to growth over the decade, respectively, against 5.1% growth for agriculture. As a result, the economy has undergone profound transformation with agriculture by 2007 ranking behind both industry and services in terms of value-added. Agriculture's share of gross domestic product (GDP) dropped from 34.4% in 2001 to 27.4% in 2010, while industry's share increased from 22.5% to 26.4% during the same period. The service sector grew steadily from 38.2% of GDP in 2001 to 40.6% in 2010.

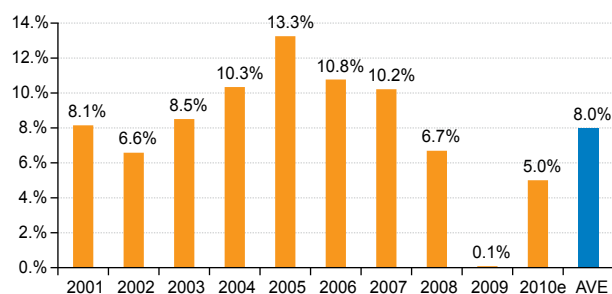
2.2. Key Drivers of Growth: from Peak Growth to Contraction

Most of the growth over the past decade has been driven by 4 sectors: garment and footwear, hotel and restaurant, construction, and agriculture. Apart from agriculture, which was resilient to the global financial crisis, these sectors registered high growth during 2001–2007 but were very volatile during 2008–2010.

Garments (and Footwear). Being the country's leading export sector, the garment and footwear industry accounted for 12% of 2010 GDP and has been growing at an average of 12.6% per annum. Exports went from almost zero in 1994 to \$4.54 billion in 2010, equivalent to 86% of total exports. Most garment factories are foreign owned, with estimates somewhere between 90% and 95%, and mainly focused on 'cut, make, and trim' (CMT), the lowest end of the garment value chain. Two key factors could explain the vibrant growth of this subsector. First is preferential treatment given by the US and EU for Cambodia's exports. They accounted for about 65% and 20% of garment and footwear exports, respectively. The second factor concerns resource endowments, in which Cambodia is labor abundant with relatively cheap labor costs.

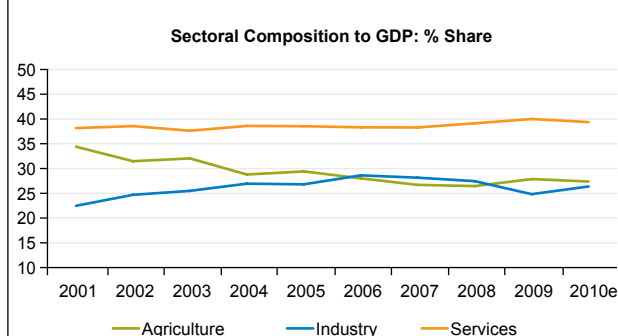
Growth was disturbed by the global financial crisis. The US recession caused the subsector to slow down in 2008, with its export value reaching \$2.9 billion. Garment exports dropped alarmingly from a monthly average of \$250 million in 2008 to \$100 million in January 2009. In terms of employment, 51,000 garment workers were laid off between September 2008 and February 2009. Apart from the layoffs, higher underemployment was also expected and in fact is already underway, with workers reportedly forced to work fewer hours (ODI, 2009). Consequently,

Figure 1: GDP Growth Rate 2001-2010



Source: National Institute of Statistics.

Figure 2: Composition of GDP 2001-2010



Source: National Institute of Statistics.

value-added of this sector went down sharply to 2.2% in 2008 and further to -9% in 2009. In 2010, growth recovered slightly yet recorded a very low growth rate at 2.2%.

Hotels and Restaurants. This sector accounts for 4.4% of 2010 GDP and has been growing at an average of 11% per annum. The growth of this sector is largely driven by tourism. Cambodia is one of the fastest growing tourist destinations in Southeast Asia. Tourist arrivals reached 2.5 million in 2010. The rapid growth of tourism is due to Cambodia's exceptional cultural heritage and its natural endowment (and its location in a dynamic region), recent stability, and key policies such as the Open Sky Policy introduced in late 1997 (World Bank, 2009a). Like garments and footwear, growth of this sector was interrupted by the 2008 crisis. Tourism arrivals at Cambodia slowed down. Growth of passenger traffic at Phnom Penh International Airport plunged rapidly, from 21% in May to a mere 3% in September 2008. The situation at Siem Reap International Airport was even worse, with the same statistic reaching -10% in September 2008. As a result, value-added of this sector went down sharply growing to 9.8% in 2008 and 1.8% in 2009. In 2010, growth recovered slightly at 4.2%.

Construction. The construction sector accounted for 6.2% of 2010 GDP and has been growing at an average of 11% per annum. Construction in Cambodia has closely followed real estate development, with most construction projects in commercial and residential real estate. The growth boomed in 2002–2006 but it has significantly decelerated since then, with signs of overheating (rising prices of labor and construction materials) and concerns about a bubble in the real estate sector. Just like other growth drivers, construction registered contraction in 2008. Some mega projects were cancelled or scaled back; while new investments decelerated by 12.5% during the first 11 months of 2008 over the same period in 2007 (ODI, 2009). In terms of employment, approximately 15,000 construction jobs in mid-2008 were lost (Kang *et al.*, 2009). An even more worrying estimate is that around 30% of the country's construction workers have so far lost their jobs following the closure or suspension of construction projects (ODI, 2009). Value-added of construction grew at only 5.8% in 2008 and decelerated further to 5% in 2009 and 3.5% in 2010.

Agriculture. Agriculture accounted for 33.2% of 2010 GDP and grew at an average of 5.1% during 2001–2010, driven by crops (mainly rice) and, to a lesser extent, livestock and fisheries. Accounting for 53% of 2010 agricultural

production and 14.5% of GDP, crop production grew at an average of 7.2% during 2001–2010. Fisheries are the second largest source, followed by livestock and poultry, representing 25% and 16%, respectively, registering an average growth rate of 3.2% and 5%, respectively, during the same period. Agriculture was the only sector not severely affected by the 2008 crisis. Unlike industry and service sectors which are highly volatile during a recession, agriculture grew at average rate of 5.3% during 2001–2007 and then fell slightly to 4.8% during 2008–2010.

2.3. Lessons from a Decade of Economic Growth

A decade of rapid economic growth highlighted several main lessons for Cambodia. First, political stability and effective macroeconomic management are key to sustaining high growth performance. Second, more liberal trade and investment policies in the context of deeper integration in regional and global economies was and will continue to be the major drivers of private sector development and economic growth. Third, growth achieved in the previous decade was very narrowly based and unlikely to be sustainable in its current form. The economy needs to increase competitiveness and diversify sources of growth. Fourth, high growth has reduced poverty but increased inequality.

The Government implemented a series of reforms focusing on macroeconomic management, public financial management, and governance of the financial sector. It also made significant headway in rehabilitating and reconstructing physical infrastructure, especially national road networks.

The Government managed to maintain macroeconomic stability in 2001–2010. Although the economy is highly dollarized,² which limits the power and effectiveness of monetary policy, the Government was able to keep inflation below 5% and maintain a stable exchange rate while maintaining a credible fiscal position.

Also, the Government continued to pursue a more liberal trade policy through opening access to markets and securing access for its products in overseas markets. Economic integration has become a main pillar of Cambodia's economic strategy. As well as joining WTO

² Measured as the ratio of foreign currency deposits to broad money, dollarization has risen from about 60% in the late 1990s to about 80% in recent years (Duma, 2010). Significant inflows of aid, FDI, and tourism receipts, and the growth of the garment export sector that transacts exclusively in dollars, have all contributed to the rise in dollarization.

and ASEAN and the associated FTAs, Cambodia has been actively participating in the Greater Mekong Subregion (GMS) and the Ayeyawady-Chao Phraya Mekong Economic Cooperation Strategy (ACMECS). Cambodia has also adopted reforms to ensure that its trade policy and practices are fair and nondiscriminatory, transparent, and predictable. Trade policy focuses not only on finding export markets, but also on improving trade facilitation, export diversification, and competitiveness and trade finance.

The investment regime was likewise liberalized, making it more attractive to private investment, especially foreign direct investment (FDI). A law on investment was adopted in 1993, setting rules and incentive schemes for FDI. The Government then set up the Cambodian Investment Board (CIB) under the Council for Development of Cambodia (CDC), as the organization responsible for approving foreign investment applications. As a result, FDI grew from almost zero in the late 1980s, to an annual average of \$163 million in 1993–2004 and \$604 million in the second half of the 2000s. FDI stock during 1993–2010 reached \$5.58 billion, accounting for 34% of total private investment, or an annual average of 5.4% of GDP. There are still some major impediments to investment, notably including corruption, bureaucracy, inefficient public institutions, and a poor regulatory framework. This prompted the Government to introduce some key measures in an attempt to improve the investment climate. For example, in 2005, the investment law was amended to make the investment regulatory framework more conducive to both domestic and foreign investment. The Government-Private Sector Forum was established, with meetings held twice a year among the Cabinet and representatives of the private sector. The forum is widely perceived as a useful platform for identifying and overcoming policy constraints to private sector development. The Government also established special economic zones (SEZs) in 2005 through a special decree, in an attempt to attract industrial and export-oriented investment projects.

Most of the growth over the last decade has been driven by a rapid expansion in garments exports, tourism, real estate, and agriculture. Such narrow-based economic

growth is highly vulnerable to external shocks and is unlikely to be sustainable in the long run. The 2008 crisis dealt a huge blow to Cambodia's garments, tourism, and construction sectors, and brought growth down to 0.5%. This experience demonstrated, more acutely than ever, the necessity for diversification.

Sustained growth has led to a dramatic decline in Cambodia's poverty levels over the last decade and a half, with the national poverty rate dropping from 39.0% in 1994 to 30.1% in 2007. Poverty levels remain higher in rural than in urban areas. Unfortunately, income disparities between the rich and the poor increased during the same period, with the Gini coefficient—derived from national consumption data—rising from 0.35 to 0.43 (Table 1). High levels of rural poverty and rising inequality are therefore a cause of concern for Cambodia. High and rising inequality can constrain the poverty reducing impact of growth, as well as the sustainability of growth itself. The challenge now is to sustain rapid growth and poverty reduction while also addressing growing inequality.

3. Aspirations for a Positive 2020 Scenario

The core of a positive set of aspirations for Cambodia in 2020 would be for a Cambodia that is no longer aid-dependent, has graduated from least-developed-country status to lower-middle-income status, and has made significant progress in achieving sustainable socioeconomic development, poverty reduction, and a more equitable distribution of national wealth. This will be achieved through

- high levels of annual GDP growth of at least 7% based on economic diversification, increased competitiveness and productivity, strengthening of key export-oriented sectors (such as agriculture, light manufacturing, and services), and the flow of benefits from exploitation of offshore oil and gas resources;
- success as a major rice exporter to markets in Asia, Africa, and the Middle East, with the model of the government's rice production and export

Table 1: Poverty and Inequality in Cambodia, 1993–2007

	Poverty Rate			Gini coefficient		
	(% below national poverty line)			(0= perfect equality, 1 = perfect inequality)		
	1993/94	2004	2007	1993/94	2004	2007
Rural	43.1	39.1	34.7	0.27	0.33	0.36
Other urban	36.6	25.8	21.9	0.44	0.43	0.47
Phnom Penh	11.4	4.6	0.8	0.39	0.37	0.34
Cambodia	39.0	34.8	30.1	0.35	0.39	0.43

Source: World Bank (2006, 2007, 2009b).

promotion strategy also applied to production and export of other crops, and associated food processing industries;

- strategic integration of Cambodia's economy into the GMS, ASEAN, and the broader ASEAN+3 (People's Republic of China, Republic of Korea, and Japan, or East Asian) region, through maintenance of open regionalism and outward-looking policies, active involvement in the evolving regional architecture (such as an East Asian Free Trade Area or Economic Community), while remaining open to other international market opportunities;
- significant progress in poverty reduction; improved infrastructure for affordable energy and transport; greater investment in social development in key areas of health care, particularly for women and children; access to affordable quality primary, secondary, vocational and tertiary education in response to market needs and changing demography; opportunities for youth; and broader human security and social protection;
- strengthening of democratic development, public institutions, and national and subnational governance, with progress in key areas of public sector reform, including service delivery, civil service salaries, capacity building of civil servants, judicial reform, the rule of law, and anti-corruption measures;
- effective use of income from offshore oil and gas exploitation for primary national development priorities, thus avoiding the so-called resource curse. In order to achieve this, the establishment and effective operation of a Cambodian sovereign wealth fund could be considered. Such a fund could work closely with other regional sovereign wealth funds on regional investment and development opportunities;
- in addition to oil and gas, improved management and governance of other natural resources (land, water, forest, and fishery) and environmental management; adaptation in response to climate change, particularly for the agricultural sector; more transparent and equitable access to natural resources for rural livelihoods and poverty reduction; and a more effective land management policy for the productive use of economic and social land concessions.

To achieve these aspirations the following factors will be key:

- A stable and well-managed macroeconomic environment that enables and promotes economic diversification, competitiveness, and productivity,

and domestic consumption.

- Increased investment in both soft and hard infrastructure, including education, trade facilitation, energy, and infrastructure. Hard and soft infrastructure for "connectivity" in the GMS, ASEAN, and ASEAN+3 in rail, road, energy generation, and regulatory and institutional capacity building.
- Improved agricultural productivity, better rural infrastructure, crop diversification, access to credit, extension services, vocational education and training.
- Improved aid effectiveness, harmonization, and alignment, with official development assistance more strategically focused to reflect key national priorities and long-term institutional capacity development; and eventual graduation from aid dependency.
- Strategic integration of Cambodia's economy and its key trade and investment relationships in the GMS, ASEAN, and ASEAN+3.

4. Policy Options

To achieve these aspirations the following policy options will be key:

- Cambodia's economic growth remains narrowly-based and vulnerable to external shocks. Economic diversification can be achieved by expanding current sources of growth. Further development of the agricultural sector, expansion of industrial manufacturing, and diversification of export products and markets are all wise economic diversification strategies.
- Growth has helped reduce poverty but has done little to address inequality. Economic policy should aim to achieve sustainable and inclusive growth.
- Trade and investment will continue to be the main drivers of growth. Deeper economic integration and more active participation in subregional, regional and global economic framework are necessary to increase trade and investment. Special and differentiated investment incentives are needed to develop other sectors where Cambodia has a comparative advantage and growth potential, particularly the 19 products and services identified in the United Nations Development Programme (UNDP) diagnostic trade integration study (DTIS) in 2007.
- A stable macroeconomic environment must be achieved by keeping inflation below 5%, ensuring

cautious and disciplined use of revenue from oil and gas sectors, closely monitoring the real estate and banking sectors, and providing enough employment opportunities to absorb to the growing labor force.

- Government budget spending must become flexible and less dependent on official development assistance. Revenue collection can be improved by strengthening the capacity of tax administration, expanding the current domestic tax base, and encouraging informal businesses to register.
- A well-managed sovereign wealth fund can be established to finance national development priorities and stimulate private sector investment in support of economic diversification, learning from the experience of other ASEAN countries.
- Public investment in priority sectors—healthcare, education, agriculture, rural development, and transport infrastructures—should be expanded in order to extend coverage of public service delivery to the poor.
- To achieve more sustainable growth and economic development, the Government, in cooperation with development partners, must prioritize the development of human capital. In the medium and long term, by (i) developing an integrated approach to improving the quality of education in all levels, and ensuring that technical and vocational education and training meet the needs of the labor market; and (ii) making research one of the missions of higher education institutions, and using such institutions as focal points for research and development.
- Investment in physical infrastructure remains a priority. Spending must be increased for building and upgrading rural infrastructure, such as rural roads and irrigation systems. Production capacity and efficiency of power generation must also be improved in order to reduce costs and achieve rural electrification.
- The agricultural sector should be promoted to make the most of factor endowments such as land and labor. Efforts to achieve poverty reduction and economic diversification will be supported by enhancement of the agricultural sector. Improving agricultural productivity and diversifying the agricultural base should be the primary objective. This will require investment in infrastructure and promotion of exports to encourage production. The growth of the sector should generate spill-over effects that will help develop the manufacturing sector, which is still in its infancy.

- Cambodia must demonstrate a commitment to sustainable use of natural resources. Governance of natural resources must be improved to ensure sustainable use and increase value-added. This includes efficiency and transparency in management processes and appropriate investment of revenues from resource use, taking into account the environment impact of natural resource extraction.

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RECENT ECONOMIC DEVELOPMENT PERFORMANCE AND SOME PERSPECTIVES ON ECONOMIC DEVELOPMENT STRATEGY FOR 2020 LAO PDR

Leeber Leebouapao¹

Abstract

The objectives of this report are to present the recent economic performance, the Lao Government Development Strategy until 2020 and to propose some policy recommendation for achieving the goals by 2020.

The main contents of this report can be summarized as follows:

After the Lao economy was hit remarkably by the East Asian Financial Crisis in 1997, which caused hyperinflation of 3 digits (134% in 1999), a slow down of economic growth, the lowest growth rate of about 4% in 2008, a decline in GDP per capita from about \$379 in 1996 to \$176 in 1998 and recovered the level of 1996 in 2003, the Lao economy has grown then relatively rapidly and been relatively stable, in particular for the last five years (2006-2010), despite the impact of the global financial crisis in 2008, the average GDP growth accounted for about 7.9 % per annum, the average inflation rate was about 5%. In 2011, GDP growth is about 8.2 % and GDP per capita is estimated about \$1,233. As a result, the World Bank has shifted Lao PDR from the list of low income countries to a low middle income country.

The long term socio-economic development goals of the Lao Government are to meet the Millennium Development Goal's by 2015 and to free from the status of Least Developed Country (LDC) by 2020. The Vision 2020 and the The VIIth Socio-Economic Development Plan (NSED) for 2011-2015 are the main development policy framework of the Lao Government.

To achieve the development goals by 2020, Lao PDR needs to make use of its potentials and opportunities and maximize the benefits from these potentials and opportunities. However, in parallel with these potentials and opportunities, there are a number of challenges

to development, which Lao PDR will be facing and needs to overcome. In this regard, the author proposes some policy recommendations on directions for a Lao PDR development strategy to achieve the country's development goals by 2020.

1. Recent Macro-economic Performance

1.1 Growth and Compositions of the Lao Economy

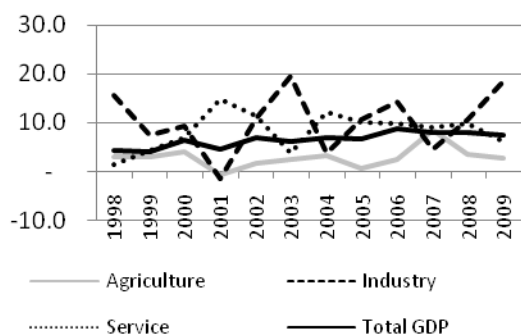
After the introduction of the New Economic Mechanism (NEM) to shift from the centrally planned economy to a more open market oriented economy in 1986, the Lao economy has grown relatively rapidly. However, the East Asian Financial Crisis erupted in 1997 and hit the Lao economy drastically, with a slow down of economic growth to the lowest point of about 4% in 2008, a decline in GDP per capita from \$379 in 1996 to \$176 in 1998, then recovered the level of 1996 by the middle of 2000's. Since the middle 2000s, the Lao economy has grown relatively rapidly with relative stability, in particular over the last five years (2006-2010), the average GDP growth accounted for about 7.9% per annum, of which agriculture, industry and services sectors have grown at an average of 4%, 12.6%, 8.4% respectively, which become the main drivers of growth. In 2011, GDP growth is about 8.2% and GDP per capita is estimated about \$1,233. As a result, the World Bank has shifted Lao PDR from the list of low income countries to a low middle income country.

With regards to economic structure, over the last decades, agriculture which was traditionally the determinant sector of the Lao economy until the early 1990's, was declining from about 45% of GDP in the middle 1990s, to about 30.5% in 2009 (Figure 2). In contrast, the industry's share increased dramatically by about 7% to 24.5% for the period 2001-2010. The industrial GDP consists of 46% manufacturing share and mining 26% share. The share of the services sector increased significantly from 30.8% in 1997 to 38.7% in 2009. The major share of service sector are hotel sale and retail trade and repair covering about half of the services sector. Other major subsectors were public service (15%) and transportation and communication (12%).

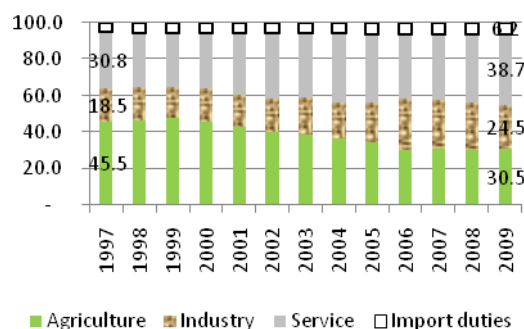
1.2 Inflation Rate

After the East Asia financial crisis erupted in 1997 hit the inflation in Lao PDR increasing dramatically as

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Figure 1: GDP Annual Growth Rate, 1998–2009

Source: Department of Statistics, 2010.

Figure 2: Structure of the GDP, 1997–2009

Source: Department of Statistics, 2010.

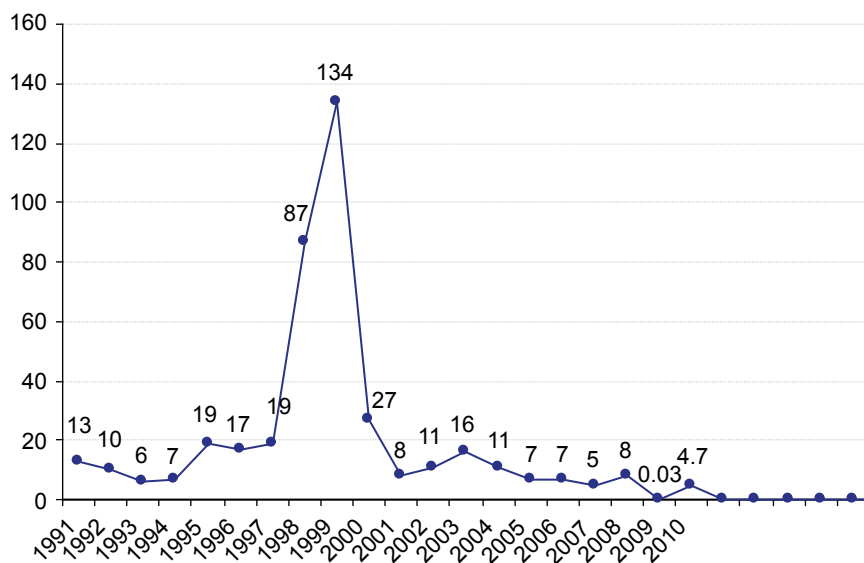
hyperinflation in the history of the Lao economy by 87% in 1998 and 134% in 1999 (Figure 3), then inflation gradually fell to a single digit, with an average rate of 7.7% for the time period 2001–2010 and about 5% for the time period 2006–2010. In 2009, inflation fell to 0.7%, the lowest level in the history of the Lao economy because of the recent global financial crisis which led in particular to the fall of global demand and in particular to the fall of world oil prices significantly and finally to lowering the transportation cost in the country. However, inflation has increased gradually again since 2010 (4.7%), as a result of the recovery of the world economy from the global financial crisis which has increased the world oil prices compounded with the severe flood in some parts of the country leading to the increase

in food prices and transportation cost as the main causes of the inflation (Figure 3).

1.3 Exports and Imports²

Overall, the Lao PDR remains relatively as a closed economy in terms of trade openness (exports plus imports), which accounted for about 54% of GDP in 2010 and 48% for the time period 2006–2010, compared to neighboring Cambodia (80%) and Viet Nam (87%).

Over the last 5 years (2006–2010), exports amounted to \$5.11 billion, accounting for 20.72% of the GDP. Imports amounted to \$6.49 billion and accounted for 26.1% of the

Figure 3: Average Annual Inflation in the Lao PDR, 1991–2010

Source: Department of Statistics, 2010.

² Trade data from Interactive Tariff and Trade Data Web is mainly used for the detail analysis, instead of the official data from Lao PDR's Ministry of Industry and Commerce because the former provides the data in the harmonized system, suitable for international comparison.

GDP (Figure 4). Trade deficit amounted to \$1.38 billion, accounting for 5.3% of the GDP. On average, annual trade deficit of \$276.80 million, which is 27.1% of the total exports. During the recent global financial crisis in 2008, exports and imports declined by 21.4% and 15.3% respectively, in the fiscal year 2008/09. Particularly, exports in mining, garments, and wood and wood product declined sharply, by 32%, 44%, and 22%, respectively.

Since 2006, major export products are in particular mineral products and hydro electricity. In 2010, mineral products and hydro electricity consisted of about 73% of the total export, of which mineral products and hydropower electricity consisting for about 57% and 16% respectively. Mineral export destinations mainly to ASEAN member countries (63%), Republic of Korea (13%) and PRC (4%). The main hydroelectricity export destination is Thailand. The next largest exported products are textiles and agriculture products, accounting for about the same shares of 9% for both representing the 3rd and 4th largest products for export

in 2010. Main export destinations for textiles are the EU (82%) due to preferential regulations for garment exports, followed by the USA (6.3%) and Japan (3.4%).

Imported items are in particular fuel, machinery, electrical products, and vehicles and spare parts. The top 6 imported products accounted for more than 60% of total imports in 2008. The import of mineral fuel, the largest import item, cost more than \$427 million in 2008 and came mainly from Thailand (91%). The second largest import products are vehicles and vehicle parts primarily from Thailand (65%), PRC (14%) and Japan (8%). Finally, machinery imports, primarily from Thailand, PRC and Germany, were the third largest imported product in 2008.

Thailand represents the most significant trading partner of the Lao PDR, with a trade volume accounting for more than 50% of the Lao PDR's total trade. Viet Nam and PRC are the second and third largest trading partners, respectively. Thailand, Viet Nam and PRC accounted for

Figure 4: Trade Performance (2006-2010)

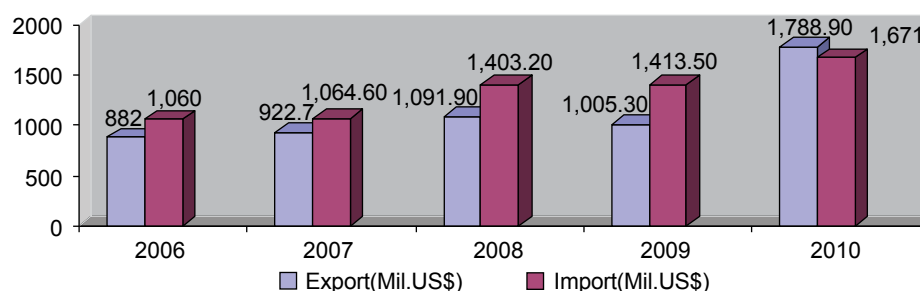
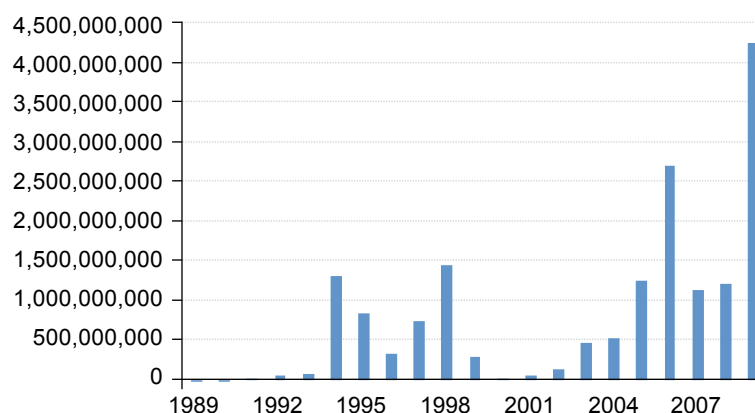


Figure 5: Approved FDI in \$ (1989-2009)



Note: 2009 data cover January to August only.

Source: Department of Investment Promotion, Ministry of Planning and Investment, 2009.

about 75% of the Lao PDR's total trade volume for the period from 2001-2008 and more than 80% in 2008. Lao PDR imported more than 87% of imports from Thailand and PRC alone. Among its top three trading partners, Laos - PRC bilateral trading volume achieved the highest annual growth rate of 34% while the growth rate for Laos-Thailand and Laos-Viet Nam bilateral trading volume were 26% and 1% respectively.

1.4 Foreign Direct Investment (FDI)

Since the adoption of the open-door policy (the first Law on FDI Promotion in 1998), FDI has increased from about \$4 million in 1989 to over \$4 billion in 2009. FDI inflow³ increased significantly in particular before the Asian

financial crisis in 1997 at an average of \$88 million per year⁴ (Figure 5). After slowing down during the crisis, it resumed rapid growth again in early 2000, in particular by the booming in electricity generation and mining sectors. Over the time period 1989 to 2009, on average, FDI inflows into the Lao PDR increased at about 173% per year.

Figure 6 indicates that the major FDI is concentrated in hydropower and mining sectors, on average about 32% and 8.8% of the total investment respectively. In addition, FDI in the labor intensive sector is also significant. For instance, FDI in industry and handicraft (excluding electricity and mining) covers about 17% of total FDI. The most outstanding business is the garment industry, which grew quite rapidly mainly due to the preferential access of

Figure 6: Approved FDI Capital by Sectors in % of total FDI (1989-2009)

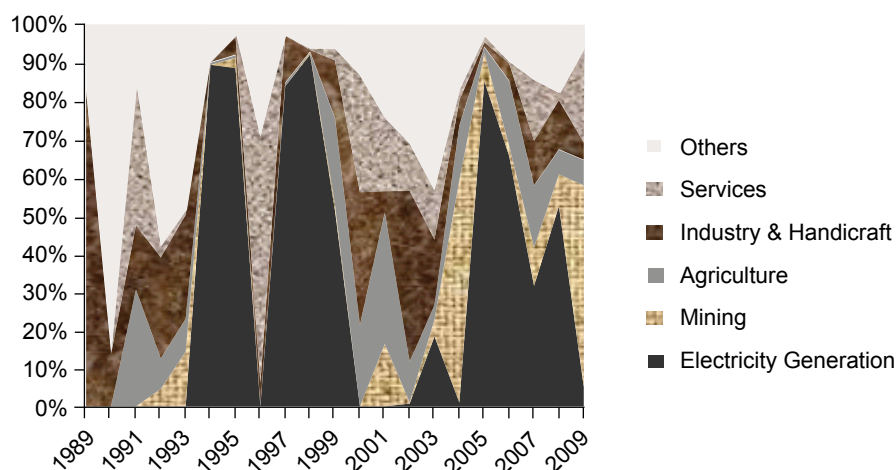
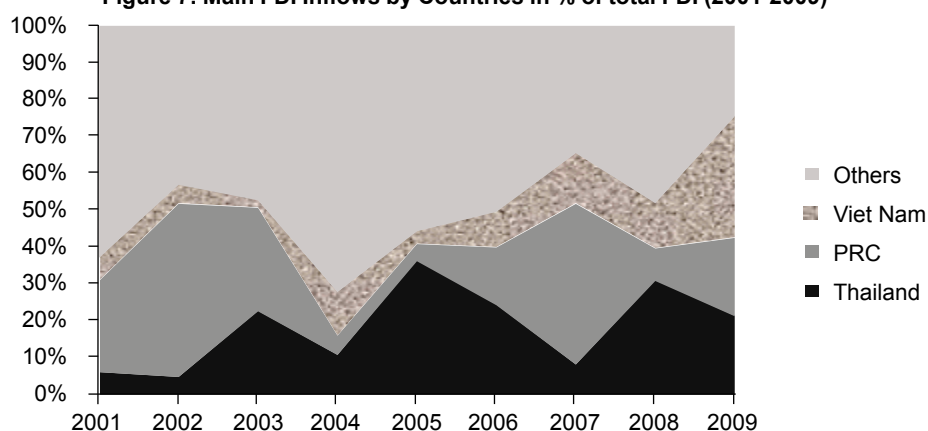


Figure 7: Main FDI Inflows by Countries in % of total FDI (2001-2009)



Note: 2009 data cover January to August only.

Source: Department of Investment Promotion, Ministry of Planning and Investment, 2009.

³ Approved investment capital.

⁴ Excluding FDI in the electricity generation sector; FDI in this sector is massive and volatile.

the Lao PDR in many export markets with “least developed country” status. Further more, FDI in the service and agriculture sectors covers about 11% and 10% of total FDI, respectively, and, while relatively small, are more stable.

The main source of FDI inflows into Laos are largely from its neighboring countries. Over the last nine years (2001-2009), the top investors were the People’s Republic of China, Thailand and Viet Nam (Figure 7), on average accounted for about 21.8%, 19.8%, and 11.4% of total FDI respectively. Other important investors include France, Japan, the Republic of Korea, India, and Australia.

2. Some Perspectives on Economic Development Strategies for 2020

2.1 Lao Government’s Development Goals and Strategy for 2020 and Steps towards Achieving the Goals

The main long term development strategy of the Lao Government is the Seventh Five Year Socio-Economic Development Plan (NSED7), which has been formulated to determine the policy directions, main macroeconomic targets and action plans for the socio-economic development of Lao PDR over the period of 2011 to 2015 as the fundamental step towards achieving the development goals by 2020. The NSED7 is considered to be the most research driven plan that comprehensively reviews both external and internal environments, presenting both opportunities and challenges for the development over the next five years. The visions of the Lao government (GOL) by 2015 and 2020 are to move the country towards a modern and industrialised society; enjoy rapid economic growth with stability; visibly improve the living standards of the people; achieve the Millennium Development Goals (MDG) by 2015 and graduate from Least Development Country (LDC) status by 2020.

To achieve the above mentioned goals and visions, the NSED7 put forwards four overall goals:

1. Ensure rapid and sustainable economic growth at no less than 8% per year. GDP per capita estimation for 2015 is about \$1,700 per person per year at current prices.
2. Achieve MDGs (including poverty reduction) by 2015, acquire modern technologies and infrastructure, and establish a diverse economic foundation to move the country out of its Least Developed Country status in 2020.

3. Ensure sustainable development by integrating economic development with socio-cultural development and environment protection to the nation’s advantage.
4. Ensure political stability, fairness, and order in the society and maintain public security.

The main macroeconomic targets for 2015 can be summarized as follows:

- GDP growth not less than 8% per annum
- GDP per capita by 2015 to be realized about \$1,700
- Inflation must be less than one digit
- Exchange rate fluctuates between + and - 5 %
- Foreign currency reserve to be maintained for more than 6 months of imports
- Government revenues to be achieved about 18%-19% of GDP
- Budget deficit is about 3%-5% of GDP
- Investment requirement: Total Investment about 32% of GDP
 - Public Investment: 8%-10 % of total investment
 - ODA 26%-28 % of total investment

2.2 Thresholds for LDC Graduation

In order to meet the development goal by 2020, in particular to free from the status of LDC, Lao PDR needs to achieve 2 of 3 criteria to qualify for the graduation, in particular:

1. Gross National Income (GNI) per capita. 2011, the threshold for graduation is \$1,086, Lao PDR’s GNI per capita is about \$1,156.
2. Human Asset Index (HAI). 2011, threshold for graduation is more than 86, Lao PDR’s HAI is about 62.3.
3. Economic Vulnerability Index (EVI). In 2011, the threshold for graduation is less than 32. However, Lao PDR’s EVI is about 59.9 and the trends of EVI for Lao PDR in the last 10 years has gone more far away from the EVI threshold.

Based on the progress of the 3 criteria so far as mentioned above, Lao PDR could qualify for the thresholds of GNI per capita and HAI. For criteria 3, it is extremely difficult to be achieved. Hence, Lao PDR may concentrate on criteria 1 and 2. However, more efforts is also to be made to improve the EVI by promoting more development projects for improving the EVI.

2.3 Some Main Opportunities and Challenges

2.3.1 Main Potentials and Opportunities

Some main opportunities are:

- Political stability:

In Lao PDR, there is only one party system, the communist party, which has ensured political stability since the foundation of Lao PDR in 1975.

- Macroeconomic stability:

After the financial East Asian crisis in 1997, and its impacts until early 2000's Lao PDR has enjoyed relatively macro-economic stability.

- Strategic location and natural resources endowment:

The country of Lao PDR has relatively huge potentials on strategic location for developing the country as a land-linked country, untapped natural resources such as mineral resources, water resources for hydro power projects, and tourism destinations, forestry, etc.

- Relative low labor cost and low land concession: Labor cost and land rent cost in Lao PDR is lower than in Thailand
- Investment incentives for FDI.

2.3.2 Main Challenges for 2020

Together with the opportunities discussed above, Lao PDR is, however, facing a number of challenges as follows:

1. How to sustainable economic growth and equity?

The relative rapid economic growth over the last two decades has been based mainly on natural resources based sector in particular mining and hydropower projects as driver of growth. In addition, economic growth has been relied and until 2020

will still rely heavily on external sources in particular ODA (about 25%) and FDI (about 55%) of the total investment. Domestic sources are only about 20%.

2. How to foster human resources ?

Human development, one of the 3 pillars of socio-economic development is a crucial issue in the Lao PDR. Lao PDR's Human Development Index is still behind many countries in the world. In 2010, Lao PDR ranked 122 in the world, and poverty incidence is 26%.

3. How to strengthen firm competitiveness?

The most recent World Bank indicators on 'Doing Business 2010' rank Lao PDR 167 out of the 183 countries that were assessed, the worst rank in the region (table1).

4. How to ensure environmental sustainability?

As a result of population growth and economic development including infrastructure development, urbanization, industrialization, agriculture development, deforestation, trade etc., all natural resources will be affected gradually.

5. How to ensure equity and social safety net?

As a result of economic growth, population growth, the improvement of the living standards of the Lao people, the increase in life expectancy, reduction of child mortality rate, there will be more students, more workers, more old people, more social problems, which need more health care and safety.

2.4 Recommendations for the Development Strategy to 2020

In order to achieve the 2020 goal as well as to deal with the challenges above, policy recommendations are proposed as follows:

Table 1: Lao PDR: "Doing Business" compared with other countries

	Laos	Singapore	Thailand	Taiwan	Viet Nam	Cambodia
Ease of doing business Rank	167	1	12	46	93	145
Starting a business	89	4	55	29	116	173
Dealing with Construction permit	115	2	13	97	69	145
Employing workers	107	1	52	153	103	134
Registering Property	161	16	6	30	40	116
Getting Credit	150	4	71	71	30	87
Protecting investors	182	2	12	73	172	73
Paying Taxes	113	5	88	92	147	53
Trading Across Borders	168	1	12	33	74	127
Enforcing contracts	111	13	24	90	32	141
Closing a business	183	2	48	11	127	183

Source: Doing Business, World Bank (2010).

2.4.1 Some Main Socio-Economic Development Targets:

- A. Main macroeconomic targets:
- GDP growth no less than 8%
 - GDP per capita \$3,154 (GNI per capita about \$2,807)
 - Shares of GDP:
 - Agriculture: 19.2%
 - Industry: 49.0%
 - Services: 31.5%
 - Import duties: 0.3%
 - Investment capital requirement: 30-32% of GDP
- B. Social development targets:
- Population: Population will be 7.6 million by a population growth rate of 2.2%
 - Poverty reduction: Reduce poverty rate from about 26% in 2010 to 5% by 2020 of total population (below 19% by 2015)
 - Education and human development:
 - Increase universal primary school enrolment rate to 100% by 2020, and ensure that girls have equal access (98 % in 2015)
 - Increase secondary school enrolment rate to 90% in 2020 (85% in 2015).
 - Increase adult literacy to 100% in 2020 (99% by 2015).
 - Health and nutrition:
 - Increase life expectancy to 70 years
 - Reduce percentage of under weight children under 5 to 10% by 2020 (20% by 2015)
 - Reduce under 5 mortality rate (<5) to 40/1,000 by 2020 (70/1,000 live births by 2015)
 - Reduce infant mortality rate (<1) to 20 /1,000% by 2020 (45/1,000 live births by 2015)
- C. Environment targets:
- Ensure forest covers about 65% of the total land areas.

2.4.2 Policy Recommendation for Development Strategy

On the development strategy for 2020 to achieve

the development goals, Lao PDR may focus on the following:

1. Lao PDR needs to increase productivity and diversify the economy for growth with equity:

In order to ensure sustainable growth and diversify the economy for the long term by 2030, some recommendations are proposed:

(1) Increase labor and production productivity

Lao PDR needs to increase labor and production productivity in particular by focusing on agriculture sectors because the majority of Lao labor forces at the present time, more than 70% of the total labor forces are still engaged in agriculture sector, however, agriculture sector's share to GDP is only about 30%. This indicates the lowest productivity sector in the Lao economy. Industrialization in agriculture sector with eco-friendly manner should be strongly promoted in particular by focusing on modernization of irrigation system and introduction of modern production techniques and concentrate on production of market demand-driven commercial goods.

In addition, human resources development in general should be strongly promoted by focusing on developing more vocational schools and more technical trainings for workers in all sectors. The national education system should focus on upgrading the education's quality to international standards. Further more, Research and Development (R&D) should be promoted by taking appropriate shares of Government budget into account.

Moreover, imports of appropriate modern production techniques, technology and machines from advanced countries should be promoted.

(2) Diversify the economy:

In parallel with the development of the natural resources based sector, Lao PDR may develop more manufacturing industries to produce more value added products, develop transit services by developing the country as a land-linked country comprehensively including logistics development, trade facilitation, transport facilitation, promote SME, tourism etc. with sound market functioning mechanism and environment, in order to maximize the benefits from its strategic location as a land-linked country.

(3) Improve macro-economic management:

As a result of increasing foreign currency inflows from the windfall of the natural resource sectors (mining and hydropower), ODA and FDI, leading to Dutch Diseases, and in particular its impacts on the real exchange rate and

weakening competitiveness of domestic export firms, Lao PDR may have to mitigate these phenomena by focusing on stabilizing exchange rate and allocating government's expenditures resulting from the resources booming sector, ODA including foreign borrowing and FDI on promoting tradable goods and human resource development, infrastructure and health care.

Fiscal policy: (a) Continue to concentrate on the current reform in public financial management with the aim to increase fiscal discipline including transparency and accountability; (b) Establish a well functioning financial management mechanism for the revenue from natural resources, of which appropriate shares for saving and investment for the long term is to be taken into account; (c) Maintain an appropriate budget deficit (no more than 5% of GDP) in particular to avoid a debt trap.

Monetary policy: (a) Well manage money supply in accordance with the need for economic growth and ensure macroeconomic stability in particular inflation rate must be less than GDP growth rate, exchange rate fluctuates between +/-5%; (b) Continue to develop the monetary framework in consistency with regional in particular ASEAN monetary integration framework; (c) Develop a prudent exchange rate policy for the purpose of stimulating export.

2. Foster Human Capital:

Foster human capital is one of the main targets of Lao Government's development strategy, which is included in the MDG's and the goals for graduation from LDC status. In order to meet the MDG's by 2015 and to graduate from LDC status by 2020, Human Resource Development is one of the key priorities in particular, Lao PDR needs to increase its Human Development Index (HDI) and Human Asset Index (HAI for more than 68) to qualify for the threshold for the graduation by 2020.

Together with HDI and HAI, fostering human capital may focus on promoting more skilled labors, technicians, engineers and researchers. Lao Government may take more share of its budget allocation for education, health care and social security into account. Private investors should be strongly encouraged to contribute to human resources development at all levels of education. Education development at all levels should be labor market demand driven development and the real need for socio-economic development in the sense of learning for doing and doing by learning.

3. Ensure Environmental Sustainability:

Some recommendations to ensure environmental sustainability are proposed as follows:

(1) A clear road map or strategy for the long term development until 2030 should be formulated and adopted for the purpose of an appropriate balance between the tree pillars of development: economic development, social development and environmental preservation. Environmental preservation should be one of the top priorities by defining clear areas, development projects, policy and institutional frameworks.

(2) All the laws and regulations related to environmental issues, environmental assessment regulations for all socio-economic development projects should be more strictly monitored and enforced. Before implementing all development projects of both government and private sectors, environment assessment should be conducted deeply.

(3) The capacity of institutions related to natural resource and environment management should be strengthen.

4. Develop Economic Infrastructure:

Lao PDR as a land-locked country among GMS countries aspiring to become a land-linked country, a significant beneficiary of GMS by improving trade and transport facilitation to reduce the costs of its global as well as its regional trade. Some proposed recommendations for developing the infrastructure to facilitate transport and reduce cost are :

(1) Enhance the regional cooperation in particular GMS cooperation, and ASEAN cooperation on the long term regional infrastructure development projects linking GMS and ASEAN member countries through Lao PDR and to link with the sea port in Thailand and Viet Nam, of which many parts are built and to be built in Lao PDR such as East-West Corridor (Rout 9), North-South Corridor (Road 3A), The Railway Boten/Bohan (Louangnamtha Province)-Vientiane to link Kunming-Singapore and others projects. However, Lao PDR may consider to maximize the benefits from these corridors in particular to develop the country as a land-linked country through developing the transit corridors into economic corridors by improving the transit road, improving logistics, improving transport facilitation, trade facilitation, developing logistic parks, developing hotels, restaurants, resorts, tourism destination, garage, gas and rest stations, shopping center, etc.

(2) Improve and expand the domestic road networks between urban and rural areas to facilitate and increase transport in particular in rainy season more efficiently to reduce transport cost. It is important to increase the percentage of paved roads (the current paved road is only about 12 %).

(3) Develop and modernize international airport in Vientiane that big air craft such as Boeing 747 can land, develop and upgrade medium international airports in Louangprabang, Pakse (Champasack), Savanakhet and Xiengkhouang to attract international tourists and expand trade network.

(4) Due to the limited budget of the Lao Government for infrastructure development, Public- Private Partnership (PPP) could be promoted. Private investors can contribute to infrastructure development.

5. Increase Firm Competitiveness:

To deal with the challenges of firm competitiveness within the context of Lao PDR's economic integration in to the regional and global economy in particular AEC, EAFTA and WTO by 2030, it is important to increase firm competitiveness. Some policy recommendation might be taken into account as follows:

(1) Reduce transportation cost: Lao Government might make great efforts to develop and modernize road infrastructure, modernize transport logistics for transport facilitation, improve trade and investment facilitation.

(2) Produce high quality products for niche market: firms from Lao PDR need to qualify themselves to produce highly quality and competitive products in particular products for niche markets such as Lao handicraft (silk, hard wood products), eco-agriculture products, mineral processing products (gold, silver, and copper), and garments.

(3) Improve investment climate: Lao Government might focus on improving the one stop services for investment approval and problem solution. All laws and regulations related to investment climate might be revised periodically for a better investment climate under the new circumstances. Lao Business Forum should be organized regularly as a platform for discussion between the government and the private sector on how to improve investment climate as well as how to strengthen Public Private Partnership (PPP).

(4) Capacity building: Lao firms should develop their workers to be skilled workers.

(5) Research and Development (R&D): Lao firms should invest also in R&D to improve their product's quality and to study market assess.

6. Develop a Sustainable Social Safety Net:

A better social safety net should be developed in particular to increase the coverage of social protection for all Lao people by promoting economic growth with fair income distribution, establishing social assistance funds for the poor, promoting establishment of community social protection funds, promote the Lao traditional and cultural value etc.

Appendix

Table 1: Main Macroeconomic Indicators (2001-2010)

Items	2001-2005	2006-2010	2001-2010
	Average	Average	Average
Population (1000 people)		6,256	
GDP Growth	6.3%	7.9%	7.1%
- Agriculture	1.8%	4.0%	2.9%
- Industry	8.4%	12.6%	10.5%
- Services	10.2%	8.4%	9.3%
Shares of GDP			
- Agriculture		30.4	
- Industry		26.1	
- Services		37.2	
GDP per capita (\$)	491	1,069	1,069
Export Growth (%)	9.8%	34.2%	22%
Import Growth	4.1%	21.9%	13%
Inflation	10.4%	5%	7.7%
Exchange rate (Kip/\$)	depreciated 6.5% against \$	Appreciated 4.66% against \$	depreciated 2.5% against \$
M2 (billion kip)***		49,949	
Ratio of Government revenue to GDP in %	13.6%	14.5%	14.05%
Ratio of Budget deficit to GDP in%	7.4%	4.3%	5.58%
Ratio of total Investment to GDP in%	27.8%	28.5%	28.15%

Source: Ministry of Planning and Investment, 2010.

Table 2: Some Main Targets for 2020

No.	Items	Targets
1.	Population in 2020 (million people)	7.6
2.	Average GDP Growth	> 8.5%
	- Agriculture	3.5%
	- Industry	15%
	- Services	6.5%
3.	Shares of GDP	100%
	- Agriculture	18.5%
	- Industry	47%
	- Services	32%
4.	GDP per capita (\$)	3,303
5.	Inflation	< GDP growth
6.	Exchange rate (kip/\$)	8,022 (+/-5%)
7.	Government Budget	
	- Revenue to GDP	24-26%
	- Budget deficit to GDP	3-5%
8.	Ratio of Investment to GDP	32-34.5%
9.	Composition of total investment	100%
	- Public investment	10-12%
	- ODA	24-26%
	- Domestic and foreign private investment	55-60%
	- Bank credit and local people	10-12%

Source: Author's estimation.

ECONOMIC GROWTH AND DEVELOPMENT IN MYANMAR, 2001 - 2010, AND STRATEGIES AND PLANS FOR 2011 - 2020

Tin Htoo Naing¹

1. Introduction

Asia, including the Greater Mekong Subregion (GMS), has become the world's fastest growing region during the last few decades and the key player in restructuring the world's economic setting in the 21st century, which is often branded as the Asian century. The economies in the region are facing a number of challenges in environmental conservation because all developmental activities involve some amount of environmental degradation. While there are a number of different challenges in each economy, the environmental issue is a common challenge for all member economies of the region. However, the nature and extent of impact vary from country to country depending on the human, institutional, technological, and financial capability of the country concerned. Therefore, the critical point to be considered in policy making is to take into account the damage to environment as a result of development, and strike a balance between development and environmental protection (Field and Field, 2002).

Although the GMS is rapidly growing on average, its countries and peoples are at different development and income levels. Since most members of the GMS are developing economies with low levels of income and, in many cases, with weak human and institutional capacity, balancing economic growth and environmental sustainability has become crucial. This study attempts to review Myanmar's economic development performance during the last decade and consider emerging issues and challenges on the path to developing the country's economic sector without causing irreparable damage to the environment in the next decade.

2. Political Economy and Policy Regimes

Myanmar was one of the wealthiest nations within the region and its high potential for development was widely recognized when it gained independence from the British

in 1948. However, from 1962 to 1988, Myanmar's fortunes underwent a dramatic turn-around for the worse, as a result of its poor marriage to a self-styled socialism.

The socialist system was dismantled and a market-oriented economic system was revived in the 1990s after the military assumed State power. With the consistent efforts made by the government and the extensive participation of private sector, the economy rapidly entered a recovery phase. Under the economic reforms, which provided an impetus to both public and private sector development, the economy underwent changes in many sectors such as infrastructure as well as the institutional and business environment and officially recorded high growth over the period. However, the restructured economic system of the post-1988 period was unable to achieve macroeconomic stability and Myanmar has remained one of the poorest countries in the world, with a per capita gross domestic product (GDP) in 2011 of about \$821, according to an IMF estimate. This figure is lower than that of other Association of Southeast Asian Nations (ASEAN) countries, including the neighboring Lao People's Democratic Republic (PDR).

The State Constitution of the Republic of the Union of Myanmar was ratified and promulgated by the National Referendum in 2008, which declares Myanmar to be a market economy.

There are indications that together with the changes in the political system and the administrative structures following the 2010 national elections, attempts are being made to learn from the weaknesses and the flaws in policy, strategy and implementation of the previous periods. Legislation enacted in 2008 and the Special Economic Zones Acts of 2011 give incentives to investors while guaranteeing the people's interests. However, many other changes in terms of policy and strategies have yet to be made to achieve macroeconomic stability and targeted outcomes, and to ensure institutional cohesiveness and private-public collaboration that are vital for the realization of development goals.

3. Economic Structure

The structure of the economy in terms of the share of GDP by major sectors has remained substantially unchanged over several decades. For example, the share of agriculture in GDP in the fiscal year 1938/1939 is estimated to be 47.9% (U Myint, 2009), which remained unchanged after 50 years in 1988/1989. It continued more or less the same

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in the first decade of the new millennium, with a declining trend in the last few years only (Table 1).

Myanmar remains an agricultural country, with 70% of its population living in rural areas. The Government must seek all possible ways and means to achieve significant development in the agricultural sector. The most productive sectors are extractive industries, especially oil and gas, mining, and forest products, which makes the country vulnerable to the resource curse, including serious environmental degradation. Industrialization has shown little development, contributing 21.7% to the GDP with 11.0% of the labor force in 2008/2009. The share of manufacturing industry as a whole is about half that in higher-income ASEAN economies. The sector is dominated by private enterprises, which produced 92% of the total industrial output. The manufacturing and other modern facilitating sectors, which are the sectors that Myanmar must exploit if it is to follow the success-paths of its neighbors, are growing slowly against expected growth rates (Tin *et al.*, 2011).

The stagnation or very slow growth of manufacturing, transportation, communications, power generation, and financial institutions is, to some extent, indicative of flawed or inconsistent and incompetent policies in promoting industrialization (Myat Thein, 2004). The energy sector has experienced high rates of growth, while fluctuating substantially year by year depending on new capacity coming on stream. The construction sector also expanded rapidly in the second half of the decade with the construction of the new capital Nay Pyi Taw in central Myanmar and the implementation of various large infrastructure projects, including the Yangon-Mandalay motorway, Dawei and Kyaukphyu deep-sea port, and hydropower projects.

3.1 Foreign Direct Investment

The Foreign Investment Law enacted in November 1988 aimed at bringing foreign capital into the country. Although incentives were given to attract foreign investors, Myanmar was not a large recipient of foreign direct investment (FDI) as it was regarded as a highly risky destination due to the uncooperative policies, inconsistent regulations, poor infrastructure, unstable financial markets, multiple exchange rates, and later, economic sanctions.

Due to the economic sanctions imposed by the United States and some European Union countries since the late 1990s and early 2000s, the Asian region is the main source of FDI inflows into Myanmar. The huge differential between the official exchange rate and the market rate also continues to negatively affect FDI inflows and the competitive environment for the private sector. The State Economic Enterprises (SEEs) for instance, can import at the official rate and hence are at a huge competitive advantage over the private sector (Verbiest and Tin, 2011).

Myanmar's top two sources of FDI, the People's Republic of China (PRC) (inclusive of Hong Kong) and Thailand accounted for 71% of the total, followed by the Republic of Korea at 8% and the United Kingdom (inclusive of enterprises incorporated in the British Virgin Islands, the Bermuda Islands, and the Cayman Islands) at 7%. The FDI levels increased dramatically in 2006/2007 and remained stable until 2009, with the total permitted foreign investment amounting to \$15,722 million as of 31 January 2009 and doubling to \$35,518.440 million as of 31 January 2011 (Table 2).

Table 1: Share of Agriculture, Industry, and Services Sectors in Myanmar's GDP, 2000/2001–2008/09 (%)

GDP, 2000/2001–2008/09 (%)	%		
Year	Agriculture Sector	Industrial Sector	Services Sector
2000/2001	42.7	17.8	39.5
2001/2002	55.9	10.6	33.5
2002/2003	52.9	12.8	34.3
2003/2004	51.9	13.6	34.5
2004/2005	50.7	14.5	34.8
2005/2006	50.1	15.3	34.6
2006/2007	45.3	18.6	36.1
2007/2008	43.7	19.8	36.5
2008/2009	41.7	21.2	37.1

Source: CSO, Ministry of National Planning and Economic Development, Myanmar.

Table 2: Foreign Investment in Permitted Enterprises by Sector (\$ million)

Sector	As of 31.3.2000	As of 31.3.2003	As of 31.3.2005	As of 31.3.2007	As of 31.3.2009	As of 31.1.2011
Approved Amount						
Power				6,311.222	6,311.222	14,529.742
Oil and Gas	2,308.373	2,403.173	2,600.023	3,073.478	3,357.478	13,815.375
Mining	524.115	526.740	534.190	534.890	1,395.886	2,395.386
Manufacturing	1,468.979	1,604.068	1,610.408	1,610.408	1,628.896	1,668.126
Hotel and Tourism	818.059	1,059.661	1,034.561	1,034.561	1,049.561	1,064.811
Real Estate	997.140	1,025.140	1,056.453	1,056.453	1,056.453	1,056.453
Livestock and Fisheries	283.617	309.758	312.358	312.358	324.358	324.358
Transport and Communication	275.687	283.272	313.272	313.272	313.272	313.272
Industrial Estate	193.113	193.113	193.113	193.113	193.113	193.113
Agriculture	14.351	34.351	34.351	34.351	34.351	96.351
Construction	17.267	37.767	37.767	37.767	37.767	37.767
Other Services	13.386	23.686	23.686	23.686	23.686	23.686
Total	6,914.087	7,500.729	7,750.182	14,535.559	15,726.043	35,518.440

Source: Statistical Yearbook, Central Statistical Organization, Ministry of National Planning and Economic Development, Myanmar. Various years.

The bulk of the FDI that Myanmar has attracted so far is concentrated in sectors related to natural resources extraction, such as power, oil and gas, and gem mining. Some 80% of total FDI is channeled to the power industry (41%), and oil and gas industry (39%). Such figures are a strong indication that the foreign investors are interested most in extracting natural resources of Myanmar. FDI levels remain low in economic sectors that require little resource use but promise high returns, with the manufacturing sector attracting 4.7%, livestock breeding 0.9%, transport and communication 0.9%, and agriculture 0.3% of FDI. The export-oriented garment industry had relatively less attraction to foreign investors, especially after economic sanctions were imposed in the early 2000s. The food and beverages industry produced 75% of total industrial output, mostly for the domestic market. Transport and communication, the most important sector to be developed in order to catch up with global market changes, received only 0.9% (\$313.27 million) of FDI (Table 2). The sectors vital for import substitution, export promotion, and job creation while having very little impact on the environment, are exactly those that received the lowest proportions of FDI.

Barriers to FDI inflow, such as economic instability, fluctuations in the value of the local currency, and the use of multiple exchange rates, need to be addressed while modernizing the banking system, issuing currency legislation for transparent regulatory framework and avoiding frequent and/or arbitrary regulatory changes. Strategies will also be required to provide more incentives for investment in agriculture, livestock breeding, consumer equipment manufacturing, industrial manufacturing, and technology, rather than in natural resources extraction and use.

The environmental problems related to natural resource extraction and use are transboundary in nature and need to be considered regional issues rather than internal affairs of particular countries. The FDI structure in Myanmar is obviously not environmentally friendly and is definitely not headed in the direction of a green economy. Moreover, the investments in natural resources extraction have physical constraints that significantly restrict prospects for long-term development. Even the export of natural resources is carried out in raw form without value-added production or processing.

In order to maximize benefits from natural resources and reduce negative impacts, short-term measures, such as careful scrutiny of proposals, attracting investment for high value-added manufacturing, production based on existing industries, and enforcing accountability for side-effects through specific legislation, may be considered. Part of the revenue from natural resource extraction may also be channeled into public investments as productive expenditure to achieve the transformation of natural resources into human resources for long-term development.

Such human capital formation and domestic knowledge accumulation have the potential to attract other forms of investments, such as market-seeking and efficiency-seeking investments, providing a pathway out of the resource curse. Beginning with the period of economic transition, Myanmar has the opportunity to take advantage of other countries' experience and incorporate environmental conservation and sustainable long-term utilization of natural resources into its economic policies and strategies.

3.2 External Trade

Since Myanmar has pursued an export-led growth policy, the Government has encouraged exports promotion through relaxation and liberalization of trade policy. However, trade strategies, very often associated with free trade and government intervention concepts, were practiced. To be in line with the changing economic system, the Ministry of Commerce amended export and import policies and procedures with a view to developing external markets and adopted trade strategies to export all exportable surpluses, to import all the country's required goods, and to utilize human and natural resources effectively. It also promoted external trade not only in traditional exports but also more value-added commodities. Border trade was regularized in order to develop and strengthen bilateral trade relations with the five neighboring countries (MOC, 2010). Trade value increased from about \$400 million in 1988/1989 to \$11.77 billion in 2009/2010, an increase of more than 25 times (Table 3). ASEAN, the PRC, and India are major destinations for Myanmar's exports, accounting for more than 70% of total exports and about 90% of total imports.

The export structure of Myanmar has changed in line with the market-oriented system since 1999/2000. The garment sector grew rapidly and became a major foreign-exchange earner and job creation industry. Garment exports reached their peak in 2000/2001 and amounted to 30% of total exports, followed by agricultural products and natural gas (nearly 9%), which was a new export product at the time.

By 2008/2009, the major export items were natural resources, including natural gas (35.1% of total exports); precious and semi-precious minerals; and agricultural products (15.5%), mainly rice and rice products, pulses, maize, raw rubber, marine products, and forestry products (Table 4). Imports were almost equally shared among capital goods at 30%, intermediate goods at 33% and consumer goods at 37%.

Under such circumstances, diversifying export products, increasing export volumes, and improving the quality of the exports products should be among the main objectives of the export promotion policy. The import policy of Myanmar is to give priority to capital goods, industrial raw materials, and spare parts and other essential items. The Government needs to encourage public and private entrepreneurs to import commodities that will contribute to infrastructure development and production sectors.

4. Economic Growth and Development

In 1992/93, a 20-year plan consisting of 4 five-year short-term plans began. The first five-year plan spanning 1992 to 1996 achieved an average annual growth of 7.5%. The main drivers for the growth were the opening of trade as a result of the government liberalisation measures, the growth in tourism industry, and a short-term construction boom together with agricultural development based on successful rice harvests. However, during the second 5-year plan from 1996 to 2001, growth slowed as a result of repercussions from the 1997–1998 Asian financial crisis and economic pressure begun in the year 2000. But official statistics claimed 10.9 % and 13.7 % growth for 1999/2000 and 2000/2001, respectively, with an average annual growth of 6%. In this period, American and European economic pressure began, in connection with the political situation in Myanmar.

In the 2001–2006 plan, the Government claimed a better than expected economic growth performance of 12.9%. The principal aims of this plan were to build a more stable and diversified formulation for sustained growth of the economy, to attain the rank of agro-based industrialized nation, and to strive for balanced economy among the regions. Against the economic sanctions imposed by Europe and the United States, Myanmar was restructured and brought firmly into the orbit of the GMS and ASEAN. In order to transform itself to an agro-based industrializing nation, 18 industrial zones were established. The Myanmar Industrial Development Committee was formed to assist private entrepreneurs to acquire capital, raw materials, machinery and equipment, modern technology, and infrastructural facilities.

The fourth 5-year plan spanned 2006/2007 to 2010/2011, and aimed to achieve an average growth rate of 12.0%, maintain rapid economic growth, reduce poverty and implement the Millennium Development Goals (MDGs). Better-than-targeted annual growth rates were again claimed (Table 5), which on paper made Myanmar the fastest growing economy in the subregion. The main drivers for such growth were claimed to be more efficient land use, higher production, industrial sector development, and increased exports.

Claims of sustained double-digit economic growth for over a decade prompted studies by experts at home and abroad, raising questions over the growth rates claimed by

Table 3: Myanmar Foreign Trade

Particulars	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009
Export	2,544.25	3,062.85	2,356.81	2,927.83	3,558.00	5,232.70	6,401.70	6,779.10
Normal	2,253.80	2,546.01	2,077.97	2,580.42	3,127.70	4,585.50	5,655.00	6,121.50
Border	290.45	516.84	278.84	347.41	430.30	647.20	746.70	657.60
Import	2,735.59	2,299.63	2,239.97	1,973.28	1,984.40	2,936.70	3,353.40	4,543.30
Normal	2,618.08	2,084.12	1,971.27	1,682.87	1,692.80	2,491.30	2,770.60	3,852.30
Border	117.51	215.51	268.70	290.41	291.60	445.40	582.80	691.00
Trade Total	5,280.84	5,362.48	4,596.78	4,901.11	5,542.40	8,169.40	9,755.10	11,322.40
Normal	4,872.88	4,630.13	4,049.24	4,263.29	4,820.50	7,076.80	8,425.60	9,973.80
Border	407.96	732.35	547.54	637.82	721.90	1,092.60	1,329.50	1,348.60
Trade balance	(191.34)	763.22	116.84	954.55	1,573.60	2,296.00	3,048.30	2,235.80
Normal	(364.28)	461.89	106.70	897.55	1,434.90	2,094.20	2,884.40	2,269.20
Border	172.94	301.33	10.14	57.00	138.70	201.80	163.90	(33.40)

Source: Ministry of Commerce, Myanmar.

Table 4: Myanmar Exports by Commodity (%)

Commodity	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009
Agricultural Products	18.15	17.63	14.07	16.59	10.95	12.28	13.31	13.26	15.53
Animal Products	0.29	0.25	0.11	0.09	0.10	0.10	0.06	0.06	0.07
Marine Products	7.33	5.03	5.59	6.84	6.20	5.56	4.52	4.68	4.06
Timber	6.30	10.97	9.38	14.51	13.43	13.32	9.79	8.40	5.97
Base Metal and Ores	2.54	1.68	1.41	2.41	3.28	3.13	2.13	1.35	0.48
Precious and Semi-precious Minerals	2.85	0.74	1.25	2.53	3.69	6.58	7.43	10.08	9.72
Gas	8.72	24.79	29.66	24.63	34.81	30.20	38.89	39.49	35.10
Garment	29.72	17.42	14.91	13.92	7.41	7.68	5.34	4.41	4.30
Other Commodities	24.09	21.48	23.61	18.47	20.13	21.15	18.55	18.28	24.77
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Ministry of Commerce, Myanmar.

the Government, especially those in the post 1999/2000 period. In the six decades of independence since 1948, the country achieved an annual double-digit growth twice in the 1950s (in 1950 and 1956) and 3 times in the 1960s (in 1962, 1964, and 1967). Those years were all immediately preceded or followed by a negative growth year. But the double-digit growth rate beginning in 1999/2000 was claimed to have continued for over a decade. Such sustained double-digit growth represents a sharp break with the country's development experience in the entire post-independence era (U Myint, 2009).

The International Monetary Fund (IMF) and World Bank noted that no developing country anywhere in the world has ever achieved such growth and that given the regional and international situation, the robust growth claimed by Myanmar was highly controversial. While real GDP growth was about 6%–7% in the 1990s and appeared to be in line with other indicators, double-digit growth claimed for 1999–2000 and continued over the last decade, together with many other indicators, suggests a substantial overvaluation of GDP. The IMF estimates average growth at around 4.5%–5% over the past decade, significantly

lower than that of Cambodia, the PRC, the Lao PDR, and Viet Nam (Table 6).

There are several reasons why Myanmar GDP growth is controversial among national and international observers. One of the reasons would be the weakness of the System of National Accounts (SNA). Compiling GDP estimates is just the first step of a comprehensive analysis of the economic development trajectory. The SNA has many weaknesses and has been revised from time to time. Two estimators using two different versions of SNA will give different GDP estimates at the same time. Although the compilation of macroeconomic variables requires special skills and extraordinary efforts, the best estimate is no more than an approximation (Studenski, 1958). However, errors are more often due to gaps and inaccuracies in the data. Also, coverage of the economy in terms of formal and informal economic activities will make GDP estimates different; the use of different methods of deflation and inflation (single/double) is another factor to be considered. In the case of Myanmar, the most questionable factor is the use of exchange rates in constructing GDP estimates (Table 7).

Table 5: Economic Growth Trajectory, Myanmar, 1981/1982–2008/2009

Fiscal Year	GDP growth rate (%)	Fiscal Year	GDP growth rate (%)	Fiscal Year	GDP growth rate (%)
1981/1982	6.4	1991/1992	-0.7	2001/2002	11.3
1982/1983	5.4	1992/1993	9.7	2002/2003	12.0
1983/1984	4.3	1993/1994	6	2003/2004	13.8
1984/1985	4.9	1994/1995	7.5	2004/2005	13.6
1985/1986	2.9	1995/1996	6.9	2005/2006	13.6
1986/1987	-1.1	1996/1997	6.4	2006/2007	13.1
1987/1988	-4	1997/1998	5.7	2007/2008	11.9
1988/1989	-11.4	1998/1999	5.8	2008/2009	10.7
1989/1990	3.7	1999/2000	10.9	2009/2010	10.4
1990/1991	2.8	2000/2001	13.7		

Source: CSO, Ministry of National Planning and Economic Development, Myanmar.

Table 6: Growth Rate of Myanmar's GDP (% per year)

	2005	2006	2007	2008	2009	2010
Cambodia	13.3	10.8	10.2	6.7	0.1	6.3
PRC	10.4	12.7	14.2	9.6	9.2	10.3
Lao PDR	7.3	8.1	7.9	7.2	7.3	7.5
Myanmar ^a	13.6	13.1	12	10.2	10.4	10.8
Myanmar ^b	4.5	7.0	5.5	3.6	5.1	5.3
Thailand	4.5	5.1	5.0	2.5	-2.3	7.8
Viet Nam	8.4	8.2	8.5	6.3	5.3	6.8

Notes: a Official GDP

b Adjusted based on weighted exchange rate, IMF

Source: ADB. 2011. *Asian Development Outlook 2011*. Manila. Table A1.

Table 7: Economic Growth and Macroeconomic Indicators, Myanmar

	Economic Growth	Inflation	Exchange Rate (Official)	Exchange Rate (Market)
1999/2000	10.9	15.2	6.2	
2000/2001	13.7	-1.7	6.5	627
2001/2002	11.3	34.5	6.7	936
2002/2003	12.0	58.1	6.5	979
2003/2004	13.8	24.9	6.0	912
2004/2005	13.6	3.8	5.7	1,067
2005/2006	13.6	10.7	5.8	1,281
2006/2007	12.7	26.1	5.7	1,302
2007/2008	10.2	32.9	5.5	1,206
2008/2009	10.4	22.5	5.5	1,081
2009/2010	10.8	8.2	5.4	973

Source: CSO, Ministry of National Planning and Economic Development, Myanmar.

Under these circumstances, a single indicator, such as GDP growth, cannot measure the economic success of a nation, which encompasses much broader areas of the economy and the people's welfare as well as the physical environment. In other words, GDP growth in Myanmar can only serve as one of the indicators and a proper overview of the country's socioeconomic life will require the consideration of other macroeconomic and social indicators.

According to the classic economic theory, investment levels play a vital role and have a strong positive correlation with GDP growth, making investment ratios a highly pertinent macroeconomic indicator. The investment ratio in Myanmar over the past decade was 12–15. Viet Nam had an investment ratio between 35 and 40 and an average growth of about 8% during the same period. Similarly, the PRC

had much higher investment ratios than Myanmar and an average growth rate of about 10% over the decade. Among the GMS countries for which investment data are available, the investment ratio in Myanmar is the lowest (Table 8).

5. Human Resources Development

The role played by human capital in the development of the country is as important as that of physical capital, if not more important, as economic growth and human resource development are mutually reinforcing. In evolutionary economics, the best investment for the future of a country is considered to be human capital formation. Myanmar's rating in the Human Development Index (HDI), a social indicator, has fallen behind that of other GMS countries (Table 9).

Table 8: Gross Domestic Investment (% of GDP)

	2000	2005	2009	2010	2011
Cambodia	17.5	18.5	16.0	18.5	19.0
PRC			48.2	23.8	
Myanmar	12.4	13.2	14.6	15.2	14.2
Thailand	22.8	31.4	21.2	26.0	27.9
Viet Nam	39.6	35.6	38.1	38.0	36.4

Source: International Monetary Fund. 2011. *World Economic Outlook Database*. April 2011 Edition. Washington, DC.

Table 9: Human Development Index in GMS Countries (country ranks and scores)

Economies	2005		2010		2005–2010 Change	
	Rank	Score	Rank	Score	Rank	Score
Cambodia	125	0.466	124	0.494	1	0.028
PRC	81	0.616	89	0.663	8	0.047
Lao PDR	126	0.460	122	0.497	4	0.037
Myanmar	138	0.406	132	0.451	6	0.045
Thailand	93	0.631	92	0.654	1	0.023
Viet Nam	114	0.540	113	0.572	1	0.032

Source: <http://hdr.undp.org/en/media/HDI-trends-1980-2010.xls> (accessed on 7 May 2011).

Table 10: Components of Human Development Index

Economies	Life Expectancy at Birth (years)		Mean Years of Schooling (adults aged 25 years and above)		Expected Years of Schooling of Children (years)		GNI Per Capita (2008 US\$ at PPP)	
	2005	2010	2005	2010	2005	2010	2005	2010
Cambodia	59.4	62.2	5.7	5.8	9.7	9.8	1,511	1,868
PRC	72.6	73.5	7.1	7.6	10.7	11.4	4,434	7,258
Lao PDR	63.6	65.9	3.9	4.6	9.0	9.2	1,693	2,321
Myanmar	60.6	62.7	3.5	4.0	8.9	9.2	1,102	1,596
Thailand	68.4	69.3	5.9	6.6	13.5	13.5	6,955	8,001
Viet Nam	73.8	74.9	4.9	5.5	10.4	10.4	2,274	2,995

Source: Human Development Report 2010 - 20th Anniversary Edition.

As can be expected of a least developed country (LCD), the HDI ranking for Myanmar is 132 out of 169 countries, significantly lower than that of other GMS countries. However, the overall HDI ranking changed faster than other member countries, showing an increase of 11% or average annual increase of about 2.1% between 2005 and 2010. Similarly, the components of HDI (Table 10) reveal progress in Myanmar over the period. In terms of gross national income (GNI) per capita, Myanmar increased 45%, below that of the PRC (64%) but higher than that of other GMS countries: Cambodia (24%), Lao PDR (37%), Viet Nam (32%) and Thailand (15%). Although most of the components are lower than those of all members, mean years of schooling and expected years of schooling increased by about 0.5 and 0.3 years, respectively, while life expectancy at birth increased slightly by over 2 years.

A quality basic education system is a prerequisite for human resources development, as is a healthy and knowledgeable workforce. For longer-term development and growth, investments in health and education sectors leading to human resources development will be essential. Myanmar's low HDI ranking is due mainly to the government's low levels of spending on health and education - 0.2 % and 0.8% of GDP in 2010 (ADO 2011), a lack of coherent and continuous education policy, failure to create knowledge-

based employment opportunities, and lack of incentives for academic pursuits. In the case of education, the frequent suspensions of tertiary education classes and changes in the education system severely affected the quality of education in Myanmar over the last two decades. Public sector expenditure on education decreased from about 1.9% of GDP in 1990 to 0.6% in 2010. Consequently, education indicators for Myanmar are well below those of its neighbors and peers. However, there has been a series of reforms introduced to improve quality and accessibility of education across the country and a substantial expansion of private sector education in the past decade.

Water quality and quantity are of economic, social, and environmental importance. The proportion of population with sustainable access to an improved water source was 66% in 2000 and increased to 71% in 2008, which is much higher than two other GMS countries, Cambodia and the Lao PDR. Similarly, the proportion of population with access to improved sanitation facilities in Myanmar increased from 65% in 2000 to 81% in 2008, while in Cambodia and the Lao PDR, the corresponding proportions were 29% and 53%, respectively (Table 11). However, Myanmar's freshwater resources are threatened by overexploitation and pollution both from industrial and domestic waste. Also, several damming projects such as the Ayeyarwady Myitsone

Table 11: GMS Social Indicators

Economies	Improved water source (% of population with access)		Improved sanitation facilities (% of population with access)	
	2000	2008	2000	2008
Cambodia	46	61	17	29
PRC	80	89	49	55
Lao PDR	48	57	26	53
Myanmar	66	71	65	81
Thailand	96	98	93	96
Viet Nam	79	94	57	75

Source: World Development Indicator, World Bank, available at <http://databank.worldbank.org/ddp/home.do> (accessed on 19 May 2011)

Hydropower project, are threatening sustainable freshwater resources and the whole ecosystem of the country.

6. Environment and Biodiversity

Different economic systems practiced in Myanmar throughout its post-independence period have shaped the Myanmar economy and will continue to shape it in the future. For several decades, Myanmar had implemented the National Development Plan with the aim of accelerating growth, achieving sustainable development, and reducing socioeconomic disparities between rural and urban areas of the country. While rapid growth is being pursued as the top priority in the short term, the long-term strategy must be to strive for sustained and stable growth of the economy guided by a philosophy of environmentally sound development that improves the quality of life of the people, makes proper use of natural resources, and protects essential ecological processes and biodiversity (MNPED, 2010). In practice, it seems easier to set the economic policy priorities in favor of rapid growth rather than balanced growth with economic sustainability. The mechanism of realizing sustainable development is usually slow in yielding concrete benefits, making it more difficult to justify the sacrifices in economic growth for future environmental sustainability.

Myanmar is indeed very rich in forest resources, with approximately half the total land area under forest cover. The variety of climatic zones from temperate to arid and tropical allows different forest types to exist: temperate forests in the north, deciduous and dry forests in the central regions, and semitropical rain forests in the south. They are home to over 7,000 different plant species, including 2,100 tree species, 840 kinds of orchid, 96 varieties of bamboo, and 32 different types of cane. Myanmar's forest cover declined from 61% in 1975 to 59% in 1989, to 52%

in 1998, and to 47% in 2010. The annual deforestation rate is about 0.3% of total country's area (MOF, 2001) while another source stated that the rate is about 1.4%, which is one of the highest among ASEAN countries (MOF, 2004).

Environmental preservation activities in Myanmar have gathered some momentum. Under the Myanmar Forest Policy (1995), 30% of the total land area is designated as reserved forests, and 5% as Protected Area System (PAS). Currently, there are 43 PAS areas, of which 34 have been notified, 9 proposed, and 121,911 km² reserved (MOF, 2009). In 2001, 19% of the country's area was legally classified as Reserved and Protected Public Forests (16.48% and 2.67% respectively). By adopting the MDGs and implementing the 1995 Myanmar Forest Policy, the total area of both types of forests increased to 23.2% of total land area in 2006 (MOF, 2009). Similarly, the private sector is now allowed to grow teak on a commercial basis. Establishment of forest plantations is making progress, albeit rather slowly.

Myanmar is also rich in biodiversity; however, loss of biodiversity due primarily to socioeconomic pressure is unavoidable in a developing country like Myanmar. The general trend toward a decrease in the wild animal population became apparent over the past 20 to 30 years, due partly to habitat destruction, and partly to small populations failing to sustain a viable rate of reproduction in the wild (FD, 2009). In particular, the downward trend is apparent with large mammals, such as tigers and elephants, because of their altered sex ratio and home range reduction by human activities.

As much as 95% of Myanmar households use solid fuels, such as firewood, for cooking. Nevertheless, Myanmar, has the lowest carbon dioxide emissions in the GMS (MOF, 2009). Also, fewer people than elsewhere in the subregion are affected on average by natural disasters (Table 12).

Table 12: Carbon Emissions and Disasters

Economies	Carbon Dioxide Emission Per Capita (ton)		Population Affected by Natural Disasters (average per year, per million people)
	1999	2006	2000–2009
Cambodia	0.1	0.3	62,992
PRC	2.3	4.6	96,359
GMS	1.1	1.8	43,613
Lao PDR	0.1	0.2	24,535
Myanmar	0.2	0.2	5,989
Thailand	3.3	4.3	46,173
Viet Nam	0.6	1.2	25,632

Source: Human Development Report 2010, Table 7, p: 170-171

Myanmar has acknowledged the need to integrate environmental considerations into its economic policies and poverty alleviation programs. It has established a National Sustainable Development Strategy (NSDS, 2009) with the vision of “Well-being and Happiness for Myanmar People” and similar plans to strengthen institutions, monitor and enhance environmental quality, provide environmental education, and raise public awareness. The most critical constraint for improving environmental management is the absence of clear institutional responsibility and the lack of effective enforcement associated with limited technological and organizational capabilities. In order to promote environmental conservation, the Government, private entities, and donors should employ both moral and profit motive approaches for the business sector and communities in rural and urban areas to take into account the damage to environment as a result of development and strike a balance between development and environmental protection.

7. Regional Connectivity

Myanmar is of geopolitical importance for regional connectivity with its location at the junction of East Asia, Southeast Asia, and South Asia, and a potential central hub for exchange of goods, services and technology. The country is a full member of several regional and subregional organizations apart from the GMS. Underdeveloped infrastructure and an unfavorable institutional and business environment seriously limit Myanmar's economic participation in regional and global networks. Cross-border connectivity plays a very important role in this scenario. Establishing better connectivity will allow Myanmar and other GMS countries to create possibilities for collaboration between them and to expand economic synergies for development in the broad Asian region.

7.1 Physical Connectivity: Transport

There are three main economic corridors that have so far been defined in the GMS Program, namely, the East-West Economic Corridor (EWEC), running from the Da Nang Port in Viet Nam, through Lao PDR, Thailand, and to the Mawlamyine Port in Myanmar; the North-South Economic Corridor (NSEC), which covers the major routes running from Kunming to Chiang Rai to Bangkok via Lao PDR and via Myanmar, and from Kunming to Hanoi to Haiphong (and most recently, from Nanning to Hanoi); and the Southern Economic Corridor (SEC), which runs through southern Thailand, Cambodia, and southern Viet Nam. The PRC

and India have suggested to the Myanmar Government that the 1,726 kilometer Stilwell Road, which could serve as an important road link between the world's two most populous nations, be reopened.

With the assistance of the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), Asian Development Bank (ADB), and Mekong River Commission, the East-West Economic Corridor project is being implemented not only to improve freight transportation and to facilitate trade in the subregion but also for the development of a transportation network across the GMS, mainly in Cambodia, Lao PDR, Myanmar, and Viet Nam (Cho, 2008). The EWEC is designed to be the direct and continuous land route between the Indian Ocean and the South China Sea. The highly efficient transport system will strengthen economic cooperation between the Lao PDR, Myanmar, Thailand, and Viet Nam by linking two port cities: Mawlamyine in Myanmar and Da Nang in Viet Nam. Although the EWEC connects eastern ASEAN countries, the Western Economic Corridor (Mawlamyine to Tamu) and SEC are the key base to establish a Mekong-India Economic Corridor (MIEC) by extending the link to Dawei in Myanmar.

The Dawei project will cover an area of approximately 250 km² (on shore) and consist of three major components: deep sea port; industrial estate; and cross-border road, rail, and pipeline link with connecting electrical transmission lines to the Myanmar/Thai border. The total project investment cost of infrastructure and supporting facilities is estimated to be \$8.6 billion, and the required investment from potential industrial investors in the industrial estate is estimated to exceed \$50 billion (ITD, 2010). The project will reduce logistical and labor costs for GMS members while creating job opportunities in Myanmar. It will bring good opportunities for the region as a whole since Dawei port will serve as a new commercial gateway providing an alternative sea route to the PRC, India, Middle East, Europe, and Africa that will reduce dependence on the congested Straits of Malacca and yield significant savings in transportation time and logistic costs (MPA, 2010).

Connecting the GMS and India was more or less initiated by the establishment of Mekong-Ganga Cooperation (MGC) in 2000 in the Lao PDR. After completion of EWEC transport network, it will be possible to travel by road from India to Viet Nam passing through Myanmar, Thailand, and the Lao PDR. India has also proposed an India-Myanmar-Thailand trilateral highway to extend to Cambodia and the Lao PDR with the aim of fostering greater cooperation within the

Mekong region (ADB, 2010). The MGC is advantageous for Myanmar as it will enable direct trade, transit trade, and the development of special economic or industrial zones along the corridors (e.g., Yangon, Mandalay, Monywa, Myingyan, Mawlamyine, Dawei, and Kyautphyu) as well as trade posts in the border areas (e.g., Myawaddy, Tamu, Rhi, and Muse). Development of economic corridors and transportation networks will reduce not only transport costs but also growth differentials among the countries in the subregion (Tin *et al.*, 2011).

The PRC is developing another project for building a deep sea port at Kyaukphyu in western Rakhine State. The main harbor at Kyaukphyu will link to a new 1,950 kilometer highway to be built from Kyaukpyu of Myanmar directly to Kunming, the capital city of Yunnan Province. The project will shorten the overall distance by thousands of kilometers and will save money and time for the PRC by sending their products to the west and Middle East through Myanmar instead of passing through the Malacca Strait (MPA, 2010). As both the Dawei and Kyaukphyu projects are designed to develop the deep sea port with industrial zones and transportation links, they will promote not only trade volume but also FDI in the GMS.

Myanmar is located at a strategic geographical location in the GMS. Development programs in the subregion will depend to a significant extent on subregional connectivity. As it is costly for GMS countries to reach the Indian Ocean through the Malacca Straits, Myanmar can serve as a gateway via the EWEC and SWEC corridors. However, the current economic projects being implemented in Myanmar are faced with delays due to economic sanctions and the effects of the international financial crisis.

Some political and security issues require bilateral and multilateral attention, especially territorial and border issues between neighboring countries. The territorial issues and armed ethnic groups along the border areas of Cambodia, the Lao PDR, Myanmar, Thailand, and Vietnam have impeded the implementation of regional cooperation programs. Illicit trade (of timber and precious stones from Myanmar to Thailand, for example), trafficking in persons and transnational crime are also challenges that require resolution before the regional cooperation programs can proceed fully.

While the infrastructure projects are implemented in order to improve regional connectivity, capacity for proper management in conservation of the natural environment needs to be built. Environmental friendly practices, such

as proper waste management, low carbon emission techniques, and systematic treatment, are to be set up in the industries of special economic zones, but some environmental degradation and pollution of soil, air, and water will occur. International organizations may give special consideration to environmental conservation in Myanmar in providing financial and technical assistance.

7.2 Institutional Connectivity: Trade

Myanmar has shown an interest in cooperating more closely with the ASEAN member countries and has joined the ASEAN Free Trade Area (AFTA) to be implemented from 2015, covering nearly 3 billion people. With the expansion of markets for ASEAN countries, competition for market share is also likely to intensify. Import prices in the region will be lower leading to greater domestic consumption and increased trade. However, the private sector in Myanmar, as well as in Cambodia, the Lao PDR, and Vietnam, have raised concerns about the consequences of imminent economic freedom.

Myanmar has little experience in market economic practices and poor access to the necessary technology and financial resources. Under such circumstances, plunging into direct competition with more experienced countries under AFTA is likely to have more harmful than beneficial effects. Within the new setting of a regional market, Myanmar will need to attain market competitiveness, quality competitiveness, and product competitiveness for its survival and growth.

The Myanmar economy is based on primary sectors and relies on exports of raw material rather than value-added products. While there are advantages, such as rich natural resources and low labor costs, much work remains to be done before the advantages can be translated into a competitive edge in trade. Export promotion is closely linked to increasing productivity. In other words, greater competitiveness in any economic sector requires greater productivity, which in turn calls for either improvements in efficiency or an increase in capital intensity, or both. There is a great potential in Myanmar to create a highly skilled labor force, strong technology, and knowledge base, high-tech infrastructure, and corporate governance through dynamic and coherent economic strategies (Rasiah, 2007; Rasiah and Myo, 2011). But at present, Myanmar's efforts to achieve market competitiveness have fallen far behind the required levels in almost every aspect. Clearly, Myanmar requires a preparatory period before it can hope to compete with countries in the region on what can be considered an equal basis.

During such a period, Myanmar needs to be considered a complementary trade partner rather than a market competitor. It can serve as a regional food basket, a logistic hub, an energy supplier, or a host to supportive manufacturing industries, while preparing for survival and growth with good long-term prospects for a strong economic position in the regional market.

8. Development Prospects for the Economy

An indicator for successful policy making by a government would be the achievement of its development objectives to the greatest extent possible with the minimum use of its natural resources. In Myanmar, a mixed economic system that originated in the colonial period was practiced after the gaining of independence until 1962. It gave way to the centrally-planned “Burmese way to socialism” between 1962 and 1988. After that, the State Peace and Development Council adopted a market-oriented economy with some success. However, according to macroeconomic indicators, Myanmar has fallen behind its neighboring countries.

An overview of the 60-year economic trajectory of Myanmar reveals a lack of balanced and accurate judgment of the realities within the country in the formulation and implementation of national economic policy, lack of competence and experience in economic management, impractical policies, high levels of corruption, and a general lack of good governance.

The new Government that came to power in April 2011 seems to be steering the country in the direction of reform, with the President U Thein Sein calling for clean government, good governance, and poverty alleviation to lift the country out of the least developed country (LCD) status. There have been efforts toward tripartite cooperation and collaboration among the Government, businesses, and professionals for national development through evaluation of the realities in the country and through reforms. For short-term economic stability and growth, the Government claims to be working to revise export-import licensing and taxation; control the extraction, utilization, and export of natural resources; control foreign exchange market fluctuations; obtain assistance from international organizations for financial sector reform and exchange rate unification; improve functioning of the banking sector and the rationalize interest rates; regularly publish accurate economic statistics; and ensure efficient good governance through transparency, accountability, and credibility.

An important issue that the new Government is facing is the rapid appreciation of the local currency, leading to widespread instability in all sectors of the economy, with significant impact on export activities such as agriculture, fisheries, and garment industry that directly impact the rural population and the labor force. While the immediate impact falls on businesses, brokers, and business owners, the price instability in the forthcoming growing and harvest seasons threatens to undermine the rural economy extensively. Damage control measures that have been put in place include reduction in tax rates (with export tax rates being reduced from 10% to 2%, while the withholding tax of 2.5% has been revoked), reduced taxes or tax holidays for agricultural exports, speedy processing of export-import procedures, and setting up of monitoring units to respond to market conditions in real time. Currently, the interest rates in Myanmar, set at 12% for deposits and at 17% for loans, are the highest in the subregion and ASEAN. This is a clear symptom of an underdeveloped banking system impeding the development of small and medium enterprises.

At the same time, agricultural development is being undertaken as part of poverty alleviation, using a multidisciplinary approach. Capital and technology investment is necessary for large-scale farming that can achieve economies of scale and boost productivity. Currently, farmers will be provided with access to microfinance and farm-related technology. To counter the effects of declining prices for agricultural produce and the local currency appreciation, government interventions for government-led economic stabilization and growth are being implemented.

Past experience suggests that the formulation and implementation of economic policies for national development can prove challenging due to weaknesses in implementation and strategy development combined with inflexibility or lack of timely response in the face of market shifts. While there has been insufficient time for a meaningful evaluation of the progress made by the new Government, the new economic measures are considered to be responsive to the needs of the market and on the right track toward economic stability.

At the same time, the principle of unity in diversity is being practiced to maintain political stability in the country, with nascent positive cooperation among political parties. To ensure social stability, measures are being planned to narrow inequalities among nationalities, regions, and the towns and villages. Policies and procedures for the

delegation of authority from the Union Government to the Regional/State government bodies is also hoped to contribute to the resolution of ethnic problems.

Projections of a nation's likely course in the future require the compilation of reliable macroeconomic variables, special skills, and extraordinary efforts as well as making various assumptions. While the best estimates cannot hope to be anything more than an approximation, the task becomes even more formidable for an underdeveloped nation that is attempting an economic transition, such as Myanmar. This exercise would be more helpful in terms of providing answers to what-if questions that policy makers and analysts may take into consideration in formulating short- and medium-term development policies and strategies, rather than in predicting economic statistics of the country at some point in the future. In this sense, the predictions in this document are no more than simple guesstimates based on the past experience of the country, similar experiences of other neighboring countries, and insights from the development literature and extant studies.

The three major assumptions for this scenario are: (1) the political and economic circumstances at the prospects of the world in general, and of Asia and the GMS in particular, remain stable in the current general form; (2) political and economic transitions in the GMS and ASEAN remain under control; and (3) there are no major climate change impacts and natural disasters. Another country-specific assumption is that significant improvements will be achieved in the following factors: (1) political will and commitments, (2) strengthening institutions and human capital formation, (3) stability in all areas, (4) economic specialization and diversification, (5) regional integration and connectivity, (6) managing natural resources and sustaining environment, and (7) an efficient monitoring and evaluating system.

In Table 13, a score of 7 is given if all factors are achieved fully to give the ideal situation; a score of 3.5 reflects an average situation; while little or no progress in most of the factors is shown by a score of 0.

9. Policy Implications

9.1 Political Will and Commitment

(1) Political will and commitment

By nature, the government's policy making is not independent from the political security interests and, therefore, does not always act in the national economic interest. Under the circumstances, although the spirit of the economic policy very often well reflected Myanmar economy's needs, its implementation caused obstacles for the set-objectives to be achieved. Adverse impact of these economic and political imbalances was linked to other dimensions of flaws, which in turn contributed to overall distortion of the economy in the past. Therefore, the policy making should be primarily motivated by the need to bolster the deteriorating national economy and to achieve growth to keep up with the other countries development and address the interests of the people.

(2) Stability by all means

Political, social and economic stability is essential. Political and social stability should be resolved by seeking unity in the diversity concept. Macroeconomic instability has remained at the core of Myanmar's economic problems and has never been tackled firmly even in recent years. Macroeconomic stability must be a priority for Myanmar policymakers looking forward. Macroeconomic stability associated with policy predictability and transparency is the cornerstone of economic policy and a precondition for accelerated economy growth and economic takeoff in Myanmar.

(3) Strengthening institutions and human capital formation

For Myanmar to be able to join the middle-income countries group, policy making institutions need considerable strengthening and to be given independence of decision making in their area of competency. Greater decentralization and reduced micromanagement are also essential (Verbiest and Tin 2011). Transparency of

Table 13: Economic Development in the Next 10 Years

Score	Per capita gross domestic product (\$)	Poverty Rate (% population)	Human Development Index	Reserved and Protected Public Forests (% of total country's area)
7.00	821 to 1,668	26 to 13	4.5 to 5.7	27.9 to 36.9
3.50	821 to 1,241	26 to 20	4.5 to 4.9	27.9 to 32.6
0.0	821 to 998	Slight change (+/-)	Slight change (+/-)	27.9 to (-)

Source: Author's guesstimates.

decision-making needs to be given due attention as should accountability. Several new institutions will also have to be set up as the economy develops and becomes more sophisticated. Similarly, policy makers need to give serious consideration to develop a strategy to address the issue of human-resource development.

(4) Economic specialization and diversification

There is a big danger that relatively high growth could be reached from rapid growth in the oil, gas and mining industry. It would put growth on a non-sustainable and non-inclusive long-term path, often leading to social unrest. Major policy reforms to revive the agriculture sector including land reform, give incentives to improve agriculture support services. A realistic industrial sector strategy should be developed in order to support the diversification of the economy mainly through private sector development, and linking investment incentives and infrastructure development to the strategic priorities.

(5) Regional integration and International supports

To support higher growth and also to become a major strategic regional player, Myanmar needs to invest massively in upgrading its infrastructure and improve institutional and regulatory framework.

(6) Managing natural resources and sustaining environment

Environmental sustainability is a major concern in Myanmar not only for high growth to be sustainable but also and mainly to preserve quality of life of its people. The pressure on natural resources including fresh water, forests and sea/coastal resources is very high and needs to be managed tightly to keep the country on a sustainable growth path. Precise targets such as carbon dioxide emissions, protected land areas, seawater quality area can be set. In exploiting its natural resources, Myanmar has still the opportunity to do it in a sustainable way, relying on the latest technology and best practices.

(7) Monitoring and evaluating system

An independent monitoring and evaluation mechanism must be set up to overview the reforms and policy implementations.

10. Conclusion

Myanmar is aiming to transform itself from a primary economy to an industrializing economy and to advance

core livelihoods from a “traditional pattern” to full integration into “capitalist modernity” during the coming decades. Its abundant natural resources will be the major factor underpinning its economic success. A stable political climate and a set of outward-oriented economic policies will help Myanmar gain reclassification as a rapidly growing developing economy in the GMS.

In retrospect, government policy regimes have consistently played a key role throughout Myanmar’s recent past in regulating markets and determined whether the economy is State-regulated or self-regulatory or somewhere in between. In other words, government performance has taken the form of either active support or active intervention. Flexibility in policy making in response to internal and external circumstances will be one of the most important determinants if the expected success story is to come true. Moreover, this policy nexus has generally succeeded in maintaining a constructive interaction between the State and the private sector by adopting proactive business policies and liberal market mechanisms. Moreover, improving regional integration will also boost growth of the country, while it strives to strike a balance between economic growth and environmental sustainability strategies.

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ECONOMIC GROWTH AND DEVELOPMENT IN VIET NAM, 2001 - 2010 AND STRATEGIES AND PLANS TO 2020

Duong Duc Ung

Abstract

Viet Nam successfully implemented a 10-year Social-Economic development Strategy 2001–2010 (SEDS) that resulted in important achievements in growth and social progress. By its own efforts and with support from development partners, Viet Nam has become a middle income country (MIC) and has greatly reduced poverty. These achievements are due to high economic growth during two 5-year plans covering the decade. A few economic sectors, such as agriculture and the textile and garment industry used the advantage of Viet Nam's former least-developed-country status to make strong contributions to meet the needs of domestic consumption and export and create more jobs for poor people.

Viet Nam has developed a Social-economic Strategy for 2011–2020 with the overall goal of transforming Viet Nam into a modern industrialized country by 2020 in a context of various opportunities and challenges. For achievement of this overall goal, the country needs to focus on three issues in its 5-year plans: developing an institutional framework for the market economy, training human resources, and modernizing infrastructure.

1. What has been achieved in Viet Nam during 2001–2010?

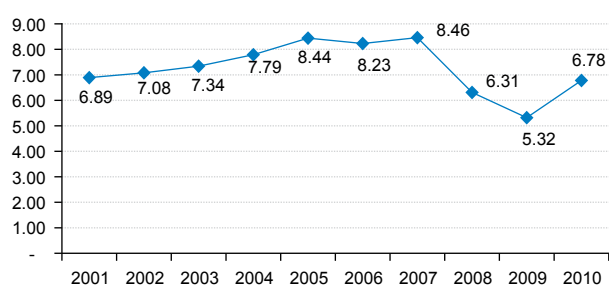
The main achievement by Viet Nam in the past 10 years is upgrading its status from the group of “underdeveloped countries with low income (LIC)” to that of “developing countries with middle income (MIC)”. The MIC classification by the World Bank includes countries with GDP per capita \$950–3,500. In 2010, GDP per capita of Viet Nam reached \$1,168.

The above-mentioned general development achievement was a combination of economic growth and social progress. Economic growth was maintained at high speed during two 5-year plans covering 2001–2010 (Figure 1). However, in the last years of the second 5-year plan (2006–2010), growth decreased slightly due to the impact of the global economic crisis and domestic macroeconomic instability, high inflation, large national currency depreciation, natural disasters, and animal disease outbreaks. As a result, average growth of the economy in 2006–2010 was about 7%, lower than the 7.5% in 2001–2005. Despite that, in comparison with many countries in the region, economic growth of Viet Nam was positive.

Early in 2011, the Government approved a package to stabilize the macroeconomy and contain inflation (Resolution No 11), including measures of monetary policy, financial, investment, and public expenditure savings. Efforts to stabilize the situation have brought some results; inflation, though still high, has tended to decline. The Asian Development Bank (ADB) predicted that inflation will fall from 18% in September 2011 to 11% in 2012. Foreign exchange reserves have increased; the International Monetary Fund estimated reserves at \$13.5 billion in May 2011, and exchange rate stability is being restored.

The relative high rate of development across sectors has been crucial in the economic growth of the economy during the past decade (Table 1).

Figure 1: Economic Growth Rate in Viet Nam, 2001–2010



Source: Government Statistics Office.

Table 1: Sector Growth during 2006–2010 (%)

Sector	Target	2006	2007	2008	2009	2010	2006-2010
Agriculture	3.83	3.69	3.76	4.68	1.82	2.78	3.3
Industry and Construction	9.5-10.2	10.38	10.32	5.98	5.52	7.70	7.9
Services	7.7-8.2	8.29	8.85	7.37	6.63	7.52	7.7

Source: Ministry of Planning and Investment.

The structure of gross domestic product (GDP) has shifted; the proportion of agriculture is declining and the proportion of industry and services is increasing, although not sufficiently to meet the targets outlined in the 2006–2010 5-year plan (Table 2).

Table 2: Economic structure of GDP in 2006–2010

Sector	Planned (%)	Implemented (%)
Agriculture, Forestry, Fishery	15–16	20.6
Industry and Construction	43–44	41.1
Services	40–41	38.3

Source: Ministry of Planning and Investment.

During 2001–2010, agriculture (including agriculture production, fisheries and forestry), industry (including garments and textiles) and construction, and services achieved encouraging results and contributed significantly to economic growth of the country, especially through trade. These sectors not only contribute to the economic growth but also create jobs for poor people in rural and urban areas, contributing to poverty reduction.

Agriculture lays the foundation for Viet Nam's social-economic stability and maintained a relative high growth rate with a decisive impact on poverty reduction by ensuring food security and generating employment and income in the rural sector, which accounts for 70% of the population. With regard to trade, rice exports increased from 3.7 million tons in 2001 to 5.8 million tons in 2010, making Viet Nam and Thailand first and second largest rice exporters, respectively, in the world. Viet Nam is not only able to ensure domestic food security but also contributes to global food security.

During the development process, some land has been transformed from agricultural use to industry and infrastructure development, including construction of roads, ports, airports, industrial parks, export processing zones, and real estate. Farmers, who lost their land have migrated to urban areas seeking work, thus creating pressures on urban areas.

The development of the textile and garment industry has contributed not only to economic growth and export, but also created more jobs in urban areas. Textile and garment exports increased strongly from \$1.9 billion in 2001 to more than \$11 billion in 2010.

Exports have contributed significantly to economic growth of Viet Nam, increasing from about \$14.5 billion in 2000

to nearly \$32.5 billion in 2005, and likely to reach \$72.2 billion in 2010. The proportion of exports in GDP increased from 46.5% in 2000 to 70% in 2010. Export value per capita increased from about \$187 in 2000 to about \$830 in 2010.

The acceleration of Viet Nam's exports is due to many reasons. Before renovation,¹ Viet Nam mainly had trade relations with countries in the socialist system. Since then, especially since Congress IX, which promulgated the Foreign Investment Law, the number of countries and territories investing in Viet Nam as well as importing goods from Viet Nam, began to expand. Since 1995, after the elimination of a United States (US) embargo, when the US and Viet Nam established normal relations, Viet Nam joined the Association of Southeast Asian Nations (ASEAN) and the number of countries and territories importing goods from Viet Nam increased rapidly. After the US-Viet Nam Trade Agreement was signed in 2000 and Viet Nam became member of the World Trade Organization (WTO) in 2007, almost all countries and territories around the world began to import goods from Viet Nam. Currently, Viet Nam has trade and investments relations with more than 200 countries and territories.

2. More Sustainable Growth and Less Poverty

Viet Nam has achieved very impressive progress with regard to poverty reduction. Viet Nam has implemented innovative policies to develop and to integrate into the world from being a poor country with a poverty rate more than 50% in 1993 to about 10% in 2010, thanks to the support from many countries and international organizations. Thus, Viet Nam has met the Millennium Development (MDG) poverty goal of halving the poverty rate by 2015.

One of the factors that ensured success in poverty reduction was its integration into the national development strategy and policies and development plans of the Government at all levels. Poverty reduction is a target in the 5-year and annual socio-economic plans and the Government balances resources for the implementation of poverty reduction target, and for monitoring and evaluation of the implementation process. In addition, the Government has targeted national programs on poverty elimination, such as the Program 135 to support poverty reduction in the especially difficult communes.

¹ Renovation or Doi Moi, refers to economic reforms initiated in Viet Nam in 1986 with the goal of creating a socialist-oriented market economy.

One of the issues widely discussed by the Government and donors in the beginning of the of the 2000s was the relationship between infrastructure development and poverty reduction. Viet Nam found that infrastructure was an important prerequisite for growth. Donors supported to the Comprehensive Poverty Reduction and Growth Strategy (CPRGS), announced by the Government in 2003, in which there was a special chapter on policies and solutions for large-scale infrastructure development.

In terms of International development assistance, there are 50 bilateral and multilateral donors that provided about \$21 billion in official development assistance (ODA) (disbursed funds) in 2001–2010, and several international nongovernment organizations (INGOs) that provided more than \$200 million per year in social-economic development in the same period. ADB, Japan, and the World Bank are the leading donors in Viet Nam. The value of international assistance is not just money but more importantly knowledge, expertise, advanced technologies, and modern management skills. Aid is considered to be “a fishing rod rather than a fish”.

Along with support from bilateral and multilateral agencies, regional cooperation has an important role. The Greater Mekong Sub region (GMS) program, established in 1992, provides a venue for cooperation among all the member countries. GMS priority sectors in cooperation are infrastructure development, energy, telecommunications, tourism, trade and investment, human resource development, and the environment. Viet Nam participates in all these areas.

3. What is the Development Orientation of Viet Nam for the Next 10 Years?

Viet Nam has developed a Socio-Economic Development Strategy for 2011–2020 with the overall goal transforming Viet Nam into a modern industrialized country by 2020. The main indicators of the Strategy are:

- Economic indicators:
 - Average annual GDP growth: 7%–8 %
 - Proportion of industry in GDP: 85%
- Social indicators:
 - GDP per capital in 2020: \$3,000
 - Life expectancy: 75 years
 - Total student population reached 450 peons per 10,000 People
 - Poverty rate reduction: 1.5%–2% annually

- Environmental indicators:
 - Forest coverage in 2020: 45% (from 38.7 % in 2008)
 - Proportion of industrial plants to meet environmental standards: 80%

To implement the Strategy, a 5-year plan has been developed with two scenarios. In the first scenario, there is no change in the indicators of social, economic, and environmental development in the Development Strategy 2011–2020, including the expected annual GDP growth of 7.0%–7.5%. Annual economic growth in 2011 is estimated at 6% and is expected to reach 6.5% in 2012. Therefore, in order to achieve an average growth rate of 7.0%–7.5% in 2011–2015, higher growth rates than in 2006–2010 would be necessary, which is hardly feasible in the context of Viet Nam's economy, now facing many difficulties due to the unstable macroeconomic situation and high inflation.

The second scenario is designed to ensure macroeconomic stability, rather than fast growth, and to hold inflation down. The expected economic growth rate in 2011–2012 period will be lower than proposed figure in the development strategy and it is hoped that the economy will recover from 2013.

The 2011–2015 five-year plan includes a total investment capital of society at current prices of about \$290 billion, accounting for about 40% of GDP during 2011–2015, an average increase of 16% per year over 2006–2010.

Regarding total development investment capital, the five-year plan 2011–2015 expects that domestic capital will make up 70%, and the foreign capital the remainder. Foreign capital sources include official development financing, investment by the foreign private sector, remittances, and some other foreign capital. Total foreign capital is expected to be about \$87 billion during the plan period.

4. Opportunities, Difficulties, and Challenges

Although Viet Nam has become a MIC, laying an important foundation for future development, the country faces considerable difficulties and challenges, mainly (i) poor infrastructure, (ii) weak national competitiveness, (iii) obstacles in human capacity, (iv) unsustainable poverty reduction, and (v) severe consequences of climate change.

The world economy has shown signs of instability recently, causing some unexpected problems. The prices of energy and raw material inputs continue rising unpredictably, which is leading to many difficulties for an economy like Viet Nam relying heavily on imports. In addition, some development partners providing development aid to Viet Nam are facing financial difficulties or are facing severe consequences of natural disasters. In addition, foreign aid for Viet Nam from development partners in coming years will have changed terms, scale, and lending conditions because of Viet Nam's upgrading to MIC status—grant aid and concessional loans will tend to decrease. The Government needs to develop aid mobilization and utilization policies to adapt to the changing situation and is preparing the ODA Strategic Framework (Policy paper) for 2011–2015.

Three breakthroughs for future success

To overcome the difficulties and challenges mentioned above the strategy sets out three breakthroughs:

(1) Developing and improving the institutions of the market economy, with a focus on creating an environment for fair competition, and implementation of administrative reform.

This breakthrough has the following priorities:

- To formulate all the elements of market economy and to develop other markets with high transparency, better management, and monitoring. Thus, the market will establish a dynamic balance, allocating resources for manufacturing and services based on market signals to ensure economic efficiency and effectiveness.

- To improve the mechanisms and policies in markets of both commodities and services, including finance, securities, real property, labor, science, and technology; to create consistent and smooth operations based on high competitiveness and better connection with world markets; and to effectively manage and monitor business to minimize monopolies in the manufacturing and service sectors in order to create an environment of fair competition.

- To strongly reform the national administration system—institutional and organizational structure, relevant administrative and public financial work in accordance with decentralization in order to improve efficiency and quality of governance; to enhance transparency and policy predictability in order to reduce uncertainty and risks for investors; to avoid speculation and corruption; and to reduce business transactions costs.

(2) High-quality human resource development, especially that associated with the development and application of science and technology.

The comparative advantage of Viet Nam's economy over the past decade, based on cheap labor, no longer meets the requirements of economic restructuring. In the new context of development, Viet Nam's economy must be based on efficiency, productivity, and competitiveness, which are driven by human capacity. Therefore, human capital is an important driving force to promote development in order to avoid "MIC trap."

The second principle includes the following prioritized activities:

- To develop strong management leadership, professional experts, good corporate managers, professional and skilled labor, and talented scientific and technological staff; to train human resources to meet diverse requirements of technology and development in different fields and industries; to implement training programs/projects for people working in key economic and public sectors; and to detect, foster, and to promote talent for a knowledge-based economy.

- To overhaul the education system in accordance with the direction of standardization, modernization, socialization, democratization and international integration, in which innovation of educational management mechanisms, training teachers and administrators are critical to serve for restructuring the economic and the growth model.

- To strongly and comprehensively renovate the organization, management mechanism, and the operating activities of science and technology. To orientate science and technology for industrialization, modernization and conversion of growth model, contributing to increasing productivity, quality, efficiency and competitiveness of the economy. To promulgate policies to encourage enterprises in technological innovation, priority utilization of material-saving technologies, energy, environmentally friendly and green economic development.

(3) Development of comprehensive modern infrastructure.

The socioeconomic infrastructure of Viet Nam is currently an obstacle for development. To develop this sector, the following prioritized activities are proposed:

- To focus on developing transportation to ensure rapid and sustainable growth (highways, ports, international airports, railway), especially the transportation network linking Viet Nam with other GMS countries.

- To develop modern infrastructure in the biggest cities in accordance with a master plan; to rapidly develop urban transport systems, especially public transport; and to address congestion and flooding in Ha Noi and Ho Chi Minh City.

- To rapidly develop power systems, power transmission, and renewable energy, using advanced technology to save energy and ensure sufficient power for development needs of the country and the people.

- To develop and modernize agriculture and irrigation systems, construct disaster prevention works, and develop modern information and telecommunication systems to meet requirements and contribute to improving productivity.

Although future development will be difficult and challenging, Viet Nam's experience in the last decade of relying on its internal strengths in combination with international support and cooperation will help the country achieve its goal of becoming an industrialized country by 2020.

THE FUTURE OF WATER IN THE GMS: IS IT HISTORY?

Arjun Thapan¹

Colleagues, friends, ladies and gentlemen:

I don't think that any of us gathered here this morning can claim to be definitive gazers of the crystal ball. We weren't when the GMS² countries embarked upon a program of economic cooperation in 1992, and we aren't now when the GMS looks forward to higher and more sustained growth over the next 20 years. But it is hard to dispute the enormous change that has been wrought upon the subregion during this period. The economies have grown, poverty has declined, incomes have risen, and an air of wellbeing and hope now envelops the Mekong peninsula. But it would do us well to remember that this rising prosperity has not been without costs in terms of the subregion's environment, and its natural resources.

I don't know what these costs are—I don't think anybody does. But there are costs and we need to determine them. Because these costs will inform us of the handicaps that we are now served with in shaping the subregion's future especially if we are going to perpetuate our business-as-usual ways much like economies in East and South Asia have done.

As I said a moment ago, I am not a clairvoyant and will not pretend to forecast the subregion's future. I will raise more questions than provide answers. And I will share with you a possible framework to look at some key issues that will guide the destiny of the GMS.

I think we are all agreed that water, energy, and food will be central to the continuing transformation of the subregion. And if we further agree that Water is an essential and principal ingredient of both energy and food, then let's take a look at the basic water endowment of the GMS countries.

I'm afraid I don't have discrete figures for Yunnan Province and Guangxi Zhuang Autonomous Region, and it would

Slide: 1

GMS: Water Resources and Usage

Country	Water Resources Total Renewable Per Capita (m ³)		Agriculture Water Withdrawal (as % of Total)	Industrial Water Withdrawal (as % of Total)	Municipal Water Withdrawal (as % of Total)
	1962	2009			
Cambodia	83,500	34,000	94.0 (2006)	1.5 (2006)	4.5 (2006)
PR China	4,113	2,080	64.6 (2005)	23.2 (2005)	12.1 (2009)
Lao PDR	149,552	54,565	92.9 (2005)	4.0 (2005)	3.1 (2005)
Myanmar	53,416	24,537	89.0 (2000)	1.0 (2000)	10.0 (2000)
Thailand	15,115	6,384	90.3 (2007)	4.8 (2007)	4.8 (2007)
Viet Nam	23,910	10,174	94.7 (2005)	3.7 (2005)	1.5 (2005)

Source: FAO Aquastat Database

¹ Chairman, WaterLinks

² Greater Mekong Subregion, comprising Cambodia, Guangxi Zhuang Autonomous Region and Yunnan Province of the People's Republic of China, the Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam.

not be fair to extrapolate from them to the overall People's Republic of China figures because Guangxi and Yunnan are not really representative of water availability and use across the country. But, with this exception, we see a precipitous decline in per capita water endowments across the subregion over the approximately 5 decades since 1962. Should we be alarmed? After all, the rates of decline have been more or less the same as in other parts of Asia, including India, the People's Republic of China, and Pakistan. But what should concern us is that (i) these numbers relate to renewable water resources, not accessible freshwater—and it is this latter category that is finally important, and (ii) the rate of decline (between 1.7% and 2.2% per annum) is higher than the rate of efficiency gains (less than 1% per annum) in water use. The People's Republic of China's case is also worrisome but since I don't have data for Guangxi and Yunnan, we will postpone a discussion on this element.

The share of water withdrawals for agriculture, industry, and municipal use are unsurprising. They broadly reflect usage patterns all over Asia. But if we look at the numbers in Slide 2, in conjunction with those in Slide 1, we note a couple of points. One, that although agriculture's value in

Gross Domestic Product (GDP) has dropped markedly (11.6% in Thailand's case in 2009, and 48% in Myanmar's case in 2004), the ratio of water withdrawals for agriculture relative to other major users has not changed. In the case of the People's Republic of China, however, it has changed. Two, that industry and municipal use share a much smaller slice of the pie but in an uneven way. Some of these figures are dated and more recent figures should reveal a clearer picture of trends in line with growth in the industrial and urban sectors.

Overall, therefore, there is an inescapable conclusion. Water endowments are under pressure. These pressures will increase as food demands grow in the GMS based on growing population, change in dietary habits toward food that is water-intensive, and an increase in tourist traffic (the GMS continues to be one of the fastest growing tourism destinations in the world). They will also increase, as we shall see, with the growth in energy production, expansion of industry, and expanded urban consumption. Water pollution, given the increase in manufacturing and intensity of chemical use in agriculture and low investments in industrial and urban wastewater treatment, will also increase and put pressure on the finite accessible freshwater resources.

Slide: 2

GMS: Agriculture Value Added to GDP (%)

Country	Base Year	End Year
Cambodia	55.6 (1990)	35.3 (2009)
PR China	39.3 (1962)	10.35 (2009)
Lao PDR	61.8 (1992)	34.7 (2009)
Myanmar	60.5 (1992)	48.3 (2004)
Thailand	34.0 (1962)	11.6 (2009)
Viet Nam	40.5 (1987)	20.9 (2009)

Source: FAO Aquastat Database

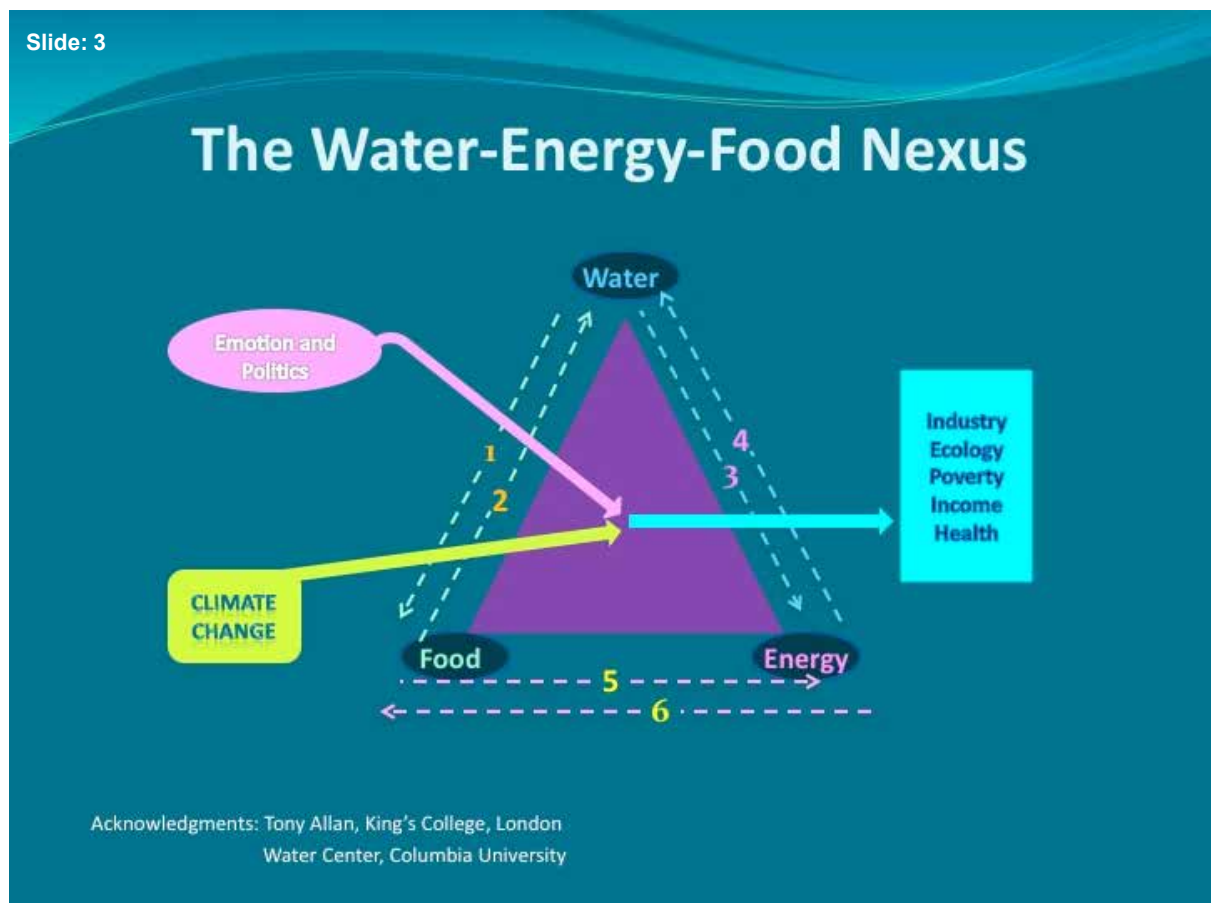
In this sense, the GMS is unlikely to be any different from the economies of East and South Asia. Their per capita water endowments declined earlier in time (both the People's Republic of China and India are water stressed countries; large parts within each are water scarce). The World Resources Institute has estimated (2010) that the Chao Phraya basin in Thailand and the Hong River basin in Viet Nam are almost water scarce today and will be absolutely water scarce by 2025. This tells us that the Mekong Basin will not be an exception to water stress and scarcity being witnessed in developing Asia.

But, again, I have a question: Can this be avoided? Of course it can, but the solution will lie in two areas. One, in rationally allocating water resources on the basis of economic costs and benefits, i.e., real integrated water resources management, or IWRM, and, two, serious gains in water use efficiency brought about through true-value pricing, technology adoption, and tough legal and administrative frameworks.

I said that I would suggest a framework within which we could substantively examine issues in shaping the future of the GMS. Let us, therefore, look at the water-energy-

food relationship, a number of sub-relationships, and how some of them operate in the GMS. Here is an illustration in Slide 3.

Each side of the triangle represents two basic relationships with several impacts. Water impacts on food—production and yields, trade in food, location, vulnerability, poverty, etc. Food, and here we are only talking of production, impacts on water through land use changes, groundwater depletion, biodiversity loss, and so on. Water's impact on energy is manifest principally through hydropower production, processing water and wastewater, and irrigated agriculture (both surface and groundwater). Energy and water are related through biofuels, cooling water for thermal energy, and the considerable thirst of renewable energy sources. Food and energy are related through food for fuel, biodiversity, and fertilizer use. Finally, energy and food are linked through the energy intensity of food production, impact of renewable energy on land use, and pricing (essentially subsidies). These relationships and impacts, of course, have numerous issues embedded in each. Addressing these comprehensively will be part of the design for tomorrow. Let me come back to this later.



I will now dwell on the energy-water relationship. Energy demand is growing between 9% and 16% annually in the GMS. Thailand and Viet Nam had planned to add 7 and 13 gigawatts (GW), respectively, over 2009–2013. Thailand's fuel mix would change from a 73% share for natural gas to 60%, an increase for hydropower from 6% to 10%, and an increase for renewables from 1% to 10%. In Viet Nam's case, hydropower would constitute 40% (up from 10%), and thermal power (coal and gas) 60%. These are sizeable expansions to capacity over and above the plans for Cambodia and the Lao PDR that we briefly discussed. In addition, there are expansion plans for Myanmar, as well as for Yunnan and Guangxi.

Both thermal and hydropower are large consumers of water. Thermal electric plants use between 720 (natural gas, combined cycle) and 2,700 liters (nuclear power) of water per megawatt hour for closed-loop cooling (in itself 40% more expensive than open cooling systems). However, the evaporative loss in hydropower is estimated at 17,000 liters per megawatt hour. While these numbers³ are significant in themselves, they mask the impacts of climate change.

These impacts, triggered by higher temperatures ranging from 1.0–1.8°C, translate into

- higher rates of evaporation,
- increased glacial and snowpack melt,
- changes in precipitation patterns, and
- saline intrusion in coastal freshwater resources.

Recent research has shown that more than 95% of the glaciers (over 40,000) in the Himalayan (including Tibet, where the Mekong rises) cryosphere⁴ are in retreat, 40% are likely to disappear by 2050, and 70% by 2100. The mass balance has critically, and negatively, altered⁵.

Higher temperatures will also affect precipitation patterns. During the 40 years to 2000, most of Southeast Asia, including the GMS, experienced a decline in rainfall and the number of rainy days. This is estimated to continue till 2060 but precipitation is expected to increase toward the end of the century with strong variations between March

and May. Essentially, the wet season is likely to become wetter, and the dry season drier.⁶

Water renewals in the Mekong River are also likely to change. In Viet Nam, for instance, the maximum monthly flow is expected to increase between 35%–41% and the minimum monthly flow decline by 17%–24% compared to levels seen during 1960–1990. Toward the end of this century, up to 25% of the Mekong's annual flow is expected to decline. But given that the Mekong no longer flushes the delta in Viet Nam for most of the year, and that saline ingress has progressed over 100 kilometers inland, this might be a generous forecast.

I would now like to look at the hydropower question. The development of hydropower has grown exponentially in the GMS. In Cambodia, power production is expected to grow 10 times from less than 1,000 megawatt (MW) in 2011, to more than 10,000 MW, mainly through the construction of at least 20 hydropower stations. In the Lao PDR, 10 hydropower stations are under construction, and another 25 are planned. Most power produced by the Lao PDR is, and will, be sold to Thailand. The People's Republic of China's construction of hydropower-related and multipurpose storages on the upper reaches of the Mekong River has been extensively documented and reported on. In 2008, Viet Nam had an installed capacity of 12 GW of which 10% was hydro-based. This is expected to expand to 40% of a total installed capacity of 25 GW by 2013. Of course, these projects translate into substantial hydropower investments based on the assumption that the GMS is water-rich. This might well be a questionable assumption in the context of the pressure on accessible freshwater sources that I referred to a short while ago. Nothing short of a full, basin-by-basin, and overall basin optimization study will guide us definitively.

What is the relationship between hydropower development and food? According to the Mekong River Commission, the annual economic value of the Mekong's fish production exceeded \$2 billion in 2005; more recent estimates⁷ indicate an annual value of \$3 billion. Cambodia leads the world in terms of its 14 million population totally reliant

³ US Department of Energy, National Energy Technology Laboratory. 2008. Water Requirements for Existing and Emerging Thermoelectric Plant Technologies.

⁴ Extensive ice and glacial fields.

⁵ Mass balance is the ability of a glacier, or a glacial field, to accumulate ice at a rate equal to or greater than its melt, or ablation, rate.

⁶ Asian Development Bank. 2009. *The Economics of Climate Change in Southeast Asia: A Regional Review*. Manila.

⁷ Dugan, P. 2008. *Examining the Barrier Effect of Mainstream Dams to Fish Migration in the Mekong, with an Integrated Perspective to the Design of Mitigation Measures. Conclusions from an Independent Expert Group Meeting*. Vientiane. 22–23 September 2008.

on fish protein. In Viet Nam, the Mekong Delta produces 80% of the country's total fish catch. Overall, more than 70% of the total fish catch in the Lower Mekong Basin is dependent on long-distance migrant species. Dams are barriers to migration and their impacts will be destructive. According to a recent report of the International Center for Environmental Management in Melbourne, if all hydropower projects are constructed as planned, fish production is likely to drop by 42% annually. I do not know of any definitive, recent analysis of the qualitative and volume impacts of hydropower and other storage-related construction on fisheries in the basin. But since fisheries are uniquely a key source of protein and livelihoods in the GMS, this is an analysis worth doing. We will then have a basis for determining one of the several energy-food relationships.

You might well query the significance of these dire forebodings on water for thermal and hydropower generation. The growth of consumptive use of water for energy is itself an issue in the GMS in terms of total withdrawals relative to other applications. However, the risk to thermal and hydropower plants from water shortages, especially during extreme weather events, and overdraws by other users as in agriculture or industry, is considerable. Thailand's eastern seaboard is a good example of thermal electric plants in a heavily industrialized but rainfall-short region being dependent on small reservoirs for cooling water needs, and coming into conflict with farmers for irrigated agriculture. There have been numerous cases of hydropower plants in the GMS being either switched off entirely, or functioning with low capacity, because of prolonged dry spells.

As a consequence, we have, for the first time, environmentalists and investment bankers coming together to determine risks to investments in energy in Southeast Asia because of water scarcity.⁸ The majority of existing and new power generating capacity for publicly listed companies in Southeast Asia is located in areas classified as water scarce and water stressed. The impacts of these investments will probably translate into serious business continuity risks, a higher risk premium, and a higher cost economy. Question: how much of this can the GMS afford?

Before I leave the energy-water relationship, let me dwell on two other sub-relationships. One concerns energy used in the provision of water and wastewater services, a subject that acquires some significance in light of the rapid industrial and urban growth in some parts of the GMS. Electricity accounts for about 80% of the costs of municipal water processing and distribution costs. Groundwater supply requires an additional 30% energy on a per unit basis. Wastewater treatment requires about 660 kilowatt hours (kWh) per million liters. Finally, desalination of brackishwater, or seawater, common in coastal cities, requires between 1,400 and 4,500 kWh per million liters.⁹ When coastal cities, and industrial centers, in Thailand, Viet Nam, and southern Cambodia begin to consider desalination options (as have coastal cities in the People's Republic of China and India), the energy costs will emerge as a key factor. The question for the GMS to consider here is: do we invest in efficiency to reduce energy costs and energy footprints per unit of production in industry, or do we invest in expanded energy production and, if so, in what mix?

A second sub-relationship is between biofuels and water. Later in this conference we will examine the question of biofuels as a proposition for the GMS. But let me start by sharing with you what my colleague, Peter Brabeck, Chairman of Nestlé, says¹⁰ very nicely: "On average, it takes half a liter of water to grow one calorie of grain. So, a thousand liters of water could grow enough calories to feed one person per day. Or, it could fuel the drive to your local bakery to buy croissants." He goes further to say: "The skeptics would say, but that's "only" a thousand liters of water and you are comparing it to 2,000 calories. But look at the relative size of the global food and energy markets. When measured in calories, the energy market is 20 times the size of the food market. So, if governments were to replace only 10% of global energy consumption with first generation biofuels, they would also be doubling agricultural water withdrawals." Currently, such withdrawals are at 70% of total water withdrawals and, therefore, a 140% withdrawal would only happen on some other planet.

Then there is the question of biofuels being emission free. It would be disingenuous to say that the urban centers of the GMS will be positively impacted by greater use of biofuels. Recent calculations have shown that the most commonly

⁸ Sauer, Amanda, Piet Klop, and Sumeet Agrawal. 2010. *Overheating: Financial Risks from Water Constraints on Power Generation in Asia*. Washington, DC: World Resources Institute.

⁹ Source: Cambridge Energy Research Associates, US.

¹⁰ Brabeck-Letmathe, Peter 2011. *Burning Up Food as Fuel: The Role of Water, Water Security: The Water, Food-Energy Climate Nexus*, The World Economic Forum Water Initiative.

produced biofuel crops release twice the amount of nitrous oxide than previously thought. In the case of rapeseed biodiesel (80% of biofuel production in Europe), the relative warming from nitrous oxide generation is 1 to 1.7 times higher than the quasi-cooling effect of saved carbon dioxide emissions. It is the same with corn bioethanol (mostly in the United States)—0.9 to 1.5 times higher. Only cane sugar-based bioethanol makes sense—until, that is, you figure out the water intensity of sugar cane production!! Overall, therefore, if biofuels are measured in terms of a lifecycle analysis of agricultural production (a complex process that generates methane and nitrous oxide), most biofuels perform worse than fossil fuels.

One often hears that second-generation biofuels will be better. After all, what's better than picking up waste from plants in fields and fallen wood in the forests and converting this cellulosic material into biofuels? But if you read the fine print of these claims, it says that the main and most efficient source of such waste would be specifically grown plants, e.g., a new variety of energy corn, grown twice as high as normal corn. These varieties will, it has been determined, draw even more water than current origins of biofuel production.

So, against this background, it is difficult to appreciate a conclusion of the Intergovernmental Panel on Climate Change (IPCC). It said that 25%–80% of today's total energy consumption by 2050 should come from biofuels. The economics of biofuel production at this level simply do not make sense even in the context of evolving research on biofuels.

To wrap up this discussion, the questions to be asked are: what will biofuels in the GMS mean in terms of the water-energy-food conundrum? And why will GMS biofuels not be affected by climate change? Why shouldn't GMS transport energy come from a whole range of instruments (including demand management instruments) instead of a formulaic dependence on some fixed element of biofuels? Finally, what constitutes "self sufficiency" in biofuels, and why must the GMS be "self-sufficient"; is some, or all, import not an economic option?

Let me now take you through some facets of the water-food relationship, one that concerns irrigated agriculture particularly. We know that agriculture, regardless of its share in the total GDP pie, is a key driver of national economic development in the Mekong countries, but particularly Myanmar and the lower four riparian countries. It provides the livelihood for 75% of the population of

the Lower Mekong Basin. The area under irrigation has expanded significantly across the GMS largely as a consequence of substantial public investments. But given the dominant share of agriculture in withdrawal of accessible freshwater, the question is: how efficient is irrigated agriculture in the GMS?

Rice, as we know, is the staple crop in the region. Its dominance in the crop hierarchy, however, has been so significant that a large majority of public irrigation systems have been designed for rice production that has made it difficult to diversify into non-rice crops. There are serious issues with water productivity, yields, and quality of service delivery. Participatory irrigation management has made very little progress and system productivity has remained weak. Cost recovery for operation and maintenance of the systems has been extremely low and, together with the reduction in financial benefits from agriculture between 1980 and 2000, put governments under considerable pressure to reduce irrigation management costs.¹¹ Irrigation investment costs in Southeast Asia were estimated to be almost the lowest in the world.¹²

A case in point is Viet Nam. It is the world's sixth largest rice producer and second largest exporter. About 85% of its exports come from the Mekong delta where 10,000 km of irrigation canals sustain 2 crops a year, sometimes 3.¹³ But saline intrusion and land shortages do not permit an expansion of production. Postharvest losses of up to 16% put further pressure on securing gains.¹⁴ The rice bowl of Southeast Asia is seriously under threat mainly because of flood irrigation practices, the absence of science and technology, and inadequate river flows in the delta.

With the underwhelming performance of most public irrigation systems (given the usual problems of inadequate design, insufficient revenues for operation and maintenance, and little or no cost recovery), atomistic irrigation has emerged as the leaner, more nimble alternative to profitable farming. Farmers scavenge water from whatever sources they can, especially groundwater.¹⁵

¹¹ Molle, Francois, Tira Foran, and Mira Kakonen, eds. 2009. *Contested Waterscapes in the Mekong Region: Hydropower, Livelihoods and Governance*. Earthscan Publications Ltd., Chiang Mai University.

¹² Inocencio et al., cited in Molden, 2007.

¹³ Rainfed rice is virtually absent in the delta.

¹⁴ Dao Trong Tu, Kim Geheb, Uchumi Susumu, and Vitoon. 2004. Mekong Rice Conference. Mekong River Commission Secretariat

¹⁵ International Water Management Institute. 2009. *Trends and Transitions in Asian Irrigation: What are the Prospects for the Future?* Sri Lanka.

But this phenomenon, increasingly widespread in the deltaic regions of Viet Nam and Thailand (Red, Mekong, and Chao Phraya rivers) is not free from worries. Saline intrusion, the decline of aquifers, and high costs of energy, especially for diesel-based pumps, are beginning to emerge as serious issues. One must not forget that due to groundwater mining, water tables are plunging in the food belts of India, Pakistan, and northern People's Republic of China, as well as in California's Central Valley and the southern portions of the High Plains' Ogallala Aquifer.¹⁶ Of course, 60% of India's irrigation is based on groundwater compared to 30% in Viet Nam, but the warning signs deserve attention nonetheless.

Let me go beyond the water-energy-food nexus that I have discussed so far, and turn to a major issue in the GMS, that of environmental flows in its rivers. We know that these flows are necessary both from an ecological perspective and from an economic one. We have seen what has happened to more than 70 major rivers in the world including the Nile, Indus, Yellow, Jordan, and Colorado rivers—they have shriveled up, and barely trickle through their respective deltas. Can this happen to the Mekong? Yes, most certainly. The fact that much less of the Mekong reaches the sea is already evident in the significant deltaic saline intrusion. And as abstraction increases, and flows decline, we will most likely witness more of this phenomenon, and not less.

So how do we respond to this peril? I am an unabashed admirer of the water reforms undertaken in Australia over the last decade. Their impact on the Murray-Darling Basin that constitutes 41% of mainland Australia, and is responsible for 40% of its agricultural output by value, has been dramatic. Ten years after the reforms commenced, Australia's economy and agriculture sector does better with 30% less water, specifically in the Murray-Darling Basin. The reforms put a premium on environmental flows, set a sustainable diversion limit, provided water rights to land holders that could be freely traded, created a \$2 billion per annum water market, and empowered the government to buy back water allocations to maintain environmental flows. Significant investments have been made in irrigation efficiency through provision of infrastructure, new technology, and monitoring networks. Water-use efficiency in irrigated agriculture is now estimated at 85%.¹⁷ In sum,

the environment has improved, the Murray and Darling rivers have regained 'life', agriculture has become adaptive to variable water allocations, and a water market ensures that demand and supply are matched through an economic price. Question: is it time for the GMS to start looking at the Murray-Darling model as a possible IWRM intervention in the Mekong Basin? In Australia's case, 4 states and 23 major river catchments need to work together. Can the GMS extend its strengths and experience in subregional cooperation to commence this task?

We know that the GMS occupies a strategic position between the large economies of India and the People's Republic of China. Water is a barrier to growth in both countries. In India, water for energy and industry is forecast to drop from 492 billion cubic meters in 2010 to 197 billion cubic meters in 2025.¹⁸ Unless the water footprints of both sectors shrink to a point where efficiency gains outweigh water scarcity, economic growth will clearly slow down, perhaps unacceptably. In the People's Republic of China, the blistering pace of industrial and urban growth has polluted up to 90% of its waterways and unless clean-ups and investments in treatment technologies and infrastructure are made and the pressure on freshwater is reduced, the collision of water, energy, and food will get worse. Can the GMS remain an unaffected island? We see water-deficit regions investing in contract farming in the GMS. We see the GMS trading virtual water with its neighbors both through food and energy. Is there a lesson that the GMS can draw from all of these developments?

I believe that the GMS would be well served by commencing some serious data capture and analytical work that will be a foundation to design a shared program of economic growth and social development that optimizes the use of water and other natural resources in the Mekong Basin. This should, at a minimum, comprise (i) the development of a comprehensive database that is spatially distributed, (ii) the identification and attribution of spatial and temporal trends among a range of key variables, (iii) a thorough analysis of climate variability and change, (iv) a comprehensive analysis of the water-energy-food nexus especially as driven by climate change impacts and extant policy, and (v) an analysis of the broader social, environmental, and political impacts. I have complete confidence that this exercise will be time and money well spent. And it will accord totally with the spirit of cooperation that the GMS has so carefully developed and nurtured.

¹⁶ Solomon, Steven. 2010. *Water: The Epic Struggle for Wealth, Power, and Civilization*. New York: Harper Collins.

¹⁷ See Irrigation Association of Australia for definition of Irrigation Efficiency at www.irrigation.org.au/

¹⁸ Infrastructure Development and Finance Company. 2011. *India Infrastructure Report 2011: Water: Policy and Performance for Sustainable Development*. Chennai.

Before I close, let me refer you to some recent headlines:

*India Faces Water Famine*¹⁹

*Choke Point: China – Confronting Water Scarcity and Energy Demand in the World's Largest Country*²⁰

*Indian Agriculture Unsustainable due to Water Crisis – Sachs*²¹

*Climate Change in Africa's Major River Basins could Impede Continent's Farm Transformation*²²

*Dhaka's Groundwater Drops 6 meters in 7 years*²³

Ladies and Gentlemen, I have spoken far too long. We could, conceivably, see a headline such as these in respect of the GMS unless, and this is a big unless, we join hands and determine to avoid the water-starved future that has now arrived in so many regions of Asia and the world beyond. I said that I am not a clairvoyant, but neither am I a prophet of doom. It is well within the capacities of this subregion to learn from history, and to shape its future.

Thank you for your attention. You have been most patient.

¹⁹ Infrastructure Development and Finance Company. 2011. *India Infrastructure Report 2011: Water: Policy and Performance for Sustainable Development*. Chennai.

²⁰ Circle of Blue. 2011. www.circleofblue.org/

²¹ Sachs, Jeffrey D. 2012. Delhi Sustainable Development Summit

²² Third International Forum on Food and Water, Tshwane, South Africa, November 2011.

²³ Bangladesh Agricultural Development Corporation. 2011. Report. 2011. Dhaka.

ENVIRONMENTAL IMPACTS: CURRENT AND FUTURE CHALLENGES IN THE GREATER MEKONG SUBREGION

Jeffrey A. McNeely¹

Abstract

The Greater Mekong Subregion (GMS) has had a decade of strong economic growth, drawing especially on its natural resources – forests, waters, fisheries, minerals, and soils. But this development has had costs as well as benefits, and the GMS is now facing environmental degradation that affects virtually all sectors of the economy and especially threatens the well-being of the forest-dwelling poor. The major environmental problems include declining ecosystem services, accelerating loss of biodiversity, increasing competition for limited land resources, continuing forest fragmentation, increasing pollution, and growing demand for limited water resources. These trends are all parts of a system of rapid change that affects human wellbeing, and their magnitude is likely to increase in the coming decade unless serious efforts are made toward more sustainable forms of development. The appropriate responses to these problems are also part of a system of responses that would support sustainable development. The proposed system begins with conserving the biological basis of resource management; it then adds improved technology for conserving biodiversity and ecosystem services, improved means of mobilizing energy and providing water resources, and generating the economic and financial support required; and finally converts these policies and technologies into reality on the ground through mobilizing an abundant renewable resource: human ingenuity. This paper concludes with some policy options that governments may wish to consider as the countries of the GMS seek to continue to prosper in the coming decade, and beyond.

Introduction

The Greater Mekong Subregion (GMS), stretching from Yunnan in the north to the southern tip of Thailand, and from western Myanmar to eastern Guangxi and Vietnam, is world-renowned for its wealth of plants, animals, and ecosystems. Yunnan, for example, has more than half of the world's species of bamboo, is a global center of diversity for rhododendrons, and supports more than half

the plant species in the People's Republic of China (PRC). Other parts of the GMS add their own unique biodiversity to the mix. This natural bounty enabled some of the world's earliest development of agriculture, led to sophisticated civilizations based on irrigation, and supported a great diversity of cultures occupying the complex ecosystems that characterize the GMS.

For centuries, people in this region lived in a sort of balance with nature, harvesting timber, medicinal plants, wildlife, and other natural resources on a reasonably sustainable basis. Forests were cleared for shifting cultivation, but relatively quickly recovered as the hill farmers moved on when crop yields began to decline after a few years. The abandoned fields resulting from the traditional forms of shifting cultivation attracted many species of wildlife, especially birds, pigs, deer, wild cattle, elephants, and their predators. Virtually all of the forests of the GMS have been cleared at various times over the centuries, but in a cyclical fashion that generally maintained significant forest cover (Spencer, 1966).

With the development of irrigation beginning as early as 1500 years ago in Pyu, Myanmar (Stargardt, 1990), primarily to grow rice, many of the lowland areas in the GMS were transformed from wetlands to croplands over the following centuries, though the resulting complex civilizations in the riverine lowlands still depended on the upland forests and their peoples for goods (such as construction materials and medicinal plants) and services (such as flood control and provision of clean water). When forests were over-exploited by civilizations, such as that centered at Angkor Wat, irrigation systems were disrupted and the civilizations collapsed (Audric, 1972).

The ecosystems of the GMS continue to provide numerous goods and services to people, including food, water, energy, clean air, and recreation. The domesticated species that provide most of the food people eat have been produced through selection from wild ancestors (many of which are native to the GMS) and are grown in fields, pastures, and ponds that once supported much more diverse ecosystems. This trade-off between species-rich natural ecosystems and species-poor managed ecosystems is generally accepted to have worked in the favor of people, judging from the expanding human population and improved welfare throughout the GMS over the past 200 years or so, accelerating in recent decades.

But globalization, population growth, and increasing pressure on land and water to drive economic development are also posing major environmental challenges to modern

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societies. The floods that affected much of the region in the latter part of 2011 provide just one dramatic example of how environmental mismanagement can have costly consequences for people in the lowlands, but deforestation has also deprived the forest-dwelling rural poor of critical resources (see RRDTTC, 2009, for details on Lao PDR). Increasing demand for land, water, and energy have put additional pressure on the natural resources that had long sustained the natural and cultural wealth of the GMS.

It is now generally accepted that the global human population will continue to increase from its current 7 billion to at least 9 billion by 2050 (UN median variant), with the 2010 GMS population being about 315 million (4.5% of global population). The global population is growing at a rate of about 1.17% per year (which produces about 78 million more people annually, more than the current total population of Thailand). Among the GMS countries, the populations of two (Lao PDR at 2.32% per year and Cambodia at 1.77%) are growing faster than average, while the other four are growing at a rate below average (Viet Nam at 1.14%, Myanmar at 0.78%, PRC at 0.66%, and Thailand at 0.63%). The countries with low population growth rates have an aging population, or soon will have, and this may pose some social problems (Tinker, 2002).

Assuring a sustainable and prosperous future will require addressing environmental issues as part of the overall development process of the region, depending on a clear definition of the problems to generate appropriate responses in policy and practice. Successfully addressing the key environmental problems over the next decade will help ensure a sustainable future for the GMS.

1. Key Environmental Issues in the GMS

This section will present a brief synthesis of several key environmental issues facing the GMS, recognizing that the individual countries have considerable differences that are likely to continue into the future. Perspectives on environmental issues also vary with scale and location. For rural communities, local ecosystem concerns, such as soil fertility, land rights, forest resources, and watershed protection, will tend to dominate their perspectives, and these will vary considerably on the basis of rainfall, history, demographics, and many other factors. For people living in cities, environmental concerns more often focus on factors like pollution, floods, water quality, recreation, land prices and global trade in commodities. The environmental problems tend to overlap, which calls for systemic solutions.

1.1 The Foundation: Maintaining Ecosystem Services

Economists have long recognized that ecosystems provide important benefits to society, and that prices can be assigned to many of them (such as land, water, and timber). The full range of benefits recently has been given the umbrella label of “ecosystem services” (Daily, 1997). As it entered the mainstream of environmental thinking, the concept of ecosystem services was given a significant boost by the Millennium Ecosystem Assessment (MA, 2005), which assessed 26 of these ecosystem services, defined simply as the benefits people receive from nature. These were divided into four broad categories: provisioning services, such as food and water; regulating services, such as flood and disease control; supporting services, such as nutrient cycling; and cultural services, such as spiritual, recreational, and cultural benefits (Figure 1).

In the GMS, some ecosystem services continue to deliver considerable benefits, especially from provisioning services such as food production or harvesting of forest products. Others are degraded to the point where they no longer provide the benefits people need. For example, deforestation and loss of wetlands contribute to flooding, a problem that is becoming more expensive by the year; deforestation also leads to greater soil erosion, which in turn can lead to sedimentation of reservoirs and shorten the productive life of water resources development projects. Thus human exploitation of ecosystems has resulted in at least short-term increased production from a small number of provisioning services, at the substantial long-term cost of other services.

More generally, the continuing degradation of ecosystem services increases the likelihood of serious negative impacts on human wellbeing, including the emergence of new infectious diseases, decline in water quality, problems from pollution, the collapse of fisheries, and shifts in regional climate (MA, 2005).

The concept of ecosystem services also has important policy implications for governments determining how to invest their scarce resources. It provides a framework for deciding the relative priority for the services that support consumptive uses, such as food, fuel, and construction materials, as opposed to those that support non-consumptive uses, such as watershed protection, disaster prevention, cultural values, pollination, health, and so forth. It also clarifies the tradeoffs that are often implicit in decision-making, especially about the distribution of

Figure 1: Ecosystem services and human well-being



Source: MA, 2005.

benefits from ecosystems. Finally, decision-makers need to be reminded that environmental conditions are changing rapidly in much of the GMS (and indeed throughout the world), which makes it all the more important to maintain healthy ecosystems that will be able to provide their functions (such as carbon sequestration, evolution, nutrient recycling, and watershed protection) as part of adapting to changing conditions. This is likely to require conserving the maximum possible biological diversity.

1.2 Biodiversity Loss

Although biological diversity (here shortened to "biodiversity") has many definitions, the one used here is from the Convention on Biological Diversity (CBD): *"the variability among living organisms from all sources, including, inter alia, terrestrial, marine, and other aquatic ecosystem, and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."* While biodiversity thus defined cannot easily be measured and is difficult to translate into policy terms, the concept has proven to be extremely useful, judging from its numerous applications in the GMS (see, for example Persson *et al.*, 2010). All GMS

countries are Party to the CBD and other biodiversity-related conventions that provide international support to national conservation initiatives.

The conservation of biological diversity is a fundamental principle of environmental management, since diversity at gene, species, and ecosystem levels provides the greatest range of options for adapting to changing conditions, and is the very basis of evolution. Reviews have shown that high plant diversity is needed to maintain ecosystem services (Isbell *et al.*, 2011). Other recent research has found that the loss of species negatively affects overall ecosystem resilience; restoration of biodiversity greatly enhances ecosystem productivity; and regions identified as having high priority for biodiversity also have very high ecosystem-service value (Butchart *et al.*, 2010). On all of these criteria, the conservation of the biological wealth within the GMS earns very high priority. Perhaps most important for the GMS, biodiversity is an essential element for fighting poverty and ensuring sustainable development.

Barrett *et al.* (2011) identified four distinct trends that threaten links between biodiversity and poverty: dependence on inherently limited natural resources;

shared vulnerabilities; failure of social institutions; and unintended consequences and lack of informed adaptive management. Ways of addressing these threats have been further elaborated in a series of activities in the GMS that will be discussed further below.

For rural people, biodiversity can be a matter of life or death because they are totally dependent on the ecosystem services supported by biodiversity. The protection of ecosystems is so important that it is included in the Constitution of Cambodia (Article 59), and is being addressed by all GMS countries through their National Biodiversity Strategies and Action Plans as well as through their collaboration in the GMS Core Environment Program.

The GMS is blessed with some of the richest biodiversity in the world, at all levels from genes to ecosystems. Many of its species are unique to the region ("endemic"), especially primates, birds, reptiles, amphibians, insects, and plants; if these species become extinct in the GMS, they are lost to the world (the kouprey, a wild species of cattle native to Cambodia that was thought to be resistant to rinderpest, and Schomburgk's deer, a swamp deer found only in Thailand and which had the most magnificent antlers of any deer, are two dramatic recent extinctions). Other more widespread species are now lost to the region, such as the Javan and Sumatran rhinoceroses; and even more are so rare as to be considered Endangered, such as tigers and many species of primates. But an estimated 1200 new species were discovered in the GMS between 1997 and 2008, including new species of monkeys, a new family of rodents from Lao PDR, and a unique species of forest ox from the Annamite Mountains known as "saola", indicating limits to knowledge about the species of the GMS.

A particular challenge for the Mekong is its tremendous diversity of fish species, which contribute to the well-being of 60 million people in the GMS (Vaidyanathan, 2011). The Mekong is one of the most species-rich rivers in the world, with at least 781 species, including four of the world's largest freshwater fish. All of the giant fish are highly threatened by fishing pressure, and will be further threatened, and possibly driven to extinction, by the construction of mainstream dams.

The combination of habitat loss, poaching, illegal trade, pollution, and the impact of invasive alien species are driving numerous species in the GMS toward extinction (Baillie, *et al.*, 2004). These species have long been an integral part of the cultures of the GMS and have provided multiple benefits in the form of food, medicines, ecological

balance, genetic resources, folklore, and esthetic pleasure. The source of some of the planet's richest biodiversity is in danger of becoming a biological desert, unless corrective measures are urgently taken.

Agricultural scientists quite rightly focus on plants, as the GMS is often considered one of the origins of horticulture, and is the original home of species now of global importance, such as sugarcane, coconut, banana, eggplant, rice, and many fruits and tubers. More recently, researchers have tended to focus especially at the genetic level of plant biodiversity, seeking to conserve the widest possible range of genetic material that is relevant to crop production. The International Treaty on Plant Genetic Resources for Food and Agriculture, for example, concentrates on 64 of the most important food and forage species. Even so, the genetic diversity of most crops is declining significantly, with GMS countries that once grew thousands of varieties of rice now growing just a few hundred. Many protected areas in GMS countries contain important genetic resources for food and agriculture, especially the wild relatives of domestic species of plants and animals, and should be considered living gene banks where evolution continues under natural conditions.

While many GMS ecosystems are losing native species, they may also be adding non-native species that are now moving more freely around the world as an externality of global trade. Non-native species help feed the world, with most agricultural species now having a global spread following the great genetic interchange that followed the 1492 contact between the eastern and western hemispheres (Mann, 2011). Imagine the GMS without chili peppers, rubber, cassava, oil palm, tomatoes, oranges, maize, potatoes, eucalyptus, and grapes – all non-native species that have enriched the productivity of agriculture in the GMS.

Most of these species introductions are beneficial to ecosystems and human well-being. But when imported into new habitats, some non-native species are highly destructive to native species, thereby fundamentally changing ecosystems. A significant, but often ignored, biodiversity problem in the GMS is the serious harm from invasive species, and the damage appears to be growing. Grasslands of *Imperata* (native to east Africa) cover many of the hills of the GMS, following shifting cultivation that has been mismanaged due largely to population pressure, are difficult to cultivate and are not attractive to herbivores (either wild or domestic). The golden apple snail (*Pomacea* sp.) was imported into Viet Nam in 1988 as a source of rich

protein for fish, ducks, and people, but it quickly became invasive and spread throughout the country, infesting over 132,000 ha of ricefields and other wetlands by 1997 and causing severe economic damage to rice (Tu and Hong, 2003). Thailand has at least 24 species of serious insect pests that are invasive and at least 190 species of alien plants (including several that are highly destructive to native ecosystems, including water hyacinth *Eichhornia crassipes*, giant water fern *Salvinia molesta*, and Siam weed *Chromolaena odorata*) (Napompeth, 2003). Similar problems affect the other GMS countries, with costs in the billions of dollars per year. Most GMS countries have established biosafety committees, but the booming international trade that carries invasive alien species as an externality is overwhelming the capacity of border controls to implement the import regulations that are designed to protect native ecosystems and agriculture.

The concept of biodiversity, in all its complexity, has provided a fairly simple way to address the living wealth of planet Earth. The genes, species, and ecosystems that comprise biodiversity provide the capacity to support life, thereby deserving the full attention of decision-makers at all levels.

1.3 Obtaining the best return from limited land resources

Land use change remains the most serious threat to the provision of ecosystem services in the GMS, a view supported by the Millennium Ecosystem Assessment (MA, 2005) and the International Assessment of Agricultural Science and Technology for Development (McIntyre *et al.*, 2009). Managing the land resources of the GMS is a major challenge, with demand for agricultural production certain to increase, along with more land needed for mining, manufacturing, urban expansion, forests, and other uses (including to be converted into reservoirs as part of water resources development). Making choices about how land is best allocated requires trade-offs and careful consideration of opportunity costs, with decision-making made more difficult by dynamic external conditions.

The growing human population in the GMS has been accompanied by the spread of human settlements into areas that previously were sparsely populated. This has resulted in converting substantial amounts of forest to agricultural land, for both arable crops and pastures (as well as wasteland). Impacts on ecosystems have been profound, including reduction of the populations of large vertebrates, disruption of watersheds, and declines of

biodiversity; for the people who live in and around forests, these impacts have worsened poverty.

At a regional level, the GMS is currently self-sufficient in food and is an active trader on the international market. Thailand exports about US\$7 billion of agricultural products per year, Viet Nam \$1.7 billion, and Myanmar almost \$300 million. Cambodia imports \$15 million of agricultural products per year and Lao PDR \$3 million. The PRC is a major importer of agricultural products, at over \$14 billion per year, but most of this is consumed outside the PRC's Mekong region (Yunnan and Guangxi provinces) (Ng and Aksoy, 2008). Still, this high demand for food by the PRC at the national level affects the GMS as a whole.

More food production will be required in the GMS in the coming years, but determining the appropriate balance between intensifying production on the most suitable lands for agricultural production and expanding production into more marginal lands is a major policy concern. As demand for agricultural land increases, people are moving into protected areas or other areas that are legally protected for biodiversity and ecosystem services (including forests and wetlands). One result is increasing forest fragmentation, with the remaining patches of natural vegetation being too small to support most of the larger species of wildlife or even trees (Primack and Lovejoy, 1995; Primack, 2010).

The GMS countries have brought deforestation under some control by greatly expanding plantations; the PRC may plant more trees per year than the rest of the world combined (FAO, 2003), but the plantations tend to be of a single species and even-aged, making them vulnerable to pests and not very attractive to native birds and mammals. Despite efforts to halt deforestation, Viet Nam is still losing about 1.08 percent of its forests per year, Myanmar 1.4 percent, Thailand 0.7%, Cambodia 0.6%, and Lao PDR 0.4 %. These figures may be underestimates, but even so, they demonstrate that forests continue to decline in the GMS at a time when more forests are needed to provide a healthy environment and important ecosystem services.

In short, land use and its ramifications for ecosystem services, human well-being, livelihoods, forests, agriculture, water, transportation, energy, and many other essential dimensions of sustainable development, are likely to remain at the top of the agenda for many sectors of society in the GMS.

1.4 The impacts of pollution on soil, air, and water

Pollution is the introduction and spread of harmful substances or other contaminants into air, water or soil. It comes in many forms, such as chemicals, radioactivity, waste products, dust, noise, or even light. It may be a natural by-product of an ecological process, such as the emission of carbon dioxide or methane by plants or animals, or the production of by-products from digestion of food that may cause disease to other species when deposited in drinking water. Pollution from modern systems of production is usually an externality of an activity that is intended to benefit people, such as farming, transportation, mining, energy generation, or construction. But pollution may sometimes be intentional and designed simply to earn a larger profit (for example, illegal additives to food) or intentionally to damage ecosystems (such as the use of defoliants, some of which may have long-term health effects on people). Different forms of pollution may affect different sectors of society or different parts of a country, but the discussion here will focus generally on environmental impacts of modern forms of pollution in the GMS.

One major source of environmental pollution in the region is chemical fertilizers, which are widely used to enhance production. The major producers of agricultural products are also the major users of fertilizer. Viet Nam, for example, uses about 1.9 million metric tons of chemical fertilizer per year, followed closely by Thailand at 1.7 million metric tons. The other GMS countries lag far behind, with Myanmar at 132,000 metric tons, Cambodia at 7,620 metric tons, and Lao PDR at 7,019 metric tons (the PRC is the world's leader, at over 39 million metric tons, with most applied outside the GMS)(2002 statistics). Used appropriately, chemical fertilizers are unquestionably beneficial to production, but excess use is damaging to soils, waters, and ecosystems more generally.

Such use can cause environmental problems such as the process of eutrophication, when nitrates and phosphates from fertilizers runoff into rivers, wetlands, and oceans lead to excess nutrients that increase phytoplankton that depletes the oxygen content of the water body, causing die-offs of many fish species. This has led to substantial "dead zones" in many parts of the GMS, including lakes, rivers, and coastal waters (Molle, *et al.*, 2009).

Pesticides are often considered essential by farmers anxious to protect their crops against insect predators. But

the pesticides also carry substantial costs, posing health problems for farmers (including increased cancer risks and disruption of endocrine systems), killing non-target species such as pollinators, earthworms, and fish, and disrupting natural control of insect pests (an ecosystem service that can form part of integrated pest management). The target species eventually build up resistance to the pesticide, requiring constant upgrading to more powerful chemicals, and the natural predators of insect pests – especially birds – often accumulate pesticides in their bodies, which can affect their reproduction (Carson, 1962).

All of the GMS countries are seeking to reduce pollution because of its damage to human health, manufacturing, energy generation, infrastructure, and so forth, which carry substantial costs. For example, the World Bank (2007b), working with the State Environment Protection Administration of China, estimated that air and water pollution cost 2.68% of the country's GDP in 2003, about \$88 billion; this did not include soil pollution, the impacts of pesticides, climate change, or the costs of eutrophication, which would have increased the costs considerably. The other industrializing countries of the GMS, Thailand and Viet Nam, are likely to have similar levels of pollution, requiring significant expenditures to address the problems; Viet Nam, for example, spent about \$2.3 billion on pollution control and abatement in 2001-2005 (Dore, *et al.*, 2008), and the impacts of atmospheric pollutants from the production of thermal power in the country could reach \$9 billion per year by 2030 unless serious efforts are taken to reduce the effluents from coal-fired power plants (Soussan and Nilsson, 2009).

But by far the most expensive and damaging result of pollution is climate change (ADB, 2007). The strong consensus is that the accumulation of anthropogenic greenhouse gasses (especially carbon dioxide from burning forests and fossil fuels and methane from livestock and ricefields) in the atmosphere is leading to accelerated climate change, which in turn is leading to changing patterns of rainfall, driving a change in the distribution of many species, creating novel ecosystems, increasing acidification of oceans, rising sea levels, and having many other impacts on ecosystems (IPCC, 2007). While no single weather event can be ascribed to climate change, the recent extremes in temperature, cyclones, rainfall and rainfall patterns are consistent with the projected impacts of global climate change. The GMS is already feeling many of these changes, including increasing salinity in the Mekong Delta (affecting rice production), catastrophic floods in Thailand, Cambodia, and Viet Nam,

ecological changes in the Gulf of Thailand as a result of the influx of freshwater from the Chao Phraya river, and coral bleaching as the ocean becomes warmer and more acidic. The costs of climate change have been estimated to be at least 5% of global GDP per year (Stern, 2006), and governments are already spending billions of dollars per year on climate mitigation and adaptation under the UN Framework Convention on Climate Change.

Much uncertainty remains about the impacts of climate change. Most agree that rainfall patterns, an essential dimension of rainfed agricultural production in the GMS, will change, adding uncertainty to crop yields. It also seems likely that some areas will benefit while others will suffer, and that dry seasons will be longer and wet seasons will be shorter and wetter (Kirby *et al.*, 2009). The flow of water in the Mekong and its tributaries is likely to become more unpredictable, requiring more sophisticated management of the dams and their reservoirs, and indeed the entire Mekong watershed.

Pollution has accompanied human development from the time fire was discovered by people half a million years ago and started producing smoke and particulates inhaled by the cave-dwelling ancestors of modern humanity. With the industrial revolution and accompanying advances in chemistry and manufacturing, the range of pollutants greatly increased and has now reached a critical level that is damaging many ecosystem services, with climate change being the most dramatic symptom.

2. Some Productive Responses to Environmental Problems in the GMS

While the problems briefly described above are daunting, and the list could be extended considerably, the governments, private sector, and civil society at local, national, and international level are becoming more aware of the problems. Solutions are not simple, and some may take years to solve. Others – such as climate change or invasive species – may never be “solved”, and instead will need to be managed at a level where damage is kept within acceptable levels. The measures described below are already being put in place and may show significant progress over the coming decade. Other papers in this volume will suggest other responses, including some that will show their impacts over the longer term.

But just as environmental problems are part of a system where the symptoms that cause human suffering are inter-

related, so are the solutions part of a package of mutually-reinforcing policies and practices that are designed to enhance human well-being by improving the health and productivity of ecosystems. They start with the biological basis of all life, then discuss new technologies, briefly touch on the critical role of water and energy, outline means of providing the necessary financial resources, and conclude with a quick review of building the human capacities to support sustainable development. All of these are sheltered under the umbrella of ADB’s Core Environment Program, though they are treated separately below.

2.1 Conserving biodiversity and ecosystem services

The most effective policy instrument for conserving native biodiversity is the establishment and effective management of protected areas, defined by IUCN (2011) as clearly delineated geographical spaces “recognized, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values”. Protected areas thus defined incorporate the traditional association between people and the rest of nature, and can be managed to provide benefits to local people.

Many international agreements also support protected areas. The Convention on Biological Diversity has a detailed Programme of Work on Protected Areas that provides principles and guidelines for all parties. UNESCO’s World Heritage Convention has established a list of natural and cultural sites that are considered to be of “outstanding universal value” and therefore worthy of international support. UNESCO’s Man and Biosphere Program (MAB) also supports the establishment of Biosphere Reserves, which have a core protected area surrounded by buffer zones and research areas; international support is primarily in the form of training and information exchange. The Convention on Wetlands of International Importance also maintains a list of these habitats, with all GMS countries (and provinces in the case of the PRC) having sites on the list (Table 1). The latter convention provides support in terms of training, policy advice, international cooperation and demonstration projects. At the country level, the government resource management agencies are supported by dozens of NGOs that are contributing to protected areas, in everything from research to ecotourism (see, for example, King *et al.*, 2009 for Cambodia).

Given the high value of biodiversity and ecosystem services in the region, it is not surprising that the GMS

Table 1: Protected Areas in GMS Countries

Country/Province	Protected Areas	World Heritage Sites	Ramsar Sites	Biosphere Reserves
Cambodia	40	*	3	1
PRC				
Yunnan	29	2	4	1
Guangxi (China)	5	1	2	1
Lao PDR	25		*	2
Myanmar	51	-	1	-
Thailand	207	2	11	4
Viet Nam	190	2	3	8

* Cambodia and Lao PDR each have 2 World Heritage Cultural Sites.

countries all have strong protected areas programs. While they are all designed with the broad objectives contained in the IUCN definition of protected areas, the national programs differ in many details. The PRC, for example, has many local protected areas that often are rather small; Myanmar does not have any World Heritage sites and Lao PDR and Cambodia have only cultural World Heritage Sites; and Thailand has by far the most sites listed under the Convention on Wetlands of International Importance. The PRC has 28 Biosphere reserves, but only one each in the GMS provinces; Lao PDR and Myanmar have not yet taken advantage of the MAB Program. These international programs all give considerable attention to the full range of benefits of protected areas, from tourism to poverty alleviation through employment opportunities for local people. The protected area agencies in most countries still give more attention to income-earning tourism than to resource management problems such as invasive alien species, but the provision of ecosystem services and forest protection is gaining more attention as these gain economic support (see 2.4 for more details).

Despite the many benefits of protected areas, the vast majority of them are too small to maintain viable populations of wide-ranging species such as elephants, tigers or vultures, or even some species of rare trees. In order to expand the effective size of protected areas, some countries depend on buffer zones, where some human uses are permitted when they are consistent with the overall objectives of the protected areas.

Far more ambitious is the effort to link protected areas with other land uses that support conservation and the provision of ecosystem services through the establishment of conservation corridors. Examples at the international level include the Yellowstone to Yukon Corridor in North America, the Mesoamerican Biodiversity Corridor, the Andean Corridor in South America, and the Southern Africa Peace Park (from Mozambique to South Africa). Many countries are establishing conservation corridors

within their own boundaries, most including community managed forests; these often have lower and less variable annual deforestation rates than formally protected forests (Porter-Bolland *et al.*, 2011). The benefits of conservation corridors are many, but the most important ones are that they build cooperation between local people and protected areas, provide sufficient habitat to conserve the key species, and are sufficiently large to enable ecosystems to adapt to climate change (especially those that have a north-south axis and altitudinal variation that enable species to move to new habitats as their existing ones are affected by changes in temperature or rainfall regimes).

The GMS has drawn on this experience to establish one of the world's most ambitious such efforts, the Biodiversity Conservation Corridors Initiative (BCI), which was launched in 2006 and now has nine pilot Biodiversity Conservation Landscapes (BCL) that cover mixed landscapes that include over 17 million hectares of forest and a total area of over 50 million ha (Moinuddin *et al.*, 2011). The Ton Le Sap Inundation Zone BCL is entirely within Cambodia, but the other BCLs cross boundaries, and thereby help promote cooperation among neighboring countries. These transboundary areas include:

- the Western Forest Complex (Thailand and Myanmar) (forest area 3,804,688 ha);
- the Cardmom and Elephant Mountains (Thailand and Cambodia) (forest area 1,218,971 ha);
- the Eastern Plains Dry Forest (Viet Nam and Cambodia) (forest area 1,704,698 ha);
- the Northern Plains Dry Forest (Cambodia, Lao PDR, and Viet Nam) (forest area 1,192,259 ha);
- the Tri-border Forests (Cambodia, Lao PDR Viet Nam) (forest area 1,422,755 ha);
- the Central Annamites (Lao PDR and Viet Nam) (forest area 2,192,903 ha);
- the Northern Annamites (Lao PDR and Viet Nam) (forest area 2,043,435);
- the Mekong Headwaters (Yunnan, Lao PDR, Myanmar, and Thailand) (forest area 3,230,579 ha).

These areas are sufficiently large to support viable populations of all species in the GMS, with some giving particular attention to conservation of tigers, elephants, or the rarest species of gibbons. They each have their own governance structure and action priorities, and many lessons are already being learned and applied more widely within the GMS and internationally (Carew-Reid *et al.*, 2007).

Most of the BCI areas include protected areas of various sorts, but they are designed to achieve more than restoring and maintaining ecosystem connectivity. They also incorporate components dealing with poverty alleviation through sustainable use of natural resources and development of livelihoods; clear definition of optimal land use and harmonized land management regimes; capacity building in local communities and among the relevant government staff; and sustainable financing mechanisms that will enable the corridors to become self-reliant in the fairly near future. They also promote collaboration among diverse agencies. The Western Forest Complex BCL, for example, is focusing on a study area within Thailand that includes two National Parks, a Wildlife Sanctuary, a National Reserved Forest, a Natural History Park, and an area supervised by the Royal Thai Army; research support is provided by Wildlife Conservation Society Thailand.

The nine Biodiversity Conservation Landscapes all include some agricultural land, but agriculture throughout the GMS depends on ecosystem services provided largely by native species, though domesticated biodiversity characterizes these systems. As indicated earlier, greater pressure is likely to be put on the agricultural lands of the GMS, but it is possible to halt agricultural expansion by closing “yield gaps” on underperforming lands, increasing cropping efficiency, changing diets, and reducing waste. Such strategies could significantly increase agricultural production while simultaneously reducing the environmental impacts of agriculture (Foley *et al.*, 2011).

Expansion of land devoted to agriculture in the GMS region has only limited potential, though yields may continue to grow as agricultural technologies continue to improve. An optimistic perspective is that the GMS by 2020 could produce more food with fewer inputs per unit of output, and less land conversion. But pressure on the agricultural system will surely increase, stimulating innovation and calling on modern research to provide solutions. The BCLs are testing some of these agricultural innovations.

2.2 Mobilizing modern technologies

Technology is the branch of knowledge that deals with the creation and use of technical means and their relation with society and the environment. Technologies come in many forms, including “soft technologies” that deal with improved regulations and means of decision-making, such as government regulations to support sustainable management, Environmental Impact Assessment, Strategic Impact Assessment, Spatial Multi-Criteria Assessment, Cost-Benefit Analysis, the concept of ecosystem services, and the renewed use of old soft technologies such as Community-based Forest Management and sustainable forestry; “appropriate technologies” that draw on a mix of the old and the new, with the latter being typically low-tech, energy-efficient, and capable of being developed and applied at the local level and at low cost (Schumacher, 1973); and modern sophisticated technologies such as computers and genomics. Virtually all forms of technology are being used in the GMS, often in combinations (such as the marriage between local knowledge and Geographic Information Systems for improving spatial management – Linde, 2009) but further development will require more effective application of them.

Mobilizing local knowledge and applying it to modern resource management has become a fundamental part of the package of technologies being applied in the GMS, especially for addressing poverty-related issues such as the management of non-timber forest products (Ingles *et al.*, 2007). Modern sophisticated technologies are drawing on local knowledge to develop a web-based interactive atlas of the GMS that is expected to be upgraded in the coming years to become even more useful for land-use planning, and perhaps other applications as yet unforeseen (Linde, 2009). Already, modern cellphones have reached into even the most remote parts of the region, enabling farmers to gain up-to-the-minute information on crop prices, weather, and various social dimensions of development. Tools such as Google Earth enable close monitoring of land uses, computers enable vast amounts of information to be collected and analyzed to support better decision-making, and photo-monitoring provides more detailed information about wildlife populations than ever before (see Lassoie and Moseley, 2007, for an example in Yunnan). Hand-held field guides to birds and other species are now becoming available, as are sophisticated GPS-based information management systems for forest rangers and other resource managers. These latter tools are already being used elsewhere, but the GMS is now ready to adapt them to local needs, perhaps using the Biodiversity Conservation Corridors as pilots for their application.

Increasing the productivity of land in the GMS is beginning to draw on the remarkable scientific and technological advances that in the past few decades have opened up a wide range of new approaches for enhancing the production of plants and animals that are useful to people. These technologies include genomics, genetic engineering, synthetic biology, and many others (Chaturvedi and Rao, 2004). Genetic engineering may well be the most controversial issue, with many people totally rejecting the technology because of its perceived threats to ecosystems and human health. Within the GMS, the PRC is by far the leader in the development of GM crops, and Myanmar is also growing some. Other countries are conducting research on GM plants but have not yet released them; many are developing their capacity for risk assessment and management of GMOs (see, for example, Mohamed and Hien, 2011 for an evaluation of Viet Nam).

But genetic engineering is far from the only kind of biotechnology, and many other biotechnologies can play a positive role for food security and sustainable development in the GMS. In forestry, it is now possible to use DNA to track logs of valuable timber trees, thereby ensuring that only legally-harvested trees are traded (Lowe *et al.*, 2010). In agriculture, the mapping of the genomes of crops, pollinators, and pests will provide agronomists with a new tool for producing crop varieties that can respond to the new conditions that seem sure to come.

This brief overview of the contribution of technologies has indicated their potential, and continuing research and development will make new such advances available in the coming years. The challenge in the GMS will be to assess these new technologies as they become available and adapt them to local needs while avoiding any negative impacts that may limit their benefits.

2.3 Improving the delivery of energy and water

This paper primarily addresses living natural resources, but water is an essential part of all ecosystem functions and the development of additional energy is essential to the economic development of the GMS but poses a serious threat to many ecosystem services. Water and energy are addressed in more detail elsewhere in these proceedings, but several points are of particular relevance here.

One of the major development objectives of the GMS countries is the mobilization of the waters of the Mekong Basin. These waters support agriculture, hydropower, and various industrial and domestic uses. The ambitious

development of infrastructure to manage these waters is therefore quite properly seen as essential to the further development of the GMS. Hydropower, for example, is seen as a clean alternative to geothermal forms of energy that are based on fossil fuels and generate considerable pollution, including greenhouse gasses that are causing climate change. However, while hydropower is a relatively clean form of energy, it comes at an environmental cost. A Strategic Environmental Assessment for Viet Nam's power development plans reported that if all 21 hydropower schemes were implemented, the value of lost farmland would be \$2.9 million annually, the resource value of forest area lost would be \$72.4 million, and over 61,000 people (mostly ethnic minorities highly dependent on access to natural resources) would be displaced (Soussan and Nilsson, 2009). Similar assessments are available for the rest of the GMS, calling for careful consideration and wide consultation about the costs and benefits of the various uses of the rich, but limited, water resources of the Mekong River and its tributaries. Lessons learned from this international river can also be applied at the national level.

While hydropower is a key concern, other modern forms of energy are also being explored, including solar, wind, and others. But a new threat to forests is coming from an ancient form of energy generation in the GMS: biofuels. In the form of firewood, biofuels reach as far back as the mid-Pleistocene in Asia (James, 1989). In many parts of the GMS, wood and charcoal still provide the primary source of energy for rural people. While biofuels are not new, enthusiasm for them recently has grown as a result of concerns about security of oil and gas supplies, interests in promoting alternative markets for agricultural producers, and a desire for lower-carbon transportation fuels that will help alleviate climate change. Such developments are likely to change production systems and affect food security, ecosystems, and livelihoods throughout the GMS.

This has led to concerns about direct impacts on forested land and food production. These concerns are shared by food companies worried that demand for at least first generation biofuels (from crops that could otherwise be used as food) will increase the cost of crops such as maize and palm oil, and thereby increase the production costs of their commercial products and the price of food (a major problem for the urban poor). Produced without consideration for the environment, biofuels could result in further deforestation, habitat fragmentation, invasive species, declining soil fertility, and even a net carbon increase (particularly where forested land is cleared for intensive biofuel feedstock production).

This brief discussion of energy and water underlines the importance of carrying out strategic environmental assessments so that the full trade-offs of the various options can be quantified, thereby providing decision-makers with the information they require.

2.4 Using economic instruments to promote sustainability

The extremely high conservation values of the biodiversity of the GMS has generated substantial funding from international agencies, such as the World Bank, the United Nations Development Program, the United Nations Environment Programme, the Global Environment Facility, the United Nations Food and Agriculture Organization, the Asian Development Bank, and many others. Major investments in conservation have also been supported by bilateral donors, including virtually all of the OECD countries.

Many international non-governmental organizations are also active in supporting conservation in the GMS, notably the Wildlife Conservation Society, The Nature Conservancy, Worldwide Fund for Nature (WWF), Conservation International, Fauna and Flora International, Birdlife International, the International Crane Foundation, Botanical Gardens Conservation International, and the International Union for Conservation of Nature. They have provided financial support, developed local capacity, and supported critically important research.

It is likely that such external support will continue in the coming decade, though the financial problems being faced by many OECD countries could well reduce the funds available and redirect investments toward the least developed countries. Therefore, the countries of the GMS are exploring other options for ensuring that the financial resources remain available for maintaining the environmental health of the region. This is sensible public policy. A recent major international effort, known as The Economics of Biodiversity and Ecosystem Services (TEEB) has concluded that the value of ecosystem services is substantially greater than the costs of maintaining their productivity (TEEB, 2010). In other words, environmental degradation is costly on both social and economic grounds, like Stern (2006) showed for climate change.

The problem is that only some ecosystem services, mostly the provisioning services such as food production or harvesting of timber, are amenable to traditional economic analysis, which tends to “externalize” (that is, ignore) the

other ecosystem services that may be sacrificed. But the concept of ecosystem services has provided a new tool that is now being more widely applied, including in the GMS.

For example, the PRC sees payment for ecosystem services (PES) as a tool for stimulating development in rural ecosystems of the country (Scherr and Bennett, 2011). Viet Nam and Cambodia, too, are promoting PES and have provided a legal basis for them. All of the GMS countries are involved in a form of PES that pays for the service of carbon sequestration. This climate mitigation program is known as Reduced Emissions from Deforestation and Forest Degradation (REDD), under which countries that emit excess carbon dioxide compensate by supporting the planting of new forests or the conservation of existing ones. An improved version goes beyond the carbon storing service to include other services such as maintaining watersheds and conserving genetic resources; this is known as REDD+.

One of the most effective ecosystem services for delivering benefits to the rural poor is the protection of forested watersheds (Warner, 2009), often as part of REDD+. Farmers in some parts of the world are growing coffee and cocoa as part of complex agroforests, earning a premium on their “Forest Friendly” labels; they are using a market mechanism to enhance earnings from helping to conserve biodiversity, an approach that could be more widely used in the GMS.

Some protected areas are also cashing in on ecosystem services, especially those that provide ecosystem services to a reservoir; a notable pioneer in this effort is the Nam Theun 2 dam in Lao PDR, which has established a special Watershed Management Protection Agency that receives \$1 million per year to conserve the watershed and support local development. Many other protected areas provide cultural services in the form of tourism, and local communities often are able to participate through establishing ecotourism facilities around the protected areas (see, for example, King *et al.*, 2009, for examples in Cambodia).

While developing markets for ecosystem services shows considerable potential, it is constrained by factors such as poorly-developed property rights, inadequate recognition of liability for environmental damages, lack of a culture of rewarding contributions to ecosystem health, and weak regulatory capacity (Bishop *et al.*, 2009). These constraints will require attention from the GMS countries in the coming years.

2.5 Building stronger capacity for conservation

Public policy decisions that affect the environment are by their nature political. While sound science is helpful in decision-making, it is not necessarily decisive. For example, solid science clearly demonstrates that primary forests are essential for sustaining biodiversity in the tropics (Gibson *et al.*, 2011), but policy makers may nonetheless be convinced that an oil palm plantation is preferable to a tropical forest. Such decisions are often made on the basis of economics (see above) and on the relative power of those who gain the greatest benefit from the decision. But much depends on how benefits are defined and who defines them. And this in turn depends on the strength of the constituency that affects such definitions. If the expected benefits are to be delivered to the rural poor from improved management of ecosystem services, then their constituency needs to be strengthened.

Delivering on the promise of the Biodiversity Conservation Corridors Initiative will require action at many levels, from the international to the local. Managing transboundary cooperation requires new forms of institutions, with new mandates and new sets of skills from the many different interest groups. Training in specific fields, from basic computer skills to GIS mapping to productive negotiation needs to be supported by improved outreach and communications. A particularly important group that may need support in developing new crops, new products, and new marketing skills are rural women, especially for minority peoples who are often ignored.

At the other end of the scale, the complexity of managing transboundary resources will call on well-trained government officials with numerous skills, from designing appropriate legal frameworks to ensuring that national interests are well represented in international negotiations. Protected area managers will need new skills too, and they will be expected to work productively with people in the surrounding lands, their own staff, and the tourists who expect to visit a well-managed protected area.

3. Conclusions and Recommendations

This brief overview has highlighted some of the most important environmental issues facing the GMS. The serious challenges that face humanity in the coming decade could greatly benefit from a stronger partnership among government agencies, the private sector, environmental organizations, scientists, and the agricultural community,

perhaps based on some of the principles outlined in this paper. Areas of controversy should be seen as stimuli for developing better approaches and stimulating further research. Easy answers should not be expected, nor should approaches that will work everywhere. Diverse systems will require diverse responses, but new insights from science and other forms of knowledge may stimulate a broad range of applications.

The following points pose some options for productive policy debate, drawing from the preceding discussion.

1. The concepts and practices developed by the Biodiversity Conservation Corridors Initiative should be applied more widely, and even promoted to other regions. Results to date indicate that looking at the scale of an individual farm or plantation, or even a protected area, will lead to only limited progress (though of course it is crucial to the individual farmer or protected area manager). Experience from the BCI has shown that working at a watershed scale is often effective, particularly when development of water resources is so central to sustainability and the equitable distribution of benefits in the GMS. While the establishment of hundreds of protected areas throughout the GMS is a notable achievement, these areas need to be connected by corridors if they are expected to conserve their full complement of species, and adapt to climate change.
2. The environmental problems facing the GMS that have been outlined in this paper would greatly benefit from interdisciplinary approaches. The more sophisticated approaches that are now being taken to environmental management will require expertise from natural resource managers, business people, experts in energy and water, geographers, the military, social scientists, and many others, working together.
3. Results from studies of the economic benefits of ecosystem services have shown that investments in their conservation are well justified. Sustainable financing mechanisms, such as Payment for Ecosystem Services and REDD+, are likely to become increasingly important, and new applications of these concepts should be explored. For example, many protected areas earn considerable income through gate fees, and regulations (where they do not already exist) should be adopted that enable the protected areas to retain the income they earn and apply the profits to improved management and benefits to communities around the protected areas.

4. New approaches to addressing the issues identified in this paper should be addressed through multiple ways of knowing. Scientific knowledge can be enriched by local knowledge, traditional experience, and other forms of knowing. For example, farmers can contribute local ecological knowledge about forests beyond the experience of professional forest scientists, through means such as assessing the percentage of leaves damaged by insects or fungi and the density of new shoot stems (Fortmann and Ballard, 2011).

5. Investments in capacity building for resource management need further expansion, at all levels but with a particular focus on the poor, ethnic minorities, and women. The future is uncertain, but building the capacity of local people to adapt to change will be an important means toward a prosperous 2020. Resource managers also need regular refreshing of the skills to address sustainable forms of management, requiring improved skills in community relations, business management, ecotourism, collaborative management, and species protection.

6. Capacity building is also needed by scientists and other researchers. Having seen amazing changes in technology in the past few decades, the GMS countries should collaborate with other countries to seek key breakthroughs that by the year 2020 would best contribute to sustainable management of biodiversity and ecosystem services. Speeding adoption of new technologies while ensuring that they are safe will be crucial elements of mobilizing the new technology, and this will require the countries of the GMS to develop an independent and self-reliant scientific capacity. Regional cooperation may also contribute to more rapid adoption of new technology, while also ensuring that any risks are carefully addressed.

7. Countries that import food, timber, medicinal plants, biofuels, and other genetic resources have responsibilities to the exporting countries, and these have been incorporated in international law such as the Convention on Biological Diversity. But this “soft law” has not yet been sufficient, and the GMS countries should consider jointly requesting the World Trade Organization to incorporate these issues as its members seek to reach a satisfactory conclusion to the Doha Round. The exporting countries should also accept their own responsibilities, using tools like Strategic Environmental Assessment and Environmental Impact Assessment to ensure that the income earned from exports does not come at the expense of environmental degradation that will impose costs on rural people, especially the poor.

8. Agricultural researchers should work with farmers to maintain the maximum possible diversity in cropping systems, genetics, and technology. The best way to adapt to change is to maintain the widest possible range of options, which in the case of agriculture include biodiversity (genes, species, and ecosystems), constantly-evolving technologies, and the cultural diversity that builds on local wisdom among the farmers, foresters, pastoralists, and fishers who are actually managing the living resources humanity needs to sustain society.

9. Biofuels should be carefully assessed for their impacts on biodiversity and ecosystem services in the GMS. Produced sustainably, biofuels could provide economic incentives for restoring and enhancing ecosystems – through, for instance, conservation farming practices such as no-till or organic farming, and forest landscape restoration. Much will depend on how the biofuel market develops in the coming years, a topic that well deserves greater attention.. Substantial investments are being made in the GMS (especially the PRC) to develop advanced biofuels into a commercially-feasible option, though high costs of production remain a significant constraint. The many unknowns surrounding biofuels calls for the countries of the GMS to take a precautionary approach to their further development, especially if they are to be grown on land that currently supports the mature forests on which so much of the region’s biodiversity depends.

10. The GMS is rich in options for building dams, and deciding which ones to build, and in what order, is a complicated process with numerous factors to be considered. The World Commission on Dams (2000) provides useful guidance. Three main points will be emphasized here: choose sites that will have the least negative impacts on biodiversity and ecosystem services; for hydroelectric dams, choose reservoir sites that provide the most energy per unit of land to be flooded; and include payments for ecosystem services within the financial arrangements of any dam.

The GMS has developed a strong foundation of environmental management upon which to build. The coming decade is sure to bring major changes to the region, and the direction of these changes will be dependent upon policy decisions that recognize the value of ecosystem services to the people of the region.

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THE IMPACT OF TRADE LIBERALIZATION ON THE ENVIRONMENT IN GMS AND SOUTHEAST ASIAN COUNTRIES: AN EMPIRICAL STUDY

Loi Nguyen Duy¹

Abstract

The relationship between trade liberalization and environmental degradation was studied using a parametric econometric model with a cross-country dataset of 3 countries in the Greater Mekong Subregion (People's Republic of China, Thailand, and Viet Nam) and 3 other (Association of Southeast Asian Nations [ASEAN]) countries (Indonesia, Malaysia, and the Philippines)² for the period 1980–2006. Two environmental indicators were used for analysis: carbon dioxide emissions from the consumption of energy and primary energy consumption. The presence of an environment Kuznets curve (EKC) was investigated to describe the interrelation between per capita income and environment quality.

No evidence for the existence of an EKC was found for the relation between per capita income and the environmental indicators. There was evidence to support the pollution heaven hypothesis (the shift of polluting industries from the North to the South), and evidence for a monotonically increasing linear trend between per capita income and both carbon dioxide emissions and primary energy consumption.

1. Trade Liberalization and the Environment: A Theoretical Overview

Since the early 1990s, many empirical studies have examined the relationship between income, trade liberalization, and pollution in different country development stages, using cross-country and time series data. An inverted U-shaped relationship between income and pollution called an environmental Kuznets curve

(EKC) is said to exist, and has attracted much attention.³ Some authors argued that the EKC should be interpreted with care because of its fragility and the weakness of the concept (Arrow *et al.*, 1995; Ekins, 1997; Stern and Common, 2001).

The skepticism about most empirical studies is due to their concentration on a few pollutants, such as sulfur dioxide (SO₂), nitrogen oxides (NO_x), carbon monoxide (CO), and energy consumption. Other pollutants have different relationships with income. The empirical results can be influenced significantly by research methods, time of studies, samples, and data quality. The impacts of economic growth on pollution depend on the source of economic growth. Evidence for the impact of trade liberalization on pollution is mixed. Antweiler *et al.* (2001) found that trade liberalization reduced pollution, whereas Dasgupta *et al.* (2002) found that trade liberalization did not have a positive effect on the environment in developing countries.

A pollution heaven hypothesis (PHH), which was supported by some studies (Mani and Wheeler 1998; Suri and Chapman, 1998), is based on the differences in environmental regulations between the North and the South;⁴ the South has a comparative advantage in pollution-intensive production while the North specializes in clean production. The South provides pollution-intensive products for the North via trade. This is the channel by which pollution is transferred from the North to the South. Some authors, such as Grossman and Krueger (1993) and Gale and Mendez (1998), found evidence against the PHH, and supported a factor endowment hypothesis (FEH).

The evidence for the PHH is also quite mixed. A number of studies have investigated the environmental consequences of trade liberalization, or the impacts of income and economic growth on the environment (Janicke *et al.*, 1997; Mani and Wheeler, 1998; Cole, 2004). However, few studies have assessed the net trade effects on environment or on an indicator of sustainable development. The United Nations Environment Programme (UNEP) (1999) found

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² Cambodia, the Lao PDR, and Myanmar were excluded due to lack of data.

³ Many authors have found the existence of an EKC, including Grossman and Krueger (1995), Shafik and Bandyopadhyay (1992), Shafik (1994), Selden and Song (1994), Suri and Chapman (1998), Agras and Chapman (1999), Cole (2004), Azomahou, Laisney, and Phu Nguyen Van (2006), and Phu Nguyen Van and Azomahou (2007).

⁴ The North implies developed countries while the South refers to developing countries.

evidence of negative impact of trade liberalization on sustainable development in several developing countries. However, another UNEP study (UNEP, 2001) showed that trade had a positive effect on sustainable development in some developing countries.

Several authors have investigated potential interactions between international trade and environment quality.⁵ Trade liberalization makes countries cope with greater competitive pressures; thus, they will use resources more efficiently and, as a result, pollution emissions decrease. Trade liberalization through free trade agreements (FTAs) and the World Trade Organization (WTO) promote technical and environmental standards so that countries may restrain imports of environment damaging goods.

Grossman and Krueger (1995) and Copeland and Taylor (1994, 2003) described three different channels through which economic growth influences environmental quality⁶ and shapes the EKC—scale effect, composition effect, and technique effect. The scale effect indicates the increase of pollution resulting from economic growth and growing market access. The composition effect implies changes in structure of an economy, as a consequence of trade liberalization, when the economy specializes growingly in activities in which it has a comparative advantage. The technique effect refers to the use of cleaner techniques of production with trade liberalization. As incomes grow, income-induced demand leads to more stringent environmental regulations, higher environmental standards and environmental protection, and access to environment-friendly techniques of production. The composition effect is the channel through which the pollution heaven hypothesis would have impacts on pollution. However, the extent of the composition effect on pollution depends on the comparative advantages of a country.

Most empirical studies used parametric specifications, such as cubic or quadratic polynomials, to examine the relations between environmental quality and per capita income, and to test the inverted U- shape⁷ hypothesis of

the EKC. Some studies investigated both the inverted U- and the N- shape hypothesis for developed countries.⁸ The effect of trade liberalization on the environment has been discussed in a number of papers.⁹ The evidence is mixed, with trade liberalization having positive or negative effects on the environment depending on sources of comparative advantage, environmental regulations, and the pattern of trade.¹⁰

2. Data and Variables

The relationship between trade liberalization and environmental degradation was studied using a parametric econometric model with a cross-country dataset of 3 countries in the Greater Mekong Subregion (People's Republic of China, Thailand, and Viet Nam) and 3 other (Association of Southeast Asian Nations [ASEAN]) countries (Indonesia, Malaysia, and the Philippines)¹¹ for the period 1980–2006. Two environmental indicators were used for analysis: carbon dioxide emissions from the consumption of energy and primary energy consumption. The presence of an environment Kuznets curve (EKC) was investigated to describe the interrelation between per capita income and environment quality.

In the analyses, the dependent environmental variables were carbon dioxide emissions from the consumption of energy and primary energy consumption. The countries in the analysis are newly industrialized and rapidly growing economies, consuming a large amount of energy (about 60% energy consumption by all non-Organisation for Economic Co-operation [OECD] Asian countries; Energy Information Administration [EIA] data, 2008) and generating a large amount of pollution, including carbon dioxide and other gases.

⁵ These authors are Grossman and Krueger 1992, 1995; Shafik and Boandypadhyay 1992; Copeland and Taylor 1994; Cole 2000 and 2004; Copeland and Taylor 2003.

⁶ Grossman and Krueger (1993) also decomposed the effects of trade and foreign investment liberalization on the environment into three different channels: scale, composition, and technique effects, the same the growth-environment relation.

⁷ Authors such as Grossman and Krueger (1995) and Shafik (1994), found evidence for an N-shape EKC which implies that as economic activities enlarge rapidly, the negative impact of the scale effect is always larger than the positive impact of the other two effects—composition and technique.

⁸ These authors are Bruyn, van den Bergh and Opschoor (1998); Canas, Ferrao, and Conceicao (2003).

⁹ They are Suri and Chapman 1998; Antweiler *et al.*, 2001; Copeland and Taylor 2003; Cole 2004

¹⁰ The standard Heckscher-Ohlin model indicates that free trade makes a country with environment abundance specialize increasingly in pollution-intensive goods. However, the Stolper-Samuelson theorem shows that as the price for the use of environment rises, techniques of friendly environment production may be used.

¹¹ Cambodia, the Lao PDR, and Myanmar were excluded due to lack of data.

Per capita primary energy consumption is measured in quadrillion (10^{15}) British thermal units (Btu). Per capita primary energy consumption is considered as a pollutant. Per capita carbon dioxide emissions from the consumption of energy are calculated in metric tons of carbon dioxide. Data are from EIA (2008). Table 1 shows descriptive statistics for dependent and explanatory variables.

The explanatory variables were as follows. Data for all explanatory variables were from the World Development Indicators (WDI) 2008.

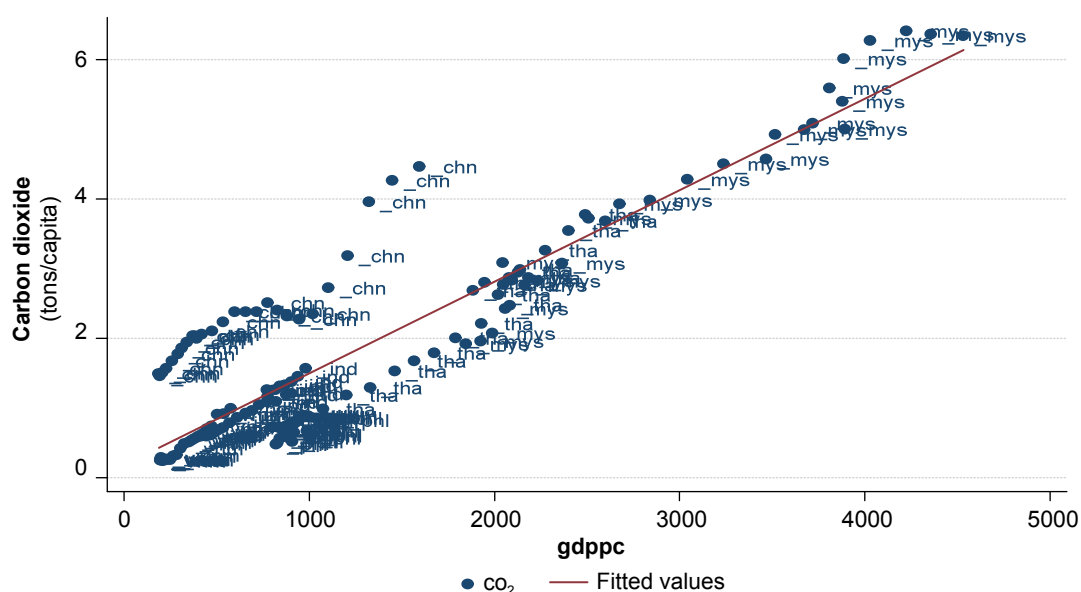
- Per capita GDP, measured in constant 2000 US dollars. Figure 1 presents the relation between carbon dioxide and per capita GDP; Figure 4 depicts the relation between energy consumption and per capita GDP.

- Level of openness or trade intensity as a percentage of GDP, measured as a share of the sum of exports (X) and imports (M) of goods and services in GDP $((X+M)/GDP)$; Figure 2 presents the relation between carbon dioxide and the level of openness; Figure 5 depicts the relation between energy consumption and the level of openness.
- Net total annual foreign direct investment (FDI), measured as percentage of GDP in current US dollars, to estimate FDI impacts on pollution in the context of trade liberalization. Figure 3 depicts the relation between carbon dioxide and FDI; Figure 6 presents the relation between energy consumption and FDI.
- Population density, measured in people per square kilometer.

Table 1: Descriptive Statistics

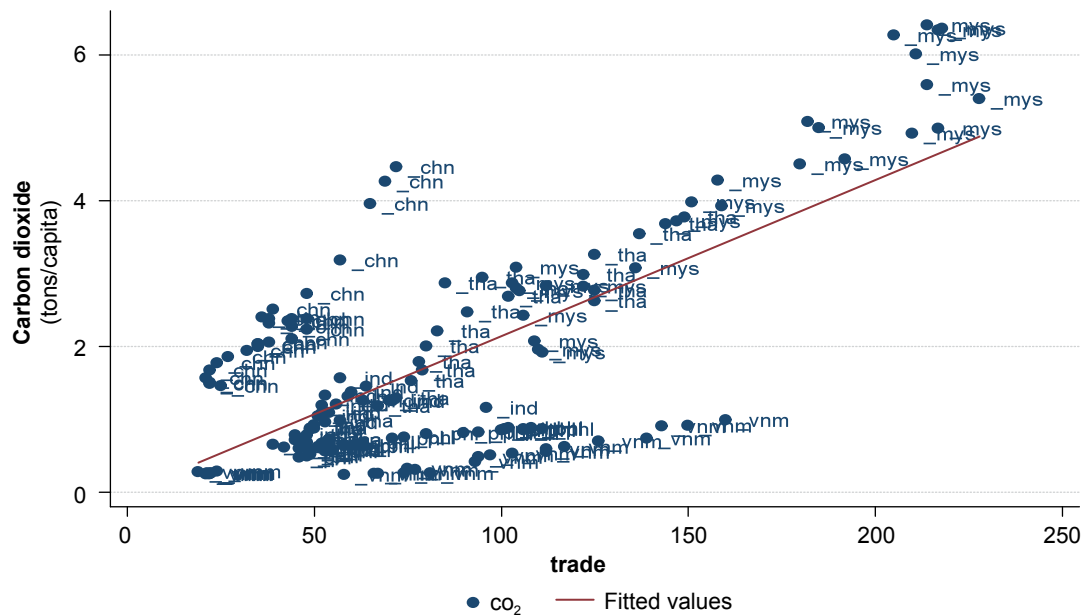
Variable	Mean	Standard Deviation	Minimum	Maximum
Energy consumption ($\times 10^{15}$ British thermal units)	26.50535	23.60734	3.08748	100.6928
Carbon dioxide (tons per capita)	1.778828	1.511246	0.23324	6.40294
Per capita GDP	1,216.451	1,028.053	186	4535
GDP growth rate	6.092407	4.124297	-13	15
Trade intensity	83.16049	50.23773	19	228
Foreign direct investment	0.0244874	0.0223661	-0.0032665	0.1193948
Population density	136.377	62.93917	41.74028	287.5457
Number of countries	6			
Number of years	27			
Number of observations	162			

Figure 1: Relationship between Carbon Dioxide and Per Capita GDP



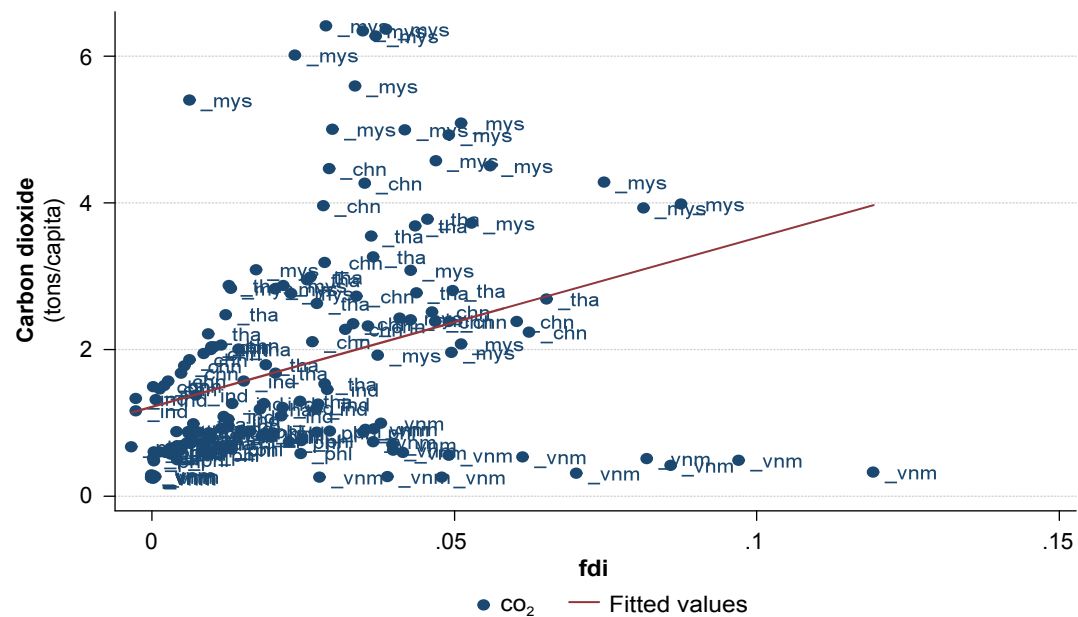
chn = People's Republic of China, co_2 = carbon dioxide, gdppc = gross domestic product per capita, ind = Indonesia, mys = Malaysia, phl = Philippines, tha = Thailand, vnm = Viet Nam

Figure 2: Relationship between Carbon Dioxide and Level of Openness



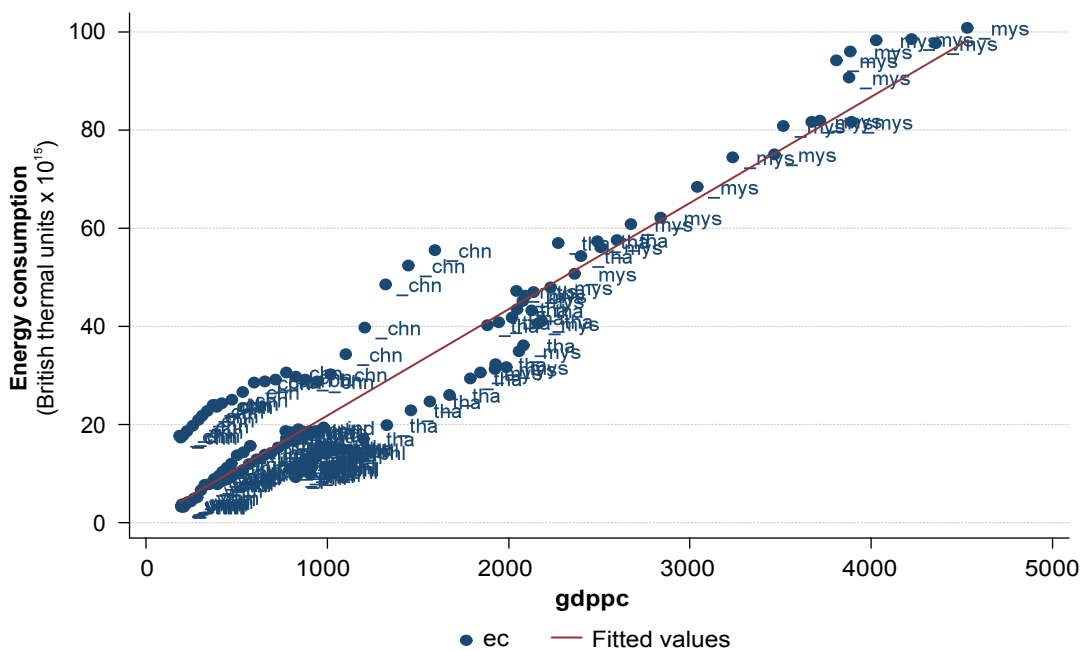
chn = People's Republic of China, CO_2 = carbon dioxide, ind = Indonesia, mys = Malaysia, phl = Philippines, tha = Thailand, vnm = Viet Nam

Figure 3: Relationship between Carbon Dioxide and FDI



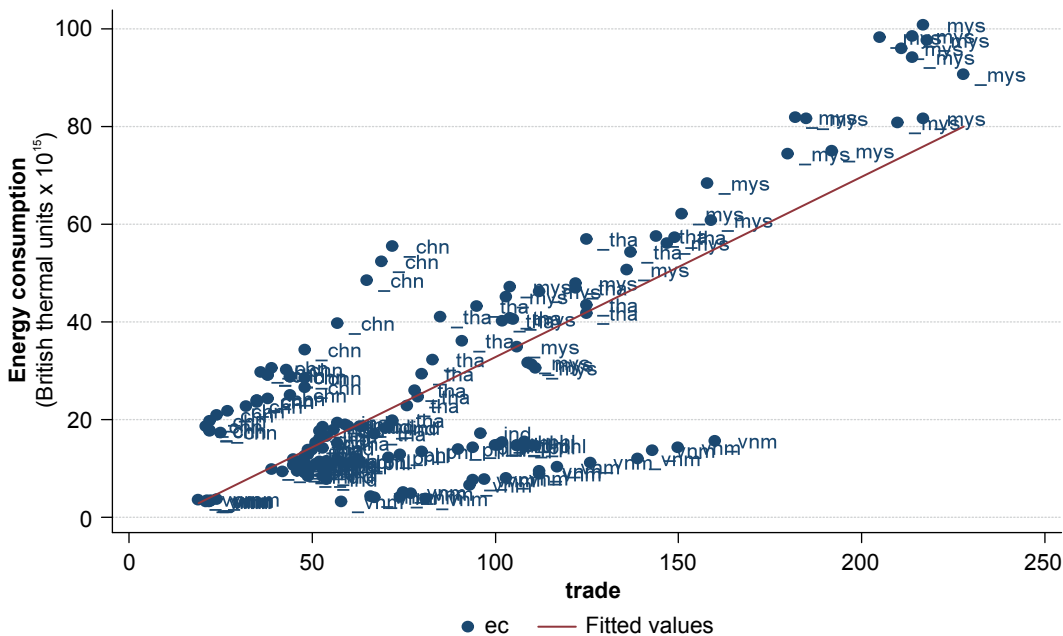
chn = People's Republic of China, CO_2 = carbon dioxide, fdi = foreign direct investment, gdpcc = gross domestic product per capita, ind = Indonesia, mys = Malaysia, phl = Philippines, tha = Thailand, vnm = Viet Nam

Figure 4: Relationship between Energy Consumption and Per Capita GDP



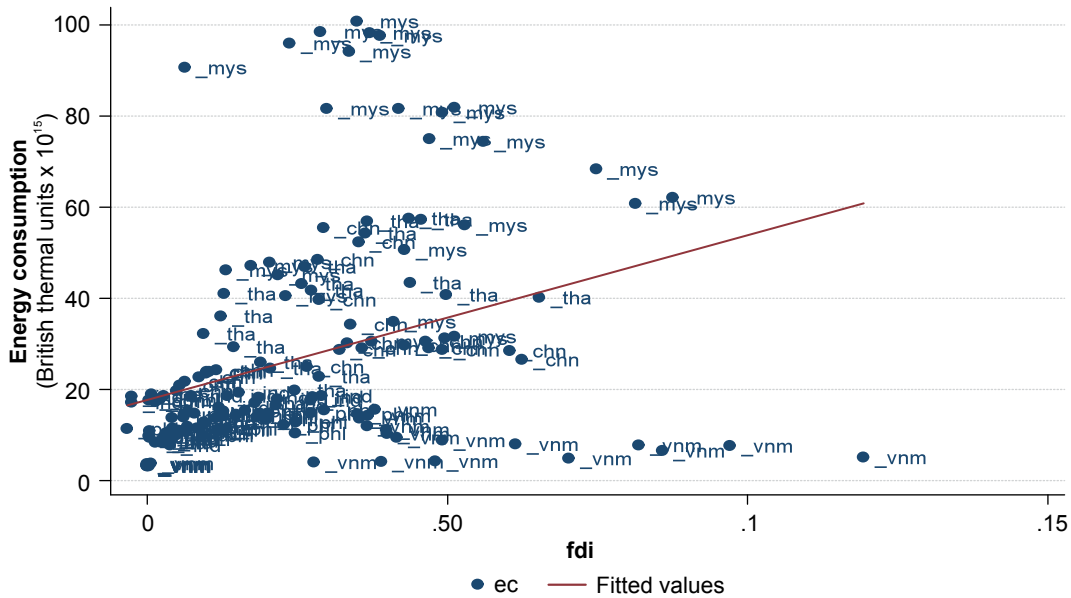
chn = People's Republic of China, ec = energy consumption, gdppc = gross domestic product per capita, ind = Indonesia, mys = Malaysia, phl = Philippines, tha = Thailand, vnm = Viet Nam

Figure 5: Relationship between Energy Consumption and Level of Openness



chn = People's Republic of China, ec = energy consumption, ind = Indonesia, mys = Malaysia, phl = Philippines, tha = Thailand, vnm = Viet Nam

Figure 6: Relationship between Energy Consumption and FDI



chn = People's Republic of China, ec = energy consumption, fdi = foreign direct investment, ind = Indonesia, mys = Malaysia, phl = Philippines, tha = Thailand, vnm = Viet Nam

3. Econometric Model

The EKC is a “reduced-form” relationship, in which the level of pollution is estimated as a function of per capita income. The advantage of the reduced-form approach is that it provides the net effect of income per capita on pollution. The econometric specification is based on the following model. Trade and FDI are included in this EKC framework, and the modifier model is estimated for the two environmental variables.

$$Y_{it} = b_0 + b_1x_{it} + b_2x_{it}^2 + az_{it} + \mu_i + \varepsilon_{it}, \quad (1)$$

Where y is the level of pollution; x is per capita income; z is a matrix of explanatory variables, including GDP growth rate, trade intensity or level of openness, FDI, and population density; b_0 is the intercept, μ_i is country-specific effects, fixed or random, and ε_{it} is error term. Subscripts i and t represent country and year, respectively. Data for this model are balanced cross country panel.¹²

¹² On the basis of earlier studies, aspects of a country that either do not change or change very slowly over time are controlled for by including country-specific fixed effects. The random effect is calculated for time-varying omitted variables and stochastic shocks that are common to all countries.

Equation (1) provides a test for various forms of economic and environmental relationships. If $b_1 > 0$ and $b_2 = 0$, it presents a monotonically increasing linear trend, meaning that rising income is accompanied by increasing pollution and energy consumption. If $b_1 < 0$ and $b_2 = 0$, it presents a monotonically decreasing linear trend, indicating the reverse relationship between income and environmental indicators. If $b_1 > 0$ and $b_2 < 0$, it indicates an EKC; If $b_1 > 0$ and $b_2 > 0$, the relationship would be U-shaped.

4. Does the EKC Exist?

Suppose y_{it} be the dependent pollutant variable (carbon dioxide and energy consumption) of country i , $i = 1, \dots, N$ in year t , $t = 1, \dots, T$; x_{it} is the level of real per capita GDP of country i at year t ; and z_{it} is the matrix ($p \times 1$) vector of the other explanatory variables. First, we test the existence of an EKC. Second, we study determinants for pollutants through examining the functional forms and testing the statistical hypothesis. The nonlinear and linear functional forms are checked to find the best fitting functional form for the data. For simplicity, the general parametric model is used:

$$Y_{it} = b_0 + b_1x_{it} + b_2x_{it}^2 + \mu_i + \varepsilon_{it}, \quad (2)$$

Where μ_i , which is country- specific effects, would be fixed or random;¹³ ε_{it} is the error term, and b_0 , b_1 , and b_2 are parameters to be estimated.

The quadratic functional form in X is taken to test for nonlinearity in the relationship between pollutants and per capita GDP, which would indicate the existence of an EKC. The Fisher test was applied to both variables. The results showed that for both carbon dioxide and energy consumption, the null hypothesis of the quadratic term could be accepted. Applying the Fisher test to linearity of the relationship showed the data for carbon dioxide and energy consumption best fitted a linear functional form.

The fixed and random effect specification for carbon dioxide resulted in $b_1 > 0$ and $b_2 < 0$, meeting the necessary condition for the existence of an EKC. However, the data did not fit the nonlinear functional form. The conclusion is that there is no evidence for the existence of an EKC for the two variables; the linear functional form best fits the data.

5. Determinants of Pollutants

Given that the linear functional form best fits the data, a modified version of equation (1) is used:

$$Y_{it} = b_0 + b_1x_{it} + az_{it} + \mu_i + \varepsilon_{it}, \quad (3)$$

where z_{it} is a matrix ($p \times 1$) vector of the other explanatory variables, including the growth rate of GDP, trade intensity, FDI, and population density.

The Fisher test for the null hypothesis of non significant conjoint explanatory variables showed that the explanatory variables were significantly conjoint. Similarly, the Fisher test for the null hypothesis of homogeneity in the presence of heterogeneity showed that the model is heterogeneous; that is, the fixed country effect model is preferred. Finally, the Fisher test for the null hypothesis of random country effect specification against the alternative fixed country effect specification for carbon dioxide showed that the fixed country effect model was preferable; estimates of the variables are given in Table 2. The results indicate that per capita GDP, GDP growth, and trade have significant positive impact on carbon dioxide emissions.

The null hypothesis for energy consumption, however, could be accepted, indicating that the random effect model was preferable for energy consumption. Specifications for the random country effect are reported in Table 3 and show that per capita GDP, GDP growth, and FDI are significant.

The chi-squared Test (X^2) for normality of residuals in the model showed that the error term followed the law of normal distribution.

The Breusch-Pagan test was used for the null hypothesis of homoscedasticity¹⁴ and showed that variables were heteroscedastic. It also showed that the random effects were very significant at the 1% level.

The Fisher and Durbin-Watson tests to look for autocorrelation of errors with AR (1) disturbance showed

Table 2: Estimates of Variables for the Fixed Effect Model for Carbon Dioxide

Variable	Coefficient	t- statistic
Intercept	-0.2110687***	-1.75
Per capita GDP	0.0015687*	29.80
GDP growth rate	-0.0081827***	-1.90
Trade intensity	0.0023365**	2.13
Foreign direct investment	0.1688006	0.19
Population density	-0.0004908	-0.42
$F(5,151)^1$	548.32**	
$F(5, 151)^2$	284.49**	
Hausman χ^2 (4) test	14.19**	
Number of observations	162	

Estimates were made with a cross-country sample of 6 Asian countries for 1980–2006 using regression. The dependent variable is carbon dioxide. The first F test (F^1) is for the significant of conjoint explanatory variables. The second F test (F^2) is for the significance of heterogeneity. The Hausman test is for differentiating between the random effect model and the fixed effect model. Significance level: *1%, **5% and ***10%.

¹³ We estimated the fixed effect models by the fixed effect within regression and random effect by generalized least squares regression.

¹⁴ In statistics, a sequence or a vector of random variables is heteroscedastic, if the random variables have different variances. In contrast, a sequence of random variables is called homoscedastic if it has constant variance. (Wikipedia)

Table 3: Estimation of Variables for the Random Effect Model for Energy Consumption

Variable	Coefficient	z-statistic
Intercept	2.219393*	0.92
Per capita GDP	0.0194815*	13.28
GDP growth rate	0.4979969*	3.35
Trade intensity	0.0185132	0.66
Foreign direct investment	55.38848***	1.78
Population density	-.0391726	-3.00
Wald chi ² (5)	1563.83*	
Number of observations	162	

Estimates were made with a cross-country sample of 6 Asian countries for 1980–2006, using the feasible generalized least squares (FGLS) regression and autocorrelation structure for the correction of heteroscedasticity and autocorrelation. The dependent variable is energy consumption. Significance level: *1% and ***10%.

Table 4: Estimation of Variables for Carbon Dioxide with Correction for Heteroscedasticity and Autocorrelation

Variable	Coefficient	z-statistic
Intercept	0.1836027	1.56
Per capita GDP	0.0012385*	18.77
GDP growth rate	-0.0002581	-0.11
Trade intensity	0.0014568**	2.10
Foreign direct investment	0.5181289	0.88
Population density	-0.0014681**	-2.18
Wald chi ² (5)	551.37*	
Common AR(1) coefficient for all panels	0.8415	
Number of observations	162	

Estimates were made with a cross-country sample of 6 Asian countries for 1980–2006, using the feasible generalized least squares (FGLS) regression and autocorrelation structure for the correction of heteroscedasticity and autocorrelation. The dependent variable is carbon dioxide. Significance level: *1%, **5%.

that there was positive first-order autocorrelation for both carbon dioxide and energy consumption

In summary, the tests for the model of best fit for the data showed that the fixed country effect model with autocorrelation and heteroscedasticity across panels was applicable for carbon dioxide; for energy consumption, the random effect model with autocorrelation and heteroscedasticity exhibited the best fit. We also correct the autocorrelation of errors in these two models. In order to fit the panel data linear model with autocorrelation and heteroscedasticity, we apply the feasible generalized least squares (FGLS) to correct heteroscedasticity and autocorrelation structure. This method allows us to estimate an adjust matrix of variance- covariance of errors in the presence of heteroscedasticity and autocorrelation.

6. Empirical Results

Results for carbon dioxide with correction for heteroscedasticity and autocorrelation (Table 4) indicate

that per capita GDP, trade intensity, and population density are statistically significant, that is, per capita GDP, trade, and population density have positive significant effects on carbon dioxide emissions. GDP growth rate, FDI, and the intercept are not significant. The positive effect of population density, however, is not consistent with our arguments. The choice of population density in urban areas as an explanatory variable would be more appropriate.

Per capita GDP and trade have significant impacts on carbon dioxide. The coefficient of per capita GDP is greater than zero, indicating a monotonically increasing linear trend, which implies that a rise in income is accompanied by an increase in the level of carbon dioxide.

The positive trade coefficient similarly implies an increasing linear trend between the level of openness and carbon dioxide. This supports the pollution heaven hypothesis, implying that poor countries are destinations for polluting industries from rich countries, and that more liberalization in trade would further increase carbon dioxide.

Results for energy consumption with correction for heteroscedasticity and autocorrelation (Table 5) also indicated that per capita GDP, trade, and population density are statistically significant, i.e., there is monotonically increasing linear trend between energy consumption and per capita GDP. This is consistent with arguments that support a linear relation between energy consumption and per capita income (Suri and Chapman, 1998). The negative coefficient of population density is inconsistent with the argument that higher population density would make the environment more polluted.

As in the case of carbon dioxide, the positive coefficient of trade also supports the pollution heaven hypothesis. The evidence indicates that trade liberalization has negative impacts on energy consumption, and an increase in the level of openness would lead to a rise in energy consumption. There is no evidence to support the factor endowment hypothesis. The coefficients of GDP growth and FDI are insignificant and ambiguous in the regression for both carbon dioxide and energy consumption. Some effects may work against each other.

Trade liberalization has resulted in increased environmental pollution in these countries. Therefore, trade openness does not tend to improve the environment through more efficient use of resources and increasing competitiveness. The use of technological advances leading to an increase in efficiency, reduction in the cost of abatement or increases in awareness of pollution issues raise demand for environmental regulations. In the presence of environmental externalities, trade liberalization would harm environmental quality and sustainable development in the countries in this analysis. These countries should take into account the important role of environmental policy.

7. Conclusion and Policy Implications

The results provide a comprehensive picture of possible effects of trade liberalization and per capita income on environment quality. The evidence indicates a monotonically increasing linear relation between per capita income and both carbon dioxide emissions and energy consumption. There is no evidence for the existence of an EKC for either variable. No evidence supports the factor endowment hypothesis that trade liberalization is good for these developing countries. However, there is an evidence to support the pollution heaven hypothesis that considers the link between trade and environment. Some other factors, such as capital-labor endowment, endowment with natural resources, or strictness of implementation of environment policies, could help to provide better insights. The model is also a useful tool to examine linear heteroscedasticity and autocorrelation data for other pollutants, such as water, industrial waste, and toxic gases.

There is an evidence that trade liberalization is harmful for the environment in developing and poor countries. This indicates that economic and environmental policies need to be coordinated to play a greater role in reducing negative effects of trade liberalization on the environment. The application of environmental policies should be consistent with specific characteristics and development stages in each country.

Some global pollution issues, such as carbon dioxide emissions and global warming, require international cooperation to avoid a “free ride problem.” Public awareness and pressure could play an important role in perceptions of environmental change and a strong driving force for policy makers.

Table 5: Estimation of Variables for Energy Consumption with Correction for Heteroscedasticity and Autocorrelation

Variable	Coefficient	z-statistic
Intercept	0.9407799	0.61
Per capita GDP	0.0191888*	21.23
GDP growth rate	-0.0036318	-0.12
Trade intensity	0.0261686*	3.19
Foreign direct investment	5.897469	0.85
Population density	-0.0143953***	-1.67
Wald chi ² (5)	678.56*	
Common AR(1) coefficient for all panels	0.8475	
Number of observations	162	

Estimates were made with a cross-country sample of 6 Asian countries for 1980–2006, using the feasible generalized least squares (FGLS) regression and autocorrelation structure for the correction of heteroscedasticity and autocorrelation. The dependent variable is carbon dioxide. Significance level: *1%, ***10%.

In developing countries, solving environmental problems should not necessarily hurt economic growth (Grossman and Krueger, 1995). However, developing countries lack the capacity to implement sound and strict environmental protection policies. This study suggests that economies that are more open to trade and FDI will face increased pollution levels. The evidence also raises concerns on the “race to the bottom” as developing countries compete for FDI. Developed countries should help developing countries to build their capacity for making and implementing sound environmental policies and for making environmentally friendly methods of production.

Insight into the relationship between trade liberalization and the environment plays a crucial role and is helpful for environmental policy makers in developing countries. At higher levels of incomes, trade liberalization requires stricter environmental regulations and investment in abatement technologies. It is not clear whether developing countries follow a similar pollution-income path as some developed countries. However, there is no doubt that income elasticity of demand for pollution-intensive products falls as incomes increase. The countries in this analysis need to build up and coordinate economic and environmental policies for the protection of the environment to achieve sustainable development.

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ECONOMIC GROWTH AND POVERTY REDUCTION IN THE GREATER MEKONG SUBREGION

Peter Warr¹

Abstract

Over the first decade of this century the Greater Mekong Subregion (GMS) has achieved both impressive growth of output per person and large reductions in absolute poverty incidence. This paper examines the quantitative relationship between these two accomplishments among the GMS members. It also examines whether the sectoral composition of growth, focusing on the agricultural, industrial, and services sectors, is relevant for the rate at which poverty incidence declines for a given overall rate of economic growth.

The results confirm that poverty reduction in the GMS is strongly related to growth of real GDP per person. The sectoral composition of this growth affects the rate of poverty reduction in so far as it affects the growth of services relative to the rest of the economy. Structural changes that promote the growth of services relative to other sectors are conducive to poverty reduction, given the overall rate of GDP growth.

Global economic imbalances developing over the first decade of the 21st century will require major adjustments. Asia has run large current account surpluses, with the United States and Europe running corresponding deficits. It is generally recognized that continuation of this cumulative imbalance is unsustainable. Major adjustment is inevitable and it will mean a switch of final demand within Asia from export dependence toward domestic sources of demand. On the supply side, this will mean a switch of output from production of tradable goods, such as agricultural and industrial goods, toward nontradables, such as services. The rate of poverty reduction in the GMS may therefore increase over the coming decade. If past overall rates of GDP growth per person can be maintained, growth will become more poverty-reducing, given the structural changes that seem to be consistent with global economic restructuring.

1. Introduction

Despite impressive economic progress in recent decades, the Greater Mekong Subregion (GMS) remains poor relative to the rest of the world, and poverty reduction is consequently an urgent priority for international attention. This paper focuses on the seven GMS entities—Cambodia; the Peoples Republic of China (PRC), specifically Yunnan Province and Guangxi Zhuang Autonomous Region; the Lao People's Democratic Republic (Lao PDR); Myanmar; Thailand; and Viet Nam. The primary focus is on 2000–2010. Both economic growth and reduction in poverty incidence were enjoyed by all the GMS members over this period, but the rates at which these two phenomena occurred varied both over time and across the member countries. After documenting these events the study asks two statistical questions.

(i) To what extent was the rate of poverty reduction determined by the rate of economic growth per person?

(ii) Did the rate of poverty reduction depend on the sectoral composition of the growth as well as the overall rate?

The answers to these questions are important for the rate at which further poverty reduction might be expected over the coming decade, ending in 2020. It is argued in this paper that significant changes in the sectoral composition of growth can be expected. It is thus important to ask what this might imply for poverty reduction.

Section 2 of the paper reviews the growth of aggregate output and its sectoral composition in each of the seven GMS entities during 2000 to 2010. Section 3 performs a similar exercise for poverty reduction. This discussion makes it possible to compare the seven GMS entities in terms of not just the rate of economic growth, but also the poverty-reducing power of that growth. Section 4 looks in detail at the statistical questions posed above. Section 5 concludes on the prospects for continued growth and poverty reduction in the GMS.

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2. Economic Growth

In 2010, the levels of GDP per person among the seven GMS entities varied widely, from \$5,000 in Thailand to less than \$1,000 in Cambodia, the Lao PDR, and Myanmar (Table 1). The Asian financial crisis (AFC) of 1997-98 affected all the GMS entities to some extent, but in widely varying degrees. Thailand was most affected, Guangxi and Yunnan the least. In the countries most affected, restoration of economic growth became a policy priority. Thailand's growth resumed, but remained sluggish throughout 2000 to 2010 and Thailand's economic performance was again battered by the global financial crisis (GFC) at the end of 2010. The level of private investment did not recover to its pre-AFC share of GDP. Among the poorer countries, Cambodia, the Lao PDR, and Viet Nam grew well throughout this period.

A lesson from reflection on the period of economic boom that preceded the AFC was that the quality of growth

is important and not just the rate. But what is "quality" growth? One criterion for determining the quality of growth, though certainly not the only one, is its effects on the poor. What kinds of growth are most (and least) beneficial for the poor? Much of the development economics literature has dealt with the manner in which the distribution of income is affected by the rate and composition of economic growth. How do relative inequality, on the one hand, and absolute poverty, on the other, change with economic growth and how do these effects depend on the characteristics of that growth, such as its sectoral composition? This paper attempts to explore these issues in the context of the GMS. It begins with data on the rates of economic growth in each of the GMS entities (Table 1 and Figures 1.1–1.7).

In the case of Myanmar, the level of GDP per person and its growth rate are contentious. The official data for Myanmar and various alternative estimates of its growth rate are described in the Appendix. The Myanmar data shown in Table 1 are based on ADB estimates.

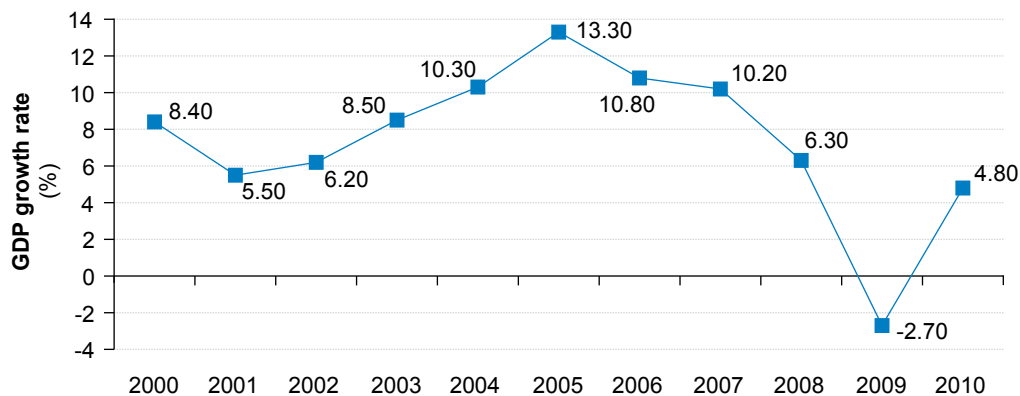
Table 1: Economic Output and its Growth in the GMS

GMS Entity	Population (million)	Population Growth Rate	GDP per Capita (current \$)	Average Annual Growth Rate of Real GDP per Capita (%)	
	(2010)	(2010)	(2010)	value	(period)
Cambodia	14.30	1.5	788.0	10.97	(2002–2010)
PRC					
Guangxi	51.59	0.8	3050.0	10.77	(2000–2009)
Yunnan	45.97	0.7	2326.3	8.88	(2000–2009)
Lao PDR	6.23	1.7	984.2	6.87	(2003–2008)
Myanmar	59.78	1.1	702.0	3.60	(2005–2010)
Thailand	67.31	0.6	4991.5	3.59	(2000–2010)
Viet Nam	86.48	1.1	1172.0	5.56	(2000–2010)

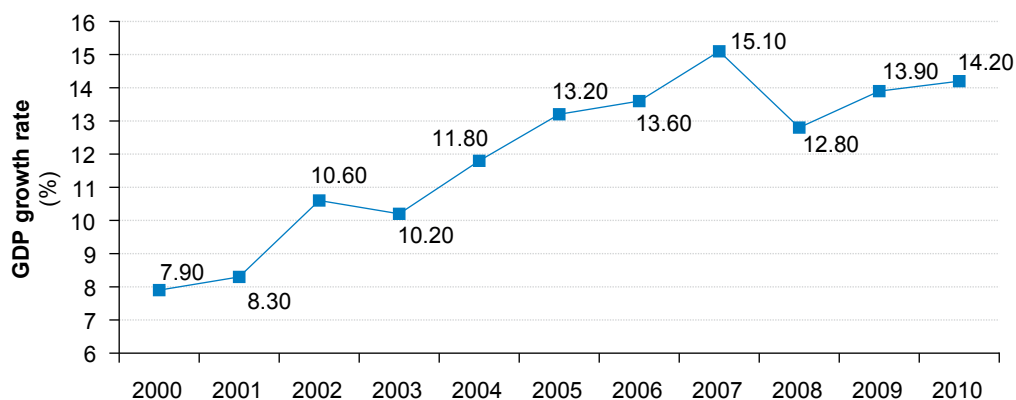
Note: Myanmar's growth data are discussed in further detail in the Appendix. Data for Myanmar shown above are from ADB *Outlook 2006*, 2010, and 2011

Sources: Council for the Development of Cambodia (2011). *Why Invest in Cambodia?*; *Statistical Communique on National Economic and Social Development of Guangxi*; *Statistical Communique on National Economic and Social Development of Yunnan*.

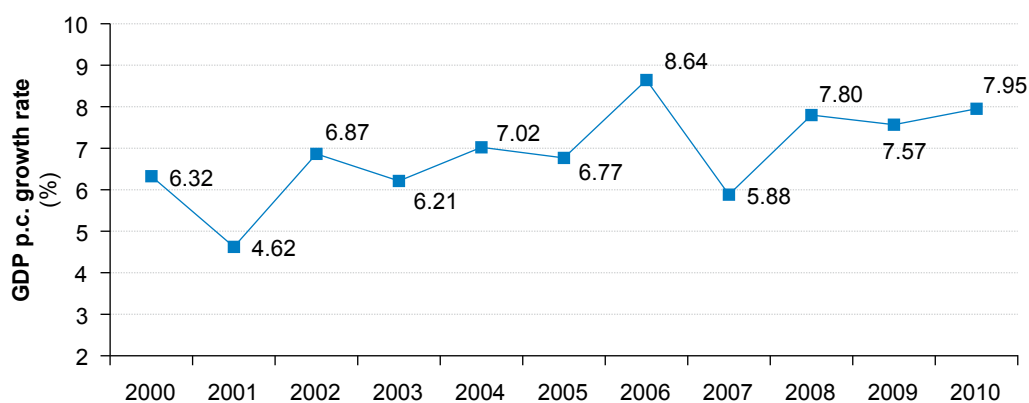
Figure 1: Cambodia: Growth of Real GDP per Person, 2000–2010



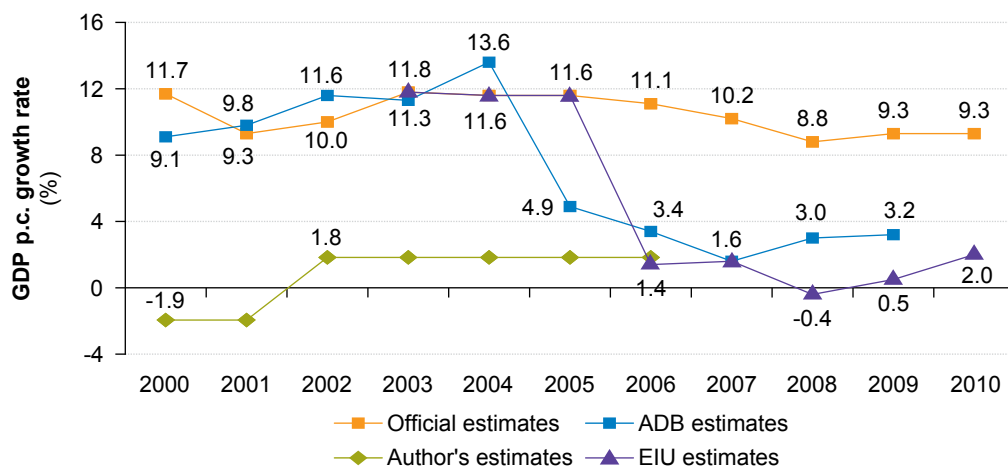
Source: See Table 1.

Figure 2: Guangxi: Growth of Real GDP per Person, 2000–2010


Source: See Table 1.

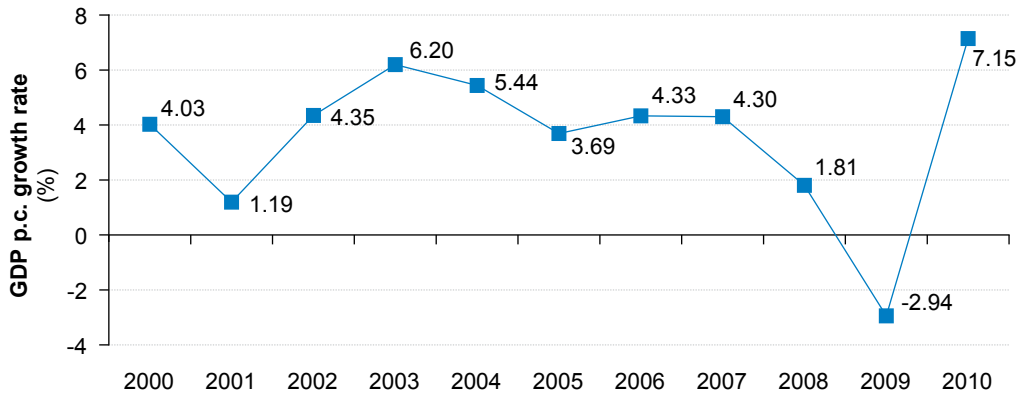
Figure 3: The Lao PDR: Growth of Real GDP per Person, 2000–2010


Source: See Table 1.

Figure 4: Myanmar: Growth of Real GDP per Person, 2000–2010


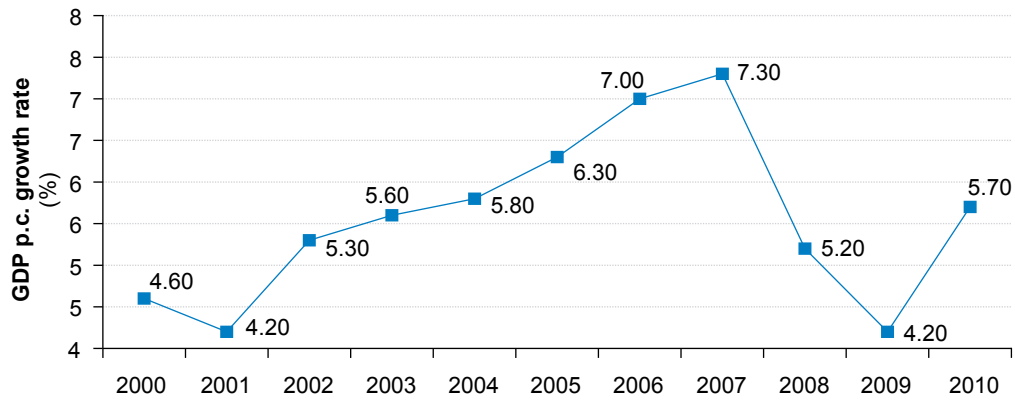
Source: See Table 1.

Figure 5: Thailand: Growth of Real GDP per Person, 2000–2010



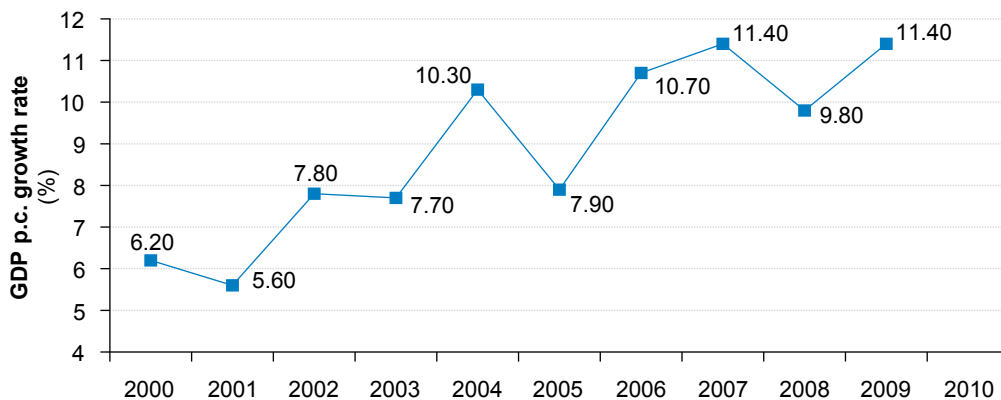
Source: See Table 1.

Figure 6: Viet Nam: Growth of Real GDP per Person, 2000–2010



Source: See Table 1.

Figure 7: Yunnan: Growth of Real GDP per Person, 2000–2010



Source: See Table 1.

3. Poverty reduction

3.1. Poverty Incidence in the GMS

Available data on poverty incidence in the seven GMS entities are summarized in Table 2 and in Figures 8 to 14. In the figures, the data are presented, where available (including all GMS entities except Guangxi and Yunnan), as aggregate poverty incidence and its rural and urban components. The poverty lines underlying these

data are the national poverty lines for the GMS entities themselves, and these poverty lines are held constant in real purchasing power over time. In some cases, the official data involve changes over time in the real purchasing power of the poverty line, but do not provide adjustments for the effects of these changes in the poverty line. This renders the poverty incidence data noncomparable over time and observations subject to this problem have been omitted from the data presented below.

Table 2: Poverty Incidence and Poverty Reduction in the GMS

GMS Entity	Level of Total Poverty Incidence		Levels of Rural and Urban Poverty Incidence			Average Annual Rate of Total Poverty Reduction	
	Value (%)	(year)	Rural (%)	Urban (%)	(year)	Value (%)	(period)
Cambodia	30.1	(2007)	34.5	11.8	(2007)	1.55	(2004–2010)
PRC							
Guangxi	41.7	(2007)	N.A.	N.A.	N.A.	0.43	(2001–2007)
Yunnan	7.0	(2006)	N.A.	N.A.	N.A.	0.70	(2002–2006)
Lao PDR	27.6	(2008)	31.7	17.4	(2008)	1.18	(2003–2008)
Myanmar	25.6	(2010)	29.2	15.7	(2010)	1.30	(2005–2010)
Thailand	8.1	(2009)	10.4	3.0	(2009)	1.43	(2000–2009)
Viet Nam	14.2	(2010)	17.4	6.9	(2010)	0.65	(2004–2010)

Note: N.A. means not available.

Sources: ADB Outlook, various years; United Nations, Millennium Development Goals Indicators (<http://unstats.un.org/unsd/mdg/Data.aspx>); Royal Government of Cambodia (2010), *Achieving Cambodia's Millennium Development Goals*; Government of Viet Nam, *Viet Nam Statistical Yearbook 2010*. Data on Myanmar are from UNDP (2010), *Integrated Household Living Condition Survey in Myanmar (2009–10)*.

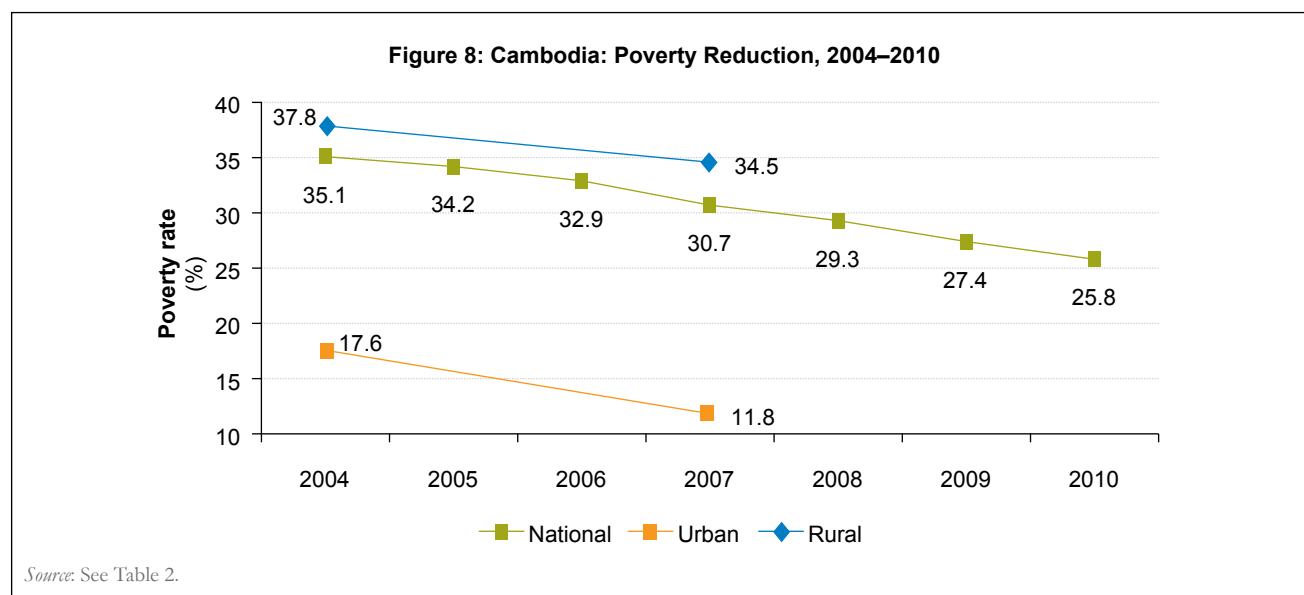


Figure 9: Guangxi: Poverty Reduction, 2001–2007

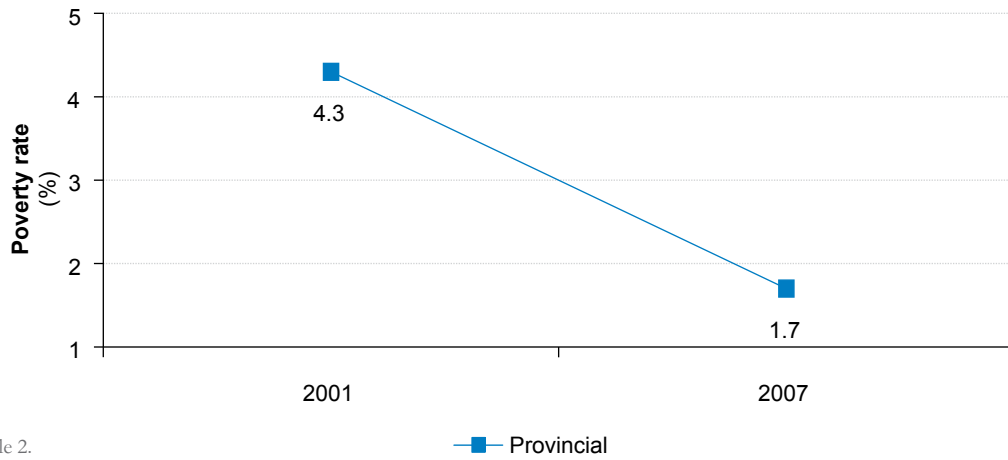


Figure 10: The Lao PDR: Poverty Reduction, 2004–2010

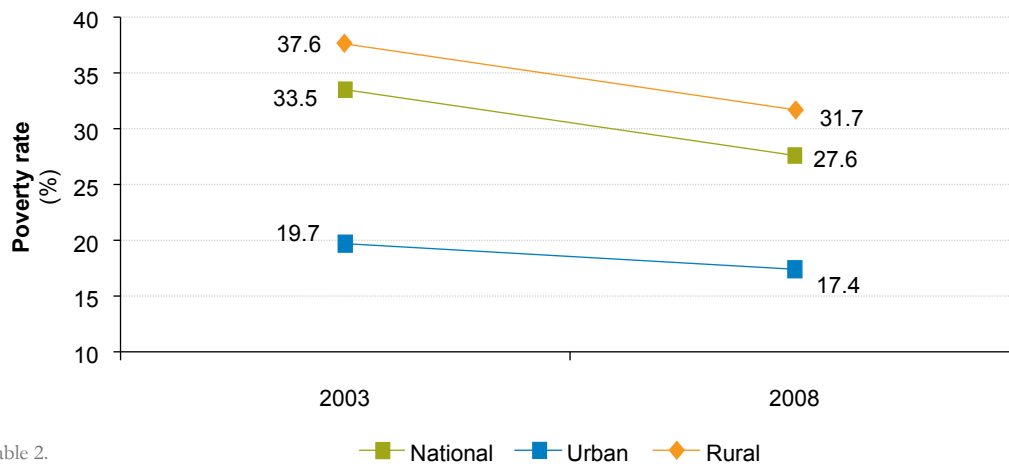


Figure 11: Myanmar: Poverty Reduction, 2005–2010

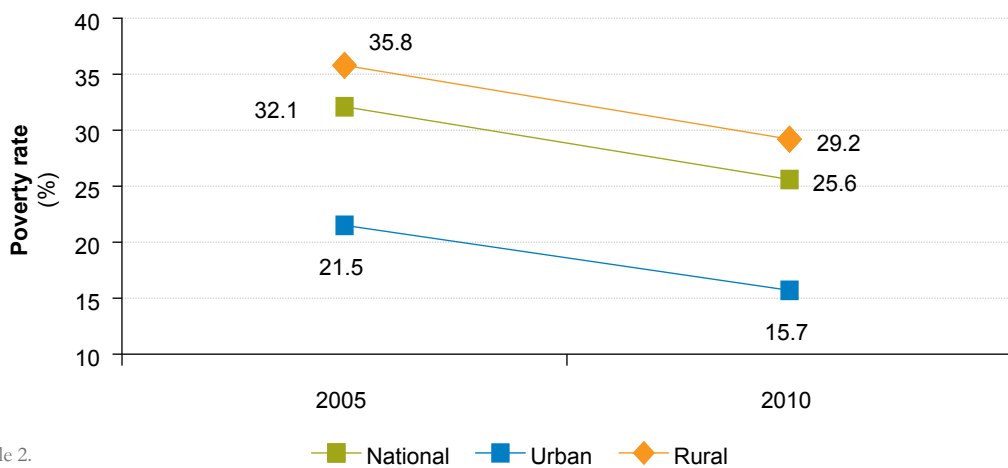
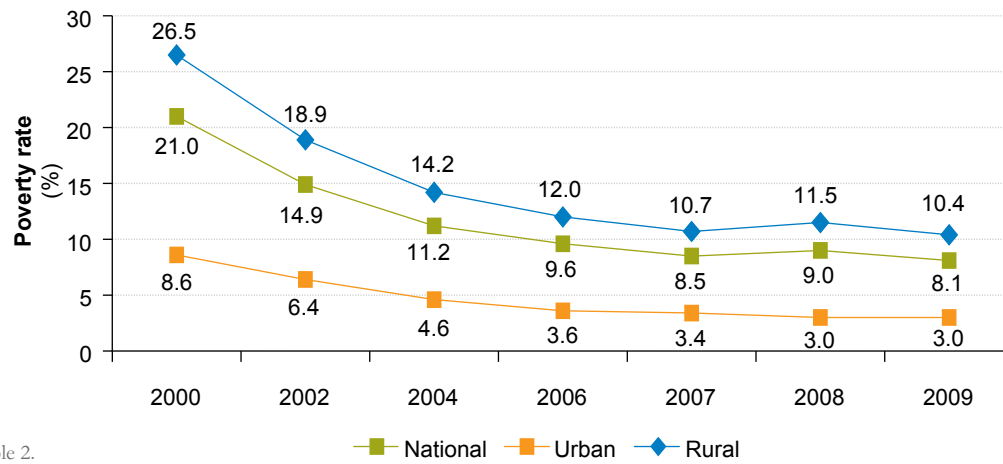
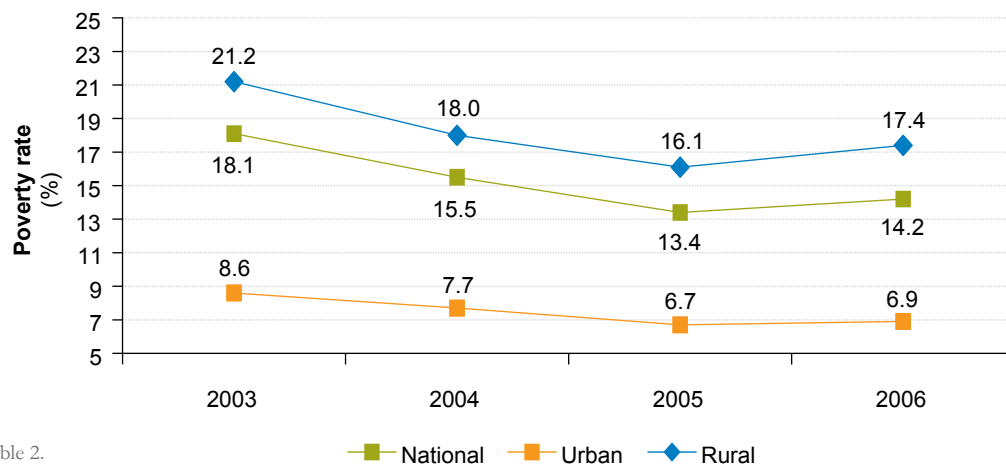


Figure 12: Thailand: Poverty Reduction, 2000–2009



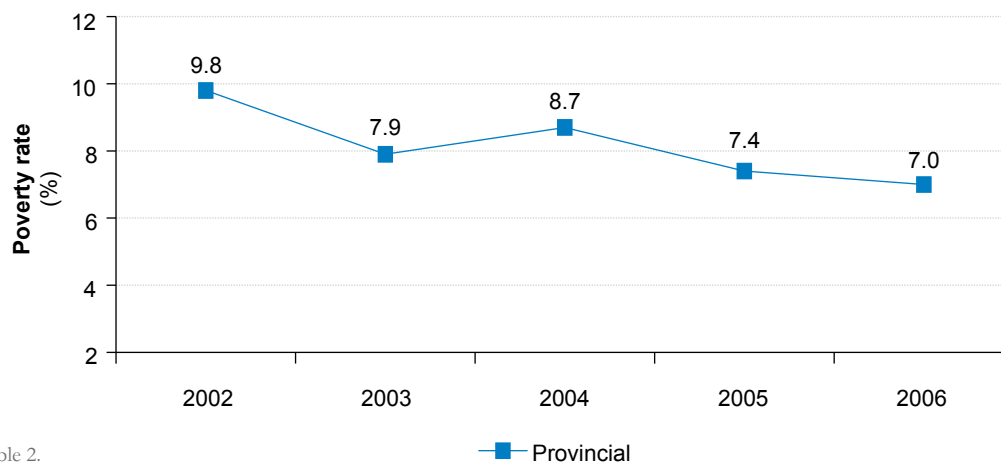
Source: See Table 2.

Figure 13: Viet Nam: Poverty Reduction, 2003–2006



Source: See Table 2.

Figure 14: Yunnan: Poverty Reduction, 2002–2006



Source: See Table 2.

3.2. Poverty Reduction per Unit of Economic Growth

To what extent does economic growth actually reduce poverty? The most direct way of answering this question is simply to relate the annual rate of reduction in poverty shown in Table 2 to the rate of real economic growth per person over the same period shown in Table 1 (second to last columns in each case). The results are shown in the first column of Table 3. This is the average annual reduction in poverty incidence (dP) divided by the average rate of real GDP growth per person. This ratio varied widely across the seven GMS members.

Table 3 also shows, in the last column, the familiar growth elasticity of poverty, which is the proportional change in poverty incidence (dP/P) divided by the rate of GDP growth per person. While this measure is frequently reported, it is potentially misleading. As the level of absolute poverty incidence declines over time due to economic growth and other factors, small absolute reductions in poverty incidence can result in very large proportional reductions in the value of the poverty measure. This occurs merely because the base of the calculation—the level of poverty incidence—is low, wrongly suggesting that growth is more effective in relieving poverty in richer countries (such as Thailand) than in poorer ones (such as Myanmar). Despite this, the ranking of the seven GMS entities according to the two measures is similar.

3.3. Total, Rural, and Urban Poverty Reduction

Data on total, rural, and urban poverty incidence can be used to derive a useful decomposition indicating the degree to which reduction in total poverty incidence is due to poverty reduction in rural areas, urban areas, or the migration of people between the two. We review first the

quantitative relationship between total, rural, and urban poverty incidence and then turn to the manner in which each of these measures is affected by economic growth. Changes in total poverty incidence may be decomposed as follows: N , N^R and N^U are the total, rural, and urban populations, respectively, where $N = N^R + N^U$, $\alpha^R = N^R / N$ and $\alpha^U = N^U / N$ are the rural and urban shares of the total population, respectively, where $\alpha^R + \alpha^U = 1$. The total number of people in poverty is given by $N_p = N_p^R + N_p^U$, where N_p^R and N_p^U denote the number in poverty in rural and urban areas, respectively. Total poverty incidence is given by

$$P = N_p / N = (N_p^R + N_p^U) / N = \alpha^R P^R + \alpha^U P^U, \quad (1)$$

where $P^R = N_p^R / N^R$ denotes the proportion of the rural population that is in poverty and $P^U = N_p^U / N^U$ the corresponding incidence of poverty in urban areas.

Differentiating (1) totally provides a key relationship:

$$dP = \alpha^R dP^R + \alpha^U dP^U + (P^R - P^U) d\alpha^R. \quad (2)$$

From (2), the change in total poverty incidence may be decomposed into three parts: (i) the change in rural poverty incidence, weighted by the rural population share; (ii) the change in urban poverty incidence, weighted by the urban population share; and (iii) the movement of people from rural to urban areas, weighted by the difference in poverty incidence between these two areas.

The last of these terms is described by Anand and Kanbur (1985) as the "Kuznets effect". As the population relocates from rural to urban areas, a change in total poverty incidence will occur even at constant levels of rural and urban poverty incidence, provided that the levels of poverty incidence in these two sectors are different. In growing economies, we expect to find that the rural population share is falling ($d\alpha^R < 0$) and that the incidence of poverty in rural areas typically exceeds that in urban areas ($(P^R - P^U) > 0$). Thus, the expected sign of

Table 3: The Poverty-Reducing Quality of Growth in the GMS

GMS Entity	Poverty Reduction per Unit of Real GDP Growth per Capita ^a	Poverty Elasticity of Growth ^b
Cambodia	0.14	0.46
PRC		
Guangxi	0.04	0.10
Yunnan	0.08	1.14
Lao PDR	0.17	0.62
Myanmar	0.36	1.41
Thailand	0.40	4.94
Viet Nam	0.17	1.20

Notes: a. calculated as $dP/(y \cdot n)$, where dP is the average annual rate of absolute poverty reduction (expressed as a percentage of total population), y is the average annual growth rate of real GDP and n is the average annual growth rate of population.

b. calculated as $(dP/P)/(y \cdot n)$, where the value of P is the value shown in the first column of Table 2.

Source: author's calculations from the second to last columns of Tables 1 and 2.

Table 4: Decomposition of Average Annual Changes in Poverty Incidence, 2000–2010

	Cambodia	Lao PDR	Myanmar	Thailand	Viet Nam
Actual					
Total ^a	-1.467	-1.180	-1.300	-1.433	-0.650
Urban ^b	-0.324	-0.132	-0.309	-0.193	-0.086
Rural ^c	-0.916	-0.842	-0.968	-1.233	-0.440
Migration ^d	-0.227	-0.206	-0.023	-0.007	-0.123
Normalized (total =100)					
Total ^a	100	100	100	100	100
Urban ^b	22.07	11.18	23.79	13.49	13.28
Rural ^c	62.44	71.33	74.46	86.02	67.74
Migration ^d	15.49	17.49	1.74	0.49	18.97

Notes: Total change = Urban change + Rural change + Migration

a Mean annual value of dP , the y-o-y change in national poverty incidence

b Mean annual value of $a^U dP^U$, the y-o-y population share-weighted change in urban poverty incidence

c Mean annual value of $a^R dP^R$, the y-o-y population share-weighted change in rural poverty incidence

d Mean annual value of $(P^R - P^U) da^R$, the y-o-y migration-induced change in poverty incidence

Source: author's calculations using data described in the text.

$(P^R - P^U) da^R$ is negative. How important the Kuznets effect is as a determinant of overall poverty reduction is, of course, an empirical matter.

Table 4 shows the results of this decomposition. Because data on rural and urban poverty incidence were unavailable for Guangxi and Yunnan, the decomposition is possible only for the other five GMS entities. All results shown in this table are evaluated at the mean values of the data set. For example, the mean annual change in the aggregate level of poverty incidence for Cambodia was -1.467%.

Equation (2), above, is an identity and must apply at all points in the data set. It must therefore apply at the means of the data. The equation therefore shows that the mean change in poverty incidence can be decomposed into components capturing mean average poverty reduction in urban areas, mean average poverty reduction in rural areas, and the average movement of population between the two.

The lower half of the table normalizes the decomposition by dividing all values by this mean change in aggregate poverty (-1.467 for Cambodia, for example) and multiplying by 100. For Cambodia reductions in rural poverty accounted for 62% of the overall reduction in poverty over the period shown in Table 2, reduced urban poverty accounted for 22%, and migration accounted for 15%. Migration effects were more important for Viet Nam and the Lao PDR and least important for Thailand and Myanmar. For all five of these GMS entities, reductions in rural poverty accounted for more than 60% of the total reduction in poverty that occurred and for all except Cambodia the proportion is more than two thirds.

The above calculations are, of course, descriptions of the data. We now turn to the question of what caused these observed changes in poverty incidence to occur.

4. The Growth-Poverty Nexus

4.1. Conceptual Background

Poverty incidence and its change over time depend on many factors, of which economic variables are at most only part of the story. Among the economic variables, many issues are relevant aside from simply the overall rate of growth. Changes in commodity prices play a role, along with tax and public expenditure policies. The sectoral composition of growth may also be important.

As incomes rise, agriculture tends to contract as a share of GDP, as resources move to the manufacturing and services sectors (Martin and Warr, 1994). Economic policies, including public infrastructure investments, foreign investment policies, trade policies, and industrial policies, also influence the sectoral composition of growth. If poverty reduction is a priority, as the pronouncements of most governments suggest, then the way in which economic policies may indirectly affect poverty incidence is important. The sectoral composition of growth may play a role, but casual perusal of the data suggests that the overall rate of growth may be the dominant part of the story. To what extent does the overall rate of growth matter, and to what extent is its sectoral composition also important in determining its effect on poverty incidence?

The literature has emphasized the sectoral composition of growth in relation to its poverty implications, but this emphasis has been based primarily on a priori theorizing, rather than evidence. The obvious argument is that in most poor countries a majority of the poor lives in rural areas and employed in agriculture. From this it has seemed probable that growth of agriculture is more important for poverty reduction than growth of industry or services. But this conclusion does not necessarily follow. Sectoral growth rates may not be independent. Expansion of capacity in one sector—say, food processing—may stimulate output growth elsewhere—say, fruit production. More importantly, people are potentially mobile; given sufficient time, even poor people can presumably move to whichever sector is generating the growth. Rural poverty may therefore be reduced by urban-based growth, drawing the poor away from rural areas (Fields, 1980; Chenery and Syrquin, 1986). When sectoral interdependence and intersectoral factor mobility are taken into account, it is not obvious whether the sectoral composition of growth is important for poverty reduction or not.

Even if labor were fully and instantaneously mobile, poverty incidence could still be affected by the sectoral composition of growth. To a first order of approximation, the level of absolute poverty presumably depends on the demand for the factors of production owned by the poor, especially unskilled labor and, to a lesser extent, agricultural land. Growth in different sectors has differential effects on the demands for these factors, depending on these sectors' factor intensities, and may have different effects on poverty, inequality, or both. Finally, the distinction rural/urban is not synonymous with the distinction agriculture/non-agriculture. Much agricultural production may occur in full or part-time farming on the fringes of urban areas and much industrial and services activity may occur in rural areas.

Only careful quantitative analysis can resolve questions of this kind, but the limited availability of data that can support statistical analysis has been an impediment to the systematic study of poverty incidence and its determinants. Some recent studies have attempted to explore the relationships involved by analyzing cross-sectional data sets across countries, or across regions or households for individual countries, while others have attempted to assemble long-term time-series data sets on poverty incidence for individual countries. The time-series approach is generally preferable, in that it makes possible a direct study of the determinants of changes in poverty at an aggregate level.

Unfortunately, in most developing countries, the consumer expenditure surveys on which studies of poverty incidence must be based are conducted only intermittently. Data are thus normally available at most only with intervals of some years between observations. This is true of all the GMS entities. The data are most extensive for Thailand, but even when all national time-series observations on poverty incidence are assembled for Thailand, the number of observations is only 7. For Viet Nam the number is only 4. In this study, data for the 1990s have been drawn on, where available, to supplement the number of data points available for statistical analysis. The number of observations is still insufficient to sustain formal statistical analysis for any one of these countries, but when all GMS entities are pooled, the total number of observations is adequate. The present study thus attempts to pool the data for the seven GMS entities. The economic growth data for Myanmar are the subject of considerable debate. The empirical exercise uses ADB estimates for Myanmar, as discussed in the Appendix.

Since the meaning of the poverty lines is different in each of the countries and also since the structure of the economies is different, we should not expect that the same quantitative relationship between poverty incidence and aggregate growth will necessarily exist in all GMS entities. In the present study, intercept dummy variables were used for 6 of the 7 GMS entities. These dummy variables were then dropped when they proved to be highly insignificant in order to preserve statistical degrees of freedom and thereby improve the quality of the estimation process. Each interval between the data points indicated in Table 2 and similar data for the 1990s are used to construct the values of the dependent variables described below, with the calculated value divided by the number of years corresponding to that time interval, giving an annual rate of change for the variable concerned. These annualized rates of change then become the variables used in the regression analysis described below.

4.2. Poverty and Aggregate Growth

We now turn to the manner in which poverty incidence is affected by economic growth and, for simplicity, hypothesize initially that the total number of households in poverty, N_p , depends on the aggregate level of real income, Y , and the size of the population, N . Thus

$$N_p = \varphi(Y, N). \quad (3)$$

The incidence of poverty is defined as

$$P = N_p / N = \varphi(Y, N) / N. \quad (4)$$

Totally differentiating this equation,

$$dP = (\varphi_Y Y/N) y + (\varphi_N - \varphi/N) n, \quad (5)$$

where lower case Roman letters represent the proportional changes of variables represented in levels by upper case Roman letters. Thus $y = dY/Y$ and $n = dN/N$ are the growth rates of aggregate real income and of population, respectively. In the special case where the function $\varphi(\cdot)$ is homogeneous of degree one in Y and N , (3) may be written $N_P = \varphi_Y Y + \varphi_N N$ and (5) reduces to $dP = (\varphi_Y Y/N)(y - n)$.

In this case, we estimate relationships of the kind

$$dP = a + b(y - n) = a + b\tilde{y}, \quad (6)$$

where $\tilde{y} = y - n$ denotes the rate of real GDP growth per person, and test whether the coefficient b is significantly different from zero.

4.3. Poverty and Sectoral Growth

Whether the sectoral composition of economic growth affects poverty reduction can be investigated as follows. The level of real GDP per person is given by

$$\tilde{Y} = \tilde{Y}_a + \tilde{Y}_i + \tilde{Y}_s, \quad (7)$$

where \tilde{Y}_a , \tilde{Y}_i , and \tilde{Y}_s denote value-added (contribution to GDP) per person in the total population, measured at constant prices, in agriculture, industry, and services,

respectively. The overall real rate of growth per person can be decomposed into its sectoral components from

$$\tilde{y} = H_a \tilde{y}_a + H_i \tilde{y}_i + H_s \tilde{y}_s, \quad (8)$$

where $H_k = Y_k / Y$, $k = (a, i, s)$, denotes the share of sector k in GDP. By estimating the equation

$$dP = a + b_a H_a \tilde{y}_a + b_i H_i \tilde{y}_i + b_s H_s \tilde{y}_s, \quad (9)$$

and testing whether $b_a = b_i = b_s$, we may test directly whether the sectoral composition of growth affects the rate of poverty reduction.

5. Estimation results

5.1. Poverty and Aggregate Growth

Equation (6) was estimated as described above and the results are summarized in Table 5. Dummy variables were estimated for all countries except Thailand. All country dummy variables were insignificant except Guangxi and Yunnan. The insignificant dummy variables were all dropped and the equation was re-estimated. The estimated relationship is significant and the Ramsey RESET test suggests that it has no omitted variables, although with low degrees of freedom, this test is relatively weak. The Breusch-Pagan/Cook-Weisberg test for heteroskedasticity indicates the absence of heteroskedasticity. Nevertheless, the adjusted R-squared of 0.23 is low and suggests that other variables may also be contributing to the behavior of the dependent variable.

Table 5: Regression Results – Poverty and Aggregate Growth

Variable	Change in Total Poverty (dP)				
	Coefficient	Standard error	t-statistic	$p > t $	95% confidence interval
Constant (a)	-0.505	0.531	-0.957	0.352	-1.607 0.597
GDP growth per capita (b)	-0.274	0.092	-2.960	0.007	-0.467 -0.082
Intercept dummy Guangxi	2.991	1.595	1.885	0.074	-0.316 6.299
Intercept dummy Yunnan	2.098	1.132	1.856	0.077	-0.250 4.447
Number of observations	26				
F (3, 22)	3.502				
Prob >F	0.032				
R-squared	0.322				
Adjusted R-squared	0.230				

Source: author's calculations using data described in the text.

Table 6: Regression Results – Poverty and Sectoral Growth

Variable	Change in Total Poverty Incidence (dP)				
	Coefficient	Standard error	t-statistic	$p > t $	95% Confidence Interval
Constant (a)	-1.218	0.861	-1.414	0.178	-3.054 0.617
Growth of agriculture GDP per capita (b_a)	0.996	1.053	0.954	0.359	-1.248 3.241
Growth of industry GDP per capita (b_i)	0.356	0.571	0.676	0.511	-0.832 1.602
Growth of services GDP per capita (b_s)	-0.672	0.320	-2.101	0.053	-1.354 0.010
Number of observations	26				
F (6, 22)	1.88				
Prob >F	0.149				
R-squared	0.429				
Adjusted R-squared	0.202				

Source: author's calculations using data described in the text.

5.2. Poverty and Sectoral Growth

Equation (9) is now estimated to capture the behavior of the dependent variable when the sectoral composition of growth appears on the right hand side of the equation. The results suffer from the low number of observations, but support the notion that growth of services in the GMS is more poverty-reducing than growth of either agriculture or industry. The expected result that agricultural growth is the strongest contributor to poverty reduction was not obtained. Instead, services growth was the only component of GDP that was significantly associated with poverty reduction (at the 10% level of significance). The hypothesis that the coefficients on share-weighted sectoral growth rates per capita were all equal ($b_a = b_i = b_s$) was rejected by an F-test at the 10% level of significance.

6. Conclusions

The results of this study confirm that poverty reduction in the GMS is strongly related to growth of real GDP per person. The sectoral composition of this growth affects the rate of poverty reduction in so far as it affects the growth of services relative to the rest of the economy. Structural changes that promote the growth of services relative to other sectors are conducive to poverty reduction, given the overall rate of GDP growth. These findings have relevance for the future rate of poverty reduction that might be achieved in the GMS over the coming decade to 2020.

Global economic imbalances developing over the first decade of the 21st century will require major adjustments. Asia has run large current account surpluses, with the

United States and Europe running corresponding deficits. The cumulative effects have been the development of a large stock of assets, denominated in foreign currencies, held by Asian countries and a corresponding stock of debt incurred by the United States and Europe. It is generally recognized that continuation of this cumulative imbalance is unsustainable.

Major adjustment is inevitable and it will mean a switch of final demand within Asia from export dependence toward domestic sources of demand. On the supply side, this will mean a switch of output from production of tradable goods, such as agricultural and industrial goods, toward nontradables, such as services. That is, the sources of growth will have to shift away from agriculture and manufacturing toward services. This will entail costs and could well mean that the rate of overall growth of GDP per person will slow, but the composition of output will shift toward services and away from agriculture and industry.

The rate of poverty reduction in the GMS may rise over the coming decade. If past overall rates of GDP growth per person can be maintained, growth will become more poverty-reducing, given the structural changes that seem to be consistent with global economic restructuring.

Acknowledgement

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Appendix: Estimates of Level and Growth Rate of GDP in Myanmar

There are divergent views on Myanmar's level of GDP and its growth rate. Myanmar's official government estimates are generally considered too high. They imply a level of investment relative to GDP that is higher than the Myanmar data indicate and they are also inconsistent with direct observation of Myanmar's economy.

Table A.1 shows alternative sets of estimates. The ADB has published alternative estimates of the growth rate of GDP per person for the years since 2005. Except for 2005 these estimates are less than half the official estimates. These are the data that were used in the econometric estimation reported in the text of this paper. The Economist Intelligence Unit has also published estimates below official data. This Appendix attempts to use another method.

Table A.1: Estimates of Annual Rates of Real GDP Growth per Person, Myanmar (%)

Source	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Official data	11.70	9.30	10.00	11.80	11.60	11.60	11.10	10.20	8.80	9.30	9.30
ADB Outlook	11.50	9.10	9.80	11.60	11.30	13.60	4.90	3.40	1.60	3.00	3.20
EIU reports	N.A.	N.A.	N.A.	11.80	11.60	11.60	1.40	1.60	-0.40	0.50	2.00
Author's estimates	-1.95	-1.95	1.83	1.83	1.83	1.83	1.83	N.A.	N.A.	N.A.	N.A.

Although Myanmar's national accounts data are considered inaccurate, the government statistical agency also conducts a periodic consumer expenditure survey, which seems more reliable. The Myanmar Statistical Yearbook reports these data for the years 1989, 1997, 2001, and 2006. There is a well-known behavioral relationship between food expenditure and total consumer expenditure and the consumer's income, known as Engel's law. As incomes rise, food expenditure accounts for a declining proportion of total expenditure. This relationship can be observed across countries as well as within countries. Data on this matter for a wide range of countries are assembled in Figure A.1. The data on food expenditures relative to total expenditures are from the Food and Agriculture Organization of the United Nations compendium of national consumer expenditure surveys. The data on GDP per capita in US dollars at 2000 prices are from the *World Bank's World Development Indicators*.

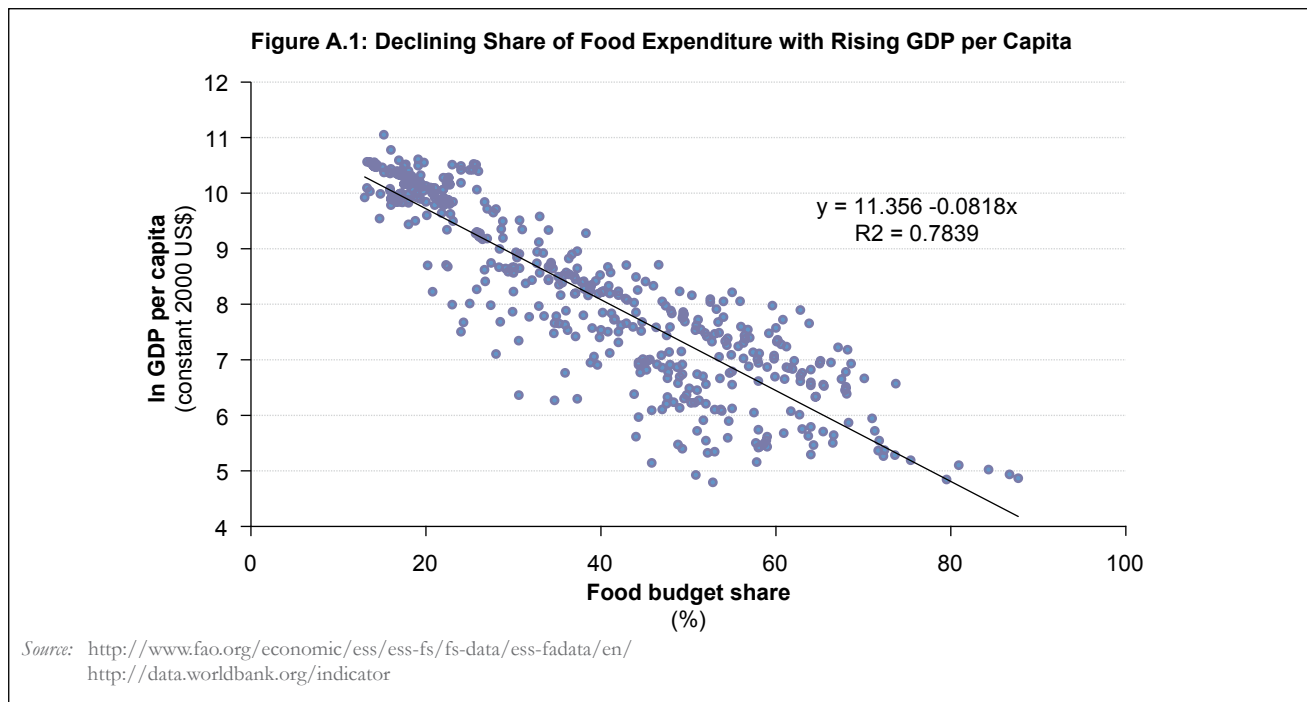


Table A.2: Myanmar: Estimates of Real GDP per Person based on Engel's Law

Year	Food share (%)	Predicted			Constant Annual Growth Rate (%)	Average Annual Growth Rate (%)
		GDP pc (2000 \$)	95% Lower bound: (GDP pc)	95% Upper bound: (GDP pc)		
1989	74.029	199.916	171.652	232.834	N.A.	
1997	70.950	257.200	223.234	296.334	3.200	
2001	71.910	237.768	205.679	274.862	-1.945	
2006	70.800	260.376	226.109	299.838	1.833	1.59

Source: author's estimates based on data described in the text.

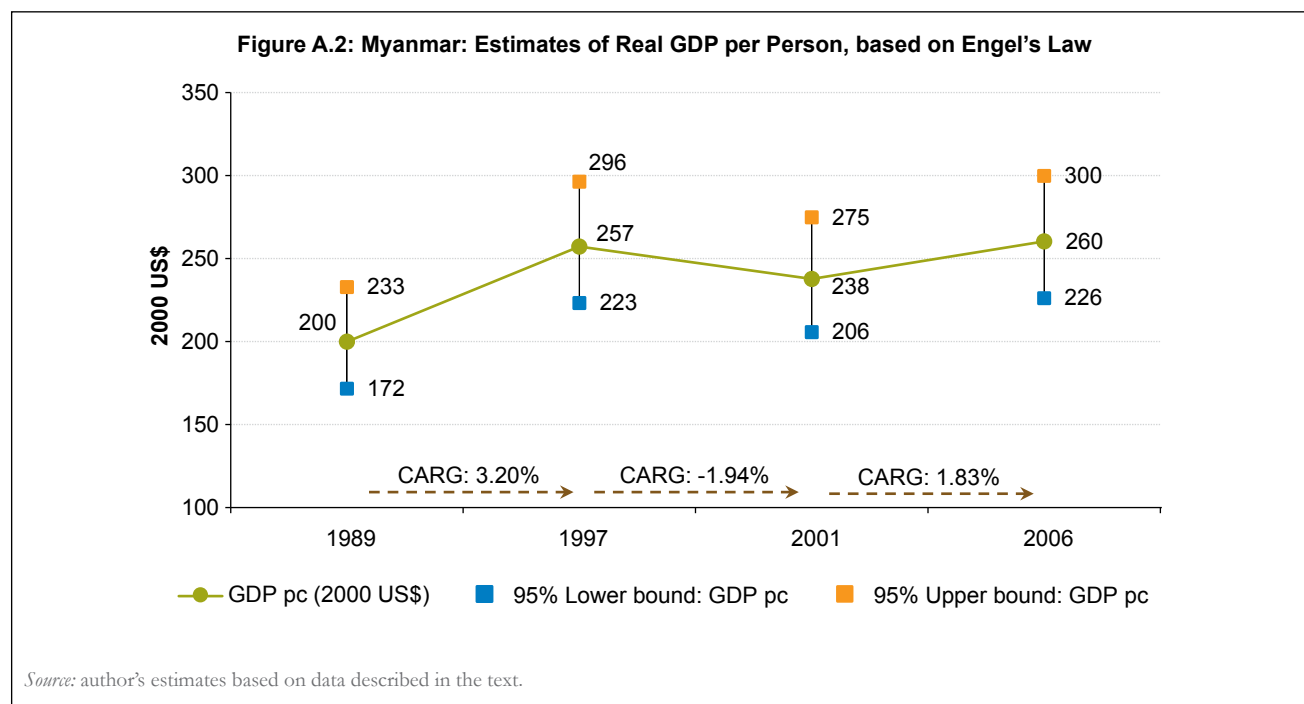


Figure A.1 also reports the regression equation fitted to these data. This relationship is used to estimate real GDP per person for Myanmar, as reported in Table A.2. Figure A.2 shows the resulting estimates and the 95 per cent confidence intervals around these estimates. The estimates are closest to the Economist Intelligence Unit's estimates, summarized in Table A.1.

WATER AND FOOD SECURITY IN THE GREATER MEKONG SUBREGION: OUTLOOK TO 2030/2050

*Mark W. Rosegrant¹, Claudia Ringler, Tingju Zhu,
Simla Tokgoz and Pascale Sabbagh²*

Abstract

While the importance of agriculture has been gradually declining in the Greater Mekong Subregion (GMS) the sector still contributes 30 percent to Gross Domestic Product (GDP) in Cambodia and over 40 percent in Lao People's Democratic Republic (PDR). In addition, while malnutrition levels have declined in much of the region since 1995, they still average 18% of the population in Southeast Asia with 26% of the population of Cambodia classified as malnourished. Importantly, reducing the food security risks in Southeast Asia through rapid agricultural and economic growth over the last two decades has required intensive use of the agricultural resource base, particularly land and water resources.

Under business-as-usual, food security will remain out of reach of key constituents in the Greater Mekong Subregion (GMS), particularly in Cambodia and the Lao PDR. Climate change impacts, higher energy prices, biofuel developments and growing water scarcity are challenges that will increase in the region and need to be addressed through pro-active policies and investments by the governments in the region. Greater trade integration, pro-poor energy and biofuel policies and investments rather than across-the-board subsidies for water and other agricultural inputs that affect the natural resource base adversely and increased focus on agricultural research and development investments to address growing water, climate and energy challenges are urgently called for to ensure that food and water security in the GMS become a reality, particularly for the poorer countries in the region.

1. Introduction

The current global food situation—marked by relatively high levels of input use and productivity levels in much of

Asia and the world, increasing land and water scarcity, and the impacts of climate change—presents a complex set of challenges to sustainable agricultural productivity growth. With lower food stocks and reduced excess capacity, the global food system is exposed to greater price volatility and instability in trade when exogenous supply shocks occur, as was seen in the food price spike of 2007 and 2008 and in the run-up of prices as of early 2011. Food price spikes (as well as sharply rising energy prices and the financial crisis) have affected all countries in differing ways, but the developing world, especially its poor and vulnerable producers and consumers, has generally fared the worst. The poor in the Greater Mekong Subregion (GMS)³ still spend 40%–60% of their income on food; even most farmers are net purchasers of food. These groups will be most impacted by price spikes and fluctuations.

In the coming decades, both demand and supply factors will pose challenges to agricultural growth and food security. On the demand side, food, feed, fertilizer, and energy demand and prices; water, and land scarcity; climate change mitigation; population and income growth; urbanization; and demand on environmental and recreational uses of natural resources will influence agricultural markets and food security. On the supply side, critical factors include climate change; water and land scarcity; limited investment in science and technology policy, particularly agricultural research; and continued need of management and governance reform affecting agricultural outputs. Water scarcity due to competition from other sectors, changes in the volume and pattern of rainfall, and declining water tables and quality will play a particularly important role. Farmers who rely on irrigation and who live in water scarce or drought and flood-affected areas—where GDP is rising and populations continue to expand—will be most affected. All of these demand and supply side factors—in addition to bioenergy-based demand for water and land—are projected to increasingly constrain food production growth, adversely impacting food security and human well-being goals.

This paper assesses challenges to water and food security for the GMS as a result of biophysical and socioeconomic changes on both the supply and demand side of water

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³ GMS countries are defined here as Cambodia, Lao PDR, Myanmar, Thailand and Vietnam. The current version of the IMPACT model combines results for Lao PDR and Cambodia. Although only the Guangxi and Yunnan provinces of China are included in the Greater Mekong Subregion, we are providing results for all of China because disaggregation by province does not exist in IMPACT; instead subnational disaggregation is done on the basis of major river basins.

and food for 2030 and 2050 using the IMPACT⁴ modeling framework, with a focus on climate change and changes in energy prices; and identifies policy options and investments to strengthen the agriculture sector.

2. Baseline results

2.1 Food supply and demand

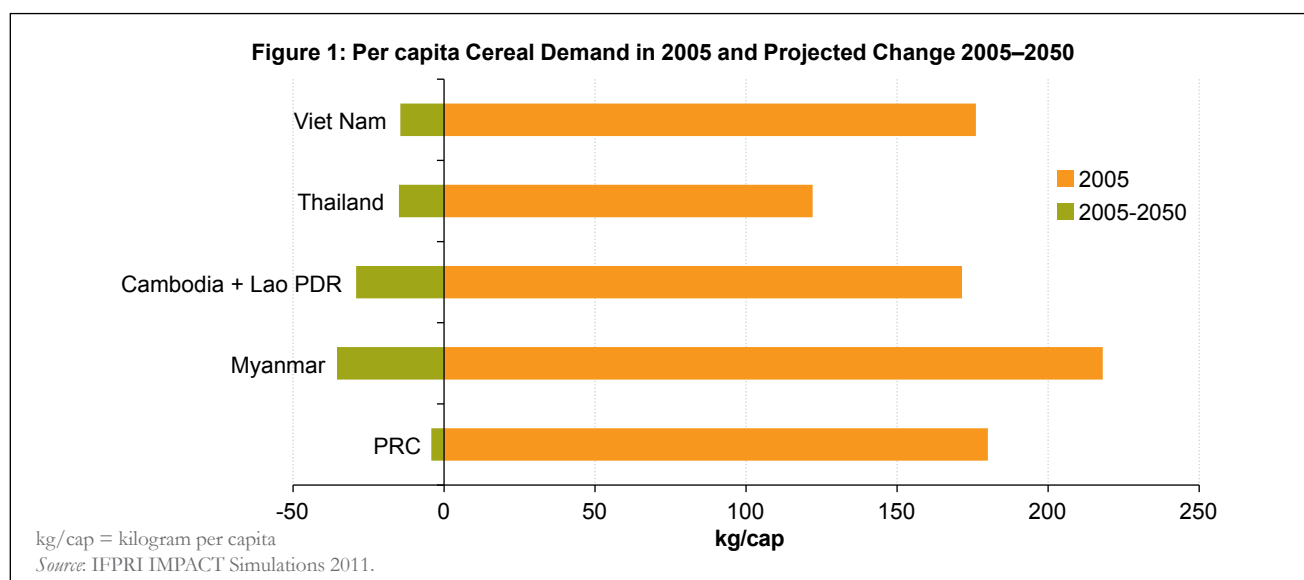
The baseline scenario assumes a continuation of current trends and existing plans in agricultural policies and investments in agricultural productivity growth. Population projections are the “medium” variant population growth rate projections from the Population Statistics division of the United Nations Food and Agriculture Organization and income projections are estimated by the authors, drawing on the Millennium Ecosystem Assessment (2005). Over the next four decades, demand for cereals⁵ in the GMS countries is expected to increase by only 6% to reach 38 million tons by 2050. This is the result of slowing population growth in much of the subregion⁶ combined with changes in dietary preferences leading to rapid growth in other food categories, particularly livestock, sugars, oils, and fruits and vegetables as a result of continued rapid income growth and urbanization. Per capita cereal food

demand, particularly rice, will decline across the subregion (Figure 1). Similarly, cereal demand growth in the People's Republic of China (PRC) is expected to slow considerably, with total demand shrinking by 3% between 2005 and 2050. Much of the projected growth in cereal demand will be used to feed livestock.

At the same time, demand for livestock products is expected to continue to rapidly increase across Asia and the GMS. In the GMS, meat demand is projected to increase by 150% during 2005–2050, from relatively low levels. In the PRC, where per capita meat demand is much higher, demand is still expected to grow by a further 64% (Figure 2).

Furthermore, demand for root and tuber products (mainly potatoes) is expected to grow by 38% in the GMS while remaining stagnant in the PRC. Demand for sugar is projected to increase by 124% in the GMS and by 120% in the PRC. Finally, demand for fruits and vegetables combined is expected to grow by 90% in the GMS and by 50% in the PRC. Fish products are expected to continue to play a major role in GMS and Chinese diets.

How will the expanding food demand be met? For meat in developing countries, increases in the number of animals slaughtered have accounted for 80%–90% of production

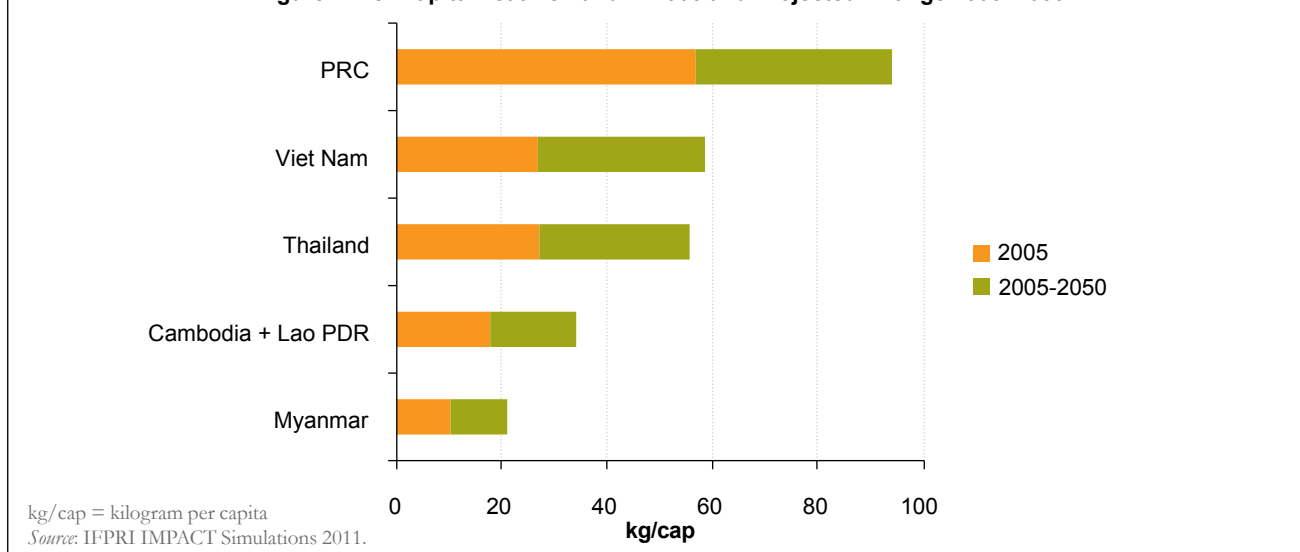


⁴ IMPACT – International Model for Policy Analysis of Agricultural Commodities and Trade

⁵ Cereals are defined as barley, maize, millet, oats, rice, rye, sorghum and wheat.

⁶ Population growth rates during 2030–2050 are expected to slow to half or less of the rates of 2010–2030 for China, Myanmar and Thailand; only Cambodia and Lao PDR and Vietnam are predicted to still experience rapid growth during 2030–2050 (UN 2010).

Figure 2: Per Capita Meat Demand in 2005 and Projected Change 2005–2050



growth during the past decades. Over the next four decades, increased production is expected to come increasingly from slaughtered carcass weight, particularly for pork and poultry in the PRC and the GMS, due to a shift to more intensive production systems and improved breeds.

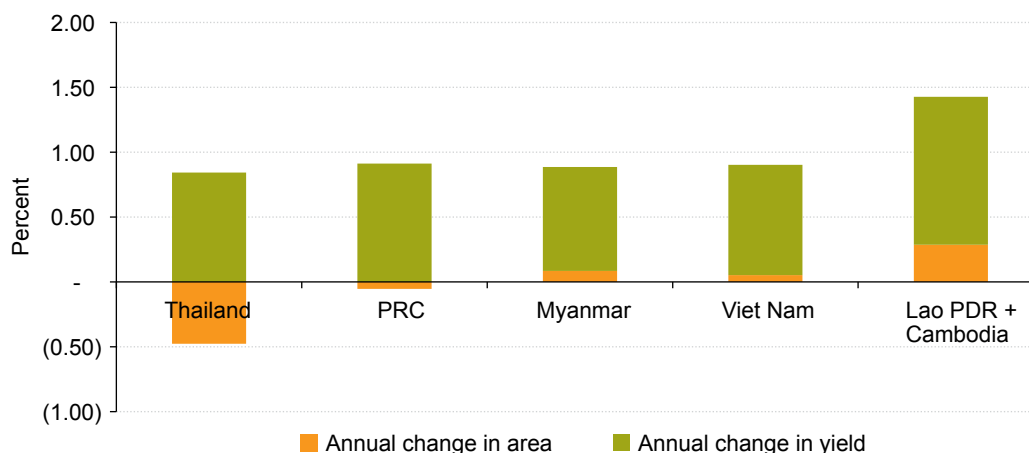
For the crops sector, water scarcity is expected to increasingly constrain production with little additional water available for agriculture due to slow increase in supply and rapid shifts of water from agriculture in key water-scarce agricultural regions. While the GMS water endowment is considerable, water scarcity is expected to increase. Water demand in the nonagriculture sectors is expected to account for 15% of total demand in Thailand by 2050, for example, up from 7% in 2005. This shift of growth in demand outside agriculture will put pressure on improving water use efficiency in agriculture.

Climate change will increase heat and drought stress in many of the current breadbaskets across the world, including in the GMS. Once plants are weakened from abiotic stresses, biotic stresses tend to set in and the incidence of pest and diseases tends to increase. With declining availability of water and land that can be profitably brought under cultivation, expansion in area is not expected to contribute significantly to future production growth; particularly not in Asia, where population density is highest. In the baseline, total crop harvested area expands from 52 million hectares (ha) in 2005 to 55 million ha by 2050 in the GMS and from 214 million ha to 221 million ha in the PRC. The projected slow growth in crop area places the burden to meet future cereal demand on crop yield growth.

Although yield growth varies considerably by commodity and country, in the aggregate and in most countries it will continue to slow. The global yield growth rate for cereals is expected to decline from 1.96% per year in 1980–2000 to 0.99% per year during 2005–2050 and in the remainder of the GMS, yield growth is expected to grow at levels below the global average. In the PRC, cereal yields are projected to increase by 0.91% per year during 2005–2050 and in the remainder of the GMS, yield growth is projected at 0.88% per year. Small contractions in harvested area and slow yield growth will put increased pressure on food prices. Figure 3 presents the contribution of area and yield growth to future cereal production growth for the individual GMS countries. Yield growth is expected to clearly dominate area growth in the GMS, with overall cereal production growth expected to grow fastest in Cambodia and the Lao People's Democratic Republic (Lao PDR) (albeit from low levels), and slowest in Thailand, where significant area contractions are expected for cereals, particularly rice, as land shifts into diversified crops.

2.2 Implications for Prices, Trade, and Food Security

In the last few years, real prices of food have increased dramatically as a result of changes in biofuel/climate policies, rising energy prices, declining food stocks, and longer-term trends in slow growth in agricultural productivity. Projections reported here show that higher food price trends are likely to stay as a result of increased pressure on land and water resources, adverse impacts from climate variability and change, and rapidly rising incomes in most of Asia and Africa. Given the long-term

Figure 3: Contribution of Area and Yield Growth to Cereal Production Growth, 2005–2050

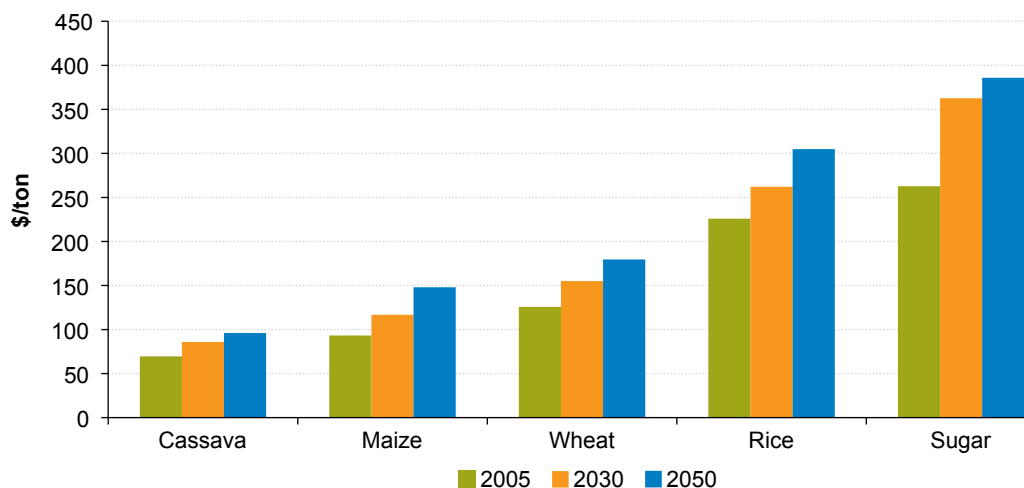
Source: IFPRI IMPACT Simulations 2011.

underinvestment in agriculture and poor government policies in response to rising food prices in many countries, it is unlikely that the supply response will be strong enough in the short to medium term.

During 2005–2050, prices for cassava, maize, wheat, rice, and sugar are expected to grow by 38%, 59%, 43%, 35%, and 47%, respectively (see also Figure 4). Maize prices are expected to increase faster than most other commodities to meet the rapid increase in demand for animal feed and ethanol. Sugar prices are also affected by use as feedstock for first-generation biofuel technologies. Higher food prices will depress food demand by net food purchasers in the longer term, increasing childhood malnutrition rates and

reversing progress made in several low-income countries in terms of nutrition and food security.

World trade in food is expected to continue to increase, driven by the increasing import demand from the developing world, particularly Asia, the Middle East, and subSaharan Africa. With much of the developing countries unable to increase food production rapidly enough to meet growing demand, the major exporting countries—mostly in high-income countries but also in Latin America and countries from the former Soviet Union—will play an increasingly critical role in meeting global food consumption needs. However, given the strong demand for food crops as feedstock for biofuels in the short to

Figure 4: Projected Change in Prices for Key Agricultural Commodities, 2005–2050

Source: IFPRI IMPACT Simulations 2011.

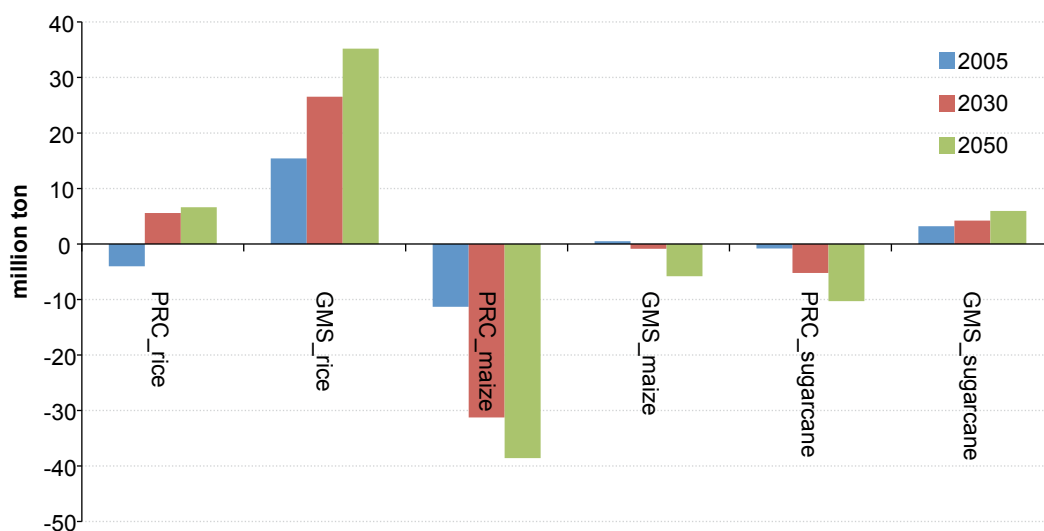
medium term, net cereal export levels are projected to be reduced in key exporting countries, notably the United States and parts of Europe, until a transition out of first-generation technologies has been implemented. The PRC is expected to significantly increase net imports of maize, from 11 million tons in 2005 to 39 million tons by 2050. Cambodia, the Lao PDR, Myanmar, Thailand, and Viet Nam are expected to see net import increases of maize of almost 6 million tons by 2050. The PRC could become a small net exporter of rice over the next few decades; and the GMS countries in the lower Mekong Basin are expected to considerably expand their net exports of rice, from 15 million tons in 2005 to 35 million tons by 2050 given their relatively favorable rice growing environments and projected increased investment in rice breeding in the subregion (Figure 5).

The substantial increase in food prices will slow growth in calorie consumption, with both direct price impacts and reductions in real incomes for poorer GMS country consumers who still spend a large share of their income on food. The PRC has had an excellent performance in reducing poverty and increasing food availability, with poverty and malnutrition levels now mostly concentrated in the western, mountainous areas of the country. The two PRC entities that are part of the GMS generally show higher poverty and lower calorie availability levels than the PRC average. Per capita calorie availability is expected to continue to increase in the PRC, by 448 kilocalories during

2005–2030 and further increase by 428 kilocalories during 2030–2050. Both Thailand and Viet Nam show similar performance, but at both lower initial calorie availability levels and with smaller improvements; calorie availability is expected to surpass 3,000 kilocalories in Thailand by 2050 and reach close to these levels in Viet Nam. Cambodia and the Lao PDR have the lowest calorie availability levels in the GMS, at just over 2,000 kilocalories per capita per day. These levels are expected to improve only slowly over the next several decades as a result of continued slow agricultural and economic growth. Myanmar, finally, has seen its agricultural and economic base eroding over the last decades and this development is unlikely to reverse unless the country's government takes deliberate steps toward more investment in the agriculture sector and the overall economy (Figure 6).

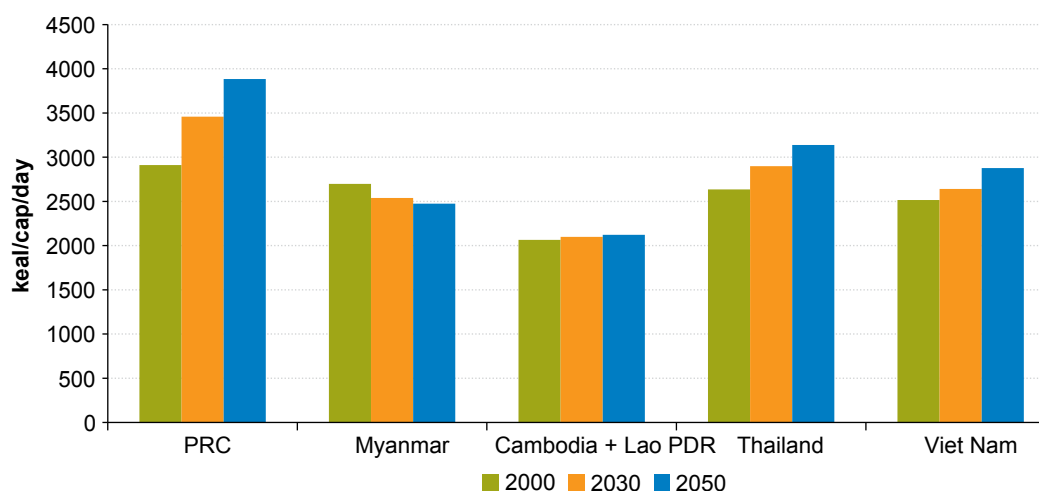
As a result of rising food prices and relatively slow growth in consumption, there will be only slow improvement in food security for the poor in many regions, including the GMS. The PRC and Viet Nam are expected to continue to reduce poverty and malnutrition level fastest in the GMS, with the PRC's rate of childhood malnutrition (children of up to 60 months) all but vanished by 2050, and Viet Nam's rate projected to drop to 27% by 2050 down from 35% in 2005. Small improvements are also expected in Myanmar and Thailand. Malnutrition levels in Cambodia and the Lao PDR are expected to remain at a high of 42% over the next several decades (Figure 7).

Figure 5: Projected Change in Net Trade for Key Agricultural Commodities, 2005–2050



GMS here refers to the summed net trade across Cambodia, Lao PDR, Myanmar, Thailand and Viet Nam

Source: IFPRI IMPACT Simulations 2011.

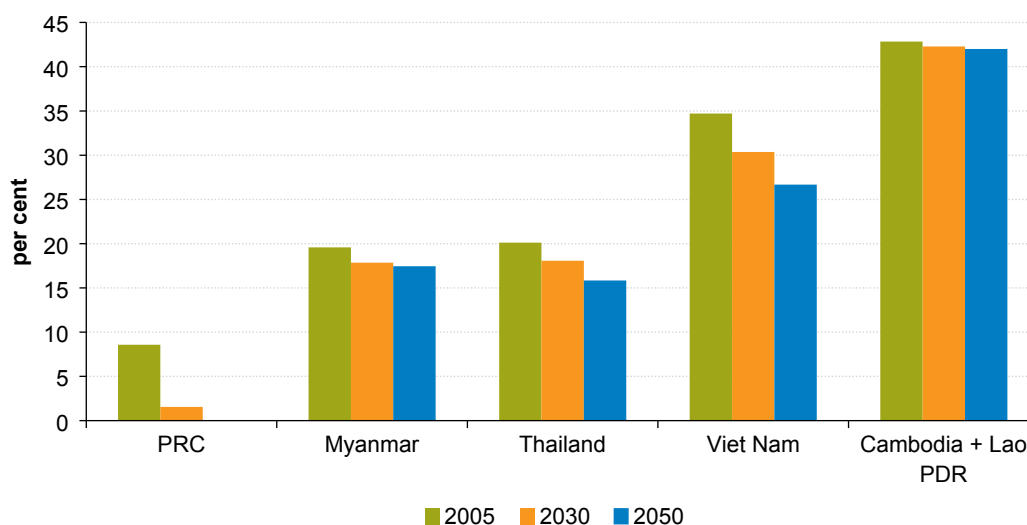
Figure 6: Projected Changes in Calorie Availability in GMS, 2005–2050

Source: IFPRI IMPACT Simulations 2011.

3. Climate Change Impacts On Water and Food

The Mekong River Basin is susceptible to climate change. To evaluate the water resources impacts of climate change in the basin, we used climate projections produced by General Circulation Models (GCM), which account for the complex set of climate-related processes occurring in the coupled atmosphere-land surface-ocean-sea ice system.

GCM projections are subject to significant uncertainties in the modeling process; as a result, different GCMs produce different geographical patterns of change for the same emissions scenario, particularly with respect to precipitation, the most important driver for freshwater resources (Kundzewicz *et al.*, 2007). We evaluated temperature and rainfall changes of the downscaled projections under the A1b and B1 emissions scenarios of the Intergovernmental Panel on Climate Change (IPCC), and selected projections from two GCMs: MIROC

Figure 7: Share of Childhood Malnutrition in the GMS, 2005–2050

Source: IFPRI IMPACT Simulations 2011.

3.2 (MIR), and CSIRO-MK3.0 (CSI).⁷ Use of these two scenarios and GCMs provides a range of climate change outcomes. The MIROC model projects increases in maximum temperatures between 2000 and 2050 of 2.3° Celsius for the B1 scenario and 2.8° Celsius for the A1b scenario. The CSIRO model projects smaller changes of 1.0° Celsius for the B1 scenario and 1.4° Celsius for the A1b scenario.

To implement these scenarios, we utilized the work of Jones *et al.* (2009), who statistically downscaled a number of GCM projections, based on data from the World Climate Research Program (WCRP) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset. We used the historical mean monthly gridded precipitation and temperature series computed from the 1951–2000 series of the CRU TS2.1 global climate database (Mitchell and Jones, 2005) as climate baseline. The climate baseline and the constructed climate change scenarios are used to drive the IMPACT Global Hydrologic Model (IGHM) to simulate evapotranspiration and water availability. For convenience, we hereafter call the baseline “NoCC” and the two GCM-based scenarios CSI and MIR.

The long term climate data are then input into the Decision Support System for Agrotechnology Transfer (DSSAT) crop modeling framework to generate the biophysical impact of climate change on crop yields. The DSSAT crop simulation model, an extremely detailed biophysical process model of the daily development of a crop from planting to harvest-ready, is used as the underlying crop model for the analysis. The model requires daily weather data, including maximum and minimum temperature, solar radiation, precipitation, a description of the soil physical and chemical characteristics of the field, and crop management, including crop, variety, planting date, plant spacing, and inputs, such as fertilizer and irrigation. The DSSAT models are used for each of the major crops to estimate the impacts of climate change on crop yields by inputting the projected climates with and without climate changes. The biophysical impacts on crop yields are then

fed into the yield growth assumptions in the IMPACT food module to assess the impacts on food supply, demand, prices, and trade.

3.1 Water Resources Impacts of Climate Change in the Mekong River Basin

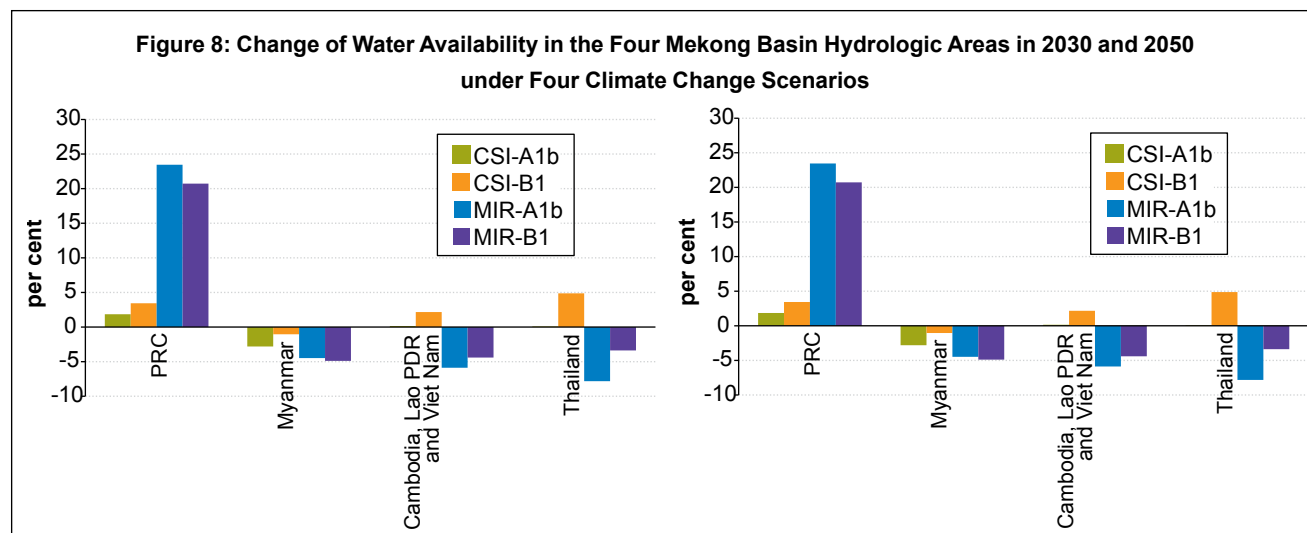
Climate change affects hydrological cycles locally and globally. It alters the amount and timing of river flow, challenges the coping capacities of existing water infrastructure and management systems, and increases the risk of extreme events, both droughts and floods. In this section, we discuss changes of water availability and irrigation water supply in the riparian country catchments of the Mekong River Basin, which were simulated using the IMPACT GHM and water simulation modules based on the climate change scenarios and climate baseline discussed above.

Climate Change Impacts on Water Availability

We computed percentage changes of annual runoff in the various riparian areas of the Mekong River Basin, as well as the runoff changes for the GMS countries (Figure 8). At both Food Producing Unit (FPU) and country levels, runoff changes display a diverse pattern across scenarios. In the Mekong River Basin, the PRC catchment has increased runoff in 2030 under all climate change scenarios, with the MIR-A1b and MIR-B1 scenarios causing the most pronounced increases—over 20%. By 2050, the two MIR GCM scenarios lead to runoff increases of more than 20%. However the two CSI GCM scenarios cause slight declines of runoff in 2050. The Myanmar catchment is projected to experience moderate declines of runoff in 2030 under all scenarios, and declines are expected to become larger by 2050 for all scenarios. For the Cambodia, Lao PDR, and Viet Nam catchments of the Mekong, a marginal increase of runoff under CSI-A1b, and a slightly larger increase under CSI-B1 are found, while MIR-A1b and MIR-B1 lead to moderate reductions by 2030; runoff changes will continue to grow out to 2050. The Thailand catchment shows largely the same pattern of runoff change as the Cambodia, Lao PDR, and Viet Nam catchment.

At the national scale, runoff in the PRC decreases moderately under the two CSI GCM scenarios and increases significantly under the two MIR GCM scenarios in 2030, with the changes continuing to 2050. Myanmar shows increased runoff for all scenarios in 2030 and the changes continue to 2050, except that MIR-B1 causes a marginal runoff decline in 2050. In Cambodia, Lao PDR and Viet Nam, runoff increases marginally under CSI-A1b,

⁷ The International Model of Policy Analysis of Agricultural Commodities and Trade (IMPACT) is a partial equilibrium model of the agricultural sector, representing a competitive agricultural market for crops and livestock. The model incorporates a Water Simulation Model (WSM) to assess the impact of water supply, demand and variability on food outcomes. To assess climate change impacts, IMPACT is linked with a semi-distributed Global Hydrological Model (GHM) to assess changes in water availability and with a standard crop model (DSSAT) to assess impacts of temperature and changes in water availability on crop yields. For additional details, see Rosegrant *et al.* (2008) and Nelson *et al.* (2010).



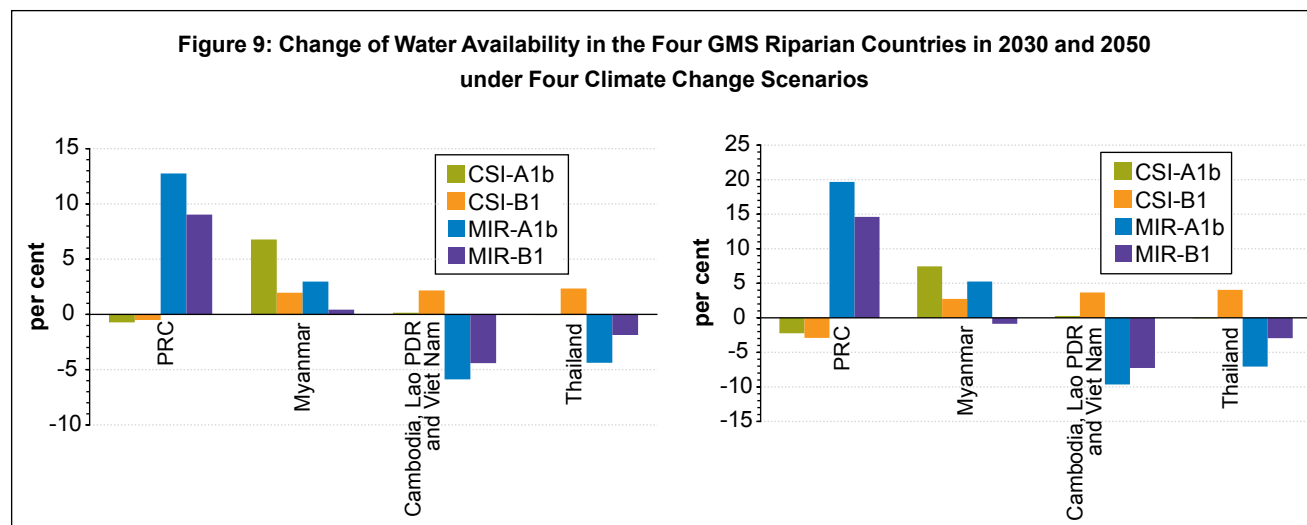
moderately under CSI-B1, and decreases under MIR-A1b and MIR-B1. Thailand is projected to experience runoff increase under CSI-B1, and runoff decline under MIR-A1b and MIR-B1. Runoff in Thailand virtually does not change under CSI-A1b.

Water-Use Impacts of Climate Change

Irrigation is the largest water user in the Mekong River Basin, particularly for rice. Climate change affects both the supply and the demand side of irrigation. We used irrigation water supply reliability (IWSR) as an indicator to depict both the irrigation water supply and demand situation. By definition, IWSR is the ratio of water supply to water demand at an annual basis. In the Water Simulation Model (WSM) model, IWSR is defined as the ratio of annual irrigation water supply to annual irrigation water demand, which represents total gross consumptive irrigation water requirement of all crops, considering “losses” by dividing total requirement by effective irrigation efficiency.

Figure 9 presents IWSR values in the PRC and Thailand catchments of the Mekong River Basin, under climate baseline and climate change scenarios, for three periods: 2000, 2030, and 2050. The computed present IWSR level in the PRC catchment is very low, reflecting the fact that irrigation infrastructure is rather under developed in the Lancang catchment. However, with infrastructure and management improvement, IWSR is expected to increase considerably by 2030 and 2050. All climate change scenarios lead to IWSR increases in 2030 and 2050, owing to increased rainfall, which reduces irrigation demand and increases runoff, augmenting irrigation water supply with the same irrigation infrastructure capacity. MIR-A1b raises IWSR from 0.5 under the climate baseline to over 0.8 by 2050, implying significant potential of climate change to alter water management outcomes.

The Thailand catchment has generally higher IWSR than that of the PRC. However, a relatively slow IWSR



improvement over 2000–2030 under the climate baseline leads to reduced IWSR under the MIR-A1b and MIR-B1 scenarios. CSI-A1b results in IWSR levels below the baseline and CSI-B1 results in IWSR levels above the baseline in 2030. By 2050, differences across scenarios are larger.

Figure 10 presents projections of IWSR for the entire PRC and Thailand. For the PRC, IWSR is expected to increase from 0.70 in 2000 to about 0.75 by 2050. During this period, considerable improvements in infrastructure and management are expected. However, strong competition for water from nonagricultural sectors squeezes irrigation water supply. The two MIR GCM scenarios lead to higher IWSR than the climate baseline and the two CSI scenarios lead to decreased IWSR. Thailand shows a largely similar pattern of IWSR changes as in the Mekong catchment alone shown in Figure 11, with IWSR under CSI-B1 being higher than the baseline and IWSR for the remaining scenarios below the baseline.

Impacts of Sea Level Rise on the Mekong River Delta

The GMS is expected to be strongly affected by sea-level rise and climate extreme events (Table 1). Sea-level rise increases the risk of coastal inundation, soil erosion, displacement of communities, loss of agricultural land, and intrusion of saline waters into surface and groundwater. Global sea level gradually rose during the 20th century and continues to rise at increasing rates (Cruz *et al.*, 2007). In Asia and the Pacific, sea level is expected to rise approximately 3–16 centimeters (cm) by 2030 and 7–50 cm by 2070 in conjunction with regional sea-level variability (Preston *et al.*, 2006). Under a conservative scenario of a 40 cm rise in sea level between 2011 and the end of 21st century, the number of people facing floods in coastal areas will increase from 13 to 94 million, annually, with a significant share of the population in Myanmar, Thailand, and Viet Nam affected (Cruz *et al.*, 2007).

Figure 10: Irrigation Water Supply Reliability in the Mekong Catchments in the PRC and Thailand under Climate Normal and the Four Climate Change Scenarios, 2000, 2030, and 2050

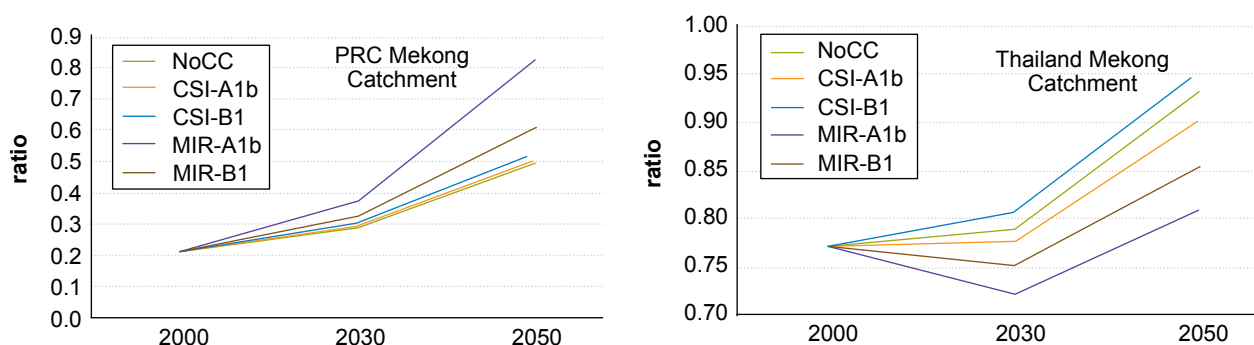


Figure 11: Irrigation Water Supply Reliability in the PRC and Thailand under Climate Normal and the Four Climate Change Scenarios, 2000, 2030, and 2050

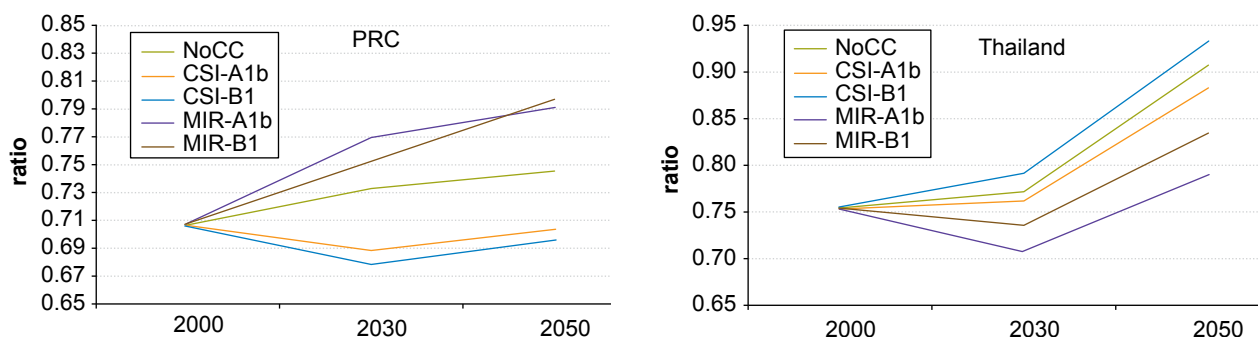


Table 1: Countries in the GMS Vulnerable to Rising Sea Levels and Extreme Climate Events

Subregion/country	Rise in sea level	Floods	Droughts	Storms
Cambodia		X	X	
PRC	X	X	X	X
EAST ASIA				
Lao PDR		X	X	X
Myanmar	X	X		X
SOUTHEAST ASIA				
Thailand	X	X	X	X
Viet Nam	X	X	X	X

Note: Disasters were taken from EM-DAT lists and represent the top ten natural disasters by numbers of people killed, affected people, and the costs of economic damage for the period 1900–2008; “X” indicates that the country is vulnerable to the indicated climate event.

Source: Adapted from EM-DAT 2009, as reported in ADB and IFPRI (2009).

The International Food Policy Research Institute (IFPRI) calculated potential impacts of sea-level rise on crop production for key Asian developing countries for sea-level rise of 1 meter and 3 meters, respectively.⁸ Under 1-meter sea-level rise, a total of 7.7 million ha of crop land is submerged, while under a 3-meter sea-level rise, the area submerged more than doubles to 16.1 million ha. Rice is by far the most affected crop. In the GMS, Viet Nam is most affected from sea-level rise, losing more than 2.5 million ha under 1-meter and close to 4.5 million ha under 3-meter sea-level rise. Myanmar ranks second with 0.3 and 1.2 million ha under 1- and 3-meter sea-level rise, respectively, followed by Thailand and Cambodia with smaller areas. The PRC ranks second in Asia regarding area affected by sea-level rise, but none of this area is part of the GMS (ADB and IFPRI, 2009).

For Viet Nam, the Ministry of Natural Resources and the Environment (MONRE) recommended the use of specific sea-level rise scenarios (MONRE, 2009). The Southern Institute for Water Resources Planning prepared a map and tables indicating what this relatively conservative sea-level rise value would mean for the Vietnamese Mekong Delta. Figure 12 presents the flood inundation situation in the Mekong River Delta with 30 cm sea-level rise under current infrastructure levels. Table 2 presents the area in the delta under water with and without sea-level rise and with and without current levels of hydraulic structures. The case without hydraulic structures assumes natural conditions in the delta, without human intervention for flood control and prevention of salinity intrusion with sluice gates or other measures. With existing hydraulic structures, when the sea-level rises by 30 cm, the inundation area

Table 2: Inundated Land Area under 30-cm Sea-Level Rise with and without Hydraulic Structures in the Mekong Delta ('000 ha)

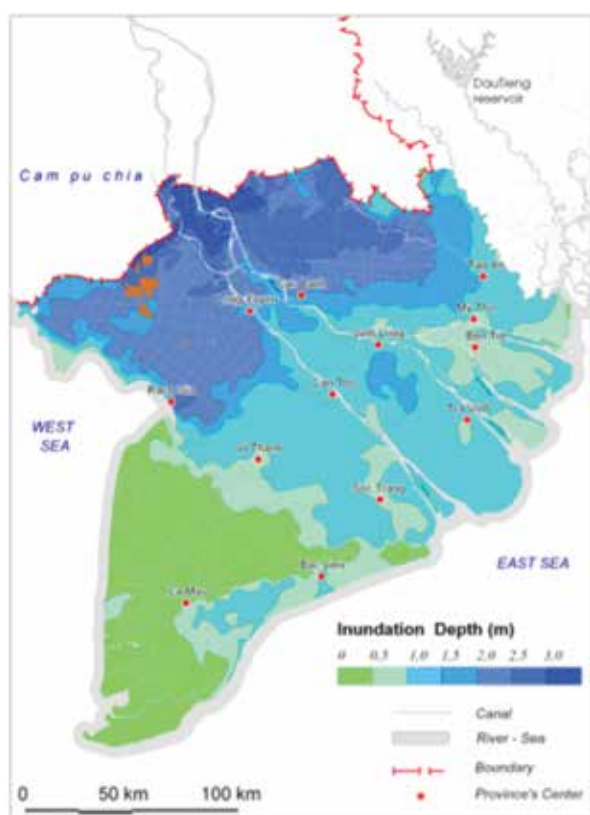
Inundation depth (m)	Present area	Area under 30 cm sea-level rise	
		Without structures	With structures
< 0.5*	1,049	623	773
0.5 - 1	1,063	688	542
1 - 1.5	724	1,207	1,218
1.5 - 2	459	685	410
2 - 2.5	288	343	578
2.5 - 3	212	240	262
> 3	66	77	78
Total	3,862	3,862	3,862

* Includes areas not being inundated.

Source: Analysis based on hydrodynamic simulations by SIWRP.

⁸ These sea-level rise assumptions are higher than IPCC predictions for 2050 and 2100. However analysis of less-than-1 meter sea-level rise requires digital elevation model (DEM) data with higher vertical resolution, which is not currently available in public domain. Moreover, IPCC (2007) predictions have underestimated the level and speed of recent Arctic ice melt, which gives more credence to the possibility of levels above the 0.5–0.6 meters generally anticipated.

Figure 12: Flood Inundation with 30 cm Sea-Level Rise and Present Hydraulic Structures in the Vietnamese Mekong Delta



Source: Southern Institute of Water Resources Planning, Viet Nam

with water depth greater than 0.5 m would increase from 2.8 million ha to 3.1 million ha (Zhu *et al.*, 2010).

Table 3 presents the areas affected by different levels of salinity intrusion in the Mekong Delta with and without hydraulic structures. With 30-cm sea-level rise, areas affected by salinity intrusion with concentration greater than 4 grams per liter increases from 1.3 million ha to 1.7 million ha. We assume that about 70% of the affected areas are paddy (personal communications with Dung Do Duc of Southern Institute of Water Resources Planning, Viet Nam). Thus, under sea-level rise of 30 cm, 0.2 million

ha of paddy area is lost due to inundation, and 0.3 million ha due to salinity intrusion, accounting for about 13% of current harvested rice area in the Mekong Delta. Flooding occurs in the rainy season, affecting the summer rice crop while salinity intrusion occurs during the dry season affecting the winter-spring rice crop (Zhu *et al.*, 2010).

3.2 Impact of Climate Change on Food Outcomes in the GMS

Under climate change, all major agricultural commodity prices are projected to increase compared to a base or no-climate change scenario. Figure 13 depicts changes in international prices for maize, rice, and sugar under the four climate change scenarios. Under climate change, 2050 maize prices would be 15%–32% higher, rice prices would be 31%–35% higher, and sugar prices 23%–33% higher than those in the no-climate change baseline.

Higher prices are a result of impacts on crop yields and areas from higher temperatures and gradual changes in rainfall under climate change. Table 4 presents changes in rice yields under the four climate change scenarios, separated for irrigated and rainfed yields, by 2050. As expected, irrigated yields will continue to outpace rainfed crop yields over the next decades, with irrigated rice yields close to double rainfed yields in the PRC and Viet Nam, and three times the level of rainfed yields in Cambodia, the Lao PDR and Thailand. Climate change is set to particularly affect the intensively grown irrigated crops, with high levels of fertilizer and water inputs. In the PRC, irrigated rice yields are projected to drop by 3%–5% as a result of climate change. Declines are expected to be much higher in the lower Mekong countries, but also vary more significantly across climate change scenarios, with irrigated rice yield falling 2%–16% below levels without climate change in Cambodia and the Lao PDR.

Higher food prices and differing changes in crop production levels in different parts of the world as a result of climate change will influence global trading patterns. Figure 14 shows the changes in net trade (exports minus imports)

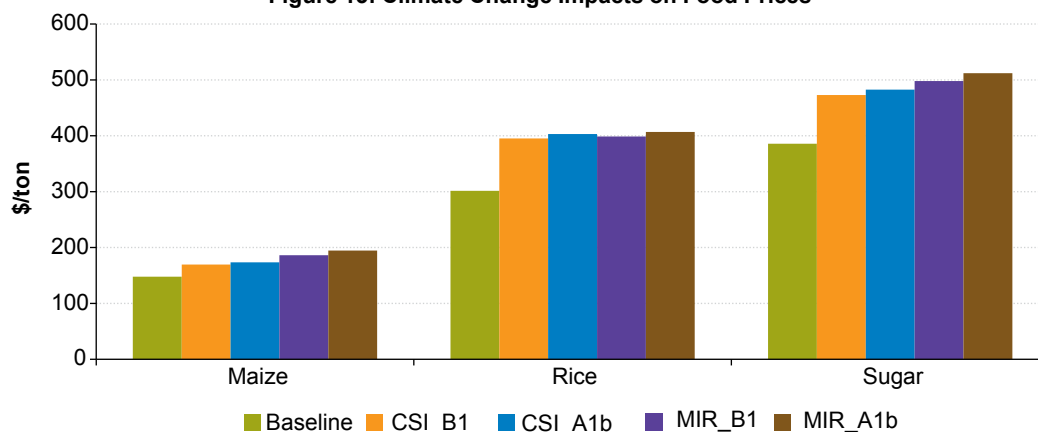
Table 3: Area Affected by Salinity Intrusion in the Mekong Delta with and without Hydraulic Structures ('000 ha)

Salinity (gram/liter)	Present	30-cm Sea-level rise	
		Without Structure	With Structure
0 – 4*	2,558	2,085	2,139
> 4	1,303	1,777	1,723
Total	3,861	3,862	3,862

Note: *Includes area without salinity problem.

Source: Analysis based on hydrodynamic simulations by SIWRP

Figure 13: Climate Change Impacts on Food Prices



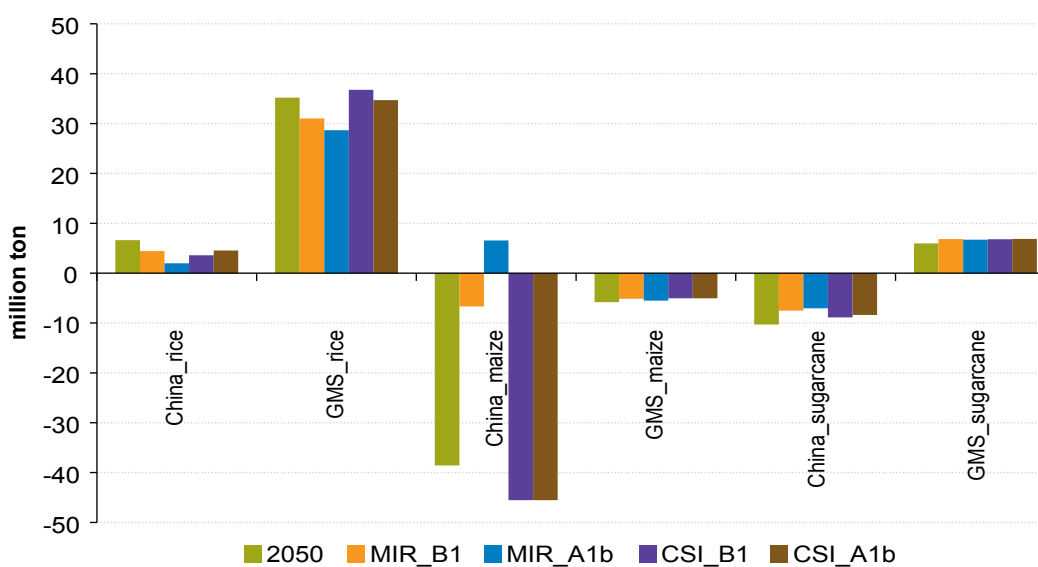
Source: IFPRI IMPACT Simulations 2011.

Table 4: Change in Rice Yields under Climate Change, Various Scenarios, Projected to 2050, GMS Countries

Country	Base2050	MIR_B1	MIR_A1b	CSI_B1	CSI_A1b
	(kg/ha harvested)	(percent change from 2050 base)			
IRRIGATED					
Cambodia + Lao PDR	4,735	-12	-16	-2	-6
PRC	4,992	-3	-5	-4	-3
Myanmar	5,371	-12	-13	-6	-10
Thailand	4,052	-13	-20	-6	-10
Viet Nam	5,004	-13	-14	-1	-4
RAINFED					
Cambodia + Lao PDR	1,557	1	-6	8	5
PRC	2,637	6	5	-1	1
Myanmar	2,257	-2	-1	0	-2
Thailand	1,137	2	-7	8	3
Viet Nam	2,856	0	-2	2	2

kg/ha = kilogram per hectare

Figure 14: Climate Change Impacts on Net Food Trade



GMS here refers to the summed net trade across Cambodia

Source: IFPRI IMPACT Simulations 2011.

for the PRC and the sum of the remaining GMS countries for rice, maize, and sugarcane. The PRC's net trade in rice declines under all four climate scenarios, while outcomes for the lower Mekong Basin countries vary depending on the scenario. The largest trade shifts by far relate to maize, as the various climate scenarios have differential impacts on the key maize growing areas, particularly the United States. Under both CSI climate scenarios, the PRC would significantly increase net imports of maize to up to 46 million tons by 2050. Under the MIR climate scenarios, net imports would drop dramatically to 7 million tons under the more 'benign' B1 emissions scenario and to net exports of 7 million tons under the A1B scenario. Changes for maize for the other GMS countries would be relatively small. Similarly, changes for net trade in sugarcane would be minor.

Changes in food prices as a result of climate change will also affect calorie availability. Table 5 presents significant and similar declines in calorie availability across all GMS countries. Average calorie availability is projected to drop by 6%–7% in the PRC, by 9%–10% in Myanmar, by 8% in Cambodia and the Lao PDR, by 5%–6% in Thailand, and by 6%–8% in Viet Nam, as a result of climate change. Thus, average calorie availability in Cambodia and the Lao PDR will be close to levels experienced in parts of sub-Saharan Africa.

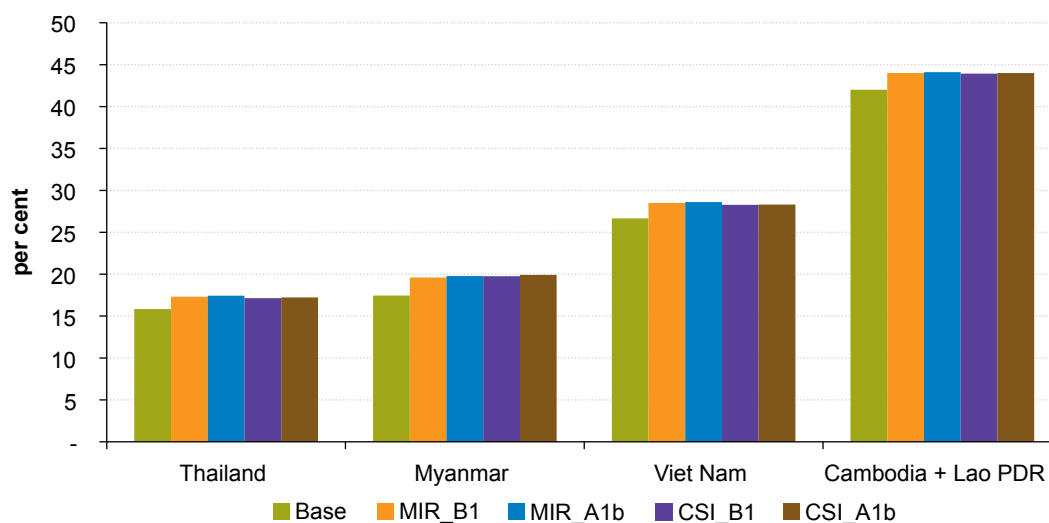
Finally, climate change will also affect childhood malnutrition outcomes in the GMS (Figure 15). The share of malnourished children is projected to increase by approximately 2% for each of four lower Mekong countries. These impacts will be particularly severe for Cambodia and the Lao PDR, where childhood malnutrition levels are extremely high, even without adverse climate change impacts.

Table 5: Impact of Climate Change on Calorie Availability in the GMS, 2050 Projections

Country	Base 2050	MIR_B1	MIR_A1b	CSI_B1	CSI_A1b
	(kcal/cap/day)	(percent change from 2050 Base)			
Cambodia + Lao PDR	2,128	-8	-8	-8	-8
PRC	3,887	-7	-7	-6	-6
Myanmar	2,486	-9	-9	-9	-10
Thailand	3,140	-6	-6	-5	-5
Viet Nam	2,883	-7	-8	-6	-7

kcal/cap/day = kilocalories per day per capita

Figure 15: Impact of Climate Change on Child Malnutrition Levels, 2050



Source: IFPRI IMPACT Simulations 2011.

4. Energy, Water, and Food

4.1 Background on Energy, Water, and Food Linkages

Energy is connected with both the food and water sectors in important ways. Higher energy prices can raise the price of agricultural inputs and reduce the availability of land and water for food production due to competition from expanded biofuel production. This dampens food demand as a result of higher food prices. The close correlation between food and oil prices is evidence of the close relation between energy and food. Higher energy prices also induce increased hydropower production, which can enhance or reduce food production outcomes. Ensuring increased energy production through hydropower development has been a long-term strategy in the GMS (see, for example, MRCS, 1995). Limited empirical evidence seems to indicate that hydropower development, focused on increasing energy supplies, supports irrigation

but reduces access by the poor to inland capture fisheries in the Mekong Basin (see, for example, Ringler, 2001; MRC, 2006; Johnston *et al.*, 2009).

Bioenergy development has been promoted to increase energy security and support climate mitigation goals. However, this strategy also competes with food production for water, land, and other natural resources. According to IFPRI research, biofuel development added 30% to weighted average cereal prices during 2000–2007. This affected maize prices the most, with increasing biofuel demand estimated to account for 39% of the increase in real prices. Increased biofuel demand is also estimated to account for 21% of the increase in rice prices and 22% of the rise in wheat prices (Rosegrant, 2008). In the GMS, Cambodia, Thailand, and Viet Nam have limited production of bioethanol from cassava and sugarcane. Thailand is the third largest biodiesel producer from palm oil, after Indonesia and Malaysia.

Table 6: Characteristics of the Four Energy Scenarios

Scenario	Description of scenario assumptions	Translation into IMPACT
IEA 450	Energy pathway consistent with the 2° Celsius goal through limitation of the concentration of greenhouse gases in the atmosphere to 450 ppm CO ₂ -equivalent by 2080	Growth rates of biofuel demand increased, as follows (2035 values): – 142% for OECD North America – 57% for Latin America – 81% for EU – 102% for Non-OECD Asia – 150% for Africa – 450% for OECD Pacific – 150% for Eastern Europe and Eurasia – 100% for the Middle East
Higher energy prices	<ul style="list-style-type: none"> • Doubling of oil prices in 2050 compared to baseline • Higher fertilizer prices 	<ul style="list-style-type: none"> • Annual growth rate of biofuel sector's demand for feedstock (first generation) increased throughout the projection period (2000–2050) so that biofuel sector's demand for feedstock (first generation) increases by 67% in all countries and crops in 2035 • Annual growth rate of fertilizer prices increased by 75% throughout the projection period (2000–2050), which corresponds to an increase in fertilizer prices by an average of 103%
Biofuel technology pessimistic	Second generation biofuels start 10 years later (in 2039 instead of 2029)	Year in which second generation biofuels start: 2039 (instead of 2029)
Higher energy prices and higher productivity	<ul style="list-style-type: none"> • Doubling of oil prices in 2050 compared to baseline • Higher in fertilizer prices by an average of 103% • Productivity growth rates for all crops increased by 20% 	<ul style="list-style-type: none"> • Annual growth rate of biofuel sector's demand for feedstock (first generation) increased throughout the projection period (2000–2050) so that biofuel sector's demand for feedstock (first generation) increases by 67% in all countries and crops in 2035 • Annual growth rate of fertilizer prices increased by 75% throughout the projection period (2000–2050), which corresponds to an increase in fertilizer prices by an average of 103% • Productivity growth rates for all crops increased by 20%

The following section presents the impact on food and water in the GMS of four energy scenarios—current policies, higher energy prices, biofuel technology pessimistic, and higher energy prices and higher productivity—on world prices, malnutrition, trade, and crop areas, analyzed with the IMPACT model.

4.2 Energy Scenario Description

The first scenario, IEA 450, describes an energy pathway consistent with the goal of a 2° Celsius temperature increase by 2080 through limitation of the concentration of greenhouse gases in the atmosphere to 450 parts per million (ppm) carbon dioxide (CO₂)-equivalent, based on the International Energy Agency's Energy Outlook (IEA, 2010). Under this scenario, renewables supply 45% of total electricity and 20% of total heat by 2035, while oil production peaks before 2020 and declines steadily to 2035. The share of biofuels in total transport fuel supply reaches 14% in 2035. To achieve such a high level of renewable requires increased investment in and expansion of renewable energy sources, including biofuels. As a result, growth rates of biofuel demand increase by 57% to 450% by 2035, depending on geographic region. We extrapolated growth from 2035 to 2050 at the 2025–2035 growth level. The other three scenarios are based on specified changes relative to the IEA “current policies” scenario, a reference scenario that postulates business as usual, with an increase in energy demand of 1.4% per year through 2035. The IEA current policies scenario is used in the IMPACT baseline described above.

The second scenario, higher energy prices, postulates a doubling of baseline oil prices by 2050, resulting in both higher fertilizer prices, a key input to agricultural production, and accelerated demand for biofuels. Under this scenario, biofuel demand for feedstocks (first generation) increases by 67% in all countries and crops by 2035. Moreover, annual growth rate of fertilizer prices increases by 75% throughout the projection period (2000–2050), which corresponds to an increase in fertilizer prices, on average, of 103%.

The third scenario, biofuel technology pessimistic, assumes that second-generation biofuel development is postponed by 10 years, putting additional pressure on the use of first-generation technologies to meet fuel standards.

The final scenario, higher energy prices and higher productivity, examines whether higher agricultural productivity growth can offset the impacts of higher energy prices on food prices, consumption, and food security. This

scenario assumes the same implications for fertilizer and biofuels as the higher energy prices scenario, but also includes a 20% increase in crop yield growth.

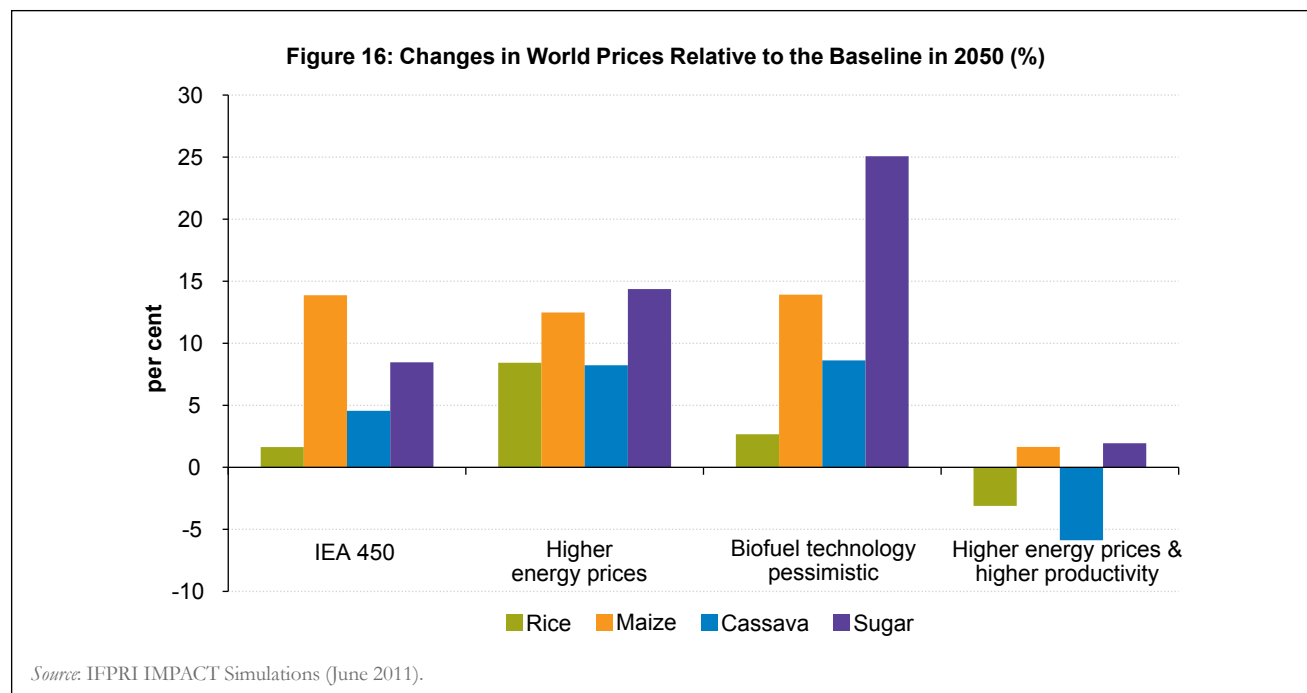
We present results for these four scenarios for four key food and biofuel crops in the GMS: rice, maize, cassava, and sugarcane. The scenario results are presented in terms of relative and/or absolute changes relative to the IMPACT model baseline by 2050.

4.3 Energy Scenario Results

Changes in energy prices have large impacts on world food markets as evidenced by impacts on global food prices (Figure 16). Under the IEA scenario, maize prices increase by 14% and sugar prices by 8%, while cassava and rice (generally not a biofuels crop) are less affected. Under the higher energy prices scenario, prices increases are somewhat similar for the biofuel crops, by 12% for maize and 14% for sugar, but higher fertilizer prices affect all crops, and rice and cassava prices also increase by almost 10% over the baseline. The biofuel technology pessimistic scenario, which assumes a delay in getting second-generation feedstock technologies online, has very large negative impacts on first-generation feedstock: maize prices increase by 14%, sugarcane by 25%, and palm oil by 21%. If investment in agricultural productivity responds to higher energy (and resulting higher food prices), then food markets will respond in the longer term, resulting in lower food prices across all crops. For the crops of importance in the GMS, this policy would result in maize and sugar price increases of only 2%, while palm oil prices would be 1% higher, and wheat, rice, and cassava prices would be 1%, 3%, and 6% below those of the reference scenario.

Higher energy prices do not only push up food prices, but also put pressure on expansion of crop area: under the IEA 450, higher energy prices and biofuel technology pessimistic scenarios, crop area expands for all four crops, but particularly for the biofuel feedstocks: maize and sugarcane (Table 7). Results shown here include the five lower Mekong countries, and for the PRC only the Lancang Jiang (Mekong) area. The higher energy prices and higher productivity scenario leads to a small decrease in rice and cassava areas and a small increase in maize and sugarcane areas as productivity growth more than outstrips pressure on land expansion, at least in the GMS.

Trade is an important means to balance climate, energy, and other shocks to agricultural production. Net trade

**Table 7: Crop Area Changes as a Result of the Four Energy Scenarios (%)**

Crop / Scenario	IEA 450	Higher energy prices	Biofuel technology pessimistic	Higher energy prices and higher productivity
Cambodia + Lao PDR				
Rice	0.00	1.10	0.00	-0.60
Maize	3.10	2.60	3.00	0.60
Cassava	0.40	0.80	1.00	-0.90
Sugarcane	1.90	2.80	5.50	0.80
PRC (Lancang Jiang area only)				
Rice	0.40	3.40	0.70	-1.40
Maize	6.70	5.10	6.00	1.40
Cassava	0.50	0.90	1.10	-0.80
Sugarcane	1.70	2.50	4.90	0.70
Myanmar				
Rice	0.30	2.40	0.50	-1.00
Maize	4.00	3.10	3.90	0.80
Cassava	0.40	0.70	1.00	-0.80
Sugarcane	1.70	2.60	4.90	0.60
Thailand				
Rice	-0.20	2.00	-0.10	-1.10
Maize	4.60	3.80	4.40	0.90
Cassava	0.50	0.90	1.10	-0.90
Sugarcane	2.00	3.20	5.90	0.70
Viet Nam				
Rice	-0.30	1.90	-0.10	-1.10
Maize	4.70	4.00	4.60	0.80
Cassava	0.40	0.70	1.00	-0.80
Sugarcane	1.70	2.60	4.90	0.60

Source: IFPRI IMPACT Simulations 2011.

in rice is least affected under the alternative energy scenarios. Rice exports decrease slightly in the GMS countries under the higher energy prices scenario, by 2.5%, and slightly increase under the remaining scenarios. Net trade for cassava also remains relatively unaffected by the energy price changes but both sugar and maize net trade change significantly under all scenarios. Net maize imports decline by 34% and by 32% under the IAE 450 and biofuel technology pessimistic scenarios, respectively, as maize is redirected to use as biofuels, particularly in the United States. Under the higher energy prices scenario and the higher energy prices and higher productivity scenario net maize imports also decline, by around 12%, but for different reasons. Higher energy prices increase the cost and reduce the access to maize use as food, whereas under concomitant higher productivity, the need for expanding imports is reduced. For sugarcane, net exports increase under all alternative energy scenarios; with the highest increase in net exports under the biofuel technology pessimistic scenario, where the subregion increases net exports by 25%. Under the other energy scenarios, the subregion increases net exports by 4%–8%.

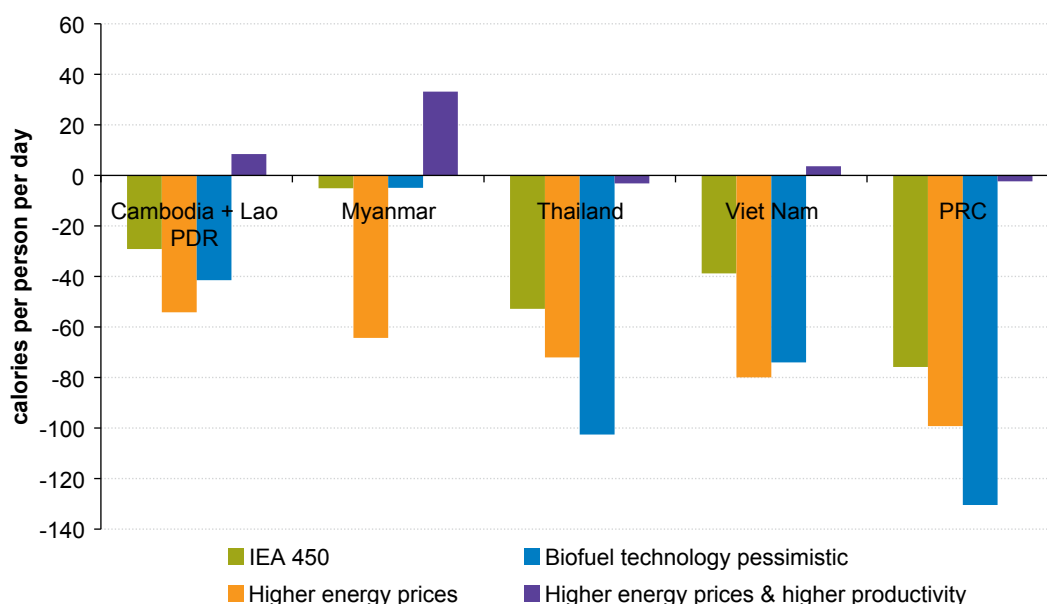
In the PRC, the energy scenarios result in sharp declines in net maize imports, by 76% and 69% under the IAE 450 and biofuel technology pessimistic scenarios, respectively; and by 19% and 17% under the higher energy prices scenario

and the higher energy prices and higher productivity scenario, respectively. Changes in net imports for sugarcane are relatively small, while net imports for cassava increase significantly and almost triple under the biofuel technology pessimistic scenario, given that cassava is used for biofuel production. Finally, rice exports, which are estimated to be very low by 2050, decline by 30% under the higher energy prices scenario, but increase by 7% under the IAE 450 and biofuel technology pessimistic scenarios.

Higher food prices reduce affordability of food, and thus dampen food consumption. The IEA 450, higher energy prices, and biofuel technology pessimistic scenarios result in a decline in calorie availability. For Cambodia together with the Lao PDR, Myanmar, and Viet Nam, the decline is strongest for the higher energy prices scenario, whereas for the PRC and Thailand, the drop is largest for the biofuel technology pessimistic scenarios. The overall largest decline, by 130 calories, is observed for the PRC under the biofuel technology pessimistic scenario, while the higher energy prices and higher productivity scenario leads to an increase in calorie availability for Myanmar (33 calories per person per day); impacts for the other countries are negligible (Figure 17).

Larger price increases correspond with larger increases in the population at risk of hunger as well as child

Figure 17: Change in Calorie Availability Relative to Baseline by 2050



Source: IFPRI IMPACT Simulations (June 2011).

malnutrition. The higher energy prices scenario leads to more than 42,000 additional malnourished children in Viet Nam. Under the biofuel technology pessimistic scenario, Thailand experiences a 5% increase, or 33,000 more, malnourished children. Under the higher energy prices and higher productivity scenario, malnutrition number barely change, by 0.3% for Cambodia together with the Lao PDR, Thailand, and Viet Nam, and decrease by less than 2% for Myanmar (Figure 18), showing that higher agricultural productivity can offset much of the negative impact of higher energy prices.

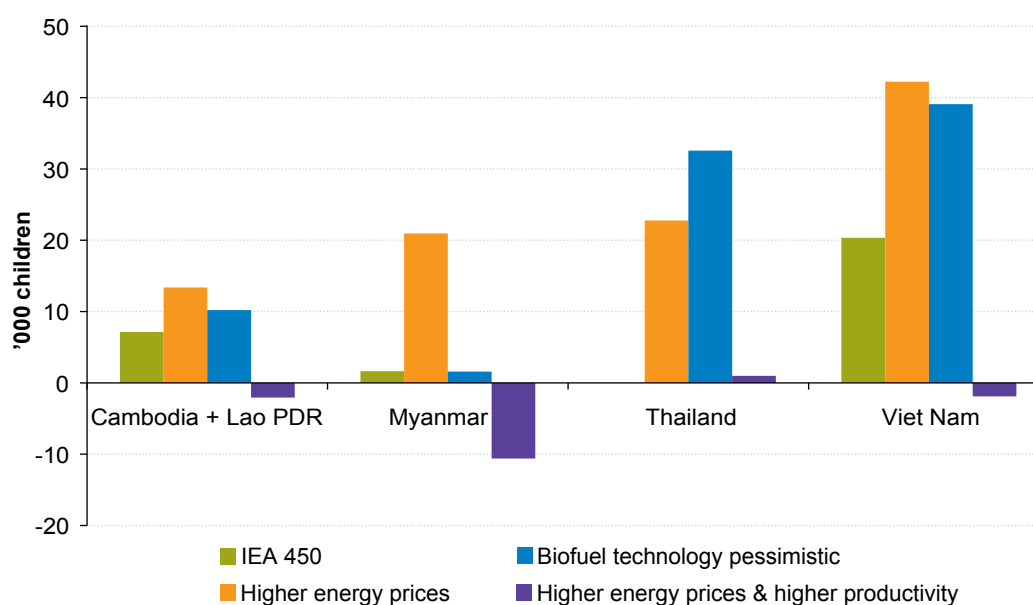
In terms of population at risk of hunger, the highest absolute increase is observed for the higher energy prices scenario for Myanmar, with an increase of the population at risk of hunger by 1.5 million people. In terms of relative changes, the increase is largest for Thailand, with a 20% increase in the population at risk of hunger under the higher energy prices scenario, and a 25% increase under the biofuel technology pessimistic scenario. Consistent with the results for calorie availability, the higher energy prices and higher productivity scenario prompts a decrease in the population at risk of hunger for Myanmar (– 4%, or – 0.7 million people) compared to the baseline. For other countries, the higher productivity scenario also virtually eliminates the negative impact of higher energy prices on food security.

5. Conclusions

The GMS is rich in natural resources and has large populations dependent on agriculture for their livelihoods. However, under business as usual, agriculture will have to face a number of new and difficult challenges. Food security will likely still be a problem 50 years from now. Agricultural production is going to be increasingly constrained by competition for land and water. Water will increasingly be transferred out of agriculture to meet domestic and industrial demands; at the same time, expansion of agricultural production will require increased irrigation water resources.

There is also heightened global concern for potential impacts on agriculture of future climate change and climate change response policies. Rising energy prices, biofuel demand, and other supply and demand drivers will lead to higher agricultural prices. Regional and national income growth, urbanization, and growing global inter-connectedness are expected to increase diet diversification and homogenization. Trade liberalization and greater integration of global food markets can support more reliable food supplies and lower food prices. But food security will remain out of reach of key constituents in the GMS, particularly in Cambodia and the Lao PDR. Many of the negative impacts of water scarcity, climate change, and

Figure 18: Change in Number of Malnourished Children between 0 and 5 years Relative to the Baseline by 2050



Source: IFPRI IMPACT Simulations (June 2011).

rising energy demand are global in nature, and will require broad global efforts to solve. But countries in the GMS can also reform their own policies to improve food security.

The scenario on high energy prices and high agricultural productivity shows that the “food and water versus fuel” tradeoff in agriculture can be reduced if innovations and technology investments in crop productivity are higher. Both improvements in biofuel conversion and crop productivity reduce the tradeoffs. Finally, biofuel development has provided new incentives for crop breeding for productivity improvement in biofuel feedstock crops.

Growing pressure on food supply and natural resources requires new investments and policies for the GMS. Under tightening food markets, a business-as-usual approach to agriculture cannot meet the development and sustainability goals of reduction of hunger and poverty; the improvement of rural livelihoods and human health; and equitable, environmentally sustainable development. Innovative agricultural technology policies, reform of management of both agricultural and natural resources, and enhanced public-private partnerships, making food security “everyone’s business,” will be essential in the years ahead. Such policies will also require more investment in agriculture. The PRC is the regional and global leader in investment in agricultural research and development. While difficult to replicate in the rest of the GMS, lessons should be learned on what can and what would not work there.

In the water sector, the GMS countries need to move rapidly toward improving water use efficiency in the agriculture sector, expanding traditional water conservation measures of canal lining with real reforms in water management. Elimination of demand side measures, such as the recent removal of irrigation fees in Viet Nam, will make it more difficult to implement reforms. Second, the countries in the GMS, particularly Viet Nam, need to increasingly prepare for climate change adaptation. The focus here needs to be two-fold: early warning and preparedness for extreme events, both floods and droughts; and investment in capacity, infrastructure, and research and development to cope with gradual, long-term changes in sea-level rise, and hotter weather. Given that all countries in the GMS tend to be affected at the same time by droughts and floods, as the 2010 and 2011 events have shown, climate change has opened an opportunity for the GMS countries to work together to mitigate adverse and enhance positive impacts from a changing climate. Technology transfer and joint

learning and capacity building events would be essential elements for such a cross-GMS collaboration.

To reduce adverse impacts of energy prices on water and food in the GMS, it will be important to work toward a global commitment to reduce both subsidies and mandates for biofuels and to liberalize trade in biofuel products, so that those countries and players who have a comparative advantage can produce biofuels with the least adverse impacts on water and land. Moreover, under a tighter water, land, and energy picture, that is, a situation where demand may outstrip supply, costs of subsidies for water and energy are rapidly increasing, putting further constraints on already strained agricultural budgets in Asia and elsewhere, reducing funds that might otherwise be available for agricultural research and development. Reduction in subsidies and shifting of funds to investments in agricultural productivity growth would have substantial benefits.

Biofuel policies and other climate mitigation policies also need to be strengthened to increase pro-poor access, through the development of production processes that bring benefits to the poor. An example is rural biogas systems using livestock waste in northern Viet Nam. Moreover, biofuel and energy saving production systems should be designed toward integrating rural households into the value chain, allowing for on-farm addition of value, rather than just extracting raw biomass. Finally, localized biofuel development provides a real pro-poor opportunity to expand electricity to those areas in the GMS still not served by the electricity grid, by producing household electricity and lamp oil.

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GENDER AND REGIONAL ECONOMIC INTEGRATION IN THE GMS: ROLE OF CROSS-BORDER TRANSPORTATION DEVELOPMENT¹

Kyoko Kusakabe²

Abstract

This paper analyzes, through three case studies, the changes in women's and men's livelihoods at the border areas of countries in the Greater Mekong Subregion (GMS) after the development of cross-border road networks. Roads provide access for formerly marginalized villagers to the market and social services, and facilitate employment and income-generating opportunities. However, varied levels of impact and benefits are enjoyed across gender, ethnicity, and class. The paper argues the importance of analyzing the effects of road development in specific situations in order to obtain an in-depth understanding of the impact.

1. Introduction

Globalization has increased the mobility of goods and people. To strengthen the economy, regional economic integration has been facilitated around the world and the Asian region is no exception. The Association of Southeast Asian Nations (ASEAN), South Asian Association for Regional Cooperation (SAARC), and Greater Mekong Subregion (GMS) are all aiming to strengthen their regional economic connections; cross-border transport facilities are one of the core activities to achieve this aim. Documents by international organizations reveal widespread support for cross-border road infrastructure development:

[Cross-border infrastructure projects] enlarge market access, reduce economic distance and facilitate trade, investment, and labor flows. The

resulting intensification of cross-border economic activities can create employment, particularly in the labor-intensive sectors of DMCs (Developing member countries), thus contributing to poverty reduction. (ADB, 2006a p. 8)

However, who will be able to benefit from such infrastructure development? As Dobbs (2007) rightly noted, transportation planning has not always included social analysis.

Research into transport planning and practice has consistently failed to apply a social science perspective to transport policy or to fully understand the way in which social organizations can play a role in determining patterns of transport and travel. (Dobbs, 2007 p. 86)

2. Cross-Border Road Development in the GMS and Development of Border Towns

International roads in Cambodia, the Lao People's Democratic Republic (PDR), Myanmar, Viet Nam, and Thailand total 20,132 kilometers (km); they are part of the ASEAN highway network, which consists of 26 roads totaling 37,193 km in 10 ASEAN countries (Regmi and Hanaoka, forthcoming). Road connectivity complemented by the Cross Border Transport Agreement (CBTA) and other bilateral agreements facilitates close trade linkages between these countries. The contribution of transport to gross domestic product (GDP) varies from 4% to 10% in GMS countries (ESCAP, 2009; cited in Regmi and Hanaoka, forthcoming). The cross-border highways not only increased trade and investment but also created flourishing border towns (Kammeire, forthcoming). This paper introduces studies conducted in the following border towns: Tachilek, Myanmar, and Mae Sai, Thailand; Laiza, Myanmar, and Jieqo, People's Republic of China (PRC); and Huayxay, the Lao PDR, and Chiang Khong, Thailand.

3. Gender Impact of Roads and Mobility

It has long been pointed out that road development can increase disparity (Leinbach, 2000; McCall, 1977), and since the 1970s, women's access to transport has been explored along with its implications for gender inequalities (Dobbs, 2007).

¹ This paper is based on selected cases from the forthcoming book *Gender, roads and mobility in Asia* (Practical Action Publishing). The author would like to acknowledge the support of Japan-ASEAN solidarity fund of ASEAN Foundation through the project "Capacity building for gender, poverty and mobility analysis of road transportation development in GMS region".

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Major gender issues identified in the literature³ are as follows:

- 1) Women's triple burden that restricts their mobility: Because of women's reproductive work, they are not expected to travel far from home.
- 2) Cultural restriction on women's mobility: Women's travel restriction is exacerbated by their cultural seclusion. In some societies, women are not permitted to travel alone.
- 3) Women's access to means of transportation: Few women ride motorbikes or private cars, and even fewer own them. Women often have less priority than men in using vehicles owned by the household. Women sometimes have difficulty accessing public transportation because of security concerns.
- 4) Women's different travel needs: Because of the gender roles, women's travel needs differ from those of men. For example, they need more convenience in transport for fetching water and fuelwood, sending children to school, etc.

Women's lesser access to transport has various effects:

- Girls' education: Difficulty in going to school can discourage girls from continuing their education.
- Access to health services: Maternal mortality is high when transport to hospitals is not easily accessible.
- Access to information and training: Since women are expected not to travel, they often do not attend training outside their villages, and hence have less access to information.
- Opportunity for social visits and strengthening their social capital: If women travel less, they will have fewer opportunities to make new contacts or strengthen old ones.
- Health: Women carrying heavy load on their heads or on their back can affect their health.
- Women's time burden in fetching water and marketing goods.
- Opportunities for income-generating activities.

The negative impacts of transport development on women include the following:

- 1) HIV/AIDS: Road development has implications on the prevalence of HIV/AIDS, and how women become more vulnerable to infection (ILO, 2006).
- 2) Lost markets and business: Highways can eliminate roadside stalls where women have been selling their wares.

3) Road safety: Women are not necessarily more vulnerable to road accidents (Turner and Fouracre, 1995), but they are the ones who look after the family members, especially those injured or disabled by road accidents. Women spend more time looking after children to prevent them from being injured by vehicles. For example, in the Lao PDR, fearing that without their constant supervision, children would run onto the road, women stopped travelling out after a highway was built in front of their village (Kusakabe and Saphakdy, 2010).

Even though the gender effect of road development has been discussed for the last 40 years, the level of gender mainstreaming in the transport sector remains low. Bamberger and Lebo, (1998; cited in Peters, 2001) reported that in fiscal year 1997, only 4% of World Bank's projects included gender component or gender actions. In comparison, 67% of the projects in population, health, and nutrition and 35% of the projects in agriculture included a gender component. A gender review of ADB loans revealed that 29% of all loans during 1998–2004 had effective gender mainstreaming, while only 3% of all loans in the transport and communication sector during 2002–2004 had such a component (ADB, 2006b).

As Mandel (2004) said,

By addressing women's ability to be mobile, development scholars and practitioners may provide opportunities for women to enhance their income generating capacity. In so doing, they may also open up spaces within which women can gain greater autonomy and independence. Facilitating mobility for women may well provide them with opportunities to reconfigure the gender ideologies that shape their lives. (p. 284)

Kronlid (2008) and Cresswell (2006) noted that mobility is a capability. And as capability, it will be different for each individual; thus, we need to make specific analysis of each case in order to understand the implications of road development to women's mobility, livelihoods, and relations.⁴

3.1. Case 1: Border development and livelihood diversification in Houayxay, Lao PDR

National Road Number 3 (NR3) links Thailand and the PRC via the Lao PDR. A study of four villages by Thammanosouth *et al.* (forthcoming) in Bokeo Province, with different degrees of connectivity through the NR3,

³ Porter, 1995, 2002; Turner and Fouracre, 1995; Fernando, 1998; Law, 1999; Leinbach, 2000; Fernando and Porter, 2002; Tanzarn, 2003; Mandel, 2004; Riverson *et al.*, 2005; Parikesit and Czuczman, 2006; World Bank, 2006; Gajewski *et al.*, 2007.

⁴ see also Wisner (2001) for the need to have a case specific analysis in order to have an indepth understanding of people's vulnerability.

found that road development does not necessarily improve people's mobility, and men get more mobility than women. Also, road development does not automatically improve income or income-generating opportunities, nor does mobility necessarily lead to better income. The study also found that an increase in women's income does not change the gender division of labor at home.

The four villages in the Thammanosouth *et al.* study were: (i) a village located near a border checkpoint, (ii) a village located near the border city center and along the road, (iii) Lao Lum (lowland Lao PDR) village located far from the border and city center but along the road, and (iv) Lao Thung (highland Lao PDR) village located far from the border and city center but along the road. Almost 25% of the respondents (18 out of 73 households) reported having multiple sources of incomes after NR3 was completed. The study found that the first two villages diversified their income sources with burgeoning border trade; tourism creating more opportunities for them; the other two villages have not changed their income source much. However, women in the border village were having more difficulty competing with larger businesses which started to operate with the development at the border. Around 30% of the respondents at the border town said that their income decreased with the border and road development. They enjoyed good business when the border town was still small, but when the economy started to grow, they began to lose out. However, the second village was able to take advantage of the growing border town by diversifying into trade while still depending mainly on agriculture. Women in this village were much in control of both the agriculture activities as well as trade. In the last two villages, opportunity to diversify income was small, since they were far from the border town. However, in Lao Thung village, whatever opportunity that was there to benefit from the border trade, was obtained by men, since men were the ones who were mobile while women were expected to stay at home. In Lao Lum village, that was not the case. There, men respondents were more enthusiastic about the development of the cross-border highway. All men interviewed said that agriculture prices increased after the highway development, while 40% of women respondents said that there was no change in price.

Although women were losing out in the border towns, the increased income-generating opportunities and associated income shifted some of their reproductive work to other people. In the border towns, women became busier and needed to spend more time for their business because of increased opportunities and higher competition. Cooking

is now done by other women in the households (such as grandmother, etc). In the outer town village, there is a higher opportunity to sell agricultural goods, and women are getting busier in both farming and trading activities. So, women are doing less cooking and women and men cook together. Similar tendencies are seen for washing clothes. Especially in border towns, clothes are now being outsourced to laundry services.

3.2. Case 2: Livelihoods at the Myanmar Border

To evaluate the impact of cross-border road development on rural livelihoods in Myanmar, Win Myo Thu (forthcoming) studied 247 respondents in 7 villages along the Kyaing Tong–Tachilek road in Shan state, northeastern Myanmar, which crosses the border at Mae Sai, Thailand, and constitutes part of the Asian Highway Number 2 (AH2). Win Myo Thu selected three sets of villages with varying access to transport facilities, such as roads and public transport: (i) villages located on the AH2 route, with good connectivity through public transport, allowing people to commute to the border in a day (termed *border villages*); (ii) villages located along the AH2, but lacking public transport facilities to commute to the border in a day (*highway villages*); (iii) villages located away from the AH2 and lacking public transport facilities (*distant villages*).

Win Myo Thu's study showed that people in the study villages depend on Tachileik road to access health services. However, since the highway and distant villages are far from the border, they are more dependent on traditional health practitioners, while nearly half (48%) of the border villages respondents sought health care in Tachileik. This was also seen in the significantly better situation in border villages for such diseases as malaria, tuberculosis, and waterborne diseases than in the other two villages. The respondents, both women and men, in border villages expressed higher satisfaction for the healthcare access with the road development than did respondents in the other two types of villages.⁵

Border villages relied more on non-agriculture income; the other villages relied on agriculture. It is the men who are engaged in non-agriculture activities, so men now enjoy more employment opportunities than women in border towns. While more than 70%–80% of the respondents in highway and distance villages replied that both husband and wife worked together to earn incomes, in the border villages, only around 40% said so and other 40% said

⁵ Note that all the studied villages were patriarchal in practice.

that only men earn incomes. More than 70% of border village respondents said that men are the ones who borrow money, while 0% in highway villages and 44% in distant villages did so. Women in the border villages found that they are now more marginalized economically, which is also reflected in their perception about the changes after the road improvement. Women in the border villages perceived income increase and family happiness to be significantly lower than did men in their own village and women in other villages. In-depth interviews showed that they were worried about their future because of unstable income. Community decision making was much more skewed to men in border villages than in other villages.⁶

3.3. Case 3: State-Facilitated Route and People's Route from Myitkyina, Myanmar to Jiego, PRC

Khin Hnin Phyu (forthcoming) studied the traders of Myitkyina in Kachin State, Myanmar, who trade with the PRC, and how the state's policy to change trade route has affected their trade. Traders in Myitkyina have been trading with the PRC, taking vegetables from Myanmar to the PRC, and bringing consumer goods and machinery/construction materials from the PRC to Myanmar. From Myitkyina, they go to Laiza (69 km; costing \$10) and from there, cross the border to the PRC and go to Yingjiang and then to Ruili and Jiego trade zone. The whole route is 160 km, taking 4.5–5.5 hour, with total transportation cost of \$20. Almost all the vegetable traders are women, and many do not even cross the border. But those women who trade in both agriculture goods and consumer goods go to Ruili and Jiego. This route is the shortest and cheapest route, and controlled by the "cease-fire group." Since the transportation cost is low, traders can start businesses with little capital.

An alternative trade road to the PRC from Myitkyina was recently constructed by the Myanmar Government. The Myitkyina-Teng Chong road is around 224 km, takes around 5.5 hours to Teng Chong and costs \$40. Goods in Jiego are cheaper than in Teng Chong, so traders prefer to use their old road to trade with the PRC. Also, along the new government-constructed route, there are checkpoints, where traders need to undertake paperwork, which is an additional cost and a barrier for them. Only large exporters are able to prepare such paperwork, and

small traders need to bribe their way through. In order to discourage traders from using the old route, the Myanmar Government has been strict in confiscating goods along the old Myitkyina-Laiza road.

Khin Hnin Phyu's study show that both women and men who had long experience in trade (more than 10 years) were able to increase their income after the new road construction, but women traders with less experience (less than 6 years) reported decreases in income. None of the men or more experienced women traders reported loss. Those who have long years of experience have established good relations with Chinese merchants; thus are able to obtain credit and expand business as well as recover from the confiscation of their goods. Men were engaged more in machinery trade, such as motorbikes. However, they tended to take a "bush" road, avoiding both the state constructed road and the old road, and hence able to avoid confiscation and arrest. Those who were most affected by confiscation and collection of fees from authorities were women trading in consumer goods, rice, and garlic. These women were able to increase their sales but their costs also increased, making them lose business in the end.

Women traders of consumer goods had the least negotiation power with consumers and the authorities. They also could not diversify to other products or other routes, since most women, with their domestic responsibilities, do not have time to explore new markets and routes.

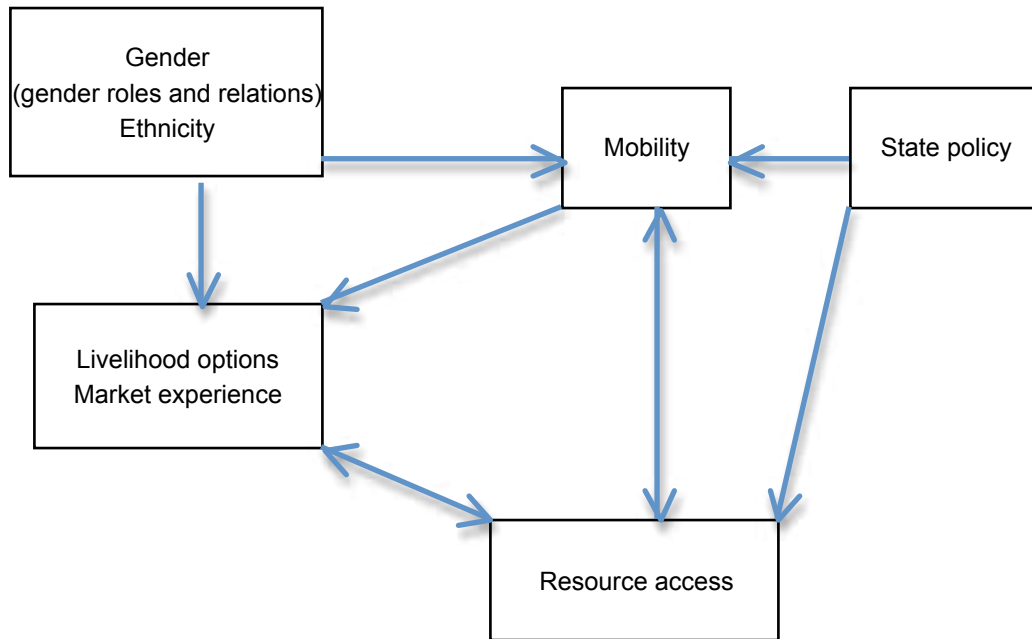
4. Discussion

The paper has explored the gender impact of road construction in three cases in GMS.⁷ From the literature and the cases discussed, we can summarize the gender effect of road development as follows. First, gender roles and relations as well as ethnicity determine women's and men's mobility as well as their business characteristics, experience in the market, and livelihood choices. For example, the Lao-Thai case showed how different ethnic groups responded differently to road development and market access. The Myanmar-PRC case showed how gender determines the type of trade they pursue and thus, the effect of road development. It was also pointed out that women were not able to diversify their trade since they were less mobile and could not travel to find new markets.

⁶ In the border village, more than 70% of men, but only 11% of women, replied that they were actively participating in village development organizations. In the other villages, 25% of women and 25% of men said that they were actively participating in village development organizations.

⁷ More than 13 cases from GMS are included in the forthcoming book *Gender, roads and mobility in Asia*.

Figure 1: Gender Effect of Road Development



The Myanmar-Thailand case showed how gender roles divide the benefit that women and men can enjoy from road and border development. In this case, women were seen to be less mobile than men because of women's domestic responsibilities.

Second, different mobility is related to the resources that women and men can access, and hence to their livelihood/business options. For example, because the mobility of Myitkyina women traders was restricted, they were not able to diversify their trade or expand their network. In the Tachilek case, women were not able to earn independent incomes because they had to stay home; this was because men's mobility had increased and they were often out of the house.

Third, state policy influences mobility and resource access. The Myitkyina case showed the gender effect of the state's forcing traders to use a road constructed by the state. There were differences between women and men and also among women in how much they were able to negotiate with the authorities and suppliers/buyers.

Figure 1 is an illustration of this summary. This shows how mobility as capability (Cresswell, 2006; Kronlid, 2008) is determined by gender and determines gender differences in livelihood options as well as gender differences in the effect of state policy. This paper argues that the effects of

road development on women and men are determined by various factors that constitute capability of individuals, and hence need specific analysis of specific cases in order to have an in-depth understanding of gender effects.

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WATER - ENERGY NEXUS: SUSTAINABLE URBANIZATION IN THE GREATER MEKONG SUBREGION

Peter Rogers¹

Abstract

This paper assesses the current energy demanded by urban water in the Greater Mekong Subregion (GMS), predicts how large the future demands could be, and reviews technical options for resolving the urban water-energy nexus in the GMS. A simple model was constructed for the water and energy uses for the largest 10 cities in the GMS and for each of the national entities, with projections into the future. The model showed that despite the relatively low rates of total population growth in the region, urban populations are likely to rise by about 60% by 2030, but the large cities in the region will only experience a modest increase of about 30%. This implies that there will be big population increases in the smaller cities and towns in the region. The really surprising result is that in the face of a 60% increase in population there will be a doubling in the demands for urban water supply and management because of increasing development and the push toward attainment of the Millennium Development Goals. This implies for Viet Nam a use by 2030 of 91% of the total water used in 2005 just for urban municipal and industrial uses, and as low as 19% for Myanmar. For Viet Nam it may be difficult to meet the needs of agriculture and other water users if its urban needs grow so rapidly. Typically in the region, electricity capacity is increasing to meet demand but, this is not the case with water supply. There are some serious limits on water availability, hence the need to conserve water in this sector. This may be quite difficult given the pressures to expand the actual quantities of water supplied and broaden the coverage of the systems.

1. The Water and Energy Nexus

This paper attempts to put the roles of energy and water into the context of maintaining the viability of the cities in the Greater Mekong Subregion (GMS). Often the word “sustainability” is applied to studies of cities; however, there is nothing that is inherently self-sustaining in modern

cities. The word “viability” best describes what can be achieved in the long run for what can be considered humanity’s greatest creation: cities. Of course, there is a long list of desirable properties associated with the concept of sustainable cities. Overall, the concept of efficient resource use is fundamental. This is strongly related to urban metabolism and urban ecology. This paper takes a narrower look at the interconnection between urban water and sanitation and attempts to show how the viability, or sustainability, of the cities is likely affected by them.

Currently (2009), of the 20 cities in the world with more than 10 million people, 9 are in Asia, and based on United Nations projections (UNDESA, 2009) out of the 10 largest cities in the world by 2050 seven will be in Asia. Over the same period, the percentage of population that is urban will rise from 42% to 65%. These numbers are unprecedented, but just for one country, The People’s Republic of China (PRC), the urban population is predicted to rise to one billion by 2030 (McKinsey, 2009). The UN report forecasts that by 2025 the following Asian cities will be megacities; Tokyo (37 million), Delhi (29), Mumbai (26), Dhaka (21), Kolkata (20), Shanghai (20), Karachi (19), Beijing (15), Manila (15), Osaka-Kobe (11), Shenzhen (11), Chongqing (11), Guangzhou, Guangdong (11), Jakarta (11), and Lahore (10); none of these are GMS cities.

Economic and population growth place an ever-greater demand on energy and finite water resources. Many countries in Asia already face major threats to their ability to provide their people with safe drinking water and food security. Water resources face additional demands with the considerable amounts of water required for energy production to support continuing economic growth. Climate change greatly complicates the water-energy insecurity of many countries. In addition, the demand for food is growing rapidly worldwide and in Asia, but particularly rapidly in East Asia where water and energy are also scarce. Water and energy supplies and limits are crucial to understanding the environmental and ecosystem aspects of sustainable urban development.

2. Why the Focus on the Greater Mekong Subregion?

The overall security of the entire globe is intimately bound up with the success of Asia. Most commentaries on global development view the current era as a period

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when economic and social development will shift from its Western domination to be replaced by the unique development approaches and priorities of Asia. However, many of the same commentators (Goklany, 2007; Cai and Rosegrant, 2010; and Brown, 2011) see serious limitations to the continued economic development of Asia because of population and resource limits, particularly on water and energy.

The GMS, consisting of Cambodia, the Guangxi Zhuang Autonomous Region and Yunnan Province of the People's Republic of China (PRC), the Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, and Viet Nam, has a current population (in 2010) of about 320 million, of which less than 25% are urban. Nevertheless, there are 4 very large cities: Hanoi (6.5 million), Ho Chi Minh City (5.7 million), Bangkok (5.7 million), and Yangon (4.5 million); and 6 other large cities, Kunming (3.2 million), Haiphong (1.8 million), Phnom Penh (1.3 million), Mandalay (1.3 million), Naypyidaw (0.9 million), and Danang (0.8 million), in the one-million population range. Despite the relatively low rates of total population increase in the GMS region (ADB and UNEP, 2004) in comparison with other low-income regions of the world, the rate of increase in urban populations will be much larger because of the already high population densities in the rural areas. The increasing population has no place to go but to the cities.

The prospects of water shortages in Asia, alone, would be a serious resource-allocation problem, but it will be confounded by climate change and its attendant effects on the hydrology of continents, regions, and nations. Water and energy issues have traditionally been researched as single issues, not as an integrated web of opportunities and limitations, particularly in urban regions. The uncertainties of climate change complicate the resource-management challenges. Studies need to go beyond traditional views of a stationary world in which not only is climate known, but also the future economic and social developments are viewed in similar narrow terms.

Becoming aware of these complex interactions, many countries have spent huge amounts of financial resources to improve their water security. Modern examples of such concerns include Israel's National Water Carrier, the Central Valley Project in California, the PRC's current work on the South-North Water Diversions, and India's attempts to interlink some river basins to bring water to water-scarce regions.

Less well known is the competition for water that exists between the demands for food and energy. For example in the PRC, 76% of the water withdrawn for industrial use was used in the generation of electricity; coal-powered generation is the number one consumer of water in the PRC's industrial sector. So as rapid economic growth leads to large increases in the demand for energy and increased food consumption, countries like the PRC and India find themselves in a serious bind; already their existing water resources are almost fully committed to agriculture and food production, leaving little available for meeting increasing urban and industrial demands. The case of the PRC is particularly severe and the Government is taking it very seriously, not only with massive water diversions (over \$60 billion) but also by beginning to implement water-saving technologies in both the water sector and the energy sector.

According to Goklany (2007) and Brown (2011), access to water and energy will be the major constraints on moving toward a sustainable planet by 2050. The big consumer of water is agriculture and its ability to feed the global populations is in doubt without major improvement in water-use efficiency in agriculture. This paper focuses more on water access in urban areas and its energy implications than on the conflicts over water for agricultural uses. Many of the destination cities of rural-urban migrants, however, are already badly served, having unsafe drinking water and inadequate sanitation. Not only do the cities typically suffer inadequate supplies of potable water but also they will have to find rapidly expanding supplies for their future growth—not an easy task given the industrial and agricultural demands being placed on the same resource base.

Generally, the relationships among urban water and wastewater treatment and their impact on the amounts of energy and types of energy infrastructure needed to meet these growing demands are poorly understood. Urban water has high embedded energy content, using as much as 1.65 kilowatt-hours per cubic meter supplied (NRDC, 2004). Depending on the nature of the water supply options and the location of the resources, meeting the new water demands could increase the total urban energy demands by 10%–15% and electrical energy by as much as 30%. In the United States, for example, as much as one quarter to one half of the electricity used by cities is consumed at municipal water and wastewater treatment facilities. Unfortunately, many of the modern ways of increasing water availability, such as by recycling, greatly increase the embedded energy

demanded. It is commonly accepted that 40% of the cost of desalination and water recovery using reverse osmosis is due to energy. This paper assesses the current energy demanded by urban water in the GMS, predicts how large the future demands could be, and reviews technical options for resolving the urban water-energy nexus in the GMS.

3. Energy Use for Water and Wastewater Management

The amounts and types of energy used in the provision of urban water supply and wastewater disposal depend to a large extent on the current water-use behavior of the populations and the nature of the technologies for supply and disposal. For low-income areas, the per capita water use could be as low as 50 liters per day (lpcd), with only 70% of the population being covered by the water systems and as low as 20% with access to sanitation systems. Working toward attaining the Millennium Development Goals (MDGs) could increase the coverage into the 90% range and increase the demand to 100 lpcd or above. Thus, even without any population increase, the total water demands placed on the GMS urban systems could increase greatly. Rapid population growth will greatly exacerbate the problem.

4. Future Urban Water-Based Demands for Energy

Water supply coverage in the GMS varies widely by country and province. Table 1 reports the most recent United Nations population forecasts (UNDESA, 2011)

for the countries of the GMS split by total and urban populations. The table presents population forecasts to 2030 based on 2010 as the starting point. The table suggests that the urban population in the GMS could reach over 150 million. This is quite small in comparison with the PRC's one billion urban dwellers predicted for 2030 by McKinsey (2009); nevertheless, it represents an almost doubling of the urban population in GMS. This huge increase will severely stress the already weak urban infrastructure and could cause water shortages and sanitation breakdowns leading to major epidemics and possibly social unrest.

Kallidaikurichi and Rao (2010) review the data on the adequacy of drinking water in 23 Asian countries. They spent a great deal of effort on developing the best available database for the region, but were critical of the quality of available national and local data for serious policy analysis. Their book developed an index of drinking water adequacy, which could be used for ranking countries from the point of view of access to safe drinking water; they did not include the associated energy inputs. McIntosh (1993, 1997) assessed water management in 50 utilities in Asia for the Asian Development Bank (ADB). He was able to assemble better quality at a more detailed level than Kallidaikurichi and Rao (2010). His compilation of economic data reveals that the majority of the utilities were unable to cover their operational costs from tariffs alone.

In the most recent summary of progress toward meeting the MDG goals, UN-ESCAP (2010) reported on data from 2008 and projected these forward to the 2015 deadline. Thailand outperformed all of the other GMS countries in both water-supply coverage of the population (98%) and

Table 1: Total and Urban Populations, 2010–2030

Country	Urban Population Assuming % Urban for 2020 and 2030								
	2010 Population			2020 Population			2030 Population		
	(million)			(million)			(million)		
	Total	Urban %	Urban Total	Total	Urban %	Urban Total	Total	Urban %	Urban Total
Cambodia	14.14	21.41	3.03	15.89	27	4.21	17.36	34	5.87
PRC									
Guangxi	47.19	24.01	11.33	53.17	28	14.64	59.90	32	18.91
Yunnan	44.83	24.00	10.76	50.51	28	13.91	56.91	32	17.97
Lao PDR	6.20	34.45	2.14	7.05	48	3.38	7.75	61	4.70
Myanmar	47.96	35.42	16.99	51.69	44	22.57	54.33	53	28.55
Thailand	69.12	33.48	23.14	72.09	39	27.81	73.32	46	33.62
Viet Nam	87.85	30.79	27.05	99.36	37	36.27	101.48	42	42.59
Total	317.29		94.43	349.75		122.79	371.07		152.21

Source: UNDESA (2011); Yunnan and Guangxi projected from ADB-UNEP (2004).

sanitation (96%). Viet Nam had improved its performance markedly for water supply (up to 94%) but still lagged in basic sanitation coverage (75%). Cambodia, Lao PDR, and Myanmar were improving rapidly in water-supply coverage, but still lagged on sanitation coverage. For Guangxi and Yunnan in the PRC, data in Seetharam and Rao (2010) were used for our projection model. Those economies appear to be progressing quite well toward attaining the 2015 MDGs.

5. Modeling the Future Urban Water-Energy Nexus

In order to assess the magnitudes of potential conflict among urban water use, urban energy use, and temporal development patterns, I constructed a simple simulation for the water and energy uses for the largest 10 cities in the GMS and for each of the national entities. As with Seetharam and Rao (2010), major data gaps were found. Obvious sources, such as AQUASTAT of the United Nations Food and Agriculture Organization (FAO), the World Bank's rapid assessment framework (ESMAP, 2010), ADB/UNEP (2004), the International Energy Agency's energy data (IEA, 2008), and the Pacific Institute's global water data (Gleick, 2009) were all utilized to assemble a workable database for initial estimations. The Southeast Asian Water Utilities Network's databases on energy use in water and wastewater utilities in Southeast Asia (SEAWUN, 2005, 2007) were very helpful sources. It should be understood, however, that the combination of data from different sources and slightly different dates can be misleading.

Results are given in Table 2; projections of urban water and wastewater supply and treatment by country are made from a 2010 base year until 2020 and 2030. The table reflects the increasing population sizes based on ADB/UNEP (2004) forecasts, on estimates of current water consumption, and estimates of percentage coverage of the population by municipal water supply and sewerage. For future dates, I assumed that the countries are on a path toward meeting the MDGs in terms of coverage and increasing per capita use. Table 2 shows the joint effect of increasing urban populations, increasing coverage by water systems, and increasing per capita use. Over the 20-year interval there is a two-and-one-half times increase in the demand for water services! This should be a wake-up call for urban planners and governments in the GMS countries—recall from Table 1 that there is only a 60% increase of the urban populations over the same period.

Similar patterns are observed in Table 3, which considers the 10 largest cities in the GMS. The urban populations are projected by the United Nations only until 2025. This table shows a 50% increase in populations from 2010 to 2025, and a twofold increase in urban water used for water supply and sanitation. This implies that there will be large increases in urban growth outside these major cities.

One important question is what are the energy and total resource implications of the shifts in demands for water supply and wastewater treatment? Table 4 shows the implications of the demand increases on the water resource base itself and on the current electrical energy

Table 2: Urban Water Use, 2010–2030

Country	Water Use (million cubic meters per year)											
	2010 Urban water use				2020 Urban water use				2030 Urban water use			
	Total mcm	Water %	Waste %	lpcd	Total mcm	Water %	Waste %	lpcd	Total mcm	Water %	Waste %	lpcd
Cambodia	23.20	81	67	21	92.29	90	90	60	214.26	100	100	100
PRC												
Guangxi	1,004.91	96	99	243	1,325.03	100	100	248	1,725.72	100	100	250
Yunnan	471.29	97	99	120	939.14	100	100	185	1,639.76	100	100	250
Lao PDR	54.57	72	86	70	104.90	75	75	85	171.51	75	90	100
Myanmar	124.03	75	86	20	411.90	86	86	50	729.32	75	90	70
Thailand	1,022.07	99	95	121	1,623.99	100	100	160	2,454.55	100	100	200
Viet Nam	2,152.05	99	94	218	3,110.97	100	100	235	3,885.88	100	100	250
Total	4,852.12				7,608.22				10,821.00			

lpcd = liters per capita per day

mcm = million cubic meters

Source: For 2010, AQUASTAT FAO, 2005; coverage and per capita usage based on Millennium Development Goals.

Table 3: Populations and Water Demands of Big Cities, 2010–2025

Big Cities	Population (million)			Water use (mcm)		
	2010	2020	2025	2010	2020	2025
Bangkok ^{a, b, c}	6.98	7.90	8.47	308.10	461.48	618.31
Danang	0.84	1.15	1.29	66.68	98.30	117.80
Haiphong ^d	1.97	2.43	2.72	156.75	208.60	248.38
Hanoi ^{a, b}	6.50	7.62	8.43	517.21	653.61	769.24
Ho Chi Minh ^{a, d}	6.17	8.07	8.96	490.71	691.95	817.33
Kunming	3.12	3.69	3.92	136.48	249.23	357.24
Mandalay	1.03	1.33	1.48	7.55	24.29	37.92
Naypyidaw	1.02	1.33	1.50	7.48	24.35	38.30
Phnom Penh ^{a, c}	1.56	2.09	2.43	39.91	64.94	88.59
Yangon	4.35	5.46	6.02	31.76	99.57	153.86
Total	33.54	41.07	45.22	1,762.63	2,576.32	3,246.97

mcm = million cubic meters

Note: Hanoi 2020–2025, estimated by author.

a World Bank's Rapid Assessment list (ESMAP, 2010)

b Asian Green City Index list (Siemens, 2011)

c SEAWUN list (2005)

d SEAWUN lists (2005, 2007)

supply for each of the countries (there were no data available for Guangxi and Yunnan). The water supply and sanitation (WSS) water demanded in 2030 will range from 164% of total 2005 municipal and industrial water use for Cambodia to 19% for Myanmar. For the water-sector energy demands as percentages of 2008 electric supply, the 2030 results imply only 1.6% for Thailand and 11.6% for Cambodia (there were no available data for Lao PDR). These results imply that as countries like Cambodia, Lao PDR and Viet Nam become more economically developed, there will be increasing conflicts between agricultural and non-agricultural water use, but

their urban electrical energy use behavior will become closer to that of the industrialized world.

This situation is seen much more clearly in Table 5, which predicts the electrical energy use for the urban water sectors in the 10 large cities in the GMS. The 2030 WSS as a percentage of the 2010 energy use for the cities as a whole takes on some alarming proportions—an average of 15%, with some cities (Mandalay, Phnom Penh, and Yangon), indicating that major attention will have to be given to improving the energy efficiency of the water sector.²

Table 4: Water and Energy in 2030 as a Percentage of Current Total Water and Energy Use

Country	Available Water km ³	2005 M&I Water Use mcm	Urban % 2030/2005	Available Electricity gwh	2030 Elec WSS gwh	% of 2008 Electricity Supply
Cambodia	476	130	164.81	1,835	214.26	11.68
Lao PDR	334	300	57.17	N.A.	171.51	N.A.
Myanmar	1,046	3,820	19.09	6,672	729.32	10.93
Thailand	410	5,500	44.63	149,032	2,454.55	1.65
Viet Nam	891	4,270	91.00	76,269	3,885.88	5.09

gwh = gigawatt hour

km³ = cubic kilometer

M&I = municipal and industrial

mcm = million cubic meters

N.A. = not available

WSS = water supply and sanitation

Note: no data available for Guangxi and Yunnan.

Uses average energy usage of 1.0 kwh/cubic meter for entire water/waste cycle.

Source: FAO, 2010; International Energy Agency (IEA) statistics, 2011.

² *Basis for calculating energy intensity.* For estimating the energy intensity of water and wastewater, the following reports were used; for the sake of simplicity a figure of 1.0 kwhe/cubic meter for combined water and waste supply and treatment was used. Cheng (2011) calculates the electrical energy requirement for providing 35 mgd of 0.22 kwhe/cubic meter for water supply alone; the World Bank's Rapid Assessment Framework (ESMAP, 2010) gives a range of 0.1–0.59 kwhe/cubic meter for potable water and 0.21–0.59 kwhe/cubic meter for wastewater; NRDC (2004) reports 0.77 kwhe/cubic meter for potable and waste treatment, and distribution; and the New York State Energy and Research Development Authority (2008) reports a national average of 0.36 kwhe/cubic meter for potable water supply, 1.25 kwhe/cubic meter for secondary treatment, and 1.78 kwhe/cubic meter for tertiary.

Table 5: Energy Use for Water and Wastewater in Major GMS Cities, 2010–2025

Big Cities	Annual Energy Use for Water and Wastewater Together							
	kwh/capita/year	2010 gwh	2010 WSS	2010 %	2020 WSS	2020 %	2025 WSS	2025 %
Bangkok ^{a, b, c}	2157	12,294.90	308.10	2.51	461.48	3.75	618.31	5.03
Danang	728	610.06	66.68	10.93	98.30	16.11	117.80	19.31
Haiphong ^d	728	1,310.40	156.75	11.96	208.60	15.92	248.38	18.95
Hanoi ^{a, b}	1000	6,500.00	517.21	7.96	653.61	10.06	769.24	11.83
Ho Chi Minh ^{a, d}	728	4,171.44	490.71	11.76	691.95	16.59	817.33	19.59
Kunming	2000	6,400.00	136.48	2.13	249.23	3.89	357.24	5.58
Mandalay	100	125.00	7.55	6.04	24.29	19.43	37.92	30.33
Naypyidaw	200	186.00	7.48	4.02	24.35	13.09	38.30	20.59
Phnom Penh ^{a, c}	93	123.69	39.91	32.27	64.94	52.50	88.59	71.62
Yangon	100	453.00	31.76	7.01	99.57	21.98	153.86	33.97
Total		32,174.49	1,762.63		2,576.32		3,246.97	

kwh = kilowatt hour

gwh = gigawatt hour

WWS = water supply and sanitation

Note: Hanoi 2020–2025 estimated by author. Assume Danang same per capita as Ho Chi Minh.

a World Bank's Rapid Assessment list (ESMAP, 2010)

b Asian Green City Index list (Siemens, 2011)

c SEAWUN (2005)

d SEAWUN lists (2005, 2007)

6. Improving the Efficiency of Urban Water and Energy: Sustainable Cities

When dealing with the approaches to solving the problems of sustainable water resources for urban areas, the type of problem addressed and the scale of the potential solutions must be defined clearly. There is a large and growing literature and databases on sustainable cities. Much of the literature (Hao *et al.*, 2010), however, focuses on smart buildings rather than entire cities. Moreover, the discussion tends to focus on new buildings rather than retrofit of the existing building stock of old traditional infrastructure. The literature also bifurcates into those specializing in actual here-and-now cases and those promoting future potential developments.

Unfortunately, many of cases reported are still largely hypothetical. Hard data on actual cases are difficult to find. For example, hypothetical cases like Qingdao and Dongtan, near Shanghai, are widely discussed (Hao *et al.*, 2010) and promoted because of their widespread integrated energy-water-transport systems approaches, but cases like The Solaire in Battery Park City, New York, or Dockside Green in Victoria, Canada, which have successfully integrated buildings, or multiple buildings with new construction and the rehabilitation of existing cities, receive little attention. While future-oriented studies are helpful in structuring future possibilities, performance data from actual experiences are more useful guidelines as to what is realistically possible.

The examples of Solaire and Qingdao are illustrative of the wide discrepancy between the empirically based data and the hypothetical data used in future-oriented studies. The Solaire has consistently achieved a 48% water-consumption reduction in comparison with comparable residential buildings in New York City and a 56% reduction in wastewater discharge. This water and wastewater reduction is achieved by a combination of wastewater reuse and water conservation where nonpotable water is distributed in closed-loop systems for uses that include toilet flushing, cooling tower make-up, laundry, and irrigation. Each building in The Solaire development is unique and the exact components vary somewhat, but the overall program of wastewater and rainwater reuse remains the same. The Qingdao Eco-city is repeatedly quoted as an excellent approach to making cities more sustainable with 85% water savings and 100% energy savings. Unfortunately, like most of the future-oriented cases, the basis for the calculations is often optimistic or unrealistic. Wherever possible, I recommend that actual performance of integrated water and waste-recycling data be used instead of the hypothetical data.

Hao *et al.* (2010) provide a critical review of city-scale developments aimed at improving the actual water and energy nexus. Hammarby Sjöstad (Sweden) actually has been developed; Dongtan, planned near Shanghai (PRC), is apparently one of the first comprehensive conceptual eco-city developments. The final population was planned to be 500,000 around 2050. However, its construction

is currently on hold. For Qingdao (PRC), eco-blocks are the foundational units in Fraker's (2008) concept of the eco-city. A super block is a typical high-rise residential development in the PRC, usually 100–200 ha with 2,000–10,000 residential units housing 6,000–30,000 people. The PRC is now building 10–15 super blocks per day. Two well-funded projects underway are in Tianjin (PRC) with \$9.7 billion invested and Masdar (United Arab Emirates), with an expected funding of \$22 billion. Two projects already developed in the United States are Treasure Island and Sonoma Mountain Village, both in California.

Table 6, from Hao *et al.* (2010), pulls together some of the salient facts about water and energy conservation in these projects. Note the huge differences between the water savings claimed for the three projects actually developed (Hammarby, Treasure Island, and Sonoma Valley) and those in planning stages. The energy savings reported for the developed projects are remarkably close to those predicted for the remaining projects, implying that energy conservation is inherently easier to accomplish than water conservation at the household and project level. Table 6 also shows the very large range of costs per unit. Fraker (2008) claims that the sustainability initiatives embedded in Qingdao would increase the capital costs by 5%–10% but the value of annual operation and maintenance savings would give payback within 10 years.

7. Conclusions

The simple models used in this paper show some unexpected results. First despite the relatively low rates of total population growth in the region, urban populations are likely to increase substantially by 2030, but the large cities in the region will experience a modest increase of about 30%. This implies that there will be big population increases in the smaller cities and towns in the region. The really surprising result is that in the face of this population increase there will be an almost tripling increase in the demands for urban water supply and management because of increasing development and the push toward attainment of the MDGs. This implies for Viet Nam a doubling of available water just for urban (M&I) uses, and as low as a 20% increase for Myanmar. For Viet Nam it may be difficult to meet the needs of agriculture and other water users if it needs so much for urban uses. Based on the electricity available in 2008, the 2030 electricity demands just for urban water supply and wastewater could amount to as much as 12% for Cambodia and 5% for Viet Nam.

For the current large cities in GMS, the electricity demands for the urban water sector could be as much as 71% of the 2010 electricity supplied for Phnom Penh, and as low as 5% for Bangkok. Of course, each city and country

Table 6: Water and Energy Performance in Eco-cities

City	Population Total	Population Density #/ha	Water Use lpcd	% Water Reclamation & Recycle	Water System ^a	% Energy Savings	Green Area m ² /person	Cost \$/unit ^b
Hammarby Sjöstad	30,000	133	100	0	Linear	50	40	200,000
Dongtan	500,000 (80,000) ^c	160	200	43	Linear centralized	100	100	~40,000
Qingdao	1500 ^d	430	160	85	Closed loop	100	~15	?
Tianjin	350,000 (50,000) ^c	117	160	60	Partially closed	15	15	60,000–70,000
Masdar	50,000	135	160	80	Closed loop	100	<10	1 million
Treasure Island	13,500	75 total area 150 built	264	25	Mostly linear	60	75	550,000
Sonoma Valley	5,000	62	185	22	Linear centralized	100	20	525,000

a Linear system is a once-through flow system from which a portion of used water may be reclaimed and used for another use (e.g., drinking water for irrigation); closed system returns highly treated reclaimed water back for reuse

b Based on average 2.5 members per household

c Phase I

d Qingdao eco-block

Source: Hao *et al.* (2010, Table 2.8).

is currently embarked on extensive expansion of their electricity supply capacity, such that electricity capacity will grow along with the demands. Unfortunately, this is not the case with water supply. There are some serious limits on water availability, hence the need to conserve water in this sector. This may be quite difficult given the pressures to expand the actual quantities of water supplied and broaden the coverage of the systems.

The analysis presented in this paper has two major problems. First and foremost is the absence of reliable data on urban water and electricity use. Equally important is that the model does not really reflect the economic behavior of the consumers who ultimately drive the systems. Nevertheless, this simple model does provide some confidence that there can be a sustainable urban future in the GMS without resort to the fancy integrated water and energy solution promoted in Hao et al. (2010), provided that careful attention be paid to the water management in the cities. One major concern, however, is the potential reduction in water available for agriculture in all the countries in the GMS region; this needs careful study.

For the sake of comparison, consider that London, which was the 30th largest city in 2010 with 8.6 million, did not make it onto the United Nations list of top 30 by 2025. In 2002, London was the subject of a comprehensive study on its resources flow and urban footprint (Chartered Institution of Wastes Management, 2002). For the year 2000 with a population of 7.4 million, Londoners consumed 154,400 gigawatt hours (gwh) of energy (including 85,494 gwh as actual electricity use), 49 million tons of materials (of which 27.8 million tons were used in the construction sector), generated 27.8 million tons of waste, and consumed 6.9 million tons of food, and 876 million cubic meters of water. This was translated by the study into an ecological footprint of 49 million global hectares³ (the equivalent size of Spain) comprised of 44% for materials and waste, 41% for food, 10% for energy, and only 0.3% for water.

It is apparent that the study did not consider the almost 800 million cubic meters of wastewater as 800 million tons of “waste.” Had it done so, water may have been a larger contributor to the ecological footprint. Nevertheless, the contribution of food was extremely important. In the context of the GMS, the food component would be directly related to land and water use in the urban hinterland of

the cities. The inclusion of food in this paper would have certainly highlighted the conflicts for land, water, and energy, which would overwhelm the narrow view taken in this paper.

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³ The global hectare is a measure of bio-capacity.

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FOOD SECURITY IN THE GREATER MEKONG SUBREGION: HISTORICAL PERSPECTIVES FROM THE MEKONG COMMITTEE

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Abstract

The Committee for the Coordination of Investigations in the Lower Mekong Basin (otherwise known as the Mekong Committee) carried out substantial agricultural research from 1966 to 1976, and many of their findings remain relevant to current efforts to address food security in the Greater Mekong Subregion (GMS). While the Mekong Committee was concerned primarily with water resources development, it also recognized that population growth, overexploitation of natural resources, and the inevitable spread of modern technology to agriculture would pose challenges to rural communities. It established an innovative network of “pioneer farms” where new approaches would be tested under practical field conditions at a scale of 5,000 to 10,000 hectares.

Even as early as 1966, this agricultural research was guided by a vision of sustainable agriculture that would be able to adapt to changing conditions, draw on locally-available resources, and maintain a healthy supporting environment in the agricultural matrix. Forty-five years later, this is still a modern approach. Research addressed land preparation, water distribution, use of agricultural chemicals, crop storage and transport, marketing, and finance. While much of the research took a long-term perspective, some activities were designed to yield short-term benefits that were specific to local needs and available resources. It was also recognized that agricultural development and food security would require different approaches in the poorer uplands and in the lowlands where more intensive farming systems could be applied; but the overall approach required considering the system as a whole, using the watershed as an appropriate scale for coordination.

One major finding from this substantial body of research was that water shortage at the end of the dry season would be a significant limiting factor to food security, calling for significant investments in new cropping systems, water resources management, and agricultural infrastructure.

Such investments would build on the integration of both conservation and development of the natural resources of the GMS to ensure optimal overall sustained production, and it was expected that this would lead to surpluses of food, feed, and fiber by the early 21st century. This paper describes some of this work, showing that approaches that were considered innovative in 1966–1977 are today in the mainstream of sustainable agriculture, with considerable credit going to the program of cooperation in the GMS.

1. Introduction

As the world’s 12th longest river (4,350 km) with an average flow of 16,000 cubic meters per second, the Mekong has always been the dominant focus for the people who lived within its 810,000 square kilometer drainage. The six countries that share the river, (Cambodia, People’s Republic of China [PRC], the Lao People’s Democratic Republic [Lao PDR], Myanmar, Thailand, and Viet Nam) each have a rather different relationship with the river, depending largely on where the river affects their respective country. The Mekong in the PRC (where it is called the Lancang) cuts through deep mountain gorges in Yunnan Province before beginning to flatten out as it enters the Lao PDR and Myanmar. For mountainous Lao PDR, the river is a dominant source of fish, transport, irrigation water, and hydropower on its tributaries. For Thailand, it provides similar services, but is not as dominant because the Chao Phraya River services the most productive part of the country, rather as the Irrawaddy and Salween do for Myanmar. For Cambodia, the Mekong has been the essential source of its spectacular civilization (with the temples of Angkor Wat and its predecessors), based on the Tonle Sap (Great Lake), which is seasonally fed by the river. And for Viet Nam, the delta of the river provides some of the country’s most important rice-growing lands, along with a rich fishery.

This very brief and incomplete introduction is merely to make the point that bringing such diverse countries and interests together to develop the resources of the lower Mekong Basin was a daunting undertaking when the Committee for the Coordination of Investigations in the Lower Mekong Basin (which did not include Myanmar or the PRC) began its agricultural program in 1966. This paper summarizes some of the main historical contributions that were made to agriculture by The Mekong Committee, as it came to be called. It draws on a more comprehensive historical review (Van Liere and McNeely, 2005).

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While the agricultural development program sponsored by the Mekong Committee was concerned with both short-term and long-term needs, its primary objective was the basin's long-term sustainable development (long before that term came into vogue). Such long-term planning was seen to be essential for three main reasons: the population was certain to grow, especially as development provided more opportunities to the resident farmers; overexploitation of natural resources was already apparent, and would need to be addressed as part of any development effort; and the large-scale application of modern technology was considered to be inevitable as transport systems and markets improved for many people who had long lived on the edge of subsistence.

A critical element was the recognition that improved farming was going to require experimentation and innovation rather than simply importing approaches that had worked in other settings. The agricultural experimentation was expected to develop new methods for enhancing agricultural production and to test them under controlled conditions at a sufficient scale to provide meaningful results. This gave birth to the idea of "pioneer agricultural projects" covering 5,000 to 10,000 hectares, including development of farm management practices, such as land preparation, water distribution, use of appropriate amounts of agricultural chemicals, crop storage, marketing, and financing. The pioneer projects tested and demonstrated the feasibility of new concepts in agriculture, beginning with relatively modest areas and progressing to ever larger areas as experience was gained, until eventually the new concepts could be broadly adapted wherever the conditions were suitable. Much of today's agriculture follows the trail blazed by the Mekong Committee.

2. Country Experiences

The lower Mekong Basin was defined as the lands and waters that flowed directly into the Mekong River. This included almost all of Laos (as it was called then) and Cambodia, but a relatively small proportion of Thailand and South Viet Nam (as it was called then). Each country determined its own priorities.

The Thai part of the lower Mekong Basin included a small part of the far north, in Chiangrai Province, most of the northeast (then the poorest part of the country and the most dependent on seasonal rains), and a small part of the southeast. Most of the effort was devoted to the northeast, where the short-term program objective was

to ensure continued economic growth. To this end, the Government launched various general improvement programs, including providing irrigation, improving upland crops, and improving livestock.

Cambodia, the Lao PDR, and Viet Nam were suffering from military conflict through most of the time described here (1966–1976). Their first priority was to regain self-sufficiency in food as quickly as possible. To this end, agricultural production programs were carried out with large-scale public participation, which ensured a speed of execution never before achieved. By the time the Mekong Committee stopped its operations in 1976, it seemed likely that the physical facilities to attain self-sufficiency would be in place in the fairly near future (an optimistic hope, in retrospect, but considerable progress was made toward that hope).

These short-term, even emergency, sorts of development were unlikely to remove the constraints that impeded sustained agricultural production, both technically and organizationally. For example, it was imperative to develop farm systems with sustained yields for the poorer uplands while simultaneously developing intensive and diversified farm systems for the lowlands and to apply these approaches at risk levels that were acceptable to the farmers. Achieving optimal overall agricultural production in both uplands and lowlands required a broader approach and the entire watershed had to be considered. Watershed management played an increasingly important role and watersheds remain the scale that most rural development in the Greater Mekong Subregion (GMS) has adopted. These approaches require patience and a long-term commitment.

Even more challenging than the agro-technical and agro-environmental problems was recognition that agricultural development would very soon be facing water shortages, especially during the latter part of the dry season, when water is most needed but supply is at its nadir. Water was clearly the limiting factor that needed to be addressed. As of 1975, considerable progress had been made in northeastern Thailand and the Lao PDR, where some 15 billion cubic meters of water were being stored in existing tributary reservoirs. A major challenge was that the short-term programs of Cambodia, the Lao PDR, and Thailand all expected to increase the use of water during the dry season, leaving little available for agriculture in the Vietnamese part of the Mekong Delta during the critical months of low flow (March-May). Even worse, saltwater intrusion could become a serious problem in the delta, significantly undermining the quality of the available water.

The water issue remains difficult. More dams on the tributaries may not be able to contribute substantially to further agricultural development of the basin. In northeastern Thailand practically all available sites appropriate for dam construction have already been used. In Cambodia the flows of the tributaries to the Great Lake are small and it depends largely on the mainstream flow from the Mekong. Additional dams on the tributaries in the Lao PDR would be primarily single-purpose power projects, with most of the electricity being sold to its neighbors. Some hoped that local storage, using small reservoirs in the relatively flat plateau of northeastern Thailand and in the Mekong Delta, could compensate for the shortage. But experience has shown that local storage is scarcely effective precisely when it is most needed, at the end of the dry season. It is also costly and occupies much valuable land that could more productively be used to grow crops.

The inevitable conclusion was that the future of agriculture in the basin could be ensured only with significant new investments across a broad front, including new cropping systems, water management, and infrastructure. Sustainable development based on these principles would enable an effective integration of both conservation and development of the natural resources of the lower basin, so that optimal overall sustained production could be achieved. Back in 1975, this was seen as a realistic prospect and assuming it could be achieved, the lower Mekong Basin would satisfy not only its own food needs, but also produce significant annual surpluses of food, feed, and fiber in the early part of the 21st century (Van Lierre, 1977). This has, in fact, occurred in Thailand and Viet Nam, while Cambodia and the Lao PDR remain minor food importers.

In the event, many of these approaches, seen as innovations in 1967–1977, are today in the mainstream of sustainable agriculture.

3. Agricultural Systems

For the purposes of this paper, the basin agricultural systems can be divided into three broad categories: traditional, extractive, and modern (although the categories have considerable overlap and considerable variability is found within each category).

Traditional agriculture includes several systems that have been used in the basin for at least 2,000 years, thus

demonstrating their essential soundness under traditional conditions. These systems can be divided into two main categories: swidden agriculture (mostly in the uplands) and banded field agriculture (mostly in the lowlands).

For both categories, the most important crop is rice; both employ systems of permanent subsistence farming, suitable for closed agricultural economies with low population pressure. Upland farmers require at least 30 hectares (ha) per family to maintain subsistence levels, whereas banded field farmers will generally be self-sufficient with 1.5 to 3 ha depending on the local situation. The total area in use for each type may be approximately equal because the population of upland farmers is only 10% of the total farmer population.

An essential part of swidden agriculture is the great diversity of crops that are grown, to some extent mimicking the diversity of natural forests. The Lua (Lawa) of northern Thailand, for example, grow about 120 crops, including 75 food crops, 21 medicinal crops, 20 plants for ceremonial or decorative purposes, and 7 for weaving or dyes. The fallow swiddens continue to be productive for grazing or collecting, with well over 300 species utilized (Kunstadter, 1970). The most important crop is upland rice, and it is not unusual that 20 varieties of seed rice are kept in a village, each with different characteristics and planted according to soil type, fertility, and humidity of the fields.

Although swidden agriculture has come under wide abuse as being destructive of forests and watersheds, it is highly adaptive to a wide range of conditions and when properly performed it may be one of the least harmful ways of cultivating areas where poor soils, steep gradients, and heavy rainfall make conventional farming methods unproductive or impossible. As practiced by stable groups, swidden agriculture was not particularly destructive of forest, land, or wildlife. Permanent villages were established, moving only if forced to do so by extremes of economic hardship, political disturbance, or population pressure, not as a logical consequence of their agricultural techniques (Hinton, 1970).

Sedentary swidden agriculturalists have a strong interest in maintaining the fertility of the village territory and practice several long-term conservation measures, including

- preservation of stands of timber in and around the swidden to serve as a seed reservoir for new secondary forest;
- sophisticated control of fire (including fire breaks, fire fighters, and coordinated burning);

- early cutting of forest to retain soil moisture, reducing transpiration losses so that swidden soil is often more moist than adjacent forest soil;
- careful rotation of swiddens, using each one for only one year (a second burn or continued use typically leads to the invasion of *Imperata* grass, deflecting the succession from forest to grassland);
- a bush-fallowing period of at least 10 years to allow the flow of nutrients to reverse the trend toward leaching and be recycled into secondary growth plants, which then release their nutrients through burning;
- careful control of weeds (which may be the dominant reason for abandoning a swidden); and
- minimal disturbance of topsoil, thus minimizing erosion.

In recent times, swidden cultivation has revealed some serious limitations. Since per capita land requirements are relatively high and upland agricultural systems seem unable to respond to labor surpluses with corresponding increases in productivity, the pressure of increasing population has forced more intensive use of the available land. The fallow periods are thus shortened, leading inevitably to a decrease in fertility and, ultimately, to *Imperata* grasslands which cannot be cultivated by traditional means. The overutilization of the potentially renewable upland agricultural resources has led to an essentially permanent depletion of those resources and reduced carrying capacity of the land.

Another variety of unstable swidden agriculture was practiced by an estimated 15%–20% of lowland farmers. Lowland swiddening is typically very destructive because land titles are seldom involved in the clearing of reserved forests, so the farmers have little motivation to take long-term conservation measures. Short periods of cultivation are followed by periods of fallow that are too short to restore soil fertility, leading to permanent abandonment of the land. Fire control measures are usually neglected and since the lowlands are usually covered by fire-prone deciduous forest, the dry season often experiences massive destruction of forested land. The extent of dry season fires in the plains of northern Cambodia is especially notable.

More sophisticated from the point of view of traditional technology is banded field farming, which has been practiced in the basin for at least 2000 years. Much of northeastern Thailand, southeastern Cambodia, and the Mekong Delta are covered with an intricate patchwork of small, traditional banded fields. For such farming, the land has to be cleared

(often by using slash-and-burn techniques), leveled, and banded. Experience has taught that it often takes about one generation for a rice field to become optimally productive; apart from perfect leveling, an impervious layer must form at shallow depths in paddies, to keep the rainwater ponded on the field with minimal infiltration losses. Contrary to swidden farming, no fallow periods are necessary other than the annual short fallow period during the dry season.

Since the range of hydrological conditions in the Mekong Basin is very wide, traditional technology was adapted to these conditions with remarkable sophistication, especially in the wide range of traditional rice varieties used.

Another part of this adaptability was traditional water manipulation. In many areas of the basin, banded-field farmers of the lowlands had since time immemorial made small canals that would help to spread wet season floodwater more equitably over their fields. In some areas, the rising waters of the rainy season were managed by temporary weirs and the water diverted for gravity-fed irrigation. Large ponds for domestic use during the dry season are still widespread throughout the basin, especially in conjunction with temples. In a few areas, very large canals were built during the Funan and Angkor periods, and some of these are still in use.

Banded field farming typically involves monoculture; other crops are seldom grown on the same land. Moreover, it is very labor-intensive and requires agricultural tools and draft animals. While optimal upland swiddens may give a slightly higher yield in any given year, their long fallow period means that the sustained yield of banded fields is typically at least 10 times higher than in upland fields. Furthermore, the banded field system is more adaptable to population pressure. The yields of the banded fields typically increase when fields become smaller with population increase, because on smaller farms better care is taken of the crop, weeds are more carefully controlled, and more work is done to ensure satisfactory hydrological conditions.

The traditional banded field systems represent a feat of land reclamation of tremendous magnitude in the lower Mekong Basin. Some 50 million individual banded fields existed in the basin, all constructed by traditional means without the benefits of agronomists, foreign agricultural experts, benefit-cost analyses, and loans from the international assistance agencies.

The rich store of down-to-earth technology for traditional agriculture was efficiently adapted to each micro-ecological

situation. This invaluable knowledge remained intact throughout the ages, in spite of historical vicissitudes. Civilizations may come and go, but the efficiency of the individual subsistence farmer seems to remain untouched. However, traditional farming systems evolved for traditional population levels, so their potential for further expansion is limited.

Beginning about 1860, traditional banded field farming entered a phase of rapid expansion. Stimulated by foreign markets and cash demand for rice surpluses, the area under rice cultivation in the Mekong Delta increased from 170,000 ha in 1872 to 1,300,000 ha in 1908, an increase of 4.7% per year. Most of the increased production was exported, with the exports of rice from Ho Chi Minh City increasing from 58,000 metric tons in 1860 to 900,000 tons in 1910, an increase of 5.6%/year (Owen, 1971).

The Vietnamese had begun opening up the delta by constructing canals as early as the beginning of the 19th century, and this development gained considerable impetus late in the century. The policy was to give large land grants to Vietnamese, Chinese, and French investors, who then recruited tenants to build canals, clear the land, and cultivate the fields. The Government built only a few of the largest canals (sometimes following the same pattern as canals built during Funan times, 15 centuries earlier). The new canals provided some limited drainage, but their most important function was to provide access to markets through boat transport; irrigation was minimal.

These developments, using essentially traditional techniques but stimulated by foreign markets and some limited foreign technology, led to a great increase in population. In 1880, an estimated 1.7 million people were living in “Cochin China”, but by 1930, this figure had increased to 4.5 million, an annual rate of increase of 2% (Netherlands Delta Team, 1974). The population has subsequently increased to over 20 million.

In the Mekong Delta, rapid expansion of agricultural land was in some ways detrimental to sound agricultural development. The way rice was farmed underwent virtually no significant changes; yields rather than increasing seem to have fallen slightly between 1880–1890 and 1930–1950, apparently due to the application of traditional technology to land somewhat less suitable for agriculture (Owen, 1971), although the time-lag factor in obtaining optimal yield from new rice fields may also contributed. The increases in crop yields which characterized agricultural development in other parts of Asia (PRC, Japan, Republic of Korea)

were rendered unnecessary by the ready availability of large expanses of new land in the river deltas of Southeast Asia.

The expansion of agricultural land and traditional agriculture has reached its limits in the lowlands and has exceeded its limits in the uplands. This is now the situation in much of the northern Lao PDR, northeastern and northern Thailand, and parts of the Annamites; it was historically the case in northern Cambodia, where much of the area was cleared of forest during the Khmer civilization, resulting ultimately in permanently depleted soils that can still be clearly seen by satellite imagery. The only alternative for increasing agricultural productivity was to increase the yields on the available land, and the Mekong Committee decided that this could best be accomplished by the techniques of modern sustained-yield agriculture.

Irrigation was expected to have many advantages. Cropping diversity would be greatly increased, with a wide variety of crops grown on what was previously monoculture rice-growing land; these would include maize, peanuts, cassava, tobacco, mung beans, cotton, and a wide variety of fruits and vegetables. Cropping intensity would also be greatly increased, ranging up to 200% (double cropping). Yields would dramatically increase, with rice yields, for example, increasing from 0.7–1.6 tons/ha to 3.0–4.0 tons/ha or even more with high yielding varieties. In addition, yields in nonirrigated areas would also increase modestly, due to improved extension, markets, and other services that will be stimulated by the greater economic productivity of irrigated areas. Net farm income and employment opportunities would double, while land value would triple.

4. The Role of Forests and Fisheries

The Mekong Committee felt that in the long run the forests may play an even more important role in human economies through their capacity to produce fuel and raw materials on a sustained-yield basis. The forests should be regarded as a renewable resource that with proper management can give sustained yields for the indefinite future. Unfortunately, overexploitation and lack of management have drastically depleted the forests in recent decades. The indications are that the rate of depletion, due to population pressures and modern technology, is far beyond the natural ability of the forests to replenish themselves. Much forested land is being converted to grasslands that are permanent in time scales relevant to land-use planning, and a major effort is

required to conserve existing forests, re-establish depleted forests, and establish plantation forests to meet the basin's requirements for forest resources.

Studies sponsored by the Mekong Committee have produced some fairly comprehensive assessments of the terrestrial and aquatic fauna of the lower basin. These show that the basin supports at least 212 species of mammals, 696 species of birds, 213 species of reptiles and amphibians, and 800 species of fish. Ten of the mammals are endemic (found only in the Mekong Basin) and 14 are considered rare and endangered. The basin birds include about 500 resident species (at least 12 endemic) and another 160 as winter migrants. Generally, the faunal diversity closely follows floral diversity, with the greatest diversity in the evergreen forests and the least in agricultural areas.

From the point of view of agricultural development, the main significance of wildlife is its role in controlling agricultural pests and as a genetic resource. The role of wildlife in controlling pests in the lower basin cannot be quantified because of lack of data but generally this role is indicated to be a major one and merits careful evaluation and assessment. With regard to genetics, the domestic animals of the lower basin not only were derived from wild species but the wild species represent in some cases raw material for developing new breeds with superior disease resistance and ability to adapt to the available food supplies.

Increasing population pressure means that the prospects for protecting the remaining forests and wildlife appear dim indeed, considering the many other problems facing the governments of the riparian countries. The Mekong program therefore focused on designing practicable remedial measures that are realistic in terms of implementation, particularly if considered and implemented as an integral part of overall water resource development planning. It appeared that the only conservation measure that could be successfully implemented at this time would be to establish a series of protected areas to preserve typical portions of the forest habitats throughout the basin, integrated with modernization and intensification of agriculture in the lowlands. A system of 29 national protected areas was suggested, totaling about 7% of the lower basin land area, including existing protected areas (McNeely, 1975). Moreover, these protected areas should be considered as "core areas" for larger land and resource management areas surrounding and incorporating them. Within the core area, no extractive activities would be allowed but the forest resources of the surrounding buffer zones would be subject to limited utilization for the benefit of the local residents.

An important aspect of the Mekong program's approach to conservation of natural resources was recognition that comprehensive water resource development in the lower basin affords an opportunity to protect forest habitats and wildlife. It is clear, by projecting current trends, that without urgent action, the forest habitats and wildlife are doomed to near extinction. However, incorporating the conservation measures noted above into water resource project development, as an integral part of these projects, and thereby ensuring the means for financing and administering these measures, provides hope for some very real progress even in the short period of the next few decades.

The aquatic fauna of the lower basin is very rich indeed, including over 800 species of finfish alone. The finfish, together with shellfish, are by far the most important animal species economically and nutritionally and also offer the greatest potential for continuing development through aquaculture. In view of the importance of fisheries to the economy, the Mekong program included a basin-wide fisheries study, the first such comprehensive attempt to quantify the complex fisheries of the basin (MBFS, 1976). While by no means representing a complete assessment of the basin fisheries, the study furnished sufficient hard data to provide the basis for basin water resource planning at this stage of the Mekong program.

In general, the fishery gains in the new reservoirs and from downstream aquaculture can both compensate eventual losses and, with good management, result in a large net increase in fish production both on a regional basis and from locality to locality. The Mekong program therefore focused on (i) achieving optimal production of desirable species from reservoirs, and management of the reservoir fisheries to ensure optimal socioeconomic gains (such management would include licensing of fishers, establishment of fishers' associations, and facilitating provision of infrastructure, such as storage and marketing facilities); and (ii) developing the most appropriate technologies for construction and operation of aquaculture systems, including improvements in fish food supplies and developing the apparently lucrative aquaculture potential of brackishwater delta areas.

5. The Agricultural Development Model of the Mekong Committee

In 1958, a mission from the Food and Agriculture Organization of the United Nations (FAO) led by G.H. Bacon was assigned to study the available basic data related to

the agricultural, fisheries, and forest production of the lower Mekong Basin, with special reference to the potential for water resources development. The mission was asked to determine the scope and nature of the further investigations that would be necessary to provide integrated knowledge of the agricultural resources of the basin, and to indicate how these resources could be best utilized in the light of the anticipated development of the water resources of the lower Mekong Basin. Their recommendations included: compiling data on climate, soils, and natural vegetation; studying fertilizer requirements, fisheries, salinity, current land use, development of forest industries, irrigation, and hydrology; establishing a set of experimental stations and pioneer agricultural projects; and training students in agricultural fields in foreign countries (FAO, 1959).

In 1961, the Ford Foundation sponsored a team invited by the Mekong Committee to study economic and social aspects of lower Mekong development (White et al., 1962). In the field of agriculture, they recommended that (a) a team of agricultural experts be organized to assess water management as a means of agricultural development; (b) an area of 3,000 to 5,000 cultivated hectares be established as a comprehensive demonstration project where the full impacts of lower Mekong management on rural life could be observed (this was essentially a pioneer agricultural project); (c) studies be conducted on opportunities for fish cultivation in ponds, reservoirs, and natural lakes; (d) prospects be assessed for marketing of rice and other potential agricultural products from irrigation, flood-control, and drainage projects; (e) maps of soils, water balance, and vegetation types be compiled from already existing material; and (f) land capability, land use, forest cover, and settlement patterns be inventoried by aerial photo interpretation. These sound like standard approaches today, but they were innovative 50 years ago.

These two reports were designed to form the early conceptual background for the agricultural work of the Mekong Committee. This was followed in January 1969 by a request from the Mekong Committee to FAO and the United Nations Development Programme (UNDP) to carry out a review of the experimental and demonstration work on irrigated agriculture initiated by the Committee on the basis of the Bacon and White recommendations. The joint FAO/UNDP mission was also asked to recommend guidelines for long-term planning of agricultural development in the basin (UNDP, 1969).

In July and August 1969, the joint mission visited the four riparian countries, finding that the work of the agricultural

stations sponsored by the Mekong Committee was not sufficiently well coordinated and the research projects were not clearly related to each other; nor were the results of the studies and research being made available for application and use. The stations were found to differ in stages of development, in operational arrangements within the governments, and in the adequacy of their budgets. While as a whole they were considered to constitute a good beginning, their work needed to be strengthened and related to the other research and experimental work carried out in the basin.

The mission recommended that the Mekong Committee should expand to include an Agricultural Division within its Secretariat and an Agriculture Sub-Committee of the Mekong Committee be established, the latter consisting of the four directors-general of the agriculture ministries of the riparian governments. This would ensure that cooperation would not only cover the stations and related works of the Mekong Committee, but would also include all similar undertakings of the riparian governments for agriculture research, demonstration, extension, training, agricultural planning, and institution-building relevant to the Mekong program. The report also called for equitable and wide distribution of benefits among the people of the four countries concerned.

The program subsequently developed by the Agriculture Division followed the basic concepts presented by the review teams. With the recent important breakthroughs in agricultural research, particularly in the development of new high-yielding varieties requiring modern techniques in the use of fertilizers, herbicides, pesticides, and water control, Mekong development became even more critical to the future of agriculture in the countries of the basin. The Mekong Agricultural Research Program was designed to create the basis for a strategy of development that would ensure the quickest possible realization of the benefits of water control provided by the various infrastructure projects that were being constructed.

The program advocated that plans for the development of agriculture in the basin should not be limited to irrigation with full water control but should encompass all patterns of cropping from dry farming to irrigation by gravity with full water control, with numerous intermediate solutions such as irrigation with partial water control, drainage only, pumping groundwater, and pumping directly from the mainstream or tributaries. Watershed management with improved shifting cultivation would also be included in the development program.

The results of these studies would help the basin governments in planning their country development plans. The experimental programs of the individual stations, their locations, and their relation to other stations in the basin, should not be limited by currently envisaged projects, or indeed to any immediate program. Circumstances and conditions in the basin were certain to change over time, and the experimental stations were geared to help agricultural practices evolve with the changing conditions.

The combined research, experimentation, demonstration, extension, and institution building was woven into the work of the Mekong countries and dispersed throughout the basin in order to take account of differing soil and moisture conditions, crops, and cultural patterns. This was the purpose of the pioneer projects, which represented an intermediate step between the demonstration area and full project development. The scope would vary, but in principle the size of a pioneer project should not be broader than required to represent an economic unit where all factors and their interactions could be tested on a “real-world” scale.

In conclusion, the agricultural development model adopted by the Mekong Committee was based on three major consecutive steps: agricultural experimentation and demonstration; pioneer agriculture project; and full project development. Some introductory aspects of each of these steps are discussed below, with further details available in Van Liere and McNeely (2005).

6. The Role of Agricultural Research

Farmers have always been innovators. Traditionally, innovation has been a slow but sure process based on long-term knowledge of local environmental conditions and on a judicious balance between needs and resources. The industrial revolution brought new pressures for increased agricultural production, through the factors of exploding human population and accelerated demand for crops for exports, stimulated by newly-accessible markets and the creation of newly perceived needs. The traditional process of slow but sure innovation was unable to respond very well to the needs of modern agriculture. The inability of traditional technology to meet increasing needs tended to set the stage for accelerated clearing of new land (often unsuitable for permanent agriculture) and the reduction of the fallow periods. This “extractive agriculture” inevitably led to rapid depletion of potentially renewable natural resources.

Thus it was necessary to call on modern agricultural research, based on rigorous scientific techniques and a worldwide fund of information and assistance. However, whether it is used as a means of accelerating the traditional process of innovation or as a tool for the introduction of exotic technology, agricultural research has often met resistance from the traditional farmers. The effect of such resistance is not always negative—it often eliminates technologies that do not bring decisive and certain improvement to the farmer. The resistance was based on numerous constraints, including financial, economic, and technical problems (growing calendar, crops, water control, etc.), and even the simple matter of taste. Mekong Committee research did not ignore any of these aspects of the farmer’s life, but attempted to integrate innovations into the traditional cultural framework.

Agricultural research, taken in a very general sense, was thus a starting point for all development projects, for efforts to halt the destruction of renewable resources, and for the introduction of new, more productive technology. While new varieties of maize and soybeans gave excellent results, the situation was different with rice, which had been cultivated for centuries in the region where the twin forces of selection by humans and by nature have resulted in varieties well adapted to the local conditions. Mekong Committee research showed that only in the Mekong Delta have the imported hybrid varieties found the necessary conditions to express their potential: control of water, subsidies that permit the use of fertilizers, and strong demographic pressure.

The introduction of agricultural machines had some impact in the basin; such machines included tractors, pumps, and small hand tractors with attachments. Tractors were typically owned by entrepreneurs who rented their machines and services to farmers on a contract basis per unit of land plowed (often to be paid after harvest); tractors were also used for local transport of agricultural produce, shelling corn, and many other farmyard tasks that significantly reduced the labor of the individual farmer. Improved hand tools were also developed at some of the research stations, but relatively few examples of new equipment adopted by farmers have resulted from research in the basin.

Livestock research was another generally neglected field, possibly because milk and beef have not been important in the traditional diet of most basin residents. While the wild cattle of the basin (gaur, banteng, and kouprey, the last mentioned probably now extinct) are massive, handsome beasts, domestic cattle tend to be rather scrawny, with little

meat or milk (being used mostly as draft animals). Private investment in ranching in Thailand was not yet profitable because of difficulty in developing an appropriate diet for breeds that are optimal for basin conditions; marketing has also been a serious problem. However, much of the basin area seems appropriate for grazing, so research and development of suitable grasses and legumes were expected to be greatly expanded in the future.

The Mekong Committee concluded that research had been a profitable activity in spite of all of its insufficiencies. However, this is neither wholly reassuring nor satisfactory. The first steps were usually the easiest and most profitable, as in the case with varietal selection, while breeding involves much greater effort and is rarely followed by rapid success. Research was thus expected to become increasingly costly, and would be justified only if it led to significant results. The ample potential for increased impact was suggested by the yawning gap between yields in the research stations and on the farmer's fields, and new research methodologies subsequently accelerated levels of production.

The best way to communicate research results to farmers is through an intermediate level, where a working model is designed to deal with the actual physical, economic, environmental, and organizational problems likely to be encountered in the implementation of full-scale agricultural development projects. The Mekong Committee therefore established a system of such models in the lower Mekong Basin, called "pioneer agriculture projects."

7. Pioneer Agriculture Projects

The Mekong Committee's vision of developing the water resources of the lower Mekong Basin included the irrigation of extensive areas of land. Although the basin farmers had for centuries practiced forms of agriculture based on sophisticated use of monsoon rains, they had very limited experience with modern irrigation. To help solve this problem, the pioneer agriculture projects were designed to remove many of the constraints that prevented the effective implementation of irrigation. Under this program, one or more pioneer projects was established in each of the riparian countries, including representation of all the major soil types and cropping patterns found in the lower basin.

The Bacon and White reports in the 1960s set the stage for the pioneer projects, but several more years of continuing efforts were required before the pioneer projects finally

became established. In July 1967, a joint committee of representatives from the governments of the Lao PDR and Thailand and the Mekong Secretariat reviewed research requirements. One of the relevant conclusions of this committee reads: "The Committee urges that a pilot irrigation scheme, in the magnitude of 10,000-20,000 ha, be centered in one of the newly constructed irrigation systems in northeast Thailand to consider all aspects of irrigated agriculture. Attention should be given to such key factors as farm size, land clearing and development methods and costs, marketing, farm credit, farmer inputs in crop production cycle, potential of developing agribusiness activities, and farmer education processes; further recommends that development channels of governmental, quasi-governmental and commercial nature be exploited to achieve maximum success in the shortest possible time."

In January 1968, the Mekong Committee approved the general aims of large-scale pioneer projects. It decided that "A pioneer project is the first sector of development in a large-scale irrigation scheme. Several thousand families are involved in each such project; these pioneer families should receive whatever assistance is necessary. The main function of a pioneer project is to build up the necessary organization for the efficient management and maintenance of the larger developments that are to follow."

The selection of this first pioneer project in northeastern Thailand was made in January 1969, at a meeting held at Khon Kaen, under the chairmanship of Dr Boonrod Binson, Member of the Mekong Committee for Thailand, with representatives from all government agencies concerned as well as the Mekong Secretariat. The project selected at this meeting (Nong Wai) was prepared by the Asian Development Bank (ADB). The general terms of reference of the project covered four main fields, irrigation, technical and scientific aspects of agriculture, the farmer, and marketing.

A review of the Mekong program undertaken by the World Bank in 1970 concluded that the Committee's pioneer agricultural programming was an undertaking worthy of being pursued and that a good many advantages might be obtained from a concerted program for pioneer projects in the context of Mekong development, instead of by a country-by-country approach. Advantages included

- greater momentum of development and with more efficient means, such as better training programs, transfer of experience to all four riparian countries, more efficient use of development

assistance (e.g., personnel and contracts), and fewer constraints on participation by riparian country personnel;

- greater appeal to the four riparian countries and effective interest in the individual pilot projects, particularly when associated with development of large scale projects; and
- greater appeal to cooperating donor countries interested in agricultural development of the Mekong and that have expressed on many occasions the priority they attach to pilot projects.

Encouraged by the initial discussion with the World Bank, the Mekong Committee formulated the scope and objectives of a comprehensive Pioneer Agriculture Projects program in 1971. The Committee then submitted a request to UNDP for assistance in the detailed preparation of the agriculture pioneer project program for the lower Mekong Basin. Subsequently, it was agreed that part of the studies provided for in the Plan of Operation would be delegated to the ADB with the World Bank retaining the overall responsibility for the program. The agreement provided for participation by ADB in all consultations relevant to the program.

The pioneer projects program by 1977 included 11 projects in addition to those prepared earlier (Nong Wai in northeastern Thailand by ADB). The planned pioneer projects program included

- three projects to provide pump irrigation facilities for riverbank areas in Cambodia, the Lao PDR, and northeastern Thailand. The projects would explore different infrastructural requirements for the intensification and diversification of land use that could eventually be applied to an estimated 500,000 ha of fertile levee soils on the Mekong and its tributaries;
- an irrigation rehabilitation project in Cambodia that would restore and improve a gravity irrigation scheme of about 30,000 ha that used the unregulated flow of a tributary of the Great Lake;
- a project that would develop staff, facilities, and organizational framework for systematic identification, adaptation, testing, and dissemination of cultivation practices and seek technology suited for the improvement of rainfed rice cultivation in northeastern Thailand;
- a project in northeastern Thailand that would improve irrigated agriculture in the command area of three small reservoirs, giving special consideration to the establishment of project organizations under local control with farmer participation in operation

and maintenance of these minor irrigation works; a viable mode of development for these three reservoirs or “tanks” could form a model for a large number of the existing tanks in northeastern Thailand and might open up the possibility of further developments of this type in other parts of the Mekong basin;

- a project in the coastal zone of the Mekong Delta that would establish an integrated salinity control system for a 50,000 ha area. The project would take maximum advantage of existing embankments and salinity control structures. Within this system, the pioneer project would develop modes of system operation to improve surface drainage in the wet season and to extend the period in which freshwater was available in the canals for irrigation by means of low-lift pumps. The project would contribute to the detailed formulation of larger-scale projects designed to protect and improve an estimated 1 million ha in the saline coastal belt of the Mekong Delta; and
- a project in the flood zone of the Mekong Delta that would promote low-lift pumping from existing drainage and irrigation canals to introduce dry-season cropping in a 30,000 ha area that was primarily devoted to floating rice cultivation. The project would test irrigation techniques and on-farm developments likely to be relevant for the intensification of land use in the flood zone of the delta, which comprises about 300,000 ha.

8. Conclusions

Agriculture in the lower Mekong basin is complex because of the wide diversity in climatic, soil, and water supply conditions, and because of the rapid technological changes that were taking place in many parts of the lower basin over the past several decades, including changes in agricultural methods and practices.

The innovative agricultural development model adopted by the Mekong Committee consisted of three major components. First, research on new and improved crops and techniques is conducted at experimental and demonstration stations. Second, the results of this research are applied to a full-scale project for testing under practical conditions in pioneer agriculture projects, which are essentially proposals for development strategies. Third, the new agricultural systems that were shown to be successful on a pioneer level would be applied to

appropriate areas in the lower Mekong Basin. The first two steps were begun by the Mekong Committee, but full project development was still in the future.

Other innovations by the Mekong Committee that have stood the test of time (although not always with full implementation) include

- working at the watershed scale, including both upland and lowland developments in the overall plan and considering individual farms as part of a larger landscape that included other land uses as well (an approach that today is often called “ecosystem management”);
- including trees and forests as part of agricultural development, thereby contributing to a healthy supporting environment;
- recognizing that conservation of forests can enhance the value of downstream water resources development, such that including protected areas within large-scale plans could provide significant benefits;
- inclusion of adapting to changing conditions as part of planning and development;
- giving particular attention to locally available resources, especially local knowledge of farmers (who should be included as part of research teams);
- recognizing the importance of fisheries as part of Mekong development (an issue that is of growing importance as more dams are built or planned on the mainstream);
- planning for long-term sustainable development; and
- coordinating all forms of research that had impacts on the development of the lower Mekong Basin, thereby increasing efficiency and accelerating innovation that used modern technologies.

In reviewing the work of the Mekong Committee from half a century ago, it is remarkable how many of the approaches that were then seen as innovations have now become part of the mainstream of development in the GMS. While much remains to be done, a solid foundation was laid by the Mekong Committee, including the basic elements of what has come to be known as “sustainable development.”

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POLICIES FOR LONG-TERM FOOD SECURITY IN THE GREATER MEKONG SUBREGION

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Abstract

Food price trends over the last few years are contradicting decades of improved global food security and are especially threatening to the world's poor. In the Greater Mekong Subregion (GMS), extensive rural poverty persists, making a dual contribution to food insecurity. Because the poor spend the majority of their income and effort on subsistence, food price uncertainty is a paramount livelihood risk. Secondly, smallholder farm production remains dominant in the GMS. For a variety of reasons, however, smallholder productivity and income potential remain well below their potential. This merely compounds food insecurity for both producers and consumers and denies the GMS a potent catalyst for poverty reduction and sustainable growth.

In this study, we review the state of knowledge regarding recent food price uncertainty, as well as the research literature on institutional and technological determinants of agricultural and food supply chain development. This background is then synthesized in a set of policy forecasts that assess opportunities for pro-poor agrofood promotion in the GMS. Our results show that the right combination of policies to facilitate market access, productivity growth, and more efficient regional investment patterns can deliver dramatically improved food security and livelihoods.

The main message of this research is straightforward. Across the GMS, and by extension across Asia, there are large disparities in market accessibility, agrofood productivity, and savings resources for enterprise development. Policies that overcome these disparities can strongly stimulating agrofood development in ways that are economywide and pro-poor, increasing rural incomes and lowering food costs for urban populations.

Investments in infrastructure and institutional reform can help remove the hard and soft barriers to greater market integration (agrofood and otherwise). Expanded agrofood research and extension services can accelerate regional agrofood productivity growth. Finally, more extensive regional capital allocation (via FDI) can shift underperforming investment resources (savings in higher income countries) to develop underperforming agrofood resources (in lower income countries and subnational localities). The result will be higher regional agrofood productivity, with higher commensurate returns to agrofood investment, and a strong pro-poor development stimulus. Poorest countries and areas have the most to gain in percentage terms because their resources have the lowest initial productivity and their domestic savings are lowest.

1. Introduction

After two generations of rising global agricultural productivity and falling average food prices, the last five years have seen disturbing signs of reversal. Surging food prices in 2007-2008 drew attention to food security issues around the world and particularly in South and Southeast Asian economies. About half the world's population, the poorest, have to commit about half their average incomes to food expenditure. This results in increased numbers of people experiencing nutrition vulnerability worldwide and worsened economic conditions in the poorest countries.

These trends are of special significance to the Greater Mekong Subregion (GMS) for two reasons. Although it include some dynamic emerging economies, the GMS is still characterized by extensive rural poverty and consequent high vulnerability to food price risk. Just as importantly, however, the GMS countries have unrealized agrofood potential that is among the world's highest. The region delineated by the Mekong River has great agricultural potential, BUT productivity of the smallholder farming population that dominates the area remains low. Moreover, poor infrastructure and institutional obstacles severely limit market access and agrofood supply chain development.

If these barriers can be overcome, increased demand in higher income Asian economies and higher food prices could support much higher agrofood production in lower income GMS countries and subnational regions, where agriculture is the primary source of livelihood. Higher agrofood productivity and improved market access could

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be potent catalysts for growth and poverty reduction, promoting sustained development and improved long-term food security.

This report surveys the state of knowledge regarding emergent food price risk, and then presents a series of long term policy forecasts showing how improved institutional change and agricultural productivity growth can transform the GMS into a dynamic agrofood exporter. The following section gives a brief profile of each of the GMS economies in terms of agrofood security. Section III, the food crisis of 2007-2008, reviews the literature on causes of high food prices and discusses the possibility of another such crisis. Section IV surveys the research literature on agricultural productivity and its linkage with economic growth and development. Section V presents long term forecasts of GMS agrofood growth and development. The final section concludes with some food-security scenarios.

2. Agrofood Security, Demand and Production: Overview from the GMS Perspective

Developing Asian economies were hit particularly hard by the 2007/2008 food price crisis. Sharp increases in rice and wheat prices threaten the food security of large segments of the population in developing Asian countries where large amounts of household income are allotted for food expenditure and rice and wheat represents a staple in the diet of the region. Faced with rice price increases in 2008 due to a variety of factors certain exporting countries, most notably India and Viet Nam, imposed restrictions on rice exports thus limiting supply in the global marketplace and pushing prices upwards. Meanwhile, large importers, such as the Philippines, were left scrambling for steady rice supply to avoid domestic shortfalls. A similar situation occurred in the global market for wheat in 2010.

This section elucidates the food security and food commodity demand situation in the GMS economies. The People's Republic of China (PRC), source of the Mekong's headwaters, as the world's most populous country, is also the world's largest consumer and producer of agrofood products and thus holds the potential to greatly impact regional and global agrofood markets. Cambodia, Lao PDR, Thailand, and Viet Nam each host the Mekong, Myanmar is embedded in the same regional watershed, and all these countries have distinct sub-regional agricultural conditions. The six GMS members also share two important characteristics in the present context: high vulnerability to food price volatility and significant

unrealized potential for agricultural productivity growth. We summarize these initial conditions in this section.

2.1 People's Republic of China (PRC)

Fan and Bzeska (2010) discuss the rapid increases in productivity that PRC has achieved over the past several decades due in large part to "major policy changes and reforms". From 1961 to 2004 production of maize, cotton, wheat and oilseed experienced average growth of 4 percent annually while rice production increased 2.8 percent annually. Area under harvest increased very little, or even experienced negative growth, as in the case of wheat cultivation while crop yields grew indicating higher rates of agricultural productivity (Fan & Brzeska, 2010).

As of 2009 the PRC was able to meet over 95 percent of its demand for wheat, maize and rice with domestic production (ESCAP, 2009). Despite the PRC's impressive agricultural productivity increases the country holds 25 percent of the world's population with only 7 percent of the world's arable land (Jha *et al.*, 2010). Rising incomes have resulted in an emerging middle class with increasing demand for agrofood products. For example, in the years from 1999-2009 Chinese consumption of milk and dairy rose more than 500 percent. Additionally, the country imports approximately 40 percent of global soybean production (ESCAP, 2009).

If current trends continue it appears that demand in the PRC will outpace domestic production which presents an opportunity for producing countries to meet that demand and increase output. Growing demand for agrofood imports combined with experience of agricultural productivity enhancement gives the PRC the tools and incentive to engage in trade enhancement with promising trade partners. Investment in, and technology transfer to, agricultural supply chains in producing countries combined with tremendous market access may be a boon to agricultural production in the region.

2.2 Cambodia

GDP growth in Cambodia has been strong in recent years averaging 9 percent growth annually before the 2009 global downturn (ADB, 2009a). In 2009 the economy contracted by 2 percent (ADB, 2009a). Despite the robust economic growth Cambodia remains a poor country with more than 25 percent of the population living on less than US\$1.25 per day as of 2007 (ADB, 2009a). The UN Development Program ranked Cambodia 131 of 177 countries placing

it among the poorest countries in the world (ADB, 2009e). Cambodia was hit much harder than Lao PDR by the 2007-2008 food crisis with the prices of rice and fertilizer doubling within a year while meat and fish prices rose a reported 30 to 60 percent (ADB, 2009e). The HLTF (2009b) estimates that the food price rises triggered an increase in the number of food-insecure people in the country by more than 50 percent to 2.8 million people. The impact of food price rises is particularly acute in Cambodia where food accounts for 60 to 70 percent of rural household expenditures with rice alone accounting for 40 to 50 percent (HLTF, 2009b). The lack of storage capacity, inadequate transportation linkages and poor access to market information are major barriers to the improvement of agricultural yields and food security in the country (HLTF, 2009b).

In Cambodia, as in Lao PDR, approximately 80 percent of the population lives in rural areas (FAO, 2011a). Also like Lao PDR, Cambodia's exports of maize have grown substantially over the last decade. In the early 2000s maize was not a significant export of the country and by 2008 maize had become the primary commodity export by value, exporting more than 311,000 tonnes (FAO, 2011c). Other major exports include rubber, palm oil and soybeans all of which are significant imports of the PRC (FAO, 2011c). In 2009 agricultural output expanded by approximately 4 percent with favorable rains cited as a primary cause (ADB, 2010). Aquaculture and marine fishing also increased substantially (ADB, 2010). The ADB estimates that in 2010 agricultural output will likely increase by approximately 4.7 percent (ADB, 2010).

Rainfed lowland rice is the primary crop in the country occupying approximately 69 percent of total cultivated area (Seng *et al.*, 2010). Seng *et al.* (2010) explore the possibilities of improved agricultural management strategies including irrigation strategies and crop diversification to increase yields in those areas with emphasis on the possibilities of poverty reduction through increased yields.

2.3 Lao PDR

Food security is a concern in Lao PDR where the FAO estimates that approximately 19 percent of the population is undernourished (FAO, 2011b). Just under 80 percent of the population lives in rural areas (ADB, 2010). Although the country has experienced strong economic growth since 1990 approximately one-third of the population remains below the national poverty line and as of 2002 44 percent of the population was living on less than US\$1.25 per day (ADB, 2009a). According to World Bank data, although

growing, GDP per capita in the country is US\$940 (World Bank, 2011).

The UN System High Level Task Force for the Global Food Security Crisis (HLTF) reported in 2009 that impact of surging food prices of 2007-2008 was less severe in Lao PDR than in other countries in the region (HLTF, 2009c). The primary staple food in the country, domestic sticky rice, is not imported and thus less vulnerable to international price fluctuations. However other factors have contributed to rice price rises in the country such as severe flooding, a major outbreak of pests, US dollar inflation and rising fuel prices. Therefore, despite the barrier from the impact of global food prices the poorest segments of the population remain extremely vulnerable to domestic price fluctuations (HLTF, 2009c).

Within Lao PDR agriculture accounts for approximately one-third of GDP while employing over 70 percent of the workforce (ADB, 2010). ADB (2010) reported that in 2009 the agricultural sector grew by an estimated 2.3 percent. Increasing demand in the PRC may offer opportunities to Lao PDR to ramp up agricultural production. Such demand has already resulted in a sharp rise in feed-maize exports destined to the PRC (World Bank, 2008). Maize and coffee are the two primary export commodities of the country (FAO, 2011c). Maize exports in particular have grown rapidly over the last decade rising from less than 1000 tonnes in 2000 to more than 126,000 tonnes in 2008 valued at more than US\$14 million (FAO, 2011c).

Millar and Viengxay (2008) find that Lao PDR is in a favorable position to capitalize on rising demand for meat in neighboring countries, particularly PRC. The authors note that livestock plays a major role in the economies of rural communities and increased livestock production and demand for livestock products may significantly contribute to poverty alleviation in the country. For detailed discussion of this issue see Millar and Viengxay (2008).

2.4 Myanmar

Among GMS economies, the Union of Myanmar has the largest share of agriculture in GDP, comprising about 40% according to independent estimates (World Bank, 2011), as well as the highest population share of low-income smallholders, of all the GMS countries. Although Myanmar is classified by its government as a food surplus economy⁴,

⁴ See <http://www.fao.org/countries/55528/en/mmtr/>

sixteen percent of its 51 million population, or a total of 7.8 million individuals, suffer from undernourishment (last recorded 2007, down from 13.5 million in 2001, FAO, 2011). Moreover, subsistence production remains the dominant pattern of agriculture in the country. All these attributes make Myanmar a leading candidate for agriculture and food oriented development strategy.

The institutions and infrastructure needed for pro-poor agricultural promotion, as well as the facilitating mechanisms for larger scale agrofood supply chain development, are at the early stages of development in Myanmar. This fact, combined with historically high capacity for rice production and evidence of substantial unexploited agricultural potential, imply that the country could become an important contributor to regional food security and strongly support its own livelihoods improvement in the process.

2.5 Thailand

With an average per capita GDP of US\$3,893 Thailand has a much more robust economy than other countries in the region such as Cambodia, Lao PDR, Viet Nam and Myanmar while a far smaller segment of the population (8.5 percent) lives beneath the national poverty line (ADB, 2009c; World Bank, 2011). Impressive growth in Thailand has contributed to decreases in the number of people undernourished in the country falling from 30 percent in 1990-1992 to 17 percent in 2003-2005 (ESCAP, 2009). The drought-prone area of northeastern Thailand presents a challenge for national food security (ESCAP, 2009). In 2010 According to an FAO GIEWS report a large area in northern, central and eastern regions were affected by insufficient rainfall and rice crops were below normal (FAO, 2010).

As the world's largest exporter of rice, Thailand experienced a positive impact to its terms of trade in the face of rising food prices (Headey, 2010). However, such price rises have the result of increasing farm incomes while adversely affecting the poor in non-farming sectors (FAO, 2010).

Agricultural production in Thailand contracted by 0.6 percent in 2009 due to price declines from the 2008 highs and pest infestations (ADB, 2010). Meanwhile, the country experienced sharp declines in manufactured and agricultural exports (ADB, 2010). It is expected that this trend will reverse as global demand and food prices rise again. Food insecurity in Thailand remains less acute in comparison with its Southeast Asian neighbors. The FAO

(2010) noted that the food security situation in Thailand was "satisfactory" as of March 2010.

2.6 Viet Nam

Export restrictions imposed by Viet Nam are widely believed to have played a significant role in the surging of world rice prices during the 2007-2008 food crisis (Headey, 2010). Viet Nam is the second largest exporter of rice and therefore such export restrictions can have a major impact on world markets. According to the ADB (2010) the agricultural sector (including forestry and fisheries) in Viet Nam grew in 2009 by a weaker than normal rate of 1.8 percent, however increased external demand is expected to increase growth in agriculture and manufacturing in 2010 and 2011.

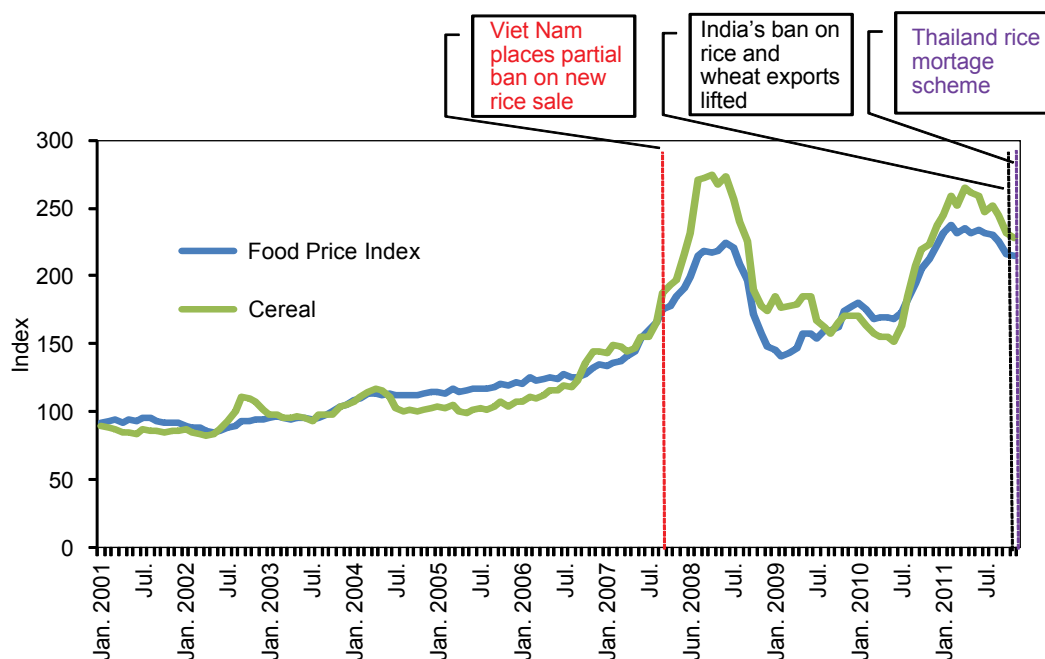
The food security situation in Viet Nam has improved dramatically over the past two decades. In 1990-1992 approximately 31 percent of the population was undernourished, a figure that fell to 14 percent by 2005 (ESCAP, 2009). GDP growth has averaged 7.1 percent between 1990 and 2009 and per capita GDP has grown from US\$631 in 2005 to US\$1,032 in 2009 (ADB, 2009d; World Bank, 2011). Incoming FDI has also risen dramatically in recent years which ranged from US\$1.3 billion to US\$1.8 billion in the 2002-2006 time period and reached US\$9.3 billion in 2008. Despite this robust growth 21.5 percent of the population still lived on less than US\$1.25/day in 2006 (ADB, 2009d).

3. Price Volatility and Food Security in the GMS

3.1 Summary of the 2007-2008 Food Crisis

Beginning in 2007 and peaking in mid-2008, food prices skyrocketed worldwide (see Figure 1). Many factors contributed to the price rise: Many countries' cereal stocks were depleted, causing increased demand for current production, biofuel's emergence, and the declining value of the dollar. However, policies also played a critical role in reinforcing adverse market conditions, which became significantly worse as major rice exporting countries began imposing restrictions on exports in an effort to control domestic rice prices. Countries that imposed export bans or other restrictions include Viet Nam, India, PRC, Egypt, and Cambodia (USDA, 2008). Thailand floated the idea of forming a rice cartel. Export restrictions also triggered "distress buying" (i.e. accelerated import contracts) by

Figure 1: Food Price Index and Cereal Prices 2001-2011



Source: Food and Agriculture Organization of the United Nations Statistics. <http://www.fao.org> (accessed 13 December 2011)

importing countries such as the Philippines, creating a “perfect storm” for soaring rice prices, which eventually peaked at over US\$1,000/ton in April of 2008 (Brahmbhatt & Christiaensen, 2008).

Global demand for food has been increasing steadily for decades (see ESCAP, 2009 for historical details). One reason for sustained robust growth in demand for cereals has been increasing incomes in many countries in the Asia-Pacific region. With rising incomes many in the region are eating more meat, which requires escalating amounts of grain-fed livestock. “On a world average, each kilo of beef requires eight kilos of grain” (ESCAP, 2009).

Food production outpaced demand growth, causing a generation-long downward trend in food prices until the 2000s, when this trend reversed as production growth began to lag behind rising demand. World stocks of cereals began to seriously erode as consumption outpaced production for multiple years from 1999 into the early 2000s. During this time, world stocks of wheat, maize, and rice fell by 31 percent, 59 percent and 50 percent respectively resulting in the lowest level of worldwide cereal stocks in 30 years. This historical market transition instigated a new upward trend in food prices at the beginning of the last decade.

In addition to a lag in production, a sharp increase in global demand for grains was augmented by a rise in demand for biofuel which Brahmbhatt and Christiaensen (2008) claim contributed significantly to increases in grain prices. Governments around the world have encouraged production and use of biofuels due to concerns regarding oil prices, energy security and climate change. Increased demand for biofuel crops (maize, soybeans and palm oil) led to land use changes and reduced planting of wheat which resulted in depletion of world wheat stocks and sharp increases in world wheat prices (Brahmbhatt & Christiaensen, 2008). Increasing use of land for biofuel production, combined with increasing energy-intensity of agriculture and the use of natural gas as a primary input for fertilizer production has caused food prices to become increasingly linked to the prices of oil and gas.

Food price increases were 9 percent in 2006, 23 percent in 2007 and 51 percent “between January-June 2007 and January-June 2008” (ESCAP, 2009). The most rapid increases of late 2007 and January-April of 2008 were largely due to export restrictions of rice exporting countries. In September of 2007 Viet Nam, the second-largest rice exporter placed a partial ban on new sales. India, the third-largest exporter, followed with an imposed minimum export price in October. In December, PRC, a

mid-level exporter imposed a tax on rice exports. At the height of the crisis in March of 2008 Viet Nam, India, Egypt and Cambodia all imposed or re-imposed bans on rice exports (USDA, 2008).

This combination of export restrictions had a massive impact on world rice prices. Imposing export restrictions or export taxes may be a first response of a food-exporting country facing a rapid increase in food prices. The purpose of such policy is to control domestic rice prices and secure domestic rice supply. This may benefit domestic consumers however it will adversely affect domestic producers and consumers in food-importing countries and more broadly it can have an adverse impact on regional and global food security. This also creates a “domino effect” provoking other exporters to follow and importers to accelerate orders (“distress buying”) (Brahmbhatt & Christiaensen, 2008).

High prices benefit the terms of trade of countries that export agricultural products and improve trade balances of such countries as was seen in Thailand. However, groups such as the rural landless and urban poor are negatively impacted by such price rises. In some countries, even farmers enjoyed relatively little benefit, much of the scarcity premium on cereals being captured by intermediaries. The poorest half of the world’s population spends about half its household income on food, which makes them extremely vulnerable to food prices increases. During the 2007-2008 crisis such high prices contributed to “social turbulence or even food riots in over 30 countries.

3.2 Recent Research on Food Prices

Literature regarding the causes of the 2007/2008 food price crisis is now quite extensive, and interpretations of the causes of food price volatility are diverse, sometimes contradictory, and even contentious. Without advocating a specific perspective, we briefly review the analysis and evidence available to date.

Trostle (2008) and Abbott *et al.* (2008) survey the 2007/2008 food price crisis citing various factors contributing to sudden price escalation. Such factors include slow production growth concurrent with rapidly growing demand, biofuel production, adverse weather conditions of 2006 and 2007, the declining value of the dollar, rising energy prices, increasing costs of production in agriculture and policies imposed during periods of high food prices by exporting and importing countries to counter domestic food price inflation. Other comprehensive reviews include ADB

(2008a), ADB (2008b), Heady and Fan (2008), Piesse and Thirtle (2009) and Von Braun (2008).

Timmer (2010) provides a review of the food price spike with particular focus on Asia and rice prices, noting the cyclical character of these crises. Focusing on rice prices and the impact this had on Asian markets Timmer asserts that “[p]anicked hoarding caused the rice price spike.” Timmer (2009) offers an analytical model that could be implemented for determination of short-run rice prices. The author finds that using representative price elasticities (-0.1 for demand and 0.05 for supply) a “sudden and unexpected” 25 percent increase in global short-run demand for rice requires a 167 percent price rise to reach a new equilibrium.

In addition, Timmer (2010) discusses the work of Gardner (1979) that found price crises to occur roughly every three decades and notes that the 2007/2008 crisis follows 35 years after the 1972/1973 crisis, thus following very closely Gardener’s observations of the cyclical nature of such events. Timmer argues that instead of focusing on short-term price signals policy must be oriented toward “stabilizing production around long-run consumption trends” and offers various suggestions for achieving such an objective.

First, investment in agricultural technology and productivity must take into account long-run consumption trends and notes that food prices “do not always send the right signals about investing in agriculture”, a subject explored in greater depth in Timmer (1995). In addition, he argues for the increase of food grain reserves during times of surplus and the release of such reserves when prices rise. Timmer points to various studies that have illustrated problems with this approach, in particular when such a reserve is managed by an international agency (Newbery and Stiglitz, 1981; Williams and Wright, 1991; Wright 2009), and thus argues that such reserves are best managed on a national basis which other research has shown to be a more viable approach to stabilizing food prices (Rashid *et al.*, 2008; Timmer, 1996). Finally, recognizing the impact that the increase of biofuel production has on demand for agricultural products the author suggests that government discourage the use of food to make biofuel rather than subsidies and mandating of biofuel production that contributes to increased food prices.

There has been considerable disagreement over the role of biofuels as a driving factor of food price increases. Mitchell (2008) concluded that an increase in biofuel

production was the most significant factor contributing to food price increases between January 2002 and June 2008. The author purports that without such increase in demand for biofuel “global wheat and maize stocks would not have declined appreciably” nor would land use changes in wheat exporting countries favoring oilseed production have occurred to such an extent both of which contributed significantly to food price increases. The author finds that 70-75 percent of food price increases over this period is a result of biofuel production “and the related consequences of low grain stocks, large land use shifts, speculative activity and export bans.” Mitchell points to various other studies that support the notion that biofuel production has been a primary driver of rising food prices such as Collins (2008). Conversely, one study by Mueller *et al.* (2011) finds that the role of biofuels in food price increases is very modest and points to other factors that contribute more significantly to such price rises. Such factors include increased energy prices, export policy changes, the declining value of the dollar, and lagging production in the face of increased global demand leading to diminished worldwide grain stocks.

Heady (2010) explores the role that trade events played in food price rises. The author provides a trade-based explanation of the crisis emphasizing the role that supply and demand shocks played in the 2007/2008 crisis. Contrary to studies such as Robles and Cooke (2009) and Timmer (2010), Heady finds that such supply and demand shocks do fully account for the rapid increase in food prices experienced during the crisis.

The work of Esmaeili and Shokoohi (2011) elucidates the effect that oil prices have on food price indices. Through the application of a principal component analysis (PCA) model the authors find that crude oil prices indirectly affect food prices. Additionally, the authors reference other recent works that have contributed to the understanding of this relationship including Abdel and Arshad (2008), Chen *et al.* (2010), Gohin and Chantret (2010), Srinivasan (2009), Tokgoz (2009), and Zhang *et al.* (2010).

According a study by Brahmbhatt & Christiaensen (2008) rising energy and fertilizer costs and the decline in value of the dollar have contributed to some 35 percent of food price rise. Higher fuel costs to supply agricultural machinery, irrigation system and transport increase the cost of agricultural production, as does the increase price of fertilizers in whose production energy is a major input. Other studies have claimed that decline in the value of the dollar increases dollar commodity prices with an elasticity

of 0.5 to 1.0 (Baffles, 1997; Brahmbhatt & Christiaensen, 2008).

Looking to the future Abbott *et al.* (2009) discusses food price volatility in the context of a global recovery from the recession. The authors note that it is likely that high food prices may return as the global economy recovers. Specifically, inflation, oil price rises and a decline in the value of the dollar have the potential to reemerge along with a recovery providing conditions that may make further food price increases likely.

3.3 Short Term Risks of another Food Crisis in the Region

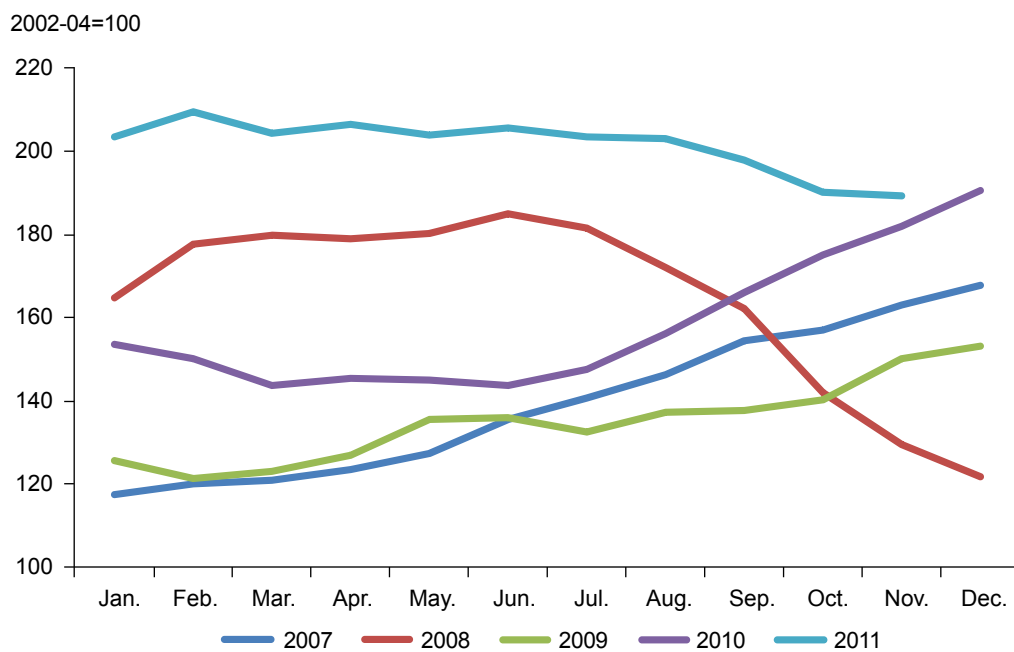
Food prices eased as the global economy slowed into recession in 2008 and by early 2009 prices were back down to levels of 2006 (in real terms) (ESCAP, 2009). However, it is widely speculated that as the global economy comes out of recession, oil and food prices are likely to rise again. The final quarter of 2010 and January 2011 have already seen rapidly rising food prices (see Figure 1). Escalation across the year has been a norm in recent years (except for unwinding in 2008). While 2011 began at very high levels and food prices subsided thereafter, they have remained stable and higher than the levels observed one year ago (Figure 2). Moreover, trends in the last year have been sharply higher than the first half of the decade across most major staples (Figure 3).

The current global wheat outlook does not appear to be favorable. Sustained export bans in Russia, last year's flooding in Canada, and drought conditions in PRC may converge to put considerable upward pressure on global wheat prices. Such concerns were articulated in a recent FAO (2011e) GIEWS Special Alert. Low precipitation in the major wheat producing areas of PRC has endangered the potential harvest and the impact could be devastating. If PRC is required to meet a significant proportion of its domestic needs with imports the demand shock to the world market will be felt worldwide.

3.4 Long-Term Risks to Food Security

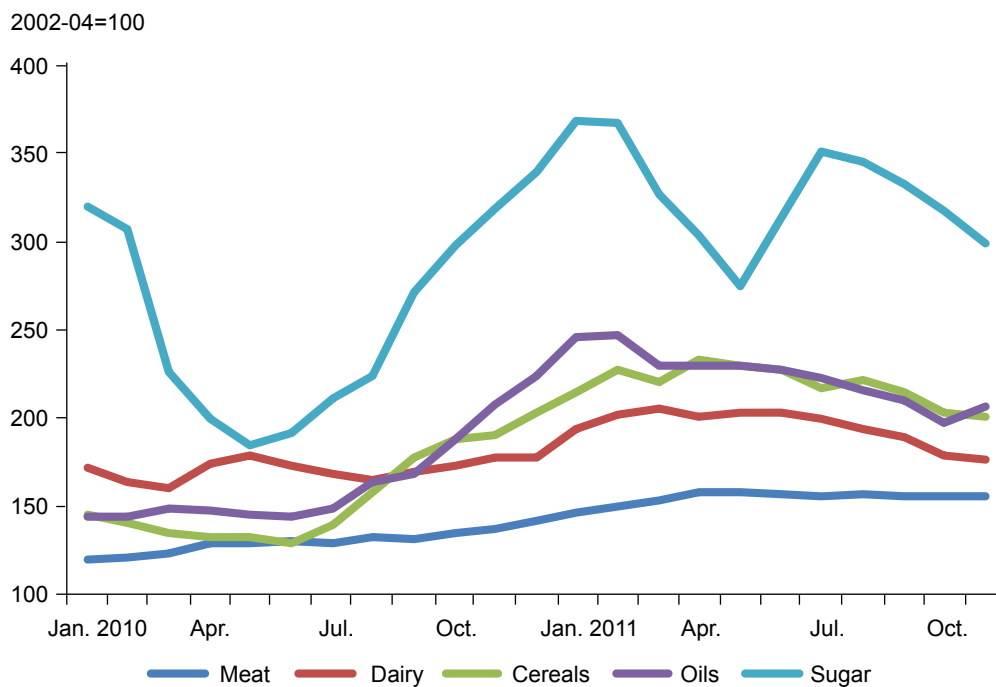
Although agrofood prices over the last decade have exhibited volatility for a variety of reasons, long term global capacity to meet nutritional needs will be determined by more fundamental issues. Among these, the most prominent are population growth, technological change, and the capacity of the natural resource base to sustain food production in concert with demand growth. As

Figure 2: Monthly Real Food Price Index by Year



Source: Food and Agriculture Organization of the United Nations Statistics. <http://www.fao.org> (accessed 13 December 2011)

Figure 3: Monthly Real Food Prices Indexes



Source: Food and Agriculture Organization of the United Nations Statistics. <http://www.fao.org> (accessed 13 December 2011)

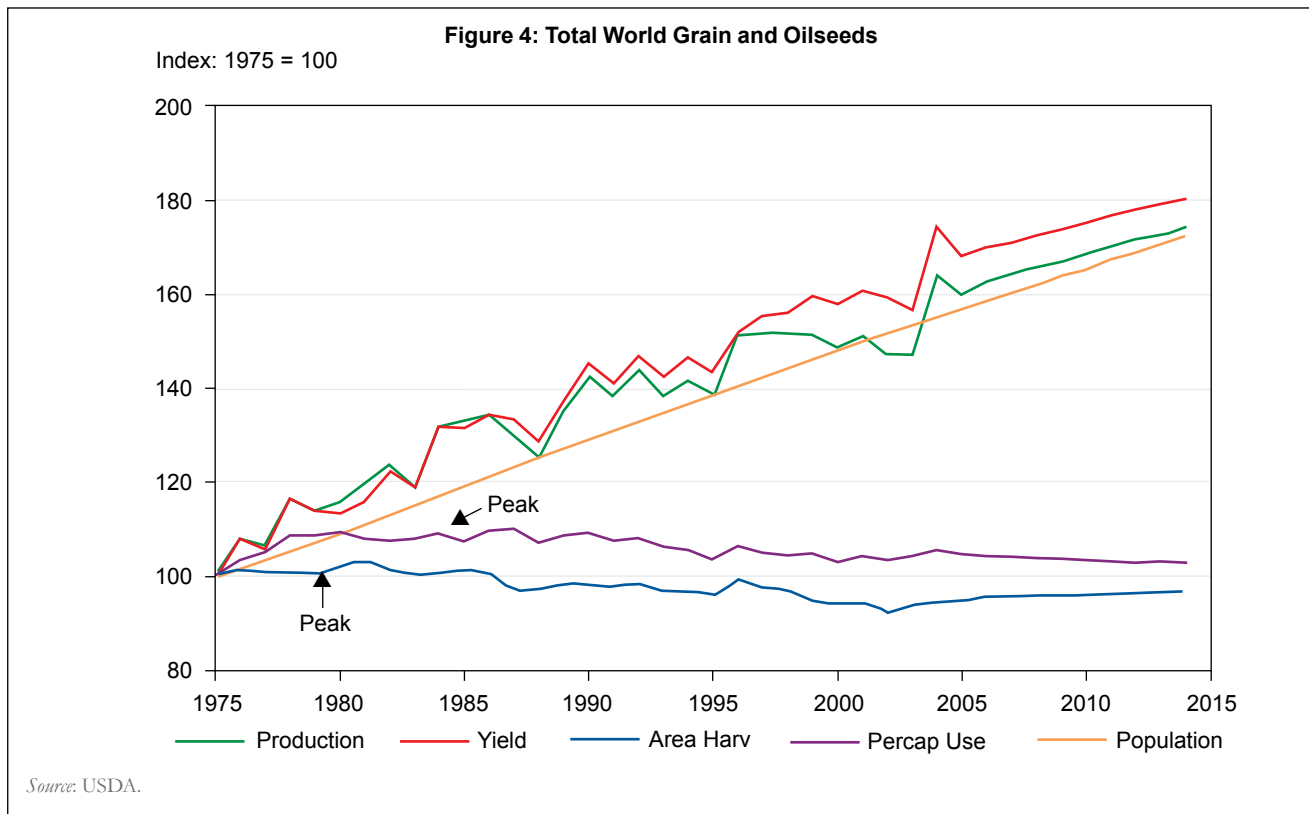


Figure 4 makes clear, our historic successes in this regard have come from a stable resource base and ever rising agricultural yields.

As Figure 4 indicates, the world managed its food security with relatively modest annual productivity increases, averaging 2-2.3 percent per annum since the 1970s. Whether or not this will be sufficient for the future depends on several factors. The first of these will be population growth, which is slowing globally, but at varying speeds (Table 1). If humankind can moderate its growth to total about 9 billion people, this growth will have converged to about 1% per annum. In this case, food production for today's diets could be sustained with historical yield growth. However, large emerging economies are rapidly changing their food consumption patterns, in particular shifting toward meat and specialty crops. These agrofood products are much more resource intensive, and if such trends are to be sustained much higher yield growth may be required. This the main threat to food security from the demand side is not really the standards Malthusian challenge of population but changing taste and rising purchasing power.

On the supply side, long term threats to food security are dominated by climate factors, particularly water

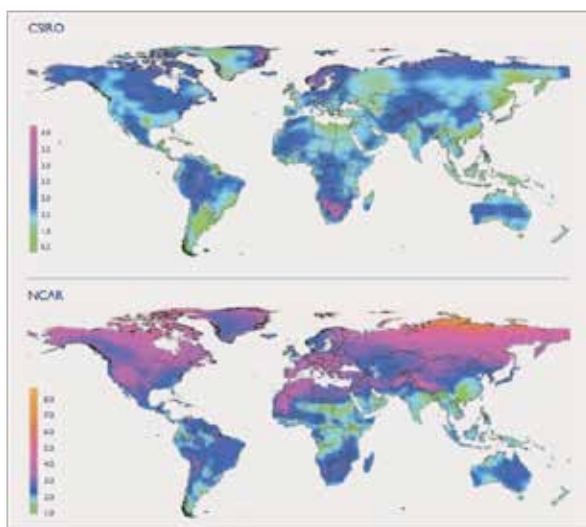
availability and attendant risks that can be expected from rising average global temperatures. The leading global climate models have somewhat divergent views regarding temperature and precipitation trends (Figures 5 and 6), yet conclusions regarding global agricultural yields are more harmonious because of the prominence of the so-called CO₂ fertilization effect. Generally speaking, temperature and precipitation trends will induce shifting of agricultural capacity, mainly from equatorial to polar latitudes. Increased CO₂ concentrations, however, will have a more uniform and positive yield effect, moderating local adverse consequences and amplifying benefits.

As Table 2 shows, despite significant estimated changes in temperature and rainfall patterns, increased CO₂ concentration will spontaneously contribute to agriculture yields in a way that significantly or in some cases fully offsets agricultural resource productivity declines. While these results give comfort to many who are concerned about the impact of climate change on global food security, it must be emphasized that the same research suggests that food prices will rise substantially during the same period, a predictable market response to animate needed resource shifting for adaptation in this sector.

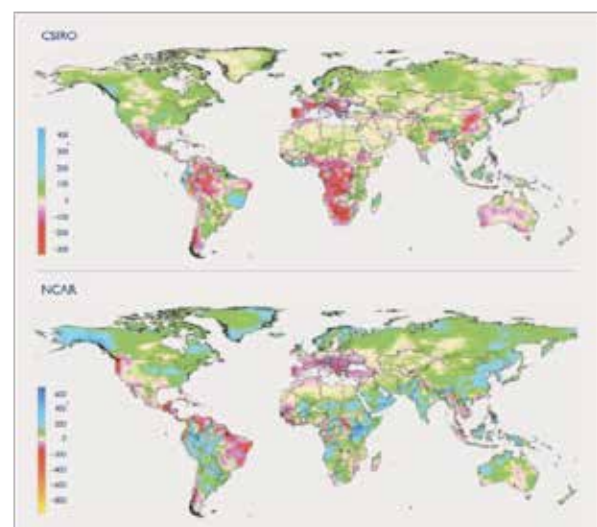
Table 1: Global Population

	Total population (millions)					
	2000	2010	2020	2030	2040	2050
North America	306	337	367	392	413	430
Europe & Russia	752	762	766	761	748	729
Pacific OECD	150	153	152	148	142	135
Africa, sub-Saharan	655	842	1,056	1,281	1,509	1,723
Latin America	505	574	638	689	725	744
Middle East & North Africa	303	370	442	511	575	629
Asia, East	1,402	1,500	1,584	1,633	1,630	1,596
Asia, South/South East	1,765	2,056	2,328	2,553	2,723	2,839
Rest of World	210	233	249	262	272	280
Developed	1,141	1,177	1,202	1,211	1,210	1,198
Developing	4,696	5,417	6,132	6,758	7,257	7,627
Rest of World	210	233	249	262	272	280
World	6,047	6,827	7,582	8,231	8,739	9,105

Source: United Nations.

**Figure 5: Average Annual Temperature Change:
2000-2050 (centigrade)**

Source: Nelson *et al.* (2009).

**Figure 6: Change in Average Annual Precipitation:
2000-2050 (mm)**

Source: Nelson *et al.* (2009).

4. Agrofood and GMS Development

4.1 Agrofood Potential and its Realization

The differential between actual, realized agricultural production and maximum potential agricultural output given available technology, current genetic material and proper management is referred to as the “yield gap”. Achieving maximum yields depends on many factors among which farmers ability to access seeds, water, nutrients, pest management, soils, biodiversity and knowledge is extremely important (Godfray *et al.*, 2010).

Increasing agricultural productivity in low-income countries thus narrowing the yield gap has the potential to greatly improve rural incomes and contribute to enhanced food security and therefore has been the focus of a significant amount of economic and scientific research.

Technical constraints often contribute to large yield gaps in low-income rural communities. Godfray *et al.* (2010) note that economic conditions may prevent food producers’ access to (1) “the technical knowledge and skills required to increase production”; (2) “the finances required to invest in higher production (e.g. irrigation, fertilizer, machinery, crop-

Table 2: Impacts of Climate Change on Cereal Production, with and without CO₂ Fertilization

	Change in cereal production compared to the Reference scenario (percent)											
	Hadley A2				CSIRO A2				Hadley A2, without CO ₂ fertilization			
	2020	2030	2050	2080	2020	2030	2050	2080	2020	2030	2050	2080
North America	1.9	-2.9	-2.9	-0.8	2.8	0.1	5.8	7.1	0.9	-3.9	-4.6	-4.8
Europe & Russia	0.8	2.0	1.8	1.5	0.5	1.7	1.0	3.1	0.1	1.0	0.1	-1.1
Pacific OECD	-2.2	2.4	9.5	14.0	2.5	6.0	7.0	18.2	-1.8	2.8	9.3	13.6
Africa, sub-Saharan	-1.3	0.3	-2.0	-2.5	-0.6	0.4	-2.9	-7.2	-0.9	0.6	-2.0	-2.2
Latin America	0.9	4.7	5.5	6.0	1.3	3.5	-0.7	0.9	1.3	5.0	6.4	8.0
Mid East & North Africa	-0.5	0.7	1.1	-1.0	5.2	7.7	7.4	-1.0	-0.7	0.3	0.3	-2.2
Asia, East	0.1	0.7	2.0	-2.8	-2.2	-2.8	-3.4	-7.2	-0.6	-0.4	0.2	-5.3
Asia, South/Southeast	-1.3	-1.3	-3.7	-12.2	-4.8	-5.9	-8.9	-12.8	-1.6	-1.9	-4.6	-13.2
Rest of World	-1.6	-1.7	-3.1	-4.6	-2.4	-2.8	-3.4	-4.6	-2.6	-3.4	-6.1	-9.0
Developed	1.2	-0.7	-0.3	0.5	1.7	1.1	4.2	5.9	0.3	-1.7	-2.0	-2.8
Developing	-0.3	0.7	0.2	-3.9	-1.8	-1.8	-4.2	-7.3	-0.6	0.2	-0.6	-4.9
World	0.3	0.1	-0.2	-2.2	-0.4	-0.6	-0.8	-2.1	-0.3	-0.7	-1.4	-4.3

Source: Fischer (2009).

protection products, and soil-conservation measures)” or (3) “the crop and livestock varieties that maximize yields”. Additionally, after harvest or slaughter, food producers in low income communities may not have access to proper storage facilities or transportation infrastructure connecting them to markets (Godfray *et al.*, 2010).

In Neumann *et al.* (2010) the authors undertake a spatial analysis of global grain production. The authors estimate global yield gaps by applying a stochastic frontier production function. Closing the yield gap is widely referred to as “intensification”. Lambin *et al.* (2001) define three discrete triggers of the intensification process: (1) land scarcity, (2) investment in agriculture, and (3) intervention of government, inter-governmental or non-governmental organizations (NGO) initiatives to encourage development. However practical achievement of intensification is highly complex and defining specific measures to facilitate increased agricultural production is highly site-specific (Godfray *et al.*, 2010).

According to some estimates, in parts of Southeast Asia where adequate irrigation is available “average maximum climate-adjusted rice yields are 8.5 metric tons per hectare, yet the average actually achieved yields are 60 percent of this figure” while “similar yield gaps are found in rain-fed wheat in central Asia” (Cassman, 1999; Godfray *et al.*, 2010). Despite seemingly large yield gaps in Asia significant progress has been made in agricultural productivity. In terms of per capita food production, Asia has increased approximately twofold, however when PRC is considered independently this has increased by a factor of nearly 3.5

(Godfray *et al.*, 2010). However, great potential remains for increasing intensification in the region.

Improving the use of nutrient inputs is a significant factor in increasing yields and closing yield gaps. Buresh (2010) discusses scientific principles that have resulted from over a decade of research with rice in Asia regarding site-specific nutrient management. The author discusses how such principles enable determination of crop needs of pre-season and within season crop needs of fertilizer nitrogen, phosphorus and potassium rates to ensure maximum yield and sustainable soil fertility.

Irrigation is a vital component of agriculture production. In much of the developing world crop systems are rain-fed. Lobell *et al.* (2009) find that yields in most irrigated wheat, rice and maize cropping systems are generally near 80 percent of potential while rain-fed systems are often at 50 percent or less of potential. Investment in improved irrigation networks in low-income countries holds great potential for improvement of crop yields and thus greater agricultural productivity. Recent work of Alauddin and Quiggin (2008) emphasizes the need for a multi-faceted, comprehensive policy approach to intensification of agriculture in the developing world. Improved irrigation and intensification of agriculture has the potential to increase economic growth but environmental and ecological externalities must be assessed in order to achieve sustainable agriculture yields and economic growth.

Inadequate transport infrastructure and market access can raise the price of inputs and increase the price of

moving agricultural produce to markets, resulting in lower returns which may lessen or reverse economic incentives to increasing agricultural production (Godfray *et al.*, 2010). Improvement of transport networks has the potential to greatly reduce the costs of agricultural production and if such outlets are available in many areas this will incentivize greater productivity.

4.2 Agriculture and Development: Recent Insights from the Research Literature

Agriculture in developing countries accounts for an extremely large share of employment and GDP. Also in developing countries productivity in the agricultural sector is often quite low relative to other sectors. Therefore increasing the share of agricultural sector within the economy will not necessarily lead to economic improvement. If labor and capital are allocated to less productive activities this may be disadvantageous to overall economic performance. Beginning as far back as Adam Smith theories of sectoral transformation have recognized that economic growth is accompanied by a movement of labor and other resources into other activities, some so-called “agro-pessimists” argue that development assistance actually suffers from an overemphasis on agriculture (Gollin, 2010). Godfray *et al.* (2010) argue that there exists a balance that must be weighed in “investing in overall economic growth as a spur to agriculture and focusing on investing in agriculture as a spur to economic growth”.

Whether or not increases in agricultural productivity will lead to economic growth is very important in decisions of development agencies in targeting assistance to low income countries. For instance, if output per worker is greater in nonagriculture sectors in a particular country, then movement of labor out of agriculture and into more productive activities can be a source of economic growth. This was the view held by early development literature such as the work of Lewis and others (Rosenstein-Rodan and Rostow) which held that industrialization was necessary for modern economic growth. Such views held that subsistence agriculture represented a pool of reserve labor while the challenge for development was to expand the modern industrial sector which would then absorb such workers (Gollin, 2010).

A differing view in early development literature claimed that many low-income economies suffered from what T. W. Schultz referred to as the “food problem”. In such a situation a “critically” high proportion of household income is spent on food, a situation that he termed “high food drain”. Such a view holds that until a country can produce enough food

products to satisfy its subsistence needs modern economic growth will not be possible (Gollin, 2010).

Not all economic theorists hold this view. There are many that have argued that increases in agricultural productivity can have a significant role in economic development. Dating back to the 1960s economists such as Mellor, Gardener and Johnston have developed models and theories indicating that increases in agricultural productivity may lead to more rapid economic development (Gollin, 2010). Mellor (1995, 1996) building on theories in early development literature of T. W. Schultz argued that agricultural productivity growth lead to a linked set of positive development impacts. This “linked set of impacts” is described by Gollin (2010):

- Increases in farm income and profitability, resulting in improved welfare of farmers and the rural poor
- Declining food prices, benefiting poor rural and urban consumers, including small farmers who might be net purchasers of food
- Reductions in the nominal wage, consistent with increases in the real wage, allowing the industrial sector to reduce costs
- Increases in the domestic demand for industrial output
- Increasing competitiveness of both agricultural and industrial exports, with positive impact on hard currency earnings
- Expansion of the domestic industrial sector, pulling labor and investment resources out of agriculture

As Gollin (2010) describes “the Mellor hypothesis” is a theory under which “agricultural productivity is necessarily the source of long-run economic growth”.

Fan (2002), Fan & Brzeska (2010) and Fan *et al.* (2004) discuss the impact of investment in various factors that lead to increases in agricultural productivity and the degree to which they have resulted in economic development. The factors discussed in this work include agriculture R&D, irrigation, education and rural development. Their results found that agriculture R&D had the largest impact on agricultural GDP growth.

Certain cross-section and panel data analyses which use various econometric techniques have been employed in recent research that have found significant correlation between increased agricultural productivity and economic development (Gollin, 2010). The recent work of Self and Grabowski (2007) uses such techniques and finds strong correlation between agricultural productivity rates and rises in per capita incomes and human development indexes (HDI).

Other methods that have been employed in recent years to analyze relationships between agricultural productivity growth and economic development include computable general equilibrium (CGE) models, development accounting, growth accounting and productivity measurement. For more information on such research see Fan (2010), Gollin (2010) and Jha (2010).

Many authors have argued that trade liberalization is a major contributor to economic growth particularly in the agricultural sector (Anderson *et al.*, 2005; Anderson & Martin, 2005; Bandara, 2007). The World Bank (2008) describes three main “types of instruments” that distort trade: (1) market access (i.e. import tariffs and quotas); (2) export subsidies; and (3) domestic support. Low-income countries often “impose relatively high taxes on farmers in the export sector as an important source of fiscal revenue, while developed countries tend to heavily subsidize farmers... These differences often create a policy bias against the poor in both domestic and international markets” while such subsidies in developed countries have the effect of depressing agricultural output in developing countries (World Bank, 2008).

Agriculture has been greatly protected worldwide and has been a major issue in World Trade Organization (WTO) negotiations. In particular it was a primary issue under the Doha Development Agenda (DDA). Bandara (2007) estimates that global welfare gains of the Doha agricultural liberalization scenario would amount to approximately US\$74.5 billion by 2015 with 44 percent of the gains (US\$32.6 billion) being enjoyed by countries in the Asia-Pacific region. However, the countries with the largest gains under this scenario are Thailand and high-income countries such as Japan, Republic of Korea, Taipei, China, Australia and New Zealand with very small gains or losses occurring in other countries. Thus, this alone does little to contribute to income convergence in the region. Alternative assessments of the benefits of agricultural trade policy under the DDA include Hertel and Keeney (2005) and Antimiani *et al.* (2005).

The PRC-ASEAN Free Trade Area went into effect on January 1, 2010. Covering an area with a population of 1.9 billion people this is the largest free trade area in the world on a population basis and it is third only to the EU and NAFTA in terms of economic value (ASEAN, 2011). Trade is expected to increase in the region and regional integration may offer benefits of more efficient capital allocation and greater market access for lower income agrofood exports.

5. Long-Term Scenarios for GMS Food Security

5.1 Scenarios

After assessing food price risk and the state of knowledge regarding agrofood development, our next objective is to empirically evaluate the prospects for improving food security in the GMS. To do this, we consider three archetype scenarios, representing the leading policy challenges to lasting food security and prosperity. In particular, we consider three sources of greater efficiency and productivity for the region, namely, reduction in barriers to domestic and transboundary market access, higher R&D and increased FDI inflows.

Our empirical results were obtained with a global dynamic CGE mode, calibrated to the GTAP 8 database and a baseline macro time series reflecting a business-as-usual (Baseline) scenario over 2010–2030.⁵ This Baseline comprises consensus forecasts for real GDP obtained from independent sources (e.g. International Monetary Fund, Data Resources International, and Cambridge Econometrics). The model is then run forward to meet these targets, making average capital productivity growth for each country and/or region endogenous. This calibration yields productivity growth that would be needed to attain the macro trajectories, and these are then held fixed in the model under other policy scenarios. Other exogenous macro forecasts could have been used and compared, but this is the standard way to calibrate these models.

5.1.1. Facilitation of Trade and Market Access

Most agricultural households in rural Asia live behind real economic and institutional “walls” restricting domestic and transboundary market access. These include high transactions and transport costs, especially for low-income farmers, who are the overwhelming enterprise majority in rural areas. These logistical barriers are often compounded by infrastructure, institutional, and information constraints within and between GMS economies. As long as distribution margins remain high, low-income agro-food enterprises with relatively low value products will be prevented from accessing markets. Worse, they are trapped in this low

⁵ This work represents an update of an earlier analysis by the same authors (see Jha *et al.* 2010). Results are congruent, but stronger in both magnitude and reliability (based on a new global data set, GTAP 8). Unfortunately, data on the Myanmar are not extensive or consistent enough to be incorporated into the GTAP database, so this country must be omitted from the current scenario analysis. It should be emphasized, however, the most of the conclusions we obtain about pro-poor agrofood development would apply with equal or even greater force to this emerging economy.

level equilibrium by insufficient savings and incentives to invest in higher value, marketable agrofood products like livestock and non-subsistence, specialty crops. By converse reasoning, lowering market access costs and related margins can enlarge the horizon of profitable trade for all, increasing commerce, capturing value added, and promoting self-directed poverty reduction.

5.1.2. Productivity Growth in Agriculture and Related Food Industries

Because of this region's geographic diversity and substantial differences in stages of development, agricultural yields and productivity in livestock production vary tremendously across the GMS (compare global variation in Table 3). In most GMS economies, agrofood production is far below its ultimate potential. Because of relatively small-scale land tenure patterns, it is unlikely that rural households in these countries can achieve significant livelihood improvements unless output per hectare improves substantially, and migration trends imply that higher output per household member will also be essential to national food security.

5.1.3 Foreign Direct Investment

One of the defining characteristics of low-income economies everywhere is limited reserves of domestic saving, which in turn limits the progress of development by restricting investment in productive assets and enterprise expansion. The era of globalization has changed the nature of this constraint, however, with the advent of

transboundary or Foreign Direct Investment (FDI) that permits low-income countries to leverage foreign savings for domestic investment, technological change, and growth. To help low-income GMS economies achieve their economic potential in the timeliest fashion, FDI can be an essential catalyst. The same logic applies to rural poor enclaves within middle-income GMS economies. Savings disparities between urban and rural areas are only partially mediated by migrant remittances and public rural development schemes. Improving domestic market access and smallholder productivity could accelerate private investment from urban to rural areas, and from large to small agrofood enterprise development.

Table 4 summarizes the three core scenarios – three external shock scenarios, followed by three scenarios representing structural change and/or policy adaptation. After detailed examination of baseline regional growth characteristics, these are thought to best represent the salient policy issues addressed in the present study.

5.2 Macroeconomic Results

In terms of overall economic impact, all three types of policy can contribute to GMS regional economic expansion, but in varying degrees. Table 5 summarizes our results for GDP growth, and we see substantial heterogeneity by both country and policy category.

Table 3: Average Annual Growth of Agricultural Output

	1970–1979	1980–1989	1990–1999	2000–2006
Sub-Saharan Africa	1.31	2.6	3.1	2.2
Latin America and Caribbean	3.07	2.37	2.87	3.13
Brazil	3.83	3.73	3.29	4.41
Middle East and North Africa	2.94	3.37	2.73	2.34
Northeast Asia, High	2.15	1.03	-0.01	-0.01
Northeast Asia, Low	3.11	4.55	5.06	3.85
PRC	3.09	4.6	5.17	3.87
Southeast Asia	3.68	3.59	3.13	3.54
South Asia	2.56	3.39	3	2.19
India	2.69	3.52	2.94	2
North America	2.17	0.73	2.03	1.1
Oceania	1.79	1.25	2.93	-0.04
Western Europe	1.54	0.94	0.46	-0.35
Eastern Europe	1.8	0.25	-2.18	-0.19
Russian Federation	1.32	0.98	-4.62	2.7
Developing countries	2.82	3.46	3.64	3.09
Developed countries	1.88	0.86	1.21	0.39
Russian Fed. & Eastern Europe	1.47	0.77	-3.88	1.81
World	2.23	2.13	2.04	2.22

Source: United States Department of Agriculture, World Bank.

Table 4: Generic Policy Scenarios

1. Infrastructure Investment and Trade Facilitation (TTT):	Assume that investments and institutional changes effect a 50% reduction in trade, transport, and transit (TTT) margins for Asian countries. Meanwhile, Asia is also assumed to achieve abolition of nominal trade distortions (import taxes and subsidies) across the region.
2. Agro-Food Productivity (AgProd):	Assume that total factor productivity grows at 4% annually in agriculture and food processing sectors. Includes Scenario 4.
3. Foreign Direct Investment (FDI):	In addition to Scenario 2, assume that, for DMC's, the stock of FDI rises to at least 15% of GDP by 2030. Includes Scenario 5.

Notes: Scenarios are inclusive from 1-3.

FDI = foreign direct investment

Generally speaking, these results are consistent with intuition and a large body of related work on regional trade, agrofood productivity, and investment. The most salient findings are summarized as follows:

- Reduction in trade, transport, and tariff margins (TTT) – As many studies of regional and global trade liberalization have already demonstrated, removing hard and soft institutional and price barriers to trade would realize substantial efficiency gains and increase regional incomes. The benefits depend on two factors: prior protection/margin levels, and export competitiveness. Many lower income countries would see greater gains because they face higher margins and trade barriers, yet they have significant initial domestic cost advantages. These results strongly support the argument that GMS regional trade facilitation is Pareto improving and promotes regional livelihoods convergence, small in overall impact, but more positive for poorer countries (Figure 7).
- Agrofood Productivity Growth (AgProd) - Given the importance of agrofood to incomes for most of the GMS poor, where rural dwellers still constitute a significant majority of total population, it is hardly surprising that rising productivity for

agrofood has a dramatic effect on regional real GDP.⁶ Because higher income countries are more diversified and less impacted on the income side, the aggregate impact is modest, but again we see much larger benefits for lower income economies. Even moderate productivity growth like that specified in Scenario 5 would increase cumulative GDP significantly in the GMS and other DMCs.⁷ Here we also see a distinct Pareto impact, improving real incomes across the region, but most so among lower income economies.

- Greater Asian Regional Foreign Direct Investment (FDI) - More intensive and extensive use of FDI within and across the GMS would sharply increase long term growth prospects for the region. These monies significantly increase real growth rates, particularly in lower income countries, in most cases more than doubling the benefit of agrofood productivity growth. Overall, they contributed to more than USD20 trillion in additional real GDP (Table 6). Clearly, regional allocation of investment resources can be a dramatic catalyst for regional agrofood productivity growth. The reason for this is the joint regional disparities in productivity and domestic savings. Re-allocating regional capital would significantly increase average regional yields, but most so in countries in lower income countries with initial low productivity where domestic savings are a serious constraint.

Table 5: Real GDP by DMC, Cumulative Percent Change 2010-2030

	TTT	AgProd	FDI
Cambodia	7%	27%	71%
PRC	1%	11%	24%
India	1%	15%	43%
Lao PDR	1%	59%	196%
Thailand	2%	17%	40%
Viet Nam	3%	22%	62%
Other DMC	1%	14%	41%
Hilnc Asia	0%	2%	4%

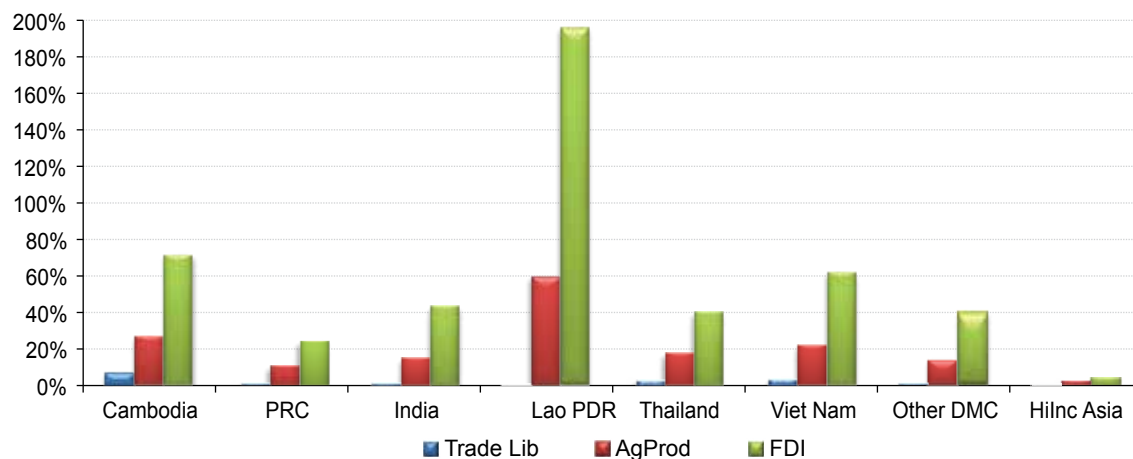
Notes: In this and subsequent tables, countries/regions are listed in order of increasing per capita income. Other DMC denotes the Rest of ADB Developing Member Countries.

Source: Authors' estimates.

The next three tables (Tables 7-9) give more detailed macroeconomic results for combinations of the generic policy scenarios. Results from a composite scenario of external risks (energy and food prices), combined with a first set of policy responses (regional trade facilitation), presented in Table 7, show that such regional integration

⁶ See Jha *et al* (2010) for more on this aspect of growth, particularly its historical context.

⁷ China's agrofood productivity was not increased in these scenarios because it is already at high growth rates in the baseline.

Figure 7: Real GDP by DMC, Cumulative Percent Change 2010-2030

Source: Authors' estimates.

Table 6: Real GDP by DMC, Cumulative 2010 USD Billions: 2010-2030

	TTT	AgProd	FDI
Cambodia	8	30	79
PRC	420	4,213	9,584
India	102	1,768	5,087
Lao PDR	0	23	76
Thailand	39	295	672
Viet Nam	23	157	439
Other DMC	81	1,346	3,947
Hilnc Asia	79	1,148	1,789

Source: Authors' estimates.

is a credible “first line of defense” in the sense that it benefits every member country and some significantly so. Indeed, real GDP benefits understate the gains to Asian households, more accurately reflected in the Equivalent Variation (EV) income effects of the last column. Although consumption prices (CPI) increase because of the adverse shocks, trade facilitation expands income opportunities to more than offset this. Significantly if not surprisingly, trade volumes increase sharply for member countries, further accelerating regional integration.

The second line of policy initiatives, promoting agrofood productivity growth, dramatically increases the benefits of a more liberal regional trading environment (Table 8). Indeed, trade volume increases in many cases are multiplies of that under simple trade facilitation (TTT). This clearly underlines the need for complementary policies to reap the full benefits of regional integration, particularly in a sector like agrofood, which has strong intersectoral linkages and pro-poor multiplier effects. In terms of incomes, we see very strong stimulus to both GDP and EV income for lower income economies, logically as these are still comprised of agrarian majorities.

On the demand side, this scenario is particularly significant because it shows the reversal of consumer price effects in many low income countries. This finding reminds us that household real income depend critically on food prices. Livelihoods protection and promotion, it is clear from these results, begins at the foundation of basic needs for the poor, food. We are also reminded here that rural development can benefit the urban poor.

Table 7: Trade Liberalization and Margin Reduction (TTT), Macroeconomic Impacts

(cumulative percent change: 2010-2030)

	GDP	Output	Exports	Imports	Cons	CPI	EV Inc
Cambodia	4%	6%	11%	19%	13%	2%	16%
PRC	1%	1%	8%	11%	2%	2%	5%
India	0%	1%	9%	12%	2%	2%	5%
Lao PDR	0%	1%	5%	13%	5%	4%	10%
Thailand	-2%	1%	3%	8%	8%	2%	11%
Viet Nam	1%	1%	9%	17%	13%	3%	17%
Other DMC	1%	1%	6%	11%	4%	2%	7%

Source: Authors' estimates.

Table 8: TTT and Agrofood Productivity Growth (AgProd), Macroeconomic Impacts

(cumulative percent change: 2010-2030)

	GDP	Output	Exports	Imports	Cons	CPI	EV Inc
Cambodia	22%	21%	14%	25%	45%	-4%	35%
PRC	10%	7%	1%	8%	19%	-1%	17%
India	16%	11%	22%	20%	20%	-4%	13%
Lao PDR	54%	53%	50%	39%	73%	-7%	54%
Thailand	9%	12%	19%	15%	19%	2%	22%
Viet Nam	21%	14%	24%	27%	33%	-1%	31%
Other DMC	15%	12%	16%	17%	19%	-2%	16%

Source: Authors' estimates.**Table 9: TTT, AgProd, and FDI, Macroeconomic Impacts**

(cumulative percent change: 2010-2030)

	GDP	Output	Exports	Imports	Cons	CPI	EV Inc
Cambodia	64%	56%	23%	45%	99%	-10%	67%
PRC	28%	19%	-10%	21%	40%	-4%	34%
India	49%	32%	38%	67%	53%	-6%	40%
Lao PDR	186%	180%	122%	120%	222%	-13%	147%
Thailand	28%	29%	50%	24%	28%	2%	31%
Viet Nam	67%	43%	62%	54%	62%	-3%	53%
Other DMC	47%	34%	37%	41%	45%	-4%	35%

Source: Authors' estimates.

Policy complementarity between more open trade and higher agrofood productivity is also further amplified by expanded investment opportunity, as it plainly evident in the FDI results. Here we see strong growth across the entire region and most so among lower income, more saving-constrained economies (Table 9). FDI is of course not merely an income transfer, but an agent for labor/resource employment, technology transfer, and access to export opportunities. All three of these features act in synergy, especially where resources are relatively abundant and low cost. For this reason, reallocation of Asian financial reserves from lower growth, higher income economies can be expected to yield higher absolute returns, returns that can benefit both the investors and those in the destination countries. It remains an ironic fact that some of the destination countries of the last great race for emerging market investment (1990-2010) are now in a position to join the other side of this process, yet they have left large financial reserves at the starting gate.

In any case, increasing the depth and scope of FDI should be a high priority for GMS policy makers, particularly in an era of global growth uncertainty. Taken together, Asian economies are no longer small relative to their historical destination markets, and it is not realistic to expect high growth rates via rapid expansion of domestic market share in slow growing OECD economies. For this reason, the GMS represents a logical source of investment diversification for itself not only for the usual portfolio risk

reduction benefits, but because the region represents most of the world's superior national growth rates already.⁸

5.3 Food Security

National policies in all countries are strongly influenced by the most basic forms of economic security, i.e. personal health, safety, and nutrition. In lower income countries, the risks associated with these basic needs are higher because a larger proportion of the population is economically vulnerable, not meeting basic needs, or worse. In countries with large poor urban populations, food vulnerability relates mainly to consumption goods, while for rural poor it affects income as well as consumption. We have seen above that the entire Asian region faces many uncertainties regarding food output and availability, and that there are many ways to measure the attendant risks. In this section we look at the long-term forecasts from this perspective.

We saw that trade facilitation, agrofood productivity growth, and greater FDI all have the potential to contribute substantially to GMS livelihoods. What they can do for food security is suggested first by the results of Table 10, which presents national changes in total agrofood output for each scenario and country/region analyzed. As above, we focus attention on the last three scenarios.

⁸ See Roland-Holst and Weiss (2004), Roland-Holst *et al* (2005), and Roland-Holst and Brooks (2007) for extensions of these arguments.

The impact of trade facilitation on national agrofood output is ambiguous, as would be expected from the logic of basic Ricardian theory. Although regional trade facilitation increases efficiency and thus induces higher aggregate income in all member countries, simply removing trade distortions has the effect of intensifying pre-existing patterns of comparative advantage. Thus countries with established and emerging competitiveness, and low resource cost in rural areas, will see resources pulled from agriculture toward light and heavy manufacturing. Even countries like Thailand, with high levels of agrofood industrialization, are more constrained by trade margins and tariffs against other industries. When these come down, the latter expand at the expense of agrofood. This threat to agrofood competitiveness has been a persistent controversy in trade agreements, particularly between (heavy agro-subsidy) North and South partners, for decades.

Agrofood's loss of competitiveness is by no means inevitable, however, and the most constructive approach to realizing the aggregate gains from greater regional trade efficiency is to promote agrofood productivity growth as a complementary policy. When this is done (AgProd scenario), our results indicate that the benefits are uniformly positive across the region (Figure 9). In particular, even moderate productivity growth (4%/annum) is enough to reverse large adverse effects and achieve over 30% higher cumulative agrofood output in some countries by 2030.

The intuition behind this process is simple. Higher farm productivity not only keeps domestic agrofood production

Table 10: Agrofood Output by DMC, Cumulative Percent Change 2010-2030

	TTT	AgProd	FDI
Cambodia	-1%	77%	261%
PRC	-1%	47%	108%
India	-1%	57%	153%
Lao PDR	0%	93%	306%
Thailand	13%	103%	238%
Viet Nam	7%	133%	360%
Other DMC	3%	83%	200%
Hilnc Asia	0%	27%	35%

Source: Authors' estimates.

competitive, but it enables the release of labor resources to other sectors stimulated by trade facilitation, creating a win-win growth setting for both rural and urban sectors. Finally, higher levels of FDI consolidate these gains in both sectors, improving national efficiency, further raising labor productivity and real wages.

As discussion of adjustment mechanisms suggests, the primary agrofood benefits in these scenarios relate to more efficient recruitment of relatively low wage and low price resources in the rural sectors of low-income countries. This logic has a corollary that the policies should be pro-poor across GMS countries. We discuss the concept of regional economic convergence in a later section, but for the present consider Figure 10, which plots percent change in agrofood output against per capita income for the AgProd Scenario. Although outcomes vary for reasons other than average income levels, there is a clear downward trend in these national results, particularly when weighted by population.

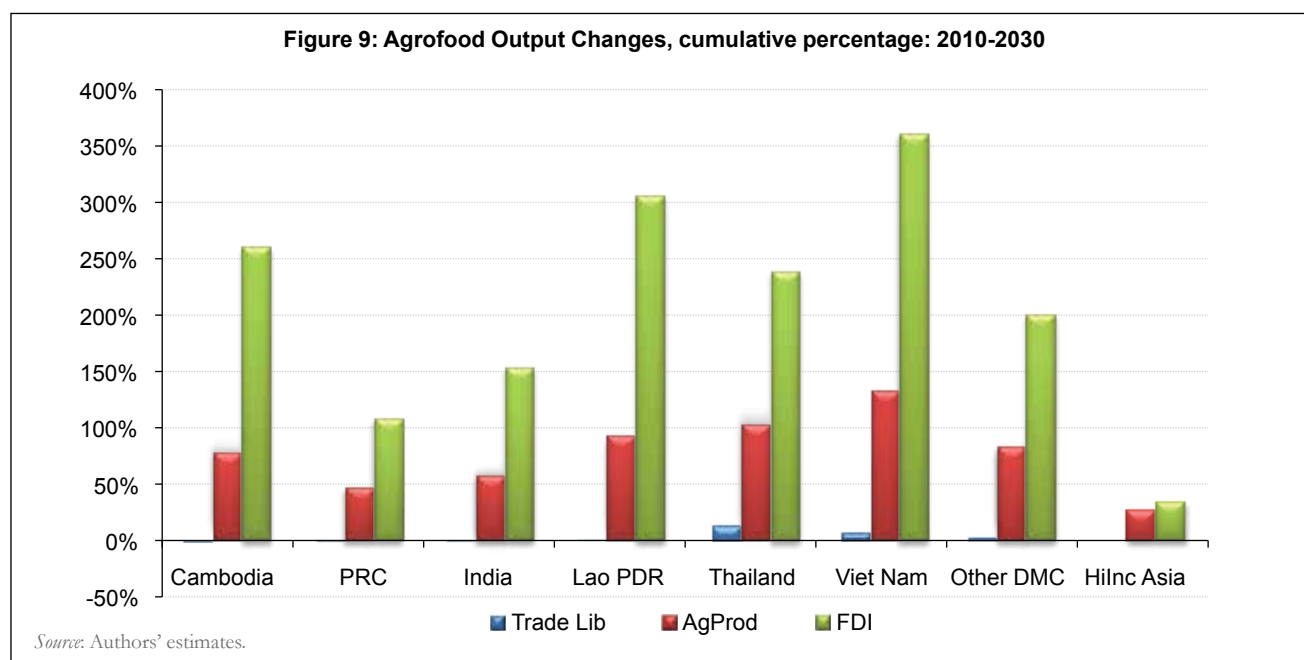
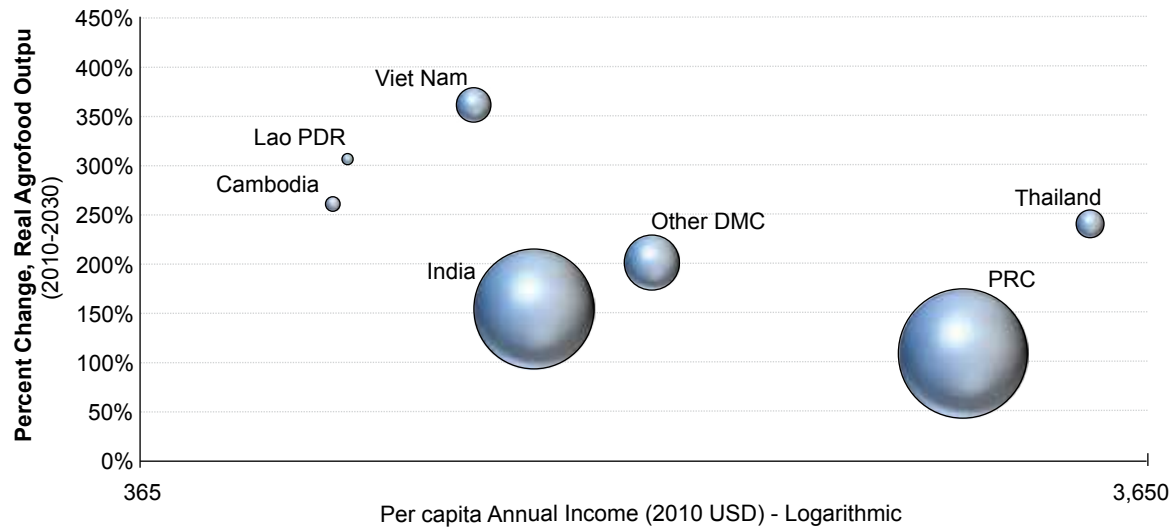
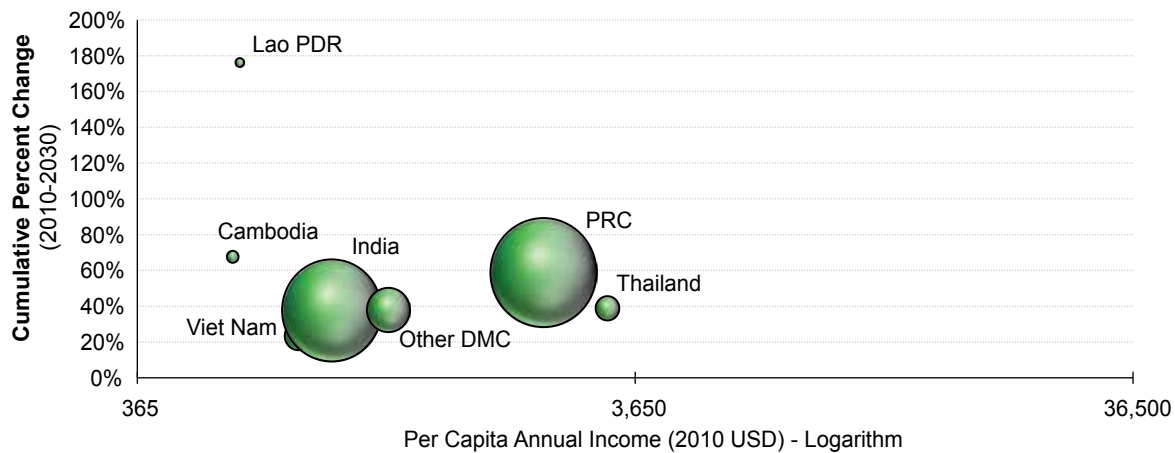


Figure 10: Changes in Agrofood Output Resulting from Productivity Growth
(cumulative percent: 2010-2030)



Source: Authors' estimates.

Figure 11: Change in Per Capita Real Income, FDI Scenario



Source: Authors' estimates.

5.4 Asian Regional Economic Convergence

Since the policy response scenarios considered here have far reaching growth, income, and institutional implications, it is reasonable to ask how they relate to regional convergence in the GMS and across Asia. Generally speaking, this is an important long-term ADB policy priority. It can be interpreted generally to mean that lower income countries should experience higher growth rates, enabling them to improve livelihoods faster and narrowing the degree of inter-country inequality across the region.

The results in Figure 11 give direct perspective on the issue of convergence, showing percent changes in real income

per capita over 2010-2030 as a result of the composite Scenario 3 (FDI). Against an x-variable of per capita baseline income, there is a clear pro-poor benefit to this combination of policy approaches. When account is taken of the size of the countries involved, it is even more obvious that promoting GMS and broader Asian regional integration, in concert with agrofood productivity growth and greater regional FDI, will contribute to higher growth rates for poorer countries.

6. Conclusions

As the emergence of Asian economies continues, with attendant rising incomes and demographic transition,

food security will become an ever more important issue. Moreover, most regional economies continue to face the challenge of extensive rural poverty, and economic growth presents the risk of dualism if these populations are left behind. The Greater Mekong Subregion (GMS) is typical of this growth dilemma, but it also suggests a solution that we examine in this report. Across the GMS (and indeed across Asia), there are large disparities in market accessibility, agrofood productivity, and savings resources for enterprise development. Policies that overcome these disparities can strongly stimulating agrofood development in ways that are economywide and pro-poor, increasing rural incomes and lowering food costs for urban populations.

In this study, we review the fundamentals of recent food price insecurity and agrofood potential, then carry out an empirical assessment of policies for more sustainable agrofood development in the GMS region. Our general findings suggest three promising areas of policy emphasis. Investments in infrastructure and institutional reform can help remove the hard and soft barriers to greater market integration (agrofood and otherwise). Expanded agrofood research and extension services can accelerate regional agrofood productivity growth. Finally, more extensive regional capital allocation (via FDI) can shift underperforming investment resources (savings in higher income countries) to develop underperforming agrofood resources (in lower income countries and subnational localities). The result will be higher regional agrofood productivity, with higher commensurate returns to agrofood investment, and a strong pro-poor development stimulus. Poorest countries and areas have the most to gain in percentage terms because their resources have the lowest initial productivity and their domestic savings are lowest.

These results have many detailed lessons at the national and sector level, but a few salient conclusions emerge:

- Reduction in trade, transport, and tariff margins would realize substantial efficiency gains and increase regional incomes. The benefits depend on two factors: prior protection/margin levels, and export competitiveness. These results strongly support the argument that GMS (as well as larger Asian) integration is Pareto improving and promotes regional livelihoods.
- Given the importance of agrofood to incomes of most of Asia's poor, where rural dwellers still constitute a significant majority of total population, it is hardly surprising that rising productivity for agrofood has a dramatic positive effect on regional real GDP. Even moderate (~4% annual) productivity

growth like that specified in our scenarios would increase cumulative GDP by double digit percentages in most DMCs. Again we see a Pareto impact, improving real incomes across the entire region, but most so among lower income economies.

- More intensive and extensive use of FDI within Asia would significantly increase long term growth in the region. These monies significantly increased real growth rates, particularly in lower income DMCs, in some cases doubling the benefit of agrofood productivity growth. The results show clearly that more efficient regional allocation of investment resources can be a potent catalysis for growth, particularly in lower income countries where domestic savings are a serious constraint.

Finally, we see strong complementarity between the policies considered, and generally very beneficial effects on two primary policy objectives – food security and economic convergence. The evidence from this study indicates that the GMS's vast reserves of food potential can be more fully utilized by policies that facilitate regional trade, agrofood productivity growth, and more extensive use of regional and international investment resources. These policies would significantly increase the region's food output and availability, and they are also good for growth, good for every country, and even better for the poor.

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THE FUTURE OF GMS FORESTRY IN THE CONTEXT OF THE FOOD-WATER-ENERGY NEXUS

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Abstract

In general, the GMS experiences a significant level of undernourishment among its populations, a good supply of water in most areas, high energy import dependence, and low carbon efficiency per unit energy production (low use of renewables). Forests in the GMS are being lost faster than they are being planted and as natural forests are lost, environmental services are being lost with them. Growing demands for timber and agricultural commodities, including food and energy products, are likely to perpetuate these trends well into the future. Assessment of the relative values of forest and non-forest land uses in relation to constraints inherent in the food-energy-water nexus can provide insight into challenges and opportunities for forests and forestry in the coming years. In relation, loss of natural forests in the GMS will impinge on the livelihoods and food security of forest dependent poor and will reduce water related ecosystem services. Forestry has the potential to provide energy feedstocks that compete less with food production, make greater use of rainfall available outside cropping seasons and more use of water present in deep soil layers than annual crops. Values of forests in relation to bioenergy production may, however, not be realized without increased economic viability, which could come about through climate change related subsidies for low carbon energy sources or higher oil prices, or technological advances. In this context, forestry agencies need to focus on increasing efficiency

of production of goods and services from forests while safeguarding forests and forest dependent people against negative impacts and implementing policy that helps to account for the non-market values of forests. Increasing demands for agricultural production should in the mean time be directed towards wastelands and highly degraded forest areas and attention should be given to improving agricultural productivity and reducing post-harvest losses. Additionally, increased use of bioenergy crops and exotic tree species in plantations should take into account increased water use and its impacts on stream flow and national water expenditure.

1. Introduction

Forests in the Greater Mekong Subregion (GMS) provide wood and non-wood forest products and also contribute ecosystem services, such as biodiversity conservation, climate change mitigation, watershed protection, and recreational, cultural, and spiritual values. Many of the region's poor rely on wood for heating and cooking needs while non-wood forest products provide food or may be traded in exchange for cash for food. A large proportion of the subregion's poor live in forested areas; and the 2015 target for attaining the Millennium Development Goal of halving poverty from 1990 levels is just around the corner.

Myanmar has the largest area of forests among GMS countries, while the Lao People's Democratic Republic (Lao PDR) has the highest proportion of forest cover as shown in Table 1. In the subregion as a whole, forest area is falling at -0.4% per annum, although this figure masks some countervailing trends among the constituent countries. In Viet Nam, forest area is increasing rapidly as a result of major public and private afforestation efforts. In Thailand, forest area is also increasing; while in Cambodia, Lao PDR and Myanmar, rapid deforestation is taking place.

Table 1: Forest Area and Rate of Change in Forest Area in GMS Countries

	Forest Area 2010 (‘000 ha)	Forest Cover (%)	Annual Change in Forest Area (%)		
			1990–2000	2000–2005	2005–2010
Cambodia	10,094	57	-1.1	-1.5	-1.2
Lao PDR	15,751	68	-0.5	-0.5	-0.5
Myanmar	31,773	48	-1.2	-0.9	-0.9
Thailand	18,972	37	-0.3	-0.1	0.1
Viet Nam	13,797	42	2.3	2.2	1.1
Total	90,387	48	-0.5	-0.3	-0.4

Note: Table excludes the People's Republic of China

Source: FAO (2010).

¹ FAO Regional Office for Asia and the Pacific, Bangkok, Thailand.

Rates of change of forest area with respect to natural and planted forests also show considerable differences. While net forest area (including natural and planted forests) fell by 8.0 million hectares between 1990 and 2010, the area of natural forests fell by 12.7 million hectares in the GMS; planted forest establishment of 4.7 million hectares accounted for the difference between these two figures. The primary cause of deforestation is agricultural expansion for production of food and other agricultural commodities, both to supply expanding populations in the subregion and for export.

By 2020, an additional 21 million people will join the subregion's population, representing net growth of 9.4%, taking the total population to 249 million people. At the same time the rural proportion of the population is expected to fall from 70% to 65% as people move to urban areas in search of employment opportunities. Economies are expected to grow rapidly and foreign direct investment in the subregion is likely to increase, including in rural sectors. Global demands for land and for agricultural commodities, including food and energy products, are set to increase further. Demands on forests, including for wood and timber, will continue to increase as populations and incomes grow, while at the same time demands for ecosystem services will continue to expand.

Forests and forestry intersect with the food-water-energy nexus at several points. For example, food is gathered in forest areas, often by poor rural dwellers; forests also help to maintain the quality of water essential for fisheries and agricultural production. Forests provide fuelwood and wood for charcoal production and potentially provide a sustainable and low carbon source of commercial energy. Trees generally differ from agricultural crops in that they often do not produce foodstuffs, but through more extensive rooting systems and their perennial nature can use more of the available water and produce greater volumes of biomass than annual, and less deep rooting, agricultural crops.

The nature of the food-energy-water nexus in the GMS differs, however, from that in more water limited areas of the world. In all except the dry zone of Myanmar, GMS total annual rainfall exceeds 1,000 mm and in large parts of the subregion exceeds 1,500 mm. In this context, the trade-offs between food, energy, and water use/production are not acute and, in comparison with most agricultural crops, the higher levels of water use by trees and forests can be viewed as a benefit under certain circumstances. Greater use of annual precipitation means higher levels of biomass production. Trees and forests can help control flooding in

small and medium-sized catchments during less extreme rainfall events (FAO, 2005). They can help desaturate soil, reducing landslide risk and also stabilize soil through deep and extensive rooting. In dryer catchments, trees can, however, lower water tables and reduce stream flow. This can be the case in particular with exotic species, which generally have higher levels of productivity and use more water.

While using more water than annual crops, forest production systems are, in general, less labor and energy intensive than agriculture. For example, fertilizer and pesticide/herbicide inputs are lower and tending operations are generally confined to planting, thinning, and harvesting on a cycle of 5 years or more. With rising energy prices, forest products prices should therefore be less affected than those of agricultural products. Although lower labour requirements may constitute an advantage with rural labour markets becoming increasingly constrained in the context of expanding industrial and service sectors in the region, forests are also generally located away from urban centres/areas of high energy demand and beyond zones that are optimal for agricultural production. While reduced competition with crop production still constitutes an advantage, distance from markets also reflects the lower comparative value of forest products.

With growing interest in the role of forests in climate change mitigation, continued availability of funds from a post-Kyoto replacement for the Clean Development Mechanism, and growing interest in afforestation and reforestation in the region, forests may be set to play a greater role in moving the region towards a green development path, including in relation to energy production. The forestry sector must be cognizant of changing demands in determining potential impacts and trade-offs and position itself for the coming challenges. Other sectors and decision makers must be made aware of the benefits forestry can offer.

The following sections look more specifically at forests and forestry in the context of food, energy, and water and the interactions between the three elements.

2. Food

Forests provide sources of food for rural GMS populations, particularly outside cropping seasons, and non-wood forest products are also often traded to pay for food. Forest dwellers are usually most dependent for subsistence livelihoods, but commercial production also supports

collectors and processors and provides food and other goods for the subregion. Although dependence on forests is often associated with poverty, forests have a proven role as safety nets in times of hardship.

In the current context of expansion of industrial and commercial agriculture in the subregion, poor rural populations often lose access to food from forest areas as clearance takes place. Villagers may also be displaced from the land and, if revenues or goods are not available from the replacement production systems, landlessness and poverty may result. Additionally, displacement and migration of populations into remaining forest areas may occur, often resulting in deforestation and forest degradation.

GMS countries have a high level of rice sufficiency and imports play only a minor role in national consumption. Thailand and Viet Nam are significant exporters as shown in Table 2. Considering the level of rice 'sufficiency' at the national level, however, the prevalence of undernourishment² in the GMS is high at 15%. Looking at individual countries, rates are highest in Cambodia and the Lao PDR, where incomes are lowest and forest cover highest.

Between 1997 and 2007, rates of agricultural expansion were highest in the Lao PDR, Myanmar, and Cambodia. A large absolute increase in agricultural land area was also seen in Viet Nam, while a small reduction was reported in Thailand.

Trends in agricultural expansion in the subregion largely result from cultivation of a relatively small number of agricultural products, mostly cash crops (Stibig *et al.*,

2007). In Cambodia, the Lao PDR, Myanmar, and the highlands of Viet Nam the production of rubber, cashew nuts, coconut and sugar cane, and of cacao, coffee, and tea in highland areas has been a major cause of forest conversion. Changes in coastal zones in Myanmar, Thailand, and Viet Nam have taken place as a result of demand for land for shrimp ponds and agriculture, and mangrove forests have been lost as a result. Large areas of forest have been cleared for rice farming in upper Bago Division and around Nay Pyi Taw.

Although the recent expansion has generated revenues, the direct contribution to undernourishment and energy production have been minimal while forests have been cleared. In the context of rising global food prices and increasing levels of foreign direct investment, further conversion of forests in areas with agricultural potential is likely to be seen but it is not clear if this will contribute directly to reductions in undernourishment or greater bioenergy production.

To increase agricultural production, reduce malnourishment, and create surpluses for possible bioenergy applications, improvements in agricultural yields and reduction in postharvest losses will be necessary. One third of the food produced worldwide is not consumed and a significant amount of energy and water inputs are embedded in these losses. The potential to improve efficiency in food utilization and distribution is all too often overlooked while arguments for agricultural expansion, often at the expense of forest area, prevail. At the same time, avoiding clearance of valuable forest resources will be necessary to avoid attendant greenhouse gas emissions and loss of ecosystem services provided by forests.

Table 2: Rice Production and Trade, 2008, and Undernourishment, 2005–2007, in GMS Countries

	Production	Imports (tonnes)	Exports	Undernourishment (% of population)
Cambodia	7,175 470	7,574	5,001	22
Lao PDR	2,927 140	22,350		23
Myanmar	32,573 000	81,000	42,801	16
Thailand	31,650 600	13,633	10,216,049	16
Viet Nam	38,725 100	683	4,735,170	11
Total	113,051 310	125,240	14,999,021	15

Note: Table excludes the People's Republic of China.

Source: FAO.

² The status of persons, whose food intake regularly provides less than their minimum energy requirements.

At present, national strategies may be more market- than policy-led, with countries focusing on high value products while importing energy and reducing undernourishment through market rather than subsistence means. With high levels of exports and high levels of undernourishment in some countries, however, review of current strategies should be considered.

It should also be considered that focus in the GMS for agricultural production may increase disproportionately in the coming years, given the availability of land and water in the subregion and that climate change impacts during the next 30 years are not expected to be as dramatic as those in many other global regions. In addition, changing tastes and the consumption of a larger proportion of meat in the diet are only likely to further escalate demand for agricultural expansion.

3. Energy

Wood energy can take many forms and is involved in a range of different processes, including traditional woodfuel³ consumption, use of wood residues (e.g., sawdust and other mill wastes), use of forest residues following logging; thinnings and woody material from forestry operations; wood chips from salvage operations; and wood from plantations grown specifically for energy. Until recent times, wood provided much of the subregion's energy needs and in many areas wood remains a core cooking and heating material. Estimates based on GDP and population growth

show that in most GMS countries, per capita levels of wood energy consumption are falling as incomes rise and alternative sources of energy become available (Figure 1).

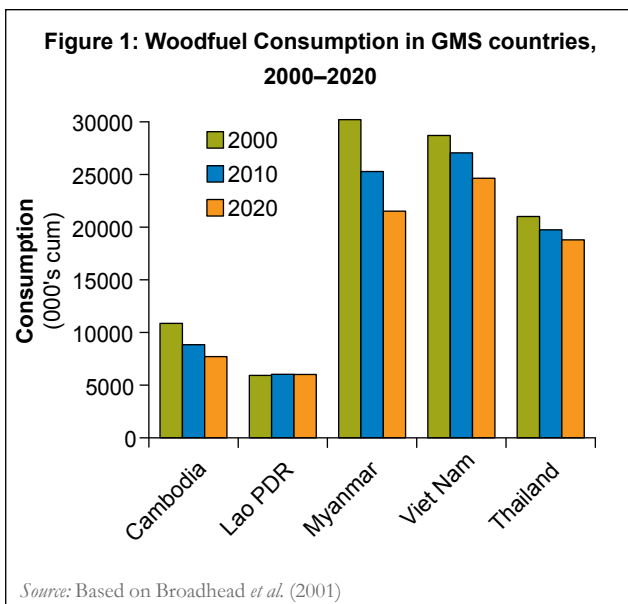
The forecasts shown do not, however, accurately reflect some of the factors influencing wood energy consumption in the GMS countries. For example, where access to alternative fuels is limited, such as in large parts of Myanmar, woodfuel consumption may remain at high levels. Woodfuel use may also remain high where it is cheaply and readily available. In Cambodia, for example, clearance of land for industrial agriculture and senescence of rubber plantations are providing wood that is being used extensively for commercial energy production. Future increases in woodfuel use as a renewable feedstock for modern bioenergy systems may also significantly alter the structure of woodfuel consumption and affect the trends shown in Box 1.

As traditional use of fuelwood and charcoal is considered undesirable due to inconvenience and health impacts, reduction in consumption is not seen as an issue even though carbon emissions associated with substitute fuels is often higher. The main impact of increasing demands for food, water and energy on traditional energy use is and will be through conversion of land where woodfuel is currently collected, with increased flows of woodfuel being a part of the conversion process.

In the broader context of modern energy usage, climate change mitigation and energy import dependency, the role of wood energy is as yet poorly defined although the potential is considerable and implications in relation to the food-water-energy nexus are greater.

Wood energy, particularly the traditional burning of woodfuel for cooking and heating, continues to meet a substantial portion of energy demand in rural areas. In GMS countries, excluding the People's Republic of China, combustible renewables and waste, including wood, is the largest single source of primary energy supply (Figure 2).

Patterns of energy consumption in the GMS are changing, however, and energy use is increasingly dominated by fossil fuels including crude oil, coal, and natural gas. Proven fossil fuel reserves in the region are relatively small and unevenly distributed. As a result, imported fossil energy will play a significant role in meeting the region's energy needs. In recent years, energy demand has been outpacing production to a greater and greater extent and this trend is set to continue (Figure 3).



³ Woodfuel refers collectively to fuelwood and wood for charcoal production.

Box 1: Woodfuel and Biofuel Use in Myanmar

Woodfuel is the most commonly used biofuel in Myanmar and consumption is dependent on availability of substitute fuels, standard of living, and climate. In northern and eastern parts of the country, households often use fuelwood for heating during the cold season. With respect to charcoal, mangroves in delta areas, especially in Ayeyarwady Division, have been major sources of production for many years and are under significant threat. Charcoal production is now restricted and substitute fuels are promoted to prevent deforestation.

Estimates of past and future energy consumption by fuel type show a falling proportion of fuelwood and charcoal although total consumption is likely to increase by 14% as a result of population growth (see Table).

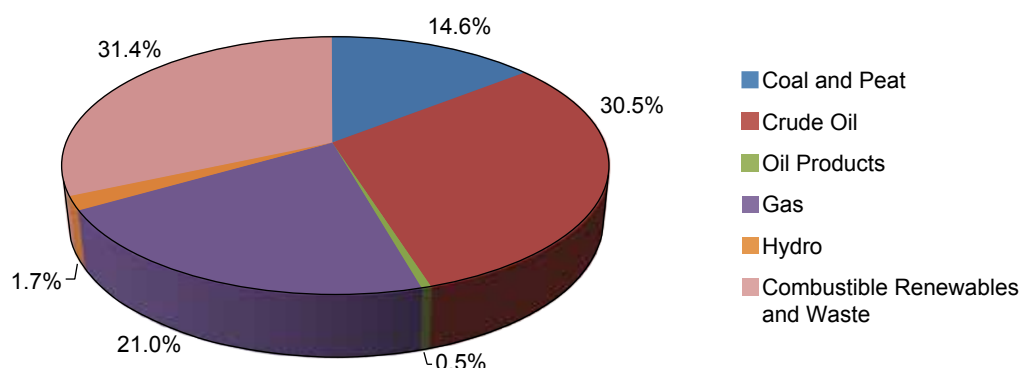
Percentage Energy Consumption by Fuel Type, 1990–2020

Type of fuel	1990	2000	2010	2020
Crude oil	6.7	8.0	8.0	9.0
Natural gas	3.9	4.5	6.0	10.0
Coal	0.3	0.4	0.8	1.0
Hydropower	1.7	6.0	9.0	13.0
Agricultural residues	3.3	4.5	6.8	9.0
Fuelwood/charcoal	84.1	76.6	69.4	58.0

To promote biodiesel as an alternative fuel, a large-scale campaign to plant *Jatropha curcus* was introduced in 2005. Other programs to reduce woodfuel consumption and deforestation have been implemented, including promotion of agri-waste briquettes, distribution of efficient stoves, household use of liquefied petroleum gas (LPG), and natural gas for brick kilns and reintroduction of kerosene. The 2001

National Forest Master Plan included targets of establishing 60,750 hectares of local wood supply plantations by 2010 followed by 48,600 hectares by 2020. However, funding constraints and low institutional capacity have hindered implementation.

Source: Tun (2009).

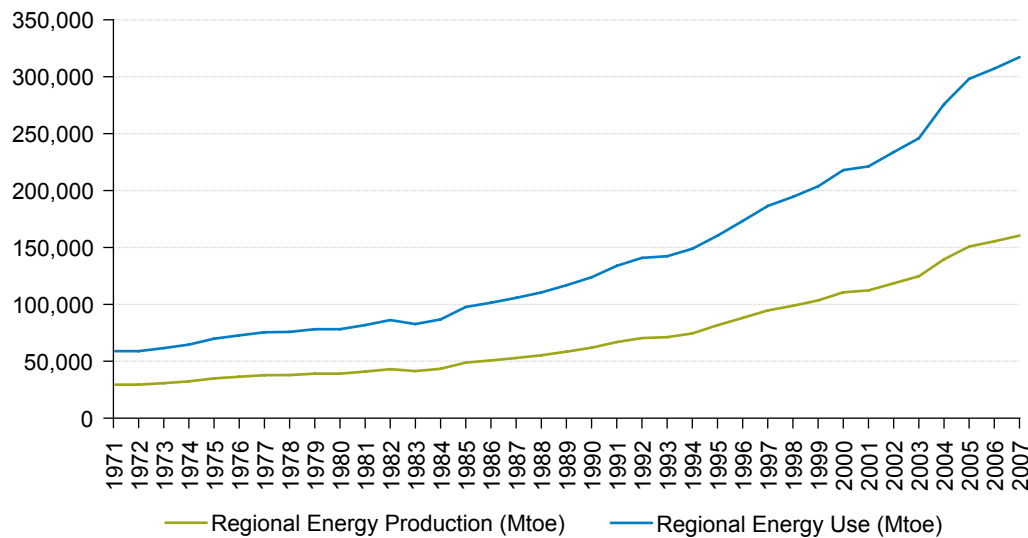
Figure 2: Total Primary Energy Supply Share in GMS countries, excluding the People's Republic of China and the Lao PDR, 2008

Source: IEA (2009).

The region's dependence on imported energy sources varies by country. While Cambodia and Thailand are already heavily dependent on imported fossil energy sources, Myanmar and Viet Nam are net energy exporters due to considerable reserves of natural gas, and coal and crude oil, respectively.

Growing demand for crude oil and oil products will be a key issue for the subregion in the medium-term due to increased vehicle ownership. Thailand's and Viet Nam's proven oil reserves are expected to be depleted within the next 12 years at current rates of production (IEA, 2009). At current rates of production, regional oil supplies have

**Figure 3: Total Energy Production and Use in GMS countries,
excluding the People's Republic of China and the Lao PDR, 1971–2008**



Mtoe = million tons of oil equivalent.

Source: IEA (2009).

to be supplemented with imported crude oil and refined product. This trend is expected to continue.

- policy and institutional issues that provide the framework within which forestry acts.

The growing dependence on imported oil products in the GMS mirrors trends in Southeast Asia. Across Association of Southeast Asian Nations (ASEAN) countries, dependence on imported oil is projected to grow from less than 30% of oil consumption in 2008 to over 70% in 2030.

The potential of any bioenergy strategy will also be highly influenced by local context, including: location relative to supply and demand; infrastructure, climate and soil; land and labor availability; and social and governance structures (FAO, 2008).

Despite recent fossil fuel price increases, these sources of energy are expected to remain cost competitive over the medium term in the absence of measures to internalize environmental costs in relation to, e.g., carbon emissions. Fossil energy also benefits from government support policies and extensive infrastructure and distribution networks. While some biomass-based energy production chains are already competitive at current energy prices, many require additional support.

Most governments in the GMS region have developed or are developing bioenergy policies in conjunction with broader support for renewable energy (Table 3). Diversifying liquid fuel supplies to reduce spending on oil imports is providing the main impetus and policies are being generally implemented through national mandates and targets for biofuel production for the transportation sector.

As a result, the extent to which wood energy will contribute to future energy production is likely to depend on several factors, including

- the competitiveness of wood-based energy in reaching the objectives of energy related policies (including strategic and climate change related objectives);
- the costs and benefits of wood-energy related systems in economic, social, and environmental terms; and

Without appropriate safeguards and in the absence of growth in agricultural productivity, expanding production of biofuels in the region is likely to have negative impacts on forest resources. In terms of climate change mitigation, benefits resulting from reduced use of fossil fuels will take decades to offset emissions resulting from forest conversion. Biofuels have also been identified as one of a number of factors leading to recent high food prices.

Second-generation biofuels produced from lignocellulosic biomass could provide greater greenhouse gas emissions benefits than existing bioenergy technologies and allow

Table 3: Bioenergy Mandates and Targets in Selected GMS Countries

Country	Biofuels Mandates/Targets	Biomass Heat and Power Targets
People's Republic of China	E10 in nine provinces; 15 billion liters of biofuel consumption by 2020	30 gigawatts by 2020
Thailand	B3 & E10; 5 billion liters of biofuel production by 2022	3,700 megawatts by 2022
Viet Nam	550 million liters of biofuel production by 2020	5% (30 gigawatts) renewable energy by 2020, including biomass

B3 is a fuel mix of three percent biodiesel and 97 percent fossil diesel; E10 is a fuel mix of 10 percent ethanol and 90 percent fossil gasoline.

Source: REN21 (2011)

countries to employ woody biomass to meet growing demands for transport fuels. These fuels would also involve less competition for agricultural resources, such as land and water, than existing biofuel production systems. However, significant technological and financial challenges still remain. The most optimistic estimates anticipate that the commercial production of second-generation biofuels globally will not commence until at least 2020.

The PRC and Thailand have incorporated support for research and development of second-generation biofuel technologies into national bioenergy policies. The presence of existing facilities and infrastructure will allow rapid adoption of these technologies as they become available. Limited financing and a lack of skilled labor and suitable infrastructure will, however, restrict the ability of other countries in the region to adopt similar strategies.

The situation in the stationary heat and power sector is expected to be somewhat different. At the broader regional level, the International Energy Agency (IEA) estimates that Southeast Asia's electricity generating capacity will need to grow from 138 gigawatts (GW) in 2007 to 381 GW in 2030. The availability of substantial agricultural and wood wastes in the subregion presents a significant opportunity to develop biomass power generation facilities and biomass-based combined heat and power (CHP) operations.

There are already a number of CHP operations in the subregion, most focusing on agricultural residues as feedstock. Agricultural residues offer great benefits because competition with food production is not an issue and current levels of usage are low. Similarly, further integration of wood energy into the regional heat and power generation sector will present a number of benefits.

The latest Intergovernmental Panel on Climate Change (IPCC) review of bioenergy research confirms that most bioenergy production chains have considerably lower greenhouse gas emissions than their fossil counterparts and that using modern wood-based bioenergy in heat and

power generation is a more cost and land efficient way to reduce greenhouse gas emissions than producing biofuels for the transport sector. Forestry also has the potential to provide energy feedstocks while competing less with food production and making greater use of rainfall available outside cropping seasons and more use of water present in deep soil layers than annual crops.

For wood to be a renewable source of energy, however, it cannot be associated with deforestation or forest degradation and realizing the carbon benefits and green credentials of woodfuel has proven to be difficult in a poor institutional environments where forests are poorly managed (FAO, 2008). Economies in the GMS are currently developing fast and several have high per capita levels of forest cover. Land is being cleared and wood is cheaply available but this supply is not sustainable. Considerations of potential impacts on natural forests and issues related to establishment of plantations would have to be considered in large-scale efforts to promote wood energy.

Additionally, to make a large impact on overall energy consumption, a huge quantity of wood would be required and water considerations may become important if afforestation of large areas of land with exotics is considered. This trade-off between the potential carbon benefits of wood energy and the water resources required needs further investigation and consideration.

4. Water

Forests are important in maintaining water quality and reducing erosion and landslides. They also have great political significance in relation to water and radical policy realignments have taken place across the Asia-Pacific region owing to the perceived importance of forests in controlling floods and droughts. In several cases, this has had important impacts on the livelihoods of upland farmers (FAO, 2001).

With climate change-related increases projected in the frequency of extreme rainfall events in the subregion, the importance of upland forests is set to increase in relation to erosion and landslide control. Reducing erosion is also of importance in relation to the proliferation of hydropower developments in the subregion. Stream sediments have deleterious effects on electricity generating equipment and also increase infilling of reservoirs.

In general, protection forests in the subregion are poorly managed. Major changes in forest policy in Thailand and Viet Nam have, however, focused attention on upland forests protection and regeneration. In the Lao PDR, major efforts are underway to protect forests in dam catchments and schemes to make payments from hydropower revenues for forest protection and community development have been piloted. In Viet Nam too, payments for ecosystem services (PES) have been piloted and national policies and legislation supporting PES have been developed. As climate in the region changes and hydropower developments go ahead, forests may become more important in relation to watershed protection. Some potential exists for impacts on the activities of upland farmers.

Despite these developments, schemes to establish payment mechanisms for watershed-related ecosystem services have not become widespread in the subregion. Past indications in Asia suggest that watershed-related services will be maintained through regulatory measures rather than payments for them and in this context it will be important to ensure that the livelihoods of upland populations are not adversely affected.

In relation to the wider food-energy-water nexus, key water issues associated with forests include not only watershed protection but also the level of water use by trees and forests in comparison with other land uses. Despite having been the stimulus for major changes in forest policy in various parts of the Asia-Pacific region, the role of forests in flood control is limited to small and medium intensity events (FAO, 2005). Forests have little effect on basin level

flooding resulting from extreme rainfall events. At the same time, trees and forests have an important role in erosion and landslide prevention; the ability of trees to desaturate soils is an important part of the latter.

In this context, the implications of upland afforestation and reforestation on stream flows have been questioned in various parts of the world. Concerns over forest water use have been particularly strong in dry areas and also in parts of the PRC where large-scale upland afforestation has taken place in the last 20 years.

With respect to water availability in the GMS, although dry areas do exist, Thailand and Chinese parts of the subregion do not experience significant water scarcity with less than 25% of water from rivers being withdrawn for human purposes (IWMI 2007). Outside the PRC and Thailand, the GMS experiences “economic water scarcity” in which “human, physical and financial capital limit access to water and although less than 25% of water from rivers is withdrawn for human purposes, malnutrition exists.” On the whole, however, per capita water availability in the GMS is greater than 5,000 cubic meters (m³) water per year - among the worlds highest.

Increasing forest cover in the GMS is therefore unlikely to result in water scarcity, except in dry areas, particularly given that historic forest cover levels are much higher than those presently seen. Table 4 shows that the major catchments in the GMS region have often lost well over half their original forest cover. Relationships between forest cover and basin yields are, however, still not well understood and seasonal water scarcity may pose problems in light of greater demand for water for agriculture. Increased storage capacity is likely to be needed regardless of levels of forest cover.

A key factor in any upland reforestation efforts will be the choice of species, with some water hungry exotics potentially reducing water flow more than indigenous and naturally regenerated forest.

Table 4: Forest Cover and Forest Cover Change in Major Watersheds in GMS Countries

Watershed	Current Forest Cover	Loss of Original Forest Cover
	(%)	(%)
Mekong	41.5	69.2
Hong (Red River)	43.2	80.0
Salween	72.3	43.4
Ayeyarwady	56.2	60.9
Chao Phraya	77.3	35.4

Source: Earthtrends - Watersheds of the world. http://earthtrends.wri.org/maps_spatial/watersheds/asiaocea.php

5. Synthesis

In general, the GMS experiences some undernourishment among its population, while having a good supply of water in most areas, high energy import dependence, and low carbon efficiency per unit energy production (low use of renewables). In this context, the main constraints related to the GMS food-water-energy nexus that are likely to impinge on forestry are competition for land for the production of food to address undernourishment and for energy feedstocks to address import dependence. Given rising levels of economic liberalization and rising demand for energy, in the PRC in particular, impacts in the GMS are likely to come from increases in global as well as domestic demand, especially in view of the large remaining areas of non-agricultural land, i.e., forestland and wastelands, such as Imperata grasslands.

Land and water resources in the GMS have already been identified by global investors and production of cash crops has increased greatly in recent years as previously noted. In Thailand and Viet Nam, although loss of primary forest continues, overall forest cover is increasing. Cambodia, the Lao PDR, and Myanmar, however, face a different situation, being less developed and having larger forest areas and higher requirements for economic development. The result could be conversion of natural forests on a large scale but also, depending on the economics and political decisions made, expansion of planted forests.

Some aspects of forests' involvement in the food-water-energy nexus will be important in determining their role in future land management, e.g., level of water use in comparison with crops, location of forests in relation to agriculture and area of energy consumption, watershed protection, carbon emissions of wood energy, and energy input requirements for forest production systems. On a longer time scale, the role of forests in climate change mitigation will also be of importance. Other areas will not be so important in direct relation to the nexus, e.g., traditional woodfuel use and food from forests.

Considering the trade-offs between food security and bioenergy production, a key issue will be whether this will result in a trade-off between food production and climate change mitigation and if so, whether forests can play a part in simultaneously providing climate change mitigation and helping reduce food price increases.

Given the carbon profile of modern stationary wood energy production and the separation of agricultural and forest

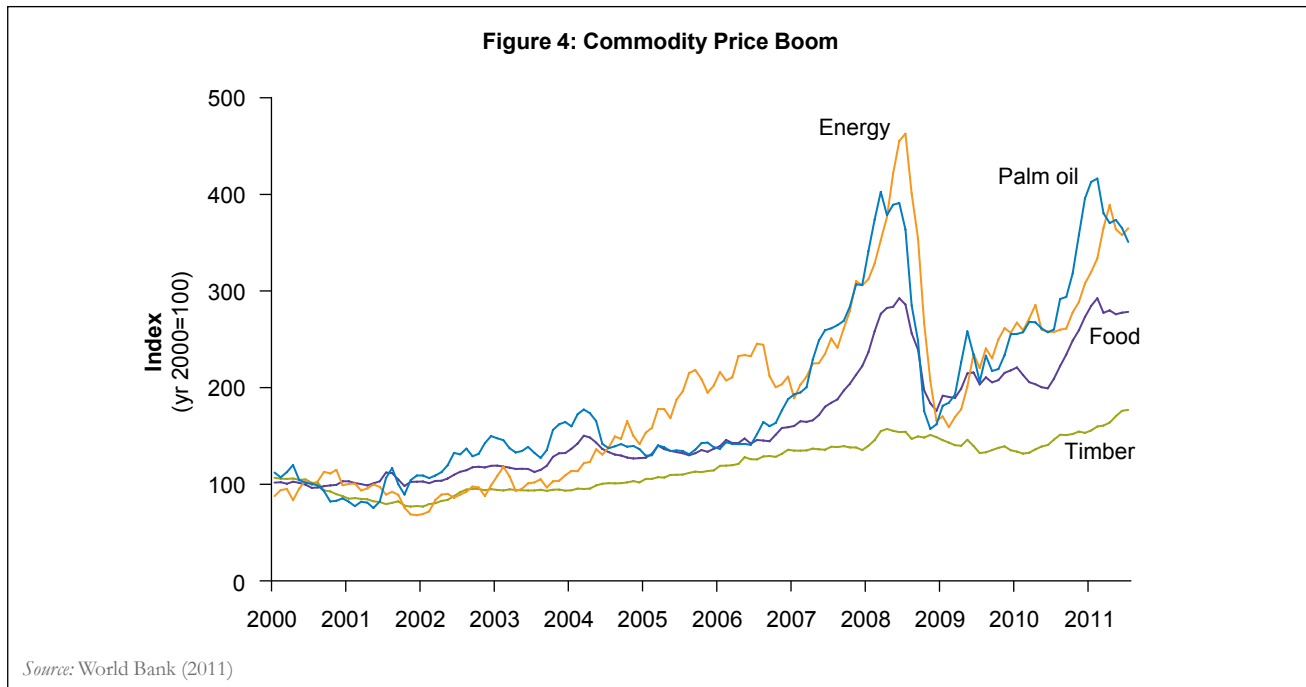
areas, there is potential for forests to play an important role in reducing energy import dependence and carbon emissions while competing less with food production than agriculture based bioenergy. The main deciding factors are the economics of wood energy production, the desire of governments to reduce energy import dependence and GHG emissions and government effectiveness in implementing policy.

With respect to the economics of wood energy generation, although there has been much discussion about the high conversion efficiencies and competitiveness of modern wood energy power generation systems, there remains some skepticism, centered on the following issues:

- The price of competing energy sources. The prices of oil and coal are still lower in real terms than during the peaks of the 1980s when wood energy was not found to be competitive in practice.
- Wood grown for energy almost always goes to a higher value use. Given the advances in wood technology, there is even more "competition" because panels and reconstituted wood products can now be made out of 'junk' wood that previously had little value other than to burn.
- Where plans are for wood to be grown to burn, there is now much greater competition for land than in the past as a result of the recent trend of rising food prices (Figure 4).
- The cost of collection/gathering/transport of wood rises with increasing costs of diesel or petrol (unless machinery is driven by wood-powered electricity) and its costs are also higher where infrastructure and mechanization are not highly developed. The IPCC bioenergy review indicates that handling and transport of biomass from production sites to conversion plants may contribute 20%–50% of the total costs of the biomass production. In large parts of the GMS, infrastructure is not well developed and mechanization is limited.

A key question is whether the situation has changed from the period of high fossil fuel prices 30 years ago. If not, wood use for commercial industrial energy (or electricity generation) is only likely to be economic in places where wood residues are plentiful and already amassed (e.g., sawmills). Locations not connected to the national grid could also be an attractive opportunity, but there are few examples of successful wood-fired power generation in such places.

Although substantially higher energy prices may be necessary before wood energy opportunities become



viable, many developed countries have wood-fired power stations as part of their energy generation “portfolio.” Such early involvement in the sector is likely to yield benefits in the longer term as energy prices rise and more detailed comparisons of the benefits offered by different renewable strategies need to be made. It should also be considered that most wood-fired power stations have been built in northern climates where potential tree growth rates are much lower than in the warm and well watered conditions of the GMS. The availability of funding for clean development and in relation to bioenergy and carbon emissions targets could also help push the balance in favor of wood energy. Furthermore, strategic interests and comparisons of the benefits of wood energy production systems with other alternative and renewable energy sources may increase the attractiveness of wood energy. Reduced competition with food production and more competitive greenhouse gas profiles are key factors.

In determining a possible role for wood energy, relative prices of goods and services will be important. While price increases for timber are not presently of the magnitude of palm oil and rubber, timber prices are nonetheless high compared to the recent past. PES associated with forests and wood use are also gaining ground, albeit slowly. This may drive some rationalization of land use and expansion of timber plantations onto land that is best suited for forestry. As such, the subregion could see increased plantation establishment on marginal agricultural land or even non-marginal land if there are strong competitive advantages

for forestry, such as proximity to a mill. Further clearance of natural forests for plantation establishment could also result. Such activity would almost certainly result in the loss of environmental services, especially where areas of high conservation value forest are concerned; safeguards against this possibility would be essential.

Other issues that will need to be considered are the impacts of purpose grown energy plantations. A main concern would be local resistance against planting eucalyptus and acacia and the risk of natural forest being cleared/consumed. Plantations also contain less biodiversity and generate less leaf litter and other organic inputs than native forests, and groundwater depletion can be exacerbated by deep-rooted exotic tree species that use more water than native species. In addition, biomass power generation technologies often do not have technical standards associated with their production and distribution and developers will usually not adopt technologies without performance insurance.

6. Conclusions

To provide the greatest benefit to current and future generations, foresters in the GMS region need to take into account changing demands on the sector and others need to be aware of the benefits forestry can offer. Demands for agricultural land for food and energy production may mean that pressures for forest conversion increase. At

the same time, climate change-related demands are likely to promote forest carbon sequestration and storage and forest-related climate change adaptation measures, particularly in relation to managing upland protection forests.

Given these demands, any conversion of forest to agricultural production should take into account trade-offs related to poverty, watershed related services, and climate change. Within the forest sector, improved efficiency of service provision and attention to the quality of the often highly degraded forest resources in the subregion will be a key priority to 2020.

Agricultural intensification will be a priority if forest clearance is to be avoided. Rice yields, for example, differ markedly between GMS countries and great increases in productivity could be made through technological improvements. Increasing intensification may, however, mean increasing risk of water pollution. Riverine and mangrove forests will be of increasing importance in mitigating eutrofication and hypoxia of water bodies and avoiding creation of marine dead zones, which in turn will have negative effects on food security, given the nutritional importance of fisheries production.

To help avoid scarcities in relation to food, energy, or water a combination of strategies encompassing the following activities will be important:

- resource planning, including water audits and assessment of water balances;
- infrastructure development;
- market-led resource pricing, including externalities; and
- technological innovation, including support for research and development.

In relation to forestry in the GMS, a key concern will be preventing further forest loss, particularly in relation to high value forests whether in terms of carbon storage, biodiversity, or watershed protection or other values. Lifting agricultural productivity and reducing extensification must be key elements of reducing pressures on forests. Reducing postharvest losses is a particularly important factor in increasing food production. Improved efficiency in food utilization and distribution is also of great importance and will help reduce demands on agricultural expansion at the expense of forest area.

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CLIMATE RISKS TO AGRICULTURE/ FOOD SECURITY IN THE GMS COUNTRIES AND EARLY WARNING SYSTEMS IN THE CONTEXT OF THE FOOD-WATER-ENERGY NEXUS

S.V.R.K. Prabhakar¹

Abstract

The Greater Mekong Subregion has undergone a rapid economic growth over the past decade with positive impacts on the human development and negative impacts on the environment and natural resources. The growing demand for energy in the region and high fuel prices during 2008 has seen several countries declaring ambitious biofuel strategies from which they retreated covertly later on. This has set a debate on nexus between food, water, and energy in the region. Though the biofuels fever has died down sooner than expected, there are chances for reemergence of debate over food-water-energy due to several traditional and non-traditional pressures discussed in this paper that include increasing energy demand, population growth, urbanization, changing life styles, and climate change. Early warning systems (EWS) can play a crucial role in averting situations like 2008 fuel and food prices. However, there are several bottlenecks to be overcome that include lack of infrastructure and capacity for implementing such EWS. In addition to EWS, this paper discusses some traditional off-the-shelf interventions such as general improvement in resource use efficiency in agriculture, water and energy sector, increasing energy supply through renewable sources, and creating an East-Asian Energy Community or a grid that could ease the food-water-energy nexus in the region to a greater extent.

1. Introduction

The well-being of countries in the Greater Mekong Subregion (GMS)—Cambodia, Guangxi Zhuang Autonomous Region and Yunnan Province of the People's Republic of China (PRC), the Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, and Viet Nam—is very much linked with the Mekong River as it influences the livelihoods of a large

proportion of the population in these countries directly or indirectly. The economies in the GMS are predominantly agrarian with 63% of the total population dependent on agriculture (FAO, 2011) contributing to 22.6% of total GDP in the subregion (World Bank, 2011) which signifies the importance of stable agriculture production to the livelihoods of majority of the population in the GMS.

The subregion has witnessed rapid economic growth in the past decade with both positive and negative consequences. The positive consequences are increased income levels and better progress in human development; the negative consequences include rapid degradation of natural environment; heavy pressure on natural resources, such as water, land, and forests; and heavy demand for all forms of energy. Despite the development gains, including steady increase of food supply over the past several years reaching a current level of 2,551 calories (kcal)/capita/day, a wide disparity in the food supply situation also exists between countries, with highest food supply in PRC (2,981 kcal/capita/day) and least in Cambodia (2,268 kcal/capita/day) and the Lao PDR (2,240 kcal/capita/day), and within the countries (World Food Program, 2004). During recent years, the global rising food prices have become a cause of concern (ODI, 2008), which was attributed to the cumulative impact of increasing population pressure; dwindling natural resources, such as land and water due to such pressures as rapid urbanization, industrialization; and introduction of biofuels that directly compete for land and water resources. These factors could be characterized as “traditional pressures” in the subregion.

Climate change brings another dimension, as a “nontraditional” pressure. Available climate projections indicate impacts on crop yields, while changes in seasonal Mekong River flows (Kingston *et al.*, 2011) might complicate the food-water-energy conflict in the GMS. This necessitates a review of current patterns of growth and alternative pathways that could reduce vulnerability to climate change while mitigating or moderating the traditional pressures, thus leading to sustainable development. This can be achieved through developing an early warning system (EWS) that keeps track of the food-water-energy nexus dynamics in the subregion and warns policy makers to take pragmatic steps to avoid catastrophic consequences. However, developing a EWS requires greater understanding of the variables underlying this food-water-energy nexus.

This paper evaluates climate risks to agriculture in the GMS, evaluates the traditional stressors that are already

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active in the subregion, helps understand the opportunities and difficulties in developing a EWS for the food-water-energy nexus, and provides a way forward in terms of policy suggestions.

2. Understanding Factors Operating on the Food, Water, and Energy Nexus

Understanding the system and different factors that determine the food-water-energy nexus is a pre-requisite for developing an effective EWS in the subregion. From the point of the nexus, the EWS constitutes the actors and the many traditional and nontraditional pressures that determine the demand and supply of food, water, and energy in the GMS.

2.1. Traditional Pressures

Rapid economic growth. The GDP of GMS economies grew at a rate of 7.3% in 2010 (International Monetary Fund, 2011) with various implications for such resources as land, water, and energy.

Growing population. The population in the subregion grew at an average rate of 0.94% during 2005–2010. Though this is less than the global average (1.16%) and that of Asia (1.08%), the populations of Cambodia, Myanmar, and Viet Nam grew at more than 1% during this period (United Nations, 2011a). In short and medium terms, the population growth rates in terms of total fertility rates in these countries are projected decline (until the 2050s); however, in long-term projections (to 2100), all the countries have positive growth rates, implying increasing population pressure on various natural resources.

Urbanization. Urbanization creates demand for land, water, and energy. The urbanization in the GMS in 2010 was 3.19%, higher than in less developed regions (2.39%) and in more developed regions (0.5%) of the world. With current policies in place, the GMS countries are projected to urbanize at the same rate until 2020 when it should start declining (United Nations, 2011b).

Energy demand. Fuelling economic and population growth has led to rapid increase in demand and consumption of primary energy in the GMS. All the countries in the subregion are net importers of energy with the PRC being the world's largest importer of primary energy. The demand for energy is set to increase until 2030 and beyond, and future energy needs are expected to be mainly met through

fossil fuel sources. To avoid climate change implications, countries in the region should seek alternative energy sources, such as biofuels, that may have implications for land and water, and hence for food.

2.2. Nontraditional Pressures

Climate Change. Climate change is known to bring some additional pressures to the traditional pressures discussed above and could be more significant than expected. Most importantly, the past climate trends in the GMS suggest a significant increase in rainfall events leading to heavy runoff losses, and projections suggest an increase in rainfall and floods with implications for water and related sectors.

Among the above discussed factors, this paper focuses on two important pressures, energy and climate change. Energy demand is chosen because all other factors (economic growth, urbanization, and population growth) are manifested in terms of energy demand, and because of the implications of biofuel production (Worldwatch Institute, 2007; Prabhakar *et al.*, 2009; Prabhakar *et al.*, 2008; Elder *et al.*, 2008). Also, energy and climate change are recognized as the most significant threats to global food security in the long run (FAO, 2009a).

3. Climate Risks to Agriculture and Food Security

Agriculture has multiple interactions with climate change. It is impacted by climate change (either negatively or positively), and it can influence climate change (both negatively through greenhouse gas emissions and positively by providing an opportunity to sequester carbon). This section reviews different observed and projected trends of climate change in the GMS for deriving implications in terms of food security and the food-water-energy nexus. Although emphasis is given to country- and GMS-specific literature, other literature that covers some GMS countries was included. The later part of this section discusses how agriculture in the region can impact the climate change.

3.1. Observed Climate Change

Few things must be kept in mind before making conclusions about the past impacts of climate change in the GMS. Some countries in the region have well established climate research programs while others are either in advanced

development phase or beginning to establish research programs with external support. In most of the GMS countries, the density of meteorological observatories and the quality of data in terms of time series are limited. Hence, conclusions on the historical observations have to be made with caution.

Climate change is a global phenomenon with uneven distribution of its impacts across different geographical locations. Climate change in GMS countries is manifested in various forms (Parry *et al.*, 2007; Asian Development Bank, 2009) and the countries in the region have already started showing signs of climate change (Asian Development Bank, 2009) with differences among countries.

Significant increase in the annual number of hot days and warm nights and significant decrease in cool days and cool nights were reported in Southeast Asian countries (Manton *et al.*, 2001). Trends in extreme temperatures were consistent across the region. Extreme rainfall trends were less spatially consistent than were those for extreme temperature.

The number of rain days (with at least 2 mm of rain) has decreased significantly throughout Southeast Asia. The proportion of annual rainfall from extreme events has increased at most stations. A regional study based on 20-year rainfall data obtained from 16 locations in Bangladesh, Indonesia, Thailand, and Viet Nam has identified positive rainfall trends in peninsular Thailand and negative rainfall trends in Sumatra and Java islands of Indonesia (Egashira *et al.*, 2003). The variability in rainfall was, however, higher in the dry season than in the wet season. In the GMS, the past trends indicated an increase in precipitation during the early monsoon season and increase in runoff (Costa-Cabral *et al.*, 2008; Jianchu *et al.*, 2009).

PRC. Since there is scant literature on Guangxi and Yunnan, general literature from the PRC has been cited here. In general, there has been a clear observation of climate change in the PRC. The past 100-year meteorological records indicated a warming of 1.1 °C manifested in terms of warmer winters, with 2007 as the warmest year in the recorded history (State Council of the People's Republic of China, 2008). Changes in terms of distribution of rainfall across the PRC were reported with distinct trends of increased precipitation in western and southern PRC and decreased precipitation in northern and northeastern PRC. Increase in heavy precipitation events was observed in the southern PRC, which has implications for the GMS since a large proportion of water in the Mekong River originates from Yunnan Province, mostly from snowmelt

in the Tibetan plateau and precipitation. There is a high probability of association between accelerated glacier melting and increased surface temperatures in this region (Barnett *et al.*, 2005) which puts this region as one of the most critical regions in the world in terms of climate change impacts on freshwater availability.

Cambodia. The meteorological data availability in Cambodia is relatively poor due to the war and destruction of meteorological observatories. To date, Cambodia has 38 meteorological observatories that record temperature and rainfall, 23 observatories that record evaporation, and 14 stations that record wind speed (Ministry of Environment, 2002). From the limited available data for the period of 1980-2000, no discernable trends were observed in temperature and rainfall (Ministry of Environment, 2001).

Viet Nam. In general, climate observations are reported to be in conformity with the regional and global trends. The monthly mean temperatures have increased by 0.07 to 0.15 °C per decade (Ministry of Natural Resources and Environment, 2003). However, these observations are not uniform throughout the country with some observatories showing a different trend from the national trend. The temperatures recorded at A Luoi and Nam Dong stations in 1974–2004 showed an increasing trend (NCAP, 2007). The temperature recorded at Hue station indicated a slight declining trend during 1991–2004 with no clear trend over 1928–1990. In most locations, the January temperatures (winter season) were observed to have become warmer when compared to the July month (summer season). The annual rainfall at A Luoi and Nam Dong has increased by 800 and 600 mm, respectively, during 1974–2004 with relatively stable rainfall before the 1990s. The rainfall has increased during the rainy season (August–December and April–May) and decreased during drier periods (June–July) with significant drought risks during drier periods and floods during the rainy season. At Hue, the trends were more complex with increasing trend of rainfall after 1996. At this location, rainfall showed a decreasing trend during January–March with values crossing the 100 mm drought threshold in most years after 1986.

Thailand. Known as the rice bowl of Asia, any changes in temperature and precipitation patterns in Thailand could lead to negative impact on the food security of the region. The observed maximum and minimum temperatures showed an increasing trend in Thailand during 1951–2002 (Greenpeace, 2006). From a long-term perspective, based on principal component analysis of temperature data available between 1951–2003, the minimum temperatures have been reported

to increase at an unprecedented rate since the early 1950s, consistent with the global and hemisphere average patterns (Limsakula *et al.*, 2008). The minimum temperatures changed quicker than the maximum temperatures leading to narrowing down of diurnal temperature ranges in Thailand. Maximum temperature increased significantly at Nan, while the increases at Prachuap Khiri Khan were not significant (Manton *et al.*, 2001). Temperature changes in other parts of Thailand are not consistent with the above observations. The northern provinces of Thailand, which include Chiang Mai, Chiang Rai, Lampoon, and Lampang, Phrae, Phayao, Nan and Pitsanulok, did not show any long-term trends (Kwanyuen, 2000).

Summer monsoon rains are a critical factor in Thailand's water resources and agriculture planning and management. Consequently, understanding the variability of the summer monsoon rains over Thailand is important for instituting effective mitigating strategies against extreme rainfall fluctuations. The observed rainfall pattern in the Chao Phraya Delta, which is considered the rice bowl of Thailand, has shown a declining trend over 1952–1991 (Kwanyuen, 2000). The reduction in rainfall was prominent in the river basins of Kok, Ping, and Nan rivers and no changes were observed in the Salawin, Wang, and Yom basins. The sub-basin level observations were consistent with the basin level observations indicating little spatial variation in rainfall trends in these basins. At Nan, the number of rainy days has decreased significantly, and the proportion of total rainfall from extreme rainfall has increased significantly (Manton *et al.*, 2001). Prachuap Khiri Khan showed a significant decrease in rainy days. There was a significant increase in extreme minimum temperature at both stations, partly owing to a peak in 1998. The number of warm nights increased and the number of cold nights and cool days decreased. Prior to the 1980s, there was weak relationship between summer monsoon and El Niño–Southern Oscillation (ENSO). However, recent studies have indicated a negative relationship between ENSO and the summer monsoon (Singhrattana *et al.*, 2005). This increasing influence of ENSO during recent decades has been attributed to Walker circulation over the Thailand-Indonesia region. In some models, a clear influence of climate change on Walker circulation has been established (Power *et al.*, 2007).

3.2. Projected Climate Change

General circulation models (GCMs) are used to simulate future climate change scenarios resulting from the accumulation of greenhouse gases (GHGs). The most common GCMs employed in generating simulations

are coupled GCMs (e.g., CSIRO global coupled ocean-atmosphere-sea-ice model), HadCM2 model, ECHAM4/OPYC3 model, and First Generation Couple General Circulation model (CGCM1) of the Canadian Center for Climate Modeling and Analysis. The outputs of these GCMs (e.g., monthly mean values of climate variables) are used to derive local impacts of climate change. More recently, multi-model ensembles became more prominent tools in providing more reliable climate projections than the single model approaches (Tebaldi *et al.*, 2007).

Climate projections in the GMS have been difficult because most GCMs have shortcomings in representing the ENSO phenomenon, which is the strong source of variability in Southeast Asia. The projected climate change over Southeast Asia is a general warming trend (Parry *et al.*, 2007; Allison *et al.*, 2009), following the global mean projections (an increase in temperature of 2.5 °C up to 2099) with likely increase in precipitation (Christensen *et al.*, 2007). There is high confidence in most of the climate change scenarios in the region that extreme rainfall events and winds associated with tropical cyclones will increase. There is a general tendency for models to project higher rainfall and more extreme floods in the GMS (Nijssen *et al.*, 2001; Jianchu *et al.*, 2009).

The conformal cubic atmospheric model (CCAM) was employed to study the impact of climate change in the lower Mekong basin (Chinvanno *et al.*, 2006). CCAM is the second-generation regional climate model developed for the Australasian region, with a resolution of 0.1 degree (about 10 km × 10 km). Three levels of simulations were carried out with varying levels of carbon dioxide concentrations. The model simulations showed increased precipitation throughout the GMS, with a range of 0–500 mm per annum, and a potential high intensity of rainfall with the same duration as in the current climate. The Mekong basin would be warmer by 0.79 °C, with greater increase toward north of the basin (Eastham *et al.*, 2008). The runoff would increase in most climate change scenarios projected in 2030 due to combination of high intensity of rainfall during the rainy season and accelerated melting of glaciers. The dry season runoff would remain the same across the basin, including in the Tonle Sap catchment in Cambodia. This has potential implications for increasing flood intensity during the rainy season and drought intensity during the dry season with negative impacts on agriculture.

The MIKE11 model was used to simulate flow and salinity intrusion from December to June (dry season) for the medium-term (mid-2030s) and long-term (mid-2090s)

scenarios using data derived from the SRES B2 climate change projection (Khang *et al.*, 2008). Models have projected +20 to +45 cm rise in sea level with a reduction in Mekong River flow by -15% to -29%. Medium- and long-term scenarios showed that the 2.5 grams per liter (g/L) saline front is likely to shift upstream by 10 km and 20 km in the main river channels, and up to 20 km and 35 km in the paddy fields, respectively. The individual country variation in the projected climate change is discussed below.

Three GCMs (UK 89, UKMO and GISS) were employed to construct temperature and precipitation scenarios over Thailand (Thailand Environment Institute, 1999). All models showed an increase in temperature, high in the central, northern and western regions (3.0–3.5 °C) and less increase in northeast (2.5 °C). Models predicted an increase in rainfall by 20% (Bachelet *et al.*, 1992; Greenpeace, 2006). The United Kingdom Meteorological Office Hadley Centre projected a warming of 1.74–3.43 °C by 2080 (Parkpoom *et al.*, 2008). Studies also indicated that the climate change could reduce the rainfall and reduce the runoff in Chao Phraya River basin with negative impact on its catchment areas (Ministry of Science, Technology and Environment, 2000). Results from an ensemble of 20 models revealed that Thailand will warm under both low and high GHG emissions scenarios during 2040–2069 compared to the mean temperatures observed during 1972–2003 (Felkner *et al.*, 2009). The magnitude of temperature increase under the high emissions scenario will be 40% higher than that in the low emissions scenario during 2040–2069. Daily precipitation will increase throughout the year under the low emission scenario and there will be less precipitation in the second half of the year, coinciding with the growing season of the rice crop, in the high emission scenario.

3.3. Projected Climate Change Impacts on Agriculture

Projecting climate change impacts on agriculture involves complex interactions between climate, agriculture systems, and crop management. In order to obtain relevant impact projections, the climate predictions of GCMs are utilized by dynamic crop simulation models (e.g., Decision Support System for Agrotechnology Transfer), and land management decision tools. Agro-ecological models are often employed to take advantage of the high resolution of dynamic crop models while still being able to handle large-scale computations with relatively good accuracy.

Climate change is expected to threaten the rice crop, the most important staple food crop in the GMS region, due to heat-induced spikelet sterility or increased crop respiration losses during grain filling (IRRI, 2006). Most of the rice crop being currently grown is at the threshold level of congenial temperatures for rice growing. In Southeast Asia, the hottest months are before the onset of the monsoon season, March–June, which coincides with the final stage of dry season rice crop. These areas are already experiencing high temperatures, 36 °C and above. Any warming in these areas would mean significant reduction in rice yields (Wassmann *et al.*, 2009). The HadCM3 global climate model using future climate scenarios projected by the Intergovernmental Panel on Climate Change (IPCC), indicated global and regional yield decline of crops such as wheat, rice, maize and soybeans (Parry *et al.*, 2004). The A1FI scenario² with large increase in global temperatures exhibited the greatest decreases both regionally and globally in yields by the 2080s. The contrast between the yield change in developed and developing countries was largest under the A2A–C scenarios. Under B1 and B2 scenarios, developed and developing countries exhibited less difference in crop yield changes, with the B2 future crop yield changes being slightly more favorable than those of the B1 scenario. In Asia, the reduction in crop yields was as high as 30%. Introducing carbon dioxide (CO₂) fertilization effects reduced the negative impact of high temperatures, especially in mid- and high-latitude areas for temperate cereals and South Asia, due to deep penetration of the monsoon in summer and a lengthened growing season. Similar benefits of CO₂ fertilization were observed in Southeast Asia.

Projected climate change scenarios suggested that the decline in yields of major crops would be: rice, 1.4% (Lobell *et al.*, 2008); wheat, 10%–95% (Fischer *et al.*, 2005); and soybeans, 10% (Lobell *et al.*, 2008). The agroecological zone models projected that the attainable wheat yields would decline substantially in the range of 10%–95% by the 2080s when compared to 1990 in Southeast Asia (Fischer *et al.*, 2005). The reduction in wheat yields is due to increasing temperatures, especially during the panicle initiation and flowering stages. The favorable area under wheat would either be reduced or move northward in the

² The IPCC A1FI scenario stands for fossil fuel intensive scenario characterized by rapid economic growth, a global population that peaks in mid century and declines thereafter; A2 family of scenarios represent a heterogeneous world, B1 family of scenarios describe a convergent world, and B2 family of scenarios represent emphasis on local solutions economic, social and environmental sustainability. For more description on IPCC SRES Scenarios, please refer to IPCC report on Emission Scenarios, Summary for Policy Makers (IPCC, 2000).

subregion, with expansion of area under subtropical and tropical crops replacing the wheat. Under various climate scenarios, the area covered by the cool, temperate wheat mega-environments could expand as far as 65°N (Ortiza *et al.*, 2008). Rising sea level can threaten crop production in many areas of Southeast Asia. The Mekong River Delta in Viet Nam and Cambodia is already facing the negative impacts of sea level rise and related intrusion of water into rice growing areas during the dry season (Wassmann *et al.*, 2007).

A global study on prioritizing adaptation needs for food security in 2030 was carried out by generating hunger importance ratings for all crops and region combinations (Lobell *et al.*, 2008). Climate change impacts were obtained from outputs of 20 GCMs and production changes for 2030 were expressed as relative to the average of 1980–1990. The study indicated a significant reduction in yield of rice and soybeans; 5% of the models projected a reduction in soybean yields by 10% or more and 50% of models projecting soybean yield reduction by 5% in Southeast Asia. Most of these reductions were attributed to the large dependence of historical production variations on temperature combined with the large projected warming overwhelming the large uncertainties in precipitation changes. Higher reduction in crop yields in climate change scenarios would mean greater impact of GHG mitigation. GHG mitigation in Southeast Asia could bring significant increase in cereal yields up to 130% compared to crop yields in 2000 in wheat, maize, rice and other coarse grains with most of the increments coming from the developing countries (Tubiello *et al.*, 2007).

The GMS is highly vulnerable to climate change impacts. Studies have indicated increased rainfall intensity in the subregion with implications for floods (Chinvanno *et al.*, 2006) and water scarcity during dry seasons due to reduced runoff and seawater intrusion (Khang *et al.*, 2008). The model projections on impact of future climate change on crop production were not uniform across the subregion and there is greater uncertainty (Eastham *et al.*, 2008). However, food scarcity may increase due to population pressure. Sea level rise could reduce the area under triple cropping of rice by 70,000 ha while the single crop area would increase by 38,000 and 179,000 ha for the near- and long-term scenarios, respectively (Khang *et al.*, 2008).

In Thailand, rice yields could drop by 57 % in Roi Et Province but increase by 25 % in Surin Province (Ministry of Science, Technology and Environment, 2000). The four climate models also demonstrated that climate change

could increase temperature during the flowering period of crops by 1–7 °C.

This would reduce flowering and harvesting periods as well as crop yields in general. A study based on ensemble-mean of 20 well recognized global climate models following the IPCC SRES scenarios along with the DSSAT model revealed the complexity of climate change impacts on rice crop in Thailand (Felkner *et al.*, 2009). The DSSAT simulations projected yield reductions of 30%–50% in both low and high GHG emission scenarios. The yield reductions were either moderated or even improved when farmers' response to rainfall change was incorporated through an economic model.

3.4. Agriculture Impact on Climate Change

Agriculture is also a contributor to climate change as an important emitter of GHGs. Rice lands occupy nearly 60 million ha in the GMS (FAO, 2011) and are a significant GHG emitter. A range of methane emission values are reported depending on microclimatic conditions, agronomic practices, and cultivars (IPCC, 1996). Taking median values, 50 grams per square meter (g/m²) for the PRC and 19 g/m² for Thailand, the region has potential to emit 12–30 million tons of methane in a single season. This range would double if there are two crops per year, and emissions from related manure management, etc., that are used for paddy cultivation are additional to these estimates. Thus, methane emissions are significant in the region and any policy intervention that aims to address climate change in the region cannot ignore these emissions.

From the above discussion, the following broad conclusions can be made that have implications for designing EWS for the food-water-energy nexus:

1. Significant observed climate change trends have been reported in the GMS in terms of warming and precipitation.
2. Climate change has specific implications for agriculture and food security, mostly through the impact on the rice crop and on freshwater availability.
3. There is great uncertainty in estimates of projected climate change impacts in the region. Most importantly, in the estimates of Mekong River flows and their impacts in various months of the year.
4. Agriculture also contributes to GHG emissions in the region and limiting these GHG emissions would have complementary impact on the water demand situation in the region.

4. Food-Water-Energy Conflict

In view of the climate change effects of fossil fuel use, many countries, including those in the GMS, are seeking alternative sources of energy, one of which are biofuels, i.e., oil obtained from biomass sourced from traditional food crops (e.g., corn, cassava, sugarcane, oil palm) or crops that have traditionally been known to provide oil for industrial purposes (e.g., jatropha). As a result, some countries in the region have rushed to set national targets of producing biofuels. The PRC has set a target of 15% share of biofuels in total transportation energy; Thailand has set a target of meeting 20% of vehicle fuel consumption by 2012 (Elder *et al.*, 2008); and Viet Nam has set a target of producing 500 million liters of fuel ethanol and 50 million liters of biodiesel by 2020 (Asia Pacific Economic Cooperation, 2008). The PRC is currently the largest producer of bioethanol in Asia and the Pacific and a global leader in biofuel production, with roughly one million tons of fuel produced annually (Weyerhaeuse *et al.*, 2007). About 1% of total transport fuel in Asia came from biofuels in 2004 (Worldwatch Institute, 2007). This was despite reports questioning the possibility of achieving national biofuel targets without causing food-fuel-water conflict, environmental degradation, and negative impacts on food security (Worldwatch Institute, 2007; Prabhakar *et al.*, 2008).

Many crops grown for food purposes (e.g., oil palm, corn, cassava, and sugarcane) were quickly converted to first generation biofuel feedstock. It is expected that the subregion will continue to promote first generation biofuels before the second generation biofuels are fully commercialized. Even though countries like the PRC have adopted policies to discourage use of food or feed crops for biofuels, concerns persisted that these policies might be difficult to implement and that biofuels would still directly or indirectly compete with food and feed (Prabhakar *et al.*, 2009). The factors that have led to the food-fuel-water conflict are elaborated below.

4.1. Conflict for Water

Producing crops require inputs, such as land, water, fertilizers, and pesticides. These inputs are essential for crops that are grown for commercial purposes where certain assured output (feedstock for biofuel) is expected in return. Biofuel crops fall under the category of commercial since they are produced for the market and are expected to return high-value commercial outputs such as feedstock for oil. Initially, there were efforts to produce biofuel from corn and food crops like cassava in the PRC but soon the

Government banned using any food crops for producing fuel, fearing food-fuel conflicts (Macartney *et al.*, 2007). Even after the focus was shifted to jatropha (Weyerhaeuse *et al.*, 2007), the competition for land and water cannot be ignored since for optimum results jatropha requires fertilizers, land, and water. Jatropha can be cultivated without additional irrigation in areas receiving a rainfall of 600 mm or above. Under practical conditions, the rainfall is intermittent and variable, such that the crop may not produce satisfactory economic yield. Irrigation is required for such contingencies as mid-season water stress and in critical periods of the crop season, such as flowering. Expecting farmers to irrigate only during critical stages of the crop can be considered as an ideal scenario, especially as farmers often tend to over-apply fertilizers and water, expecting good returns when they have huge stakes to produce crops like jatropha as is happening with most cash crops globally. More often than not, farmers apply certain amounts of fertilizers and water even if the crop does not require them. The PRC Government has set a target of producing jatropha in an area of 1.03 million ha of wastelands in southwestern provinces, including Sichuan and Yunnan that fall in GMS. Expecting wastelands to produce an economic output from jatropha is questionable. The argument for this is that wastelands have remained wastelands because they are not fit for cultivation, either because of the poor fertility or lack of irrigation facilities (Elder *et al.*, 2008; McGahey, 2008). From this logic, growing biofuels on wastelands without using external inputs, such as water and fertilizers, is doubtful. Considering the practical scenario explained above, even if 50% of farmers require water for 50% of jatropha's water requirements (i.e., 300 mm), the total water requirement amounts to an additional 3 million liters per ha or 3 trillion liters of water for 1 million ha, the target set by the PRC. This may affect the water available for the countries downstream in the GMS.

4.2. Conflict for Land with Implications for Food

An important question concerns the extent of wastelands that can be brought into cultivation without substantial investments and environmental consequences and the alternative cost of bringing these lands into cultivation for food crops. From this point of view, if bringing wastelands into cultivation is economically feasible, food production should be the main competitor for wastelands rather than biofuels, since most parts of the region have reached a plateau in crop yield gains (vertical expansion) and there is a need for horizontal expansion of agriculture to feed the millions beyond 2050 (FAO, 2009b). Allocation of these wastelands

to sustainable food production makes more sense than converting them to biofuel production with environmental consequences, particularly at a time when global food prices have risen at rapid rate partly due to diversion of crops, such as corn, raised on premium agricultural land to feed cattle in countries like the PRC. This argument is even more valid in the Lao PDR and Cambodia where high rates of hunger and food poverty exist today, and for achieving relevant MDG goals rated as “unlikely” in the Lao PDR (United Nations Development Programme, 2011) and “slow” in Cambodia (Royal Government of Cambodia, 2010).

4.3. Do Biofuels Pose any More Threat to Food and Water?

The initial expectations and gains made under biofuel production and consumption could not be sustained because of a combination of factors listed below:

1. The global economic depression during 2008–2009 further reduced the demand for oil.
2. The steady decline in global crude oil prices reached a level that is a disincentive for biofuel companies to produce fuel for the domestic market.
3. Reduced emphasis on biofuels has been made by the European Union in its revisions of energy policy.
4. Pressure from environmental activists made some players realize that biofuel targets cannot be achieved without substantial impact on food security and environmental health and made them covertly retreat from those targets.

However, the demand for energy is never-ending and, depending on global economic growth, developmental path, and energy choices made, there is a probability that global crude oil prices will rise in the medium and long term. According to the United States Energy Information Administration’s latest projections, global energy consumption will rise from 505 quadrillion British thermal units (Btu) in 2008 to 619 quadrillion Btu in 2020 and 770 quadrillion Btu in 2035, mainly with demand from developing countries, notably the PRC and India,

surpassing that from members of the Organisation for Economic Co-operation and Development (OECD) by 2015 (US Energy Information Administration, 2011). Most of this demand is said to be driven by long-term economic growth. The result will be sustained upward pressure on oil prices, which would allow ethanol and biodiesel producers to pay much higher premiums for corn and oilseeds than was conceivable just a few years ago.

Resource-use efficiency also requires greater attention in the GMS and has close linkage with the issue of biofuels and the food-water-energy nexus. Hence, biofuels are still at the center stage of policy discourse.

4.4. The Food-Water-Energy Nexus and Resource-Use Efficiency

Resource-use efficiency is especially important in agriculture for food and in energy production and utilization. Further, resource-use efficiency in one influences the other; for example, poor efficiency in energy could have implications for agriculture and poor efficiency in agriculture could influence the biofuel energy sector.

The 2008 global food price crisis was argued to have been caused or worsened by diversion of crops to biofuel production, though other factors, such as increasing population, changing consumption trends, and weather abnormalities, may have also contributed. During this crisis, many countries took extreme steps, such as restricting food exports to allay fears of food insecurity, including in some cases, measures to restrict biofuel production from food or feed-based crops; however, it was not clear how effective these measures were (Katz, 2008; MacInnis *et al.*, 2008).

A simple indicator for efficiency of combined inputs is to measure the productivity of major crops grown in these countries. The productivity of rice and nitrogen use efficiency levels in the GMS (Table 1) exhibit wide variation; rice yields in the GMS increased at an average rate of only 2.7% per annum during 1990–1999 as against an increase in

Table 1: Productivity Levels of paddy in the GMS

Country	Productivity (tons/ha)	Nitrogen (N) fertilizer use rate (Kg N/ha)	Estimated N use efficiency (kg rice per kg N)
Cambodia	2.8	17 (FAO FertiStat, 2001)*	164.7
PRC	6.6	250 (Zhao <i>et al.</i> , 2009)	26.4
Lao PDR	3.6	55 (FAO FertiStat, 2001)	65.5
Myanmar	4.1	91 (Win, 2006)	45.1
Thailand	2.9	62 (FAO FertiStat, 2001)	46.8
Viet Nam	5.2	130 (Soong, 2006)	40.0

* This figure was crosschecked with other references, such as USDA, (2010), which states that Cambodia has the “lowest rates of fertilizer use rate in rice in Southeast Asian countries”.

Source: FAO ProdSTAT (2011).

N fertilizer use of 15% (Mutret *et al.*, 2002), which shows stagnation in yields despite of steady increase in input use.

While reasons for poor input use efficiency in each GMS country are different, improving nitrogen use efficiency would mean increase in crop yields, reduced resource use, and hence reduced pressure on land and water resources. The same logic applies to other inputs used in agricultural production systems.

5. Understanding EWS in the context of Food-Water-Energy Nexus

For the purpose of this paper, EWS in the context of food-water-energy nexus can be defined as a collection of dependent and independent variables that lead to detection and assessment of impending problems based on feedback connections operating between demand and supply of food, water, and energy. AEWS can be as simple as a collection of indicators that can provide an early warning to policy makers and other development planners at various levels. It can also be complex, employing dynamic simulation models that can quantitatively represent the real world based on the conditions defined/assumed within the model (the system).

Due to complex feedback connections and dependencies operating between food-water-energy, some of which was discussed in the previous section, most often it is difficult for most decision makers operating at specific sector level to project/expect impacts of changes happening in other sectors. The ramifications of lack of understanding on interconnected nature of different sectors have become more evident with the global food price crisis of 2007-08 and subsequent repetition of the same in 2010-11. Several arguments have been put forward to explain reasons behind increase in global food prices which include reduced grain yields due to poor weather in Australia, changing diet patterns such as increased meat consumption in developing Asia, cultivation of biofuels on agricultural fields, rising oil prices, low stocks, export restrictions, depreciation of United States Dollar, low interest rates,

and investor speculation (Headey, 2011; Lagi *et al.*, 2011). Among all these reasons, researchers have concluded that at least land conversion to biofuels, export restrictions and investor speculation have strong influence on global food prices (Table 2), some of which are more intuitive than others (Headey, 2011; and Lagi *et al.*, 2011). For example, possible impact of land conversion to biofuel use on food security has long been discussed in the policy and scientific literature. However, none could emphatically project that it could lead to global food crisis of the magnitude or none could help in taking preemptive measures ahead of the food crisis. The experience from 2008 food crisis couldn't help project and prepare for another one in 2010-11.

One may argue that an early warning system that considers various interconnected factors underlying events such as food crisis 2008 could have avoided the catastrophe. Examining the lessons from the existing examples would help validate this argument. Some examples of EWSs for policy decisions are European Union proposal for building a EWS for energy that simulates the supply and demand situation in the region (European Union, 2009); it includes early warning for long-term energy conditions as well as for oil shortages in short time scales. The Crop Weather Watch Group (CWWG), India aims to provide early warning of an impending drought and help take preemptive measures. The flood mitigation and management center of Mekong River Commission collects data on Mekong river flows and provides early warning to the countries in downstream. However, these early warning systems suffer from several limitations. The CWWG has failed to warn impending crop losses and couldn't take advantage of recovering monsoon in 2004 drought. Several other drought monitoring tools are being used in the region, including a West Asia drought monitor based on the USDA drought monitor and it is not clear from the literature on the success of these drought monitors in avoiding the impending drought events. The currently available early warning systems are highly specialized in nature and are narrowly defined in the scope. For example, they are either limited to only energy or only water or only food sector and don't consider the impacts of decisions taken in other sectors. In other instances, they are limited to

Table 2. Role of different factors behind food crisis

Reasons put forward for global food price crisis	Marco Lagi <i>et al.</i> , 2011	Headey, 2011
Adverse weather (Drought in Australia)	No evidence	
Land conversion to biofuel use	Strong evidence	
Shifting investor speculative focus from mortgage and stock markets to commodity markets	Strong evidence	
Change in dietary patterns in developing countries	No evidence	
Export restrictions/trade factors		Strong evidence

hazard-mitigation approach (drought or flood forecasting) and end with projecting a physical event.

An effective EWS can be built using dynamic simulation models since they can consider the element of time and related dynamics in determining the status of outcomes that could be useful to policy makers. The use of simulation models in the public policy research is not new. Some examples are:

- The general algebraic modeling system (GAMS) has provided a good tool in understanding environment and economics in a single framework.
- The Asia-Pacific Integrated Model (AIM) has provided a tool to simulate the impact of climate change on natural environment and socio-economics in Asia and the Pacific.
- Computable general equilibrium (CGE) models have been used for understanding the economy-wide impacts of policies.
- Multi-regional input-output (MRIO) models have been employed to understand and forecast material flows across different regions.

All the above simulation models are largely used for research purposes that have partially contributed to development of policies rather than for providing real-time early warning for preemptive response. Partially, this could be attributed to the limited understanding of natural, socioeconomic, and institutional systems.

5.1. Prerequisites for Development of an EWS

Development of EWS is dependent on various factors related to the system in question and it has to do with how best the EWS can represent the real world.

Determinants of an effective EWS are:

1. How the system is defined (components of the system),
2. Understanding of relationships and feedback connections between different actors/components of the system,
3. The precision with which these dynamic and static forces are quantified and represented in the model, and
4. Interpretation of the outcomes of the model as against what it actually means, with implications for the institutions that use the EWS for policy purposes.

5.2 What an EWS should be Able to Do

A EWS for the food-water-energy nexus should be able to:

1. visualize demand and supply situation of food, water, and energy in the region on a short-, medium-, and long-term basis;
2. give projections on prices of food, water, and energy on an immediate and long-term basis so that countries can make preventive and proactive strategies;
3. help policy makers at various levels to plan appropriate crops, water usage, and water conservation practices, and how energy is produced and consumed at the regional and national scales;
4. help in appropriate allocation of resources for food and energy production while keeping in view such constraints as environmental health, climate change, food prices, and sustainability of resources employed; and
5. help develop a set of standard operational procedures to be invoked in a situation like the 2008 energy and food crisis.

5.3 Opportunities and Challenges for Developing an EWS

From the above discussion, it can be concluded that several factors determine the food-water-energy nexus in the GMS and that there are both opportunities and challenges for developing an effective EWS for decision making in the subregion.

5.3.1. Opportunities:

The main opportunity for developing and implementing a EWS in the GMS comes from three integrating factors operating in the subregion:

1. *Institutional system.* The Mekong River Commission (MRC) integrates nations in the subregion through its significant impact on the way other institutions set policies and processes in managing resources.
2. *Growing economic integration.* Countries in the subregion are increasingly integrated in terms of economic activities (e.g., trade of goods and services).
3. *The Mekong River.* The Mekong River acts as a single, most important integrating factor, providing the opportunity to develop the EWS around it.

5.3.2. Challenges:

1. *Complex nature of the food-water-energy nexus.* This is largely brought by the uncertainty in climate projections, future growth patterns, and changing food preferences of the people that can introduce

many “unknowns” that influence the effectiveness with which the EWS can work.

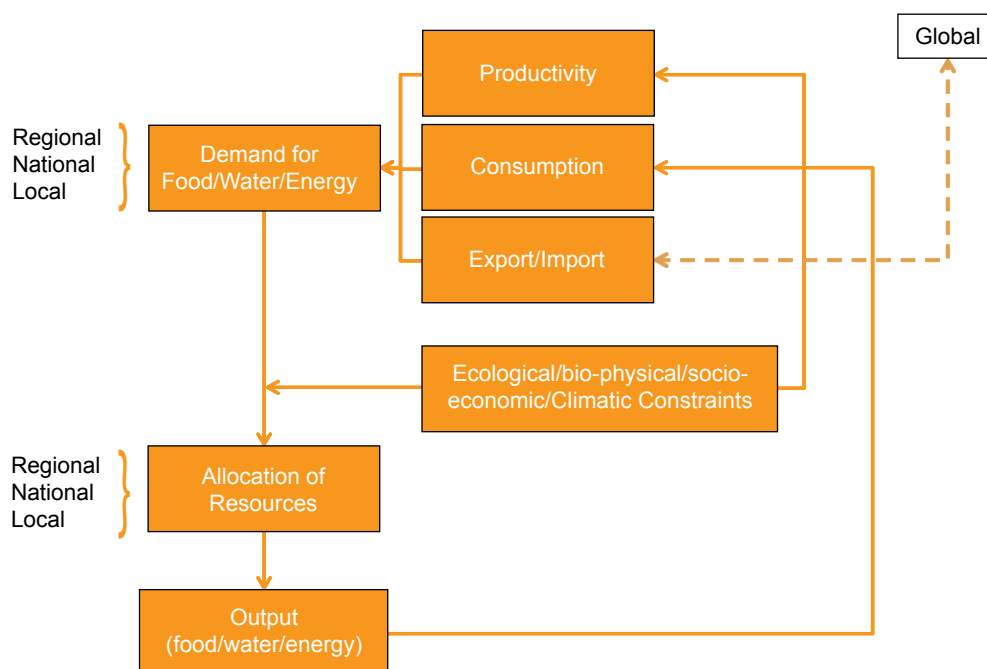
2. *Poor availability of data.* Real time and quality data are often a problem in the subregion and can greatly influence the effectiveness of a EWS. Such approaches as integrated river basin level resource management using water balance models could be useful to avoid water shortages. These are data-intensive approaches and lack of quality data hinders their adoption and effectiveness.
3. *Attitudinal factors of stakeholders.* As with any other EWS, different actors in the region may not trust the EWS and may not consider it as a decision-making tool. Thus, there is a need for capacity building of different stakeholders.
4. *Poor development of regional coordination mechanisms for the use of certain common natural resources.* As an example of both the solution and problem, disputes related to how the water in the Mekong River should be equitably used by various countries on upstream and downstream has not been resolved. Development of a EWS may help resolve this problem since stakeholders in the region would be able to visualize how downstream users are affected by overexploitation by upstream users, leading to amicable allocation of water resources to individual countries.

5.4 Simple Representation of an EWS

Figure 1 shows an oversimplified schematic representation of the concept behind an EWS for food-water-energy nexus in the region. This idea need to be further refined since it does not capture all the complexities operating in the food-water-energy nexus. The proposed EWS consists of integration of three modules, one each for food, water, and energy production and demand (in the figure they are shown as a single diagram for simplicity). Each module will feed into the other module based on allocation of resources following constraints set by the decision maker. The output in the diagram can represent either the quantitative or health status of resources, prices of products, or their combination.

This module need to be integrated with a climate and weather early warning system that can inform the policy makers and local natural resource managers and cropping experts to decide and strategize various operations according to the climate and weather forecasts. However, for this to work satisfactorily there is a need to strengthen climate and weather forecasts in the region.

Figure 1: Oversimplified Schematic of an Early Warning System for Food-Water-Energy



6. Policy Suggestions for Avoiding Food-Water-Energy Conflicts

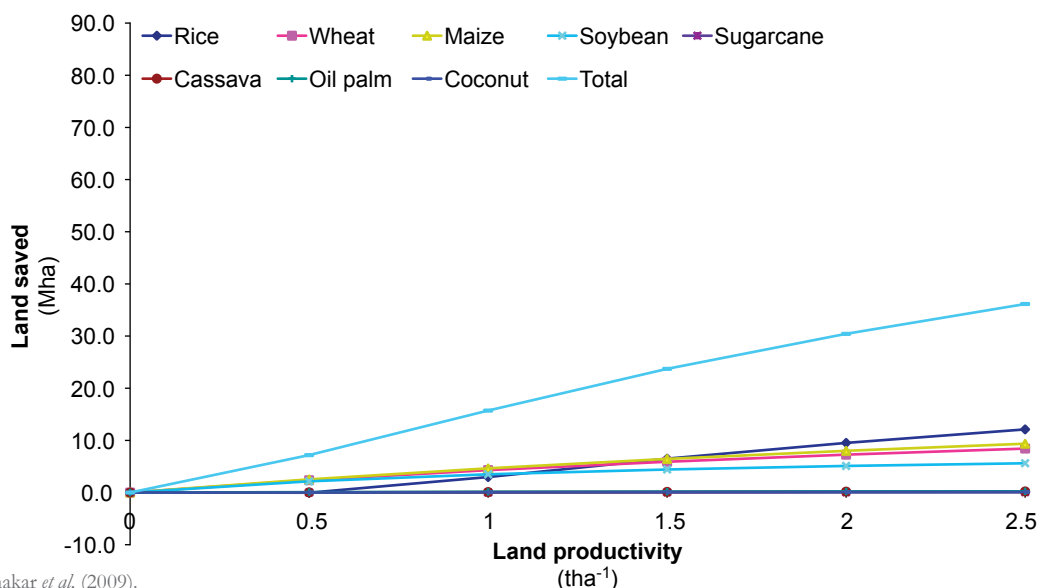
While developing an EWS for food-water-energy could provide several benefits, we are far from the point of developing such EWS that satisfies the criteria discussed above. Hence, it would be logical to promote some of the off-the-shelf policies that could reduce the food-water-energy conflict.

6.1. Improving Resource Use Efficiency in Agriculture and Water

Increasing the use efficiency of water, land, and other resources in the subregion could reduce pressure on these resources and make them available for other competing users. This can be achieved through few example practices listed below:

- Identification and promotion of agro-technologies that provide synergistic advantage in terms of improved productivity, profits, and climate benefits. Introduction of such practices as the system of rice intensification, organic agriculture, and conservation tillage practices are known to reduce water use and provide both mitigation and adaptation benefits (Prabhakar *et al.*, 2010). Simple strategies, such as increasing the productivity of crops, can ease pressure on the land (Figure 2).
- Moving from local watershed-based approaches to integrated river basin level water management approaches and harmonizing the available water with land-use practices in the subregion could drastically increase overall water-use efficiency.
- Reducing vulnerability to weather fluctuations through assured irrigation facilities would provide insurance against vagaries of weather. Despite the huge irrigation potential in the GMS, actual utilization of this potential is not significant (Tu *et al.*, 2004). Expanding the area under irrigation could reduce the weather-linked agricultural risk, provide assured income to farmers, and avoid fluctuations in food production.
- Moving to full-life-cycle assessment of benefits and costs of producing biofuels has been suggested for fully accounting the environmental costs involved in biofuel production and consumption (Prabhakar *et al.*, 2009). There are suggestions to go beyond these methodologies and include new innovative methods, such as system perturbation analysis (SPA) (Worldwatch Institute, 2007), which examines geographic system balances of resources and the resulting effects rather than comparing well-to-wheel trajectories; or graphical pinch analysis (Tan *et al.*, 2009), which helps in solving the source-sink problems while allocating the limited resources in production processes, enabling optimal use of resources.
- Market distorting policies, such as subsidies, affect the way the benefits from biofuels are assessed and promoted. For example, countries

Figure 2: Land Saved from Agriculture by Increasing Land Productivity in the People's Republic of China, Thailand, and Viet Nam



Source: Prabhakar *et al.* (2009).

where inputs are subsidized for agriculture do not differentiate whether these inputs are used for agriculture for food or for fuel. Targeted subsidies could be more effective.

- Improving the weather and climate forecasting systems in the region could help in strategic planning in agriculture and water sectors and avoid undue sudden shocks and hence improve overall productivity of these resources. Establishing dense weather stations, capacity building of ground staff, strengthening data archival systems, and strengthening weather and climate models suitable for the region are necessary.

6.2. Improving Energy Use Efficiency

Energy use efficiency in the subregion is presently low. For example, in the PRC, energy utilization efficiency (GDP output per unit of energy consumption) is around 20%–40% that of developed countries, depending on the GDP description (exchange-rate converted GDP or PPP-converted GDP) (Li *et al.*, 2005). This indicates a huge potential for improving energy efficiency. Realizing this potential, the PRC Government has placed great importance on structural reforms and economic development patterns with a focus on energy conservation (National Development and Reform Commission, 2009). This strategy includes enhancing the share of service industry in the overall GDP, implementing rigorous standards for manufacturing industries, and promoting the concept of a circular economy, which has implications in terms of GHG emissions while maximizing the energy use efficiency. As a result of these policies, energy intensity dropped by 19.06% over the 11th 5-year-plan period. However, the prospects for improving energy intensity in the 12th 5-year plan may not be high in view of progress already achieved; speculation has been that maintaining high targets on energy intensity could even cost the country more (Fuqiang, 2011). For improving energy intensity in other GMS countries, there is a greater need for analysis and policy focus.

6.3. Increasing Energy Supply from Renewable Sources

The PRC has recognized the domestic potential for renewable energy and has invested in use of its renewable resources. The country has set a non-fossil fuel target of 15% of its primary energy consumption by 2020 (National Development and Reform Commission, 2009). Currently, the PRC produces about 24 million kilowatts of wind energy, which is only second to the United States, as a result of

rapid investments in wind energy in the past 5 years. However, the literature suggests even greater potential for expansion of renewable energy in the country (Meisen *et al.*, 2009), with huge potential in hydro-, wind, and solar power (Meisen *et al.*, 2009). Harnessing this potential could reduce demand for biofuels and the pressure on land and water resources. Reproduction and utilization in other GMS countries are still in nascent stages and need a greater fillip through promoting a combination of demand and supply side policies.

6.4. Creation of an East Asia Energy Community/ Grid

There have been several proposals for establishment of an East Asian energy community or a grid, in view of the different supply and demand situation for energy among the countries in East Asia. Such a network would greatly benefit countries in the GMS as they can use the already well-developed economic cooperation and trade ties in the subregion easing burden on natural resources in some of the countries.

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IMPACT OF SOIL, MANAGEMENT PRACTICES AND CLIMATE CHANGE ON WATER PRODUCTIVITY OF WINTER RICE IN THE MEKONG DELTA

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Abstract

We examined the impact of climate, soil, field management, and irrigation management on water productivity and yield of winter irrigated rice in the Mekong delta of Viet Nam using a crop growth simulation model called AquaCrop. Two study sites in the provinces of Trà Vinh and Kiên Giang having different rainfall patterns were chosen. Climate change data used in the study were the future climate projection for 2010–2050 for the Intergovernmental Panel on Climate Change Special Report on Emission Scenarios (IPCC SRES) scenarios A2 and B2, based on ECHAM4 General Circulation Model downscaled to the Mekong region using the PRECIS system. The model was calibrated and validated using observed yield data of 1995–1999.

Results suggest that the soil does not influence water productivity or yield, whereas field management and especially fertility level have an important influence on yield, and thus on water productivity in both sites. Concerning irrigation management, a small decrease in the amount of water provided to the crop can have a significant impact on yield and water productivity. For scheduled irrigation, with an irrigation schedule every 10 days, the depth maximizing water productivity of evapotranspiration and yield for both sites is 50 mm whereas a depth of 30 mm maximizes water productivity of irrigation. Climate change does not have an impact on that schedule. For an irrigation schedule every 5 days, a depth of 20 mm maximizes water productivity of evapotranspiration and yield, whereas an irrigation depth of 15 mm maximizes water productivity of irrigation. In that case, with climate change, more water is required. Concerning the alternate wetting and drying schedule, consisting of a 10-day wet period alternately with a 10-day dry period, water productivity of evapotranspiration and yield are similar to the baseline case, but the amount of irrigation is very high, so water productivity of irrigation is

very low. This schedule is not effective in saving water. The results of this study can be useful in selecting adaptation options to minimize the negative impact of climate change on yield and water productivity.

1. Introduction

The Mekong Basin is home for more than 60 million people (MRC, 2010), and the Mekong River is a resource for many activities. Agriculture is the most important one and is based on a few major crops like rice, which provides food for 300 million people a year (MRC, 2010). With a population expected to increase up to 82 million by 2030 (Mainuddin *et al.*, 2008, based on UN Population division, 2006), and a predicted spatial and temporal change in water resources repartitioning due to climate change, meeting the increasing food demand in this area becomes more and more challenging. Rice cultivation is central for the region's agriculture and is the major economic activity (Facon, 2000). Rice represented more than 70% of the total harvested area in the basin during 1995–2003 (Mainuddin *et al.*, 2008), and is a staple food for the region's inhabitants. Rice crops are either rainfed or irrigated, depending on the location and season. In Thailand, 96% of the rice grown is rainfed (Mainuddin *et al.*, 2008), while in Viet Nam, located in the delta, a major part of the rice is irrigated. Indeed, this area considered as the most productive rice growing area of the basin (Kirby *et al.*, 2009), over 1.6 million hectares are under irrigation, fed by some 10,000 km of irrigation canals (Tong Tu *et al.*, 2004). Unlike rainfed agriculture, which is dependent on rainfall patterns, it is possible to manage water provided to irrigated crops in order to save water. Efficient use of water for irrigation is important because diversion of water for irrigation is predicted to increase by 11%–12% due to climate change. With combined impact of climate change and high irrigation development the diversion will increase by 24%–25% (Mainuddin, 2010). An increase of the areas under irrigation would lead to an increase of salt intrusion in the delta, which would reduce rice production in the region (Kirby *et al.*, 2009). Thus producing more rice with less water in the region is very important and a real challenge.

The objective of this study is to use a crop water productivity modelling approach to assess the impact of soil, field management, irrigation management, and climate change on water productivity of evapotranspiration, water productivity of irrigation, and yield. The final aim is to determine whether some management practices would enable water saving, while keeping yield constant to meet food demand.

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2. Method

2.1. Definition of Water Productivity

Reducing the amount of water used for irrigation must not have a negative impact on rice production, as the increasing food demand must be met. Thus, a good indicator is water productivity. It is defined as the mass of product per unit of water consumed (kg/m^3) (Immerzeel *et al.*, 2008). We considered here water productivity of evapotranspiration which is the yield per unit of water evapotranspired and water productivity of irrigation, which takes into account the amount of water lost by runoff and drainage in addition to evapotranspiration.

2.2. Study Site, Data, and Model

We focused on two sites in the Mekong delta in Viet Nam, where irrigated winter rice is cultivated. The two areas chosen were in the provinces of Trà Vinh and Kiên Giang, respectively, because the planted area of rice was higher than in other provinces of the area. Trà Vinh belongs to an area where rainfall averages less than 1,900 mm per year, whereas Kiên Giang is part of an area where average rainfall is more than 1,900 mm per year.

The observed climate data—rainfall, temperature, solar radiation, and wind speed—were taken from Mekong River Commission (MRC) (Mainuddin, 2010). Future climate data were based on the future daily projection made under the scenarios A2 and B2 from the Intergovernmental Panel on Climate Change Special Report on Emission Scenarios (IPCC SRES). These data were downscaled to the Mekong Basin region using the PRECIS model, taking into account regional characteristics (Mainuddin *et al.*, 2010), and adjusted to observed data. The soil data are from the detailed soil classification map with physical and hydraulic properties for the whole basin used in the MRC Decision Support System (Mainuddin *et al.*, 2010). The planting date and duration of growing period were chosen in reference to the cropping management data used in Mainuddin *et al.* (2010), and in Luu (2003). The observed data for yield in the region of the Mekong delta in Viet Nam come from the General Office of Statistics of Viet Nam. (http://www.gso.gov.vn/default_en.aspx?tabid=491)

The AquaCrop model of the Food and Agriculture Organization of the United Nations (FAO) was used because it is designed to simulate the yield response to specific hydrological conditions of different crops cultivated worldwide. AquaCrop is a robust model, easy to use by

any practitioner. It also requires only a limited amount of data, which is often easily available. Although it requires less data than other models like CropSyst and WOFOST, it performs equally well in simulating biomass and yield at harvesting (Todorovic *et al.*, 2009).

2.3. Model Calibration

Yield data are the only observed data available for the calibration of the model. The observed yield data are for 1995–2009 and the observed climate data for a longer period, 1985–2000. We chose to run the calibration on 5-year periods starting in November 1995 and ending in February 2000. If we took a longer period, parameters like irrigation or fertilization practices would be more variable, and this could bias the results. The calibration was done using two parameters: harvest index and fertility level of soil during the growing period. For the other parameters, we consider that the net irrigation water requirements are met, and that 0% depletion of the readily available water (RAW) of the root zone is allowed. This is obviously not the case in real conditions, but irrigation management was one of the parameters that we wanted to test, so we assumed that for the baseline case and calibration, the crop was not exposed to water stress. The soil characteristics used for calibration were those of the paddy soil file of AquaCrop model that represent the common soil type on which rice is cultivated. The crop parameters were those used for irrigated rice by Mainuddin *et al.* (2010). The growing period considered is 120 days, in reference to Mainuddin *et al.* (2009).

3 Results

3.1. Baseline Case

The parameters used for the baseline case are similar to the ones of calibration, but the simulation was run for the period 1985–2000. The average results for water productivity of evapotranspiration are shown in Table 1.

The variations in water productivity of evapotranspiration followed the same pattern on each site. However, it was always lower in Kiên Giang than in Trà Vinh, particularly at the end of the period, due to the difference in average yield and climatic parameters.

a. Impact of Soil

According to the data in the detailed soil classification map with physical and hydraulic properties for the whole basin used in the MRC Decision Support System (Mainuddin

et al. 2010), Kiên Giang soil is characterized being Gleysol and Trà Vinh soil is characterized as both Gleysol and Fluvisol. The results are presented in Table 2. At both sites, there is no difference of average water productivity of evapotranspiration and yield for the different soils. For rice cultivation, and especially for irrigated rice, it is not the soil's characteristics which influence yield and water productivity, as long as there is standing water. When there is no more standing water, the ability of the soil to retain water can influence water productivity and yield.

b. Impact of Field Management

Field management and especially the fertility level are important in building the harvest index, and have thus an impact on yield and water productivity. We assessed the extent to which a decrease of the fertility level affects

yield and water productivity. Results are presented in Table 3. For both sites, in comparison with a scenario without fertility stress, decreasing fertility level by a half leads to a decrease in yield by half and to a decrease of water productivity of evapotranspiration by 40%.

c. Impact of Irrigation Management

Net irrigation water requirements

The objective here was to see to what extent the crop, especially the yield, is affected by a decline in water availability in the root zone. Three scenarios were studied. First, root zone depletion was not allowed, like for the baseline case. Second, root zone depletion was not allowed to drop below 25% of readily available water (RAW). Third, root zone depletion was not allowed to drop below 50% of RAW. The results are shown in Table 4.

Table 1: Average Water Productivity, Yield, Amount of Water from Irrigation, and Amount of Evaporation and Transpiration for the Baseline Case

	Average water productivity of evapotranspiration (kg/m ³)	Average Yield (tonne/ha)	Average amount of irrigation (mm)	Average amount of evaporation (mm)	Average amount of transpiration (mm)
Trà Vinh	0.63	3.00	377	202	301
Kiên Giang	0.58	2.63	350	220	260

Table 2: Average Water Productivity, Yield, Amount of Water from Irrigation, and Amount of Evaporation and Transpiration for Different Soils

	Average water productivity of evapotranspiration (kg/m ³)	Average Yield (tonne/ha)	Average amount of irrigation (mm)	Average amount of evaporation (mm)	Average amount of transpiration (mm)
Trà Vinh					
Baseline case	0.63	3.00	377	202	301
Fluvisol Umbric	0.63	3.00	382	197	300
Gleysol Thionic	0.63	3.00	385	200	301
Gleysol Umbric	0.63	3.00	388	199	301
Kiên Giang					
Baseline case	0.58	2.63	350	220	260
Fluvisol Umbric	0.59	2.63	354	215	260
Gleysol Thionic	0.58	2.63	357	217	260
Gleysol Umbric	0.58	2.63	361	217	260

Table 3: Average Water Productivity, Yield, Amount of Water from Irrigation, Amount of Evaporation and Transpiration for Different Fertility Levels

	Average water productivity of evapotranspiration (kg/m ³)	Average Yield (tonne/ha)	Average amount of irrigation (mm)	Average amount of evaporation (mm)	Average amount of transpiration (mm)
Trà Vinh					
Baseline case - 70% fertility level	0.63	3.00	377	202	301
100% fertility level	0.78	4.34	451	116	442
50% fertility level	0.48	2.17	347	249	229
Kiên Giang					
Baseline case - 60% fertility level	0.58	2.63	350	220	260
100% fertility level	0.80	4.34	438	111	435
50% fertility level	0.50	2.17	337	243	225

Table 4: Average Water Productivity, Yield, Amount of Water from Irrigation, and Amount of Evaporation and Transpiration, for Different Net Irrigation Water Requirements

	Average water productivity of evapotranspiration (kg/m ³)	Average Yield (tonne/ha)	Average amount of irrigation (mm)	Average amount of evaporation (mm)	Average amount of transpiration (mm)
Trà Vinh					
Baseline case	0.63	3.00	377	202	301
25% depletion	0.60	2.88	353	216	286
50% depletion	0.51	2.41	335	263	236
Kiên Giang					
Baseline case	0.58	2.63	350	220	260
25% depletion	0.56	2.52	325	230	246
50% depletion	0.49	2.18	306	264	210

In Trà Vinh, when depletion of the root zone does not drop below 25% of readily available water, the decrease in average water productivity of evapotranspiration is low: 30 g/m³ on average. The average decrease in yield is 0.12 tonne/ha and the decrease of irrigation water requirements is quite low: 23 mm. With this scenario, the average amount of evaporation is increasing, whereas the average amount of transpiration is decreasing, which means that even if irrigation water requirements are decreased, they are less efficient for the crop. When depletion of the root zone is allowed to drop down to 50% of RAW, the decrease in water productivity of evapotranspiration is more important: 120 g/m³ on average, but the results are very different from one year to another. The decrease in yield is also more important; 0.59 tonne/ha. However, the irrigation water requirements are significantly lower than for the baseline case; 42 mm on average. Decrease in water-use efficiency (more evaporation and less transpiration) becomes more important. In this case, the soil becomes dry between two irrigation schedule events, and more water is needed to refill the soil. The results for Kiên Giang follow the same pattern as in Trà Vinh.

Scheduled irrigation

In this part, two irrigation schedules were studied. The first was irrigating the crop every 10 days (10-day schedule). This is a common timing used for irrigation of rice fields in modelling. It was used by Smith (1992) for irrigation during most of the development stages (initial phase, development stage, and late season), in the CROPWAT model. The second schedule was irrigation every five days (5-day schedule). The aim of the second schedule was to assess whether a more labor-intensive irrigation schedule could improve water-use efficiency. For the two schedules, different depth of irrigation were applied: 100 mm, 50 mm, 30 mm, 25 mm, 20 mm, 15 mm or 10 mm.

Figures 1–3 show the yield, average water productivity of evapotranspiration, and irrigation for both sites.

In both sites, average water productivity of evapotranspiration and yield in the 10-day schedule began to decrease when the irrigation depth was below 50 mm. The irrigation depth that maximized water productivity of irrigation was 30 mm. For the 5-day schedule, water productivity of evapotranspiration and yield started to decrease when the irrigation depth fell below 20 mm. The irrigation depth that maximized water productivity of irrigation was 15 mm.

Considering water productivity of evapotranspiration and yield, the 5-day schedule was better, as the depth of water that maximized these parameters was 20 mm, compared with 50 mm for the 10-day schedule. With the 5 day-schedule, 10 mm of water, or 100 m³/ha, is saved every 10 days. The disadvantage of the 5-day schedule is that it requires more labor than the 10-day schedule.

The two schedules maximize water productivity of irrigation with the same amount of water (whether 15 mm every 5 days, or 30 mm every 10 days). In Trà Vinh, irrigation at a depth of 30 mm every 10 days would reduce the average yield to 2.43 tonne/ha and irrigation at a depth of 15 mm every 5 days would reduce yield to 2.28 tonne/ha, compared to the baseline case yields of 2.95 and 3.00 tonne/ha, respectively. In Kiên Giang, irrigation at a depth of 30 mm every 10 days would reduce the average yield to 2.23 tonne/ha and irrigation at a depth of 15 mm every 5 days would reduce it to 2.04 tonne/ha, compared to the baseline case yields of 2.58 and 2.63 tonne/ha, respectively.

The choice of depth of irrigation to improve water productivity of irrigation rather than maximizing water

Figure 1: Average Yield for Different Irrigation Depths and Schedules

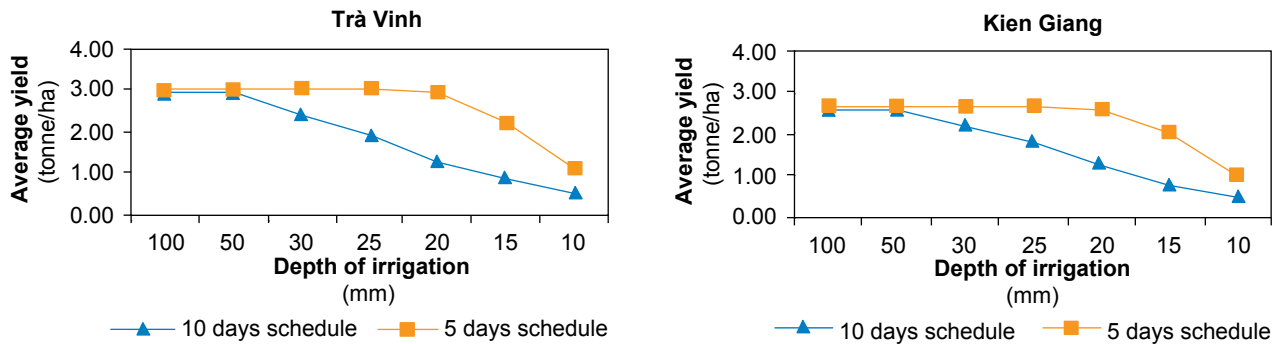


Figure 2: Average Water Productivity of Evapotranspiration for Different Irrigation Depths and Schedules

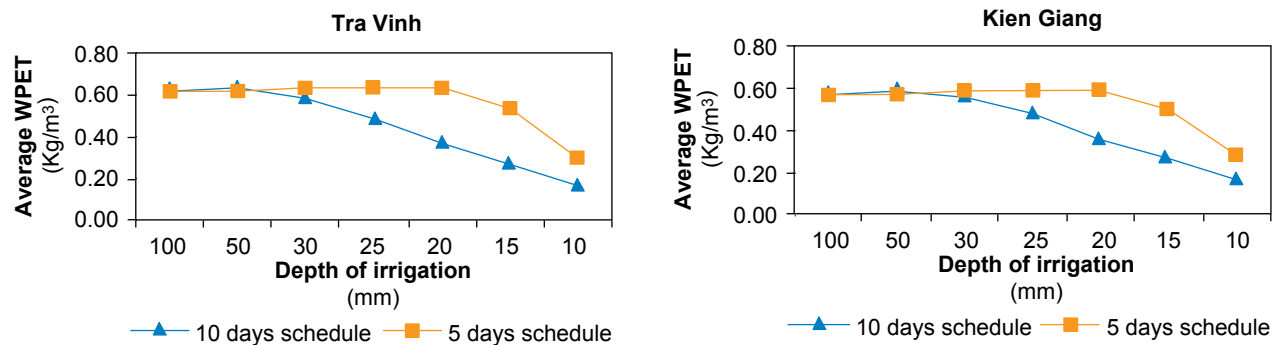
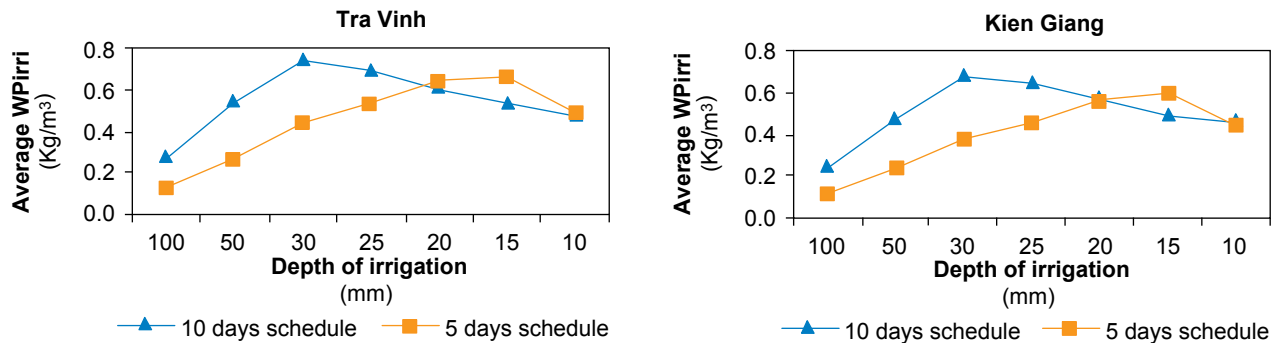


Figure 3: Average Water Productivity of Irrigation for Different Irrigation Depths and Schedules



productivity of evapotranspiration and yield depends on the decrease of yield that is acceptable, while the choice of a 5- or 10-day schedule in order to save water depends on the feasibility of increased labor at the farm level.

Alternate wetting and drying

Many reports have focused on the possible improvements offered by the alternate wetting and drying technique, which consists in allowing the disappearance of ponded water on the rice field for a determined period before irrigating again. For example, Bouman *et al.* (2000) considered that water inputs could be reduced by an alternate wetting and drying; according to FAO (2003), water-saving irrigation techniques like alternate wetting and drying can reduce the unproductive water outflows drastically and increase water productivity. We assessed the impact of this irrigation management on water productivity and yield in the two study sites.

The schedule of alternate wetting and drying chosen was a 10-day wet period and 10-day dry period for the whole growing period. During the wet period, a standing level of water of 50 mm was maintained; in the dry period, a depletion of the root zone of 80 mm was allowed. This level of depletion is defined as the safe depletion level by the AquaCrop model. The results are shown in Table 5.

The alternate wetting and drying schedule considered here did not increase yield significantly or increase water productivity of evapotranspiration, while the amount of water used for irrigation was much higher than in the baseline case. Water productivity of irrigation is thus very low. In this study, the alternate wetting and drying technique did not enable water saving. However, this might be due to the fact that we used a very simple schedule, which might require adjustments to account for local conditions.

3.2 Impact of Climate Change

Climate change scenarios are based on the A2 and B2 scenarios from the IPCC SRES. For each of these scenarios, carbon dioxide (CO₂) levels and maximum and minimum temperatures are different from the baseline case. We considered CO₂ concentration to change linearly from 401 to 536 parts per million (ppm) for A2 scenario and 389 to 478 ppm for B2 scenario, respectively, during 2010–2050 (IPCC, 2000). The A2CC and B2CC scenarios of IPCC have the same characteristics as A2 and B2 scenarios, except the carbon dioxide level, which remains at the concentration in year 2000, 369.41ppm.

In this section, the baseline case is no longer the one used in the previous section. The new baselines are the scenarios of the previous part with the same irrigation method and without climate change. Table 6 shows the results under the four climate change scenarios. Water productivity and yield are higher with the A2 and B2 scenarios than in the baseline case. The increase is slightly higher in the A2 scenario than in the B2 scenario, as the yield also increases more with the A2 scenario. For the A2CC and B2CC scenarios, water productivity and yield are lower than with A2 and B2 scenarios and about the same as in the baseline scenario.

The difference between A2 and A2CC scenarios and between B2 and B2CC scenarios is that CO₂ concentration remains equal to the baseline scenario in the A2CC and B2CC scenarios. Thus, the increase in temperatures of the A2CC and B2CC scenarios has no impact on water productivity, but it is responsible for a slight increase in yield. The increase in CO₂ concentration is responsible for the increase of water productivity and the major part of the increase in yield. The more CO₂ increases (A2 compared to B2), the more water productivity increases.

Table 5: Average Water Productivity, Yield, Amount of Water from Irrigation, and Amount of Evaporation and Transpiration for the Alternate Wetting and Drying Technique

	Average water productivity of evapotranspiration (kg/m ³)	Average Yield (tonne/ha)	Average amount of irrigation (mm)	Average amount of evaporation (mm)	Average amount of transpiration (mm)
Trà Vinh					
Baseline case	0.63	3.00	391	201	301
Alternate wetting-drying	0.63	2.96	853	208	295
50 mm every 10 days	0.63	2.95	550	210	292
Kiên Giang					
Baseline case	0.58	2.63	364	219	260
Alternate wetting-drying	0.60	2.59	833	231	255
50 mm every 10 days	0.59	2.58	550	232	252

These results are in accordance with Mainuddin (2010), who showed that the increase in yield with climate change compared to the baseline case was due to the increase of CO₂ concentrations, and not to the increase in temperature. The increase in temperature in some places can be responsible of a very small increase of yield, but in most cases, it leads to a small decrease of yield compared to the baseline case.

Scheduled irrigation

In both sites, for a 10-day schedule and for every climate scenario, water productivity of evapotranspiration and yield start to decrease when the irrigation depth is below 50 mm and the irrigation depth that maximizes water productivity of irrigation is 30 mm (Figures 4-6). The results are similar to the ones without climate change. For a 5-day schedule,

water productivity of evapotranspiration and yield start to decrease when the irrigation depth is below 25 mm (Figures 7 and 8). The irrigation depth that maximizes water productivity of irrigation is 20 mm (Figure 9). These results are slightly different from the first ones. The amount of water necessary to maximize water productivity of evapotranspiration, water productivity of irrigation and yield is higher than without climate change.

Alternate Wetting and drying

With A2 and B2 scenarios, average water productivity of evapotranspiration and water productivity of irrigation are higher than for the baseline case, due to an increase in yield (Table 7). The increase in CO₂ is responsible for the increase in yield, as there is no increase with the scenarios A2CC and B2CC, in which CO₂ is constant.

Table 6: Average Water Productivity, Yield, Amount of Water from Irrigation, Amount of Evaporation and Transpiration for the Baseline Case, under A2, B2, A2CC and B2CC Scenarios

	Average water productivity of evapotranspiration (kg/m ³)	Average Yield (tonne/ha)	Average amount of irrigation (mm)	Average amount of evaporation (mm)	Average amount of transpiration (mm)
Trà Vinh					
Baseline climate	0.63	3.00	377	202	301
A2 Scenario	0.78	3.87	431	210	317
B2 Scenario	0.74	3.60	417	205	313
A2CC Scenario	0.62	3.10	431	210	317
B2CC Scenario	0.63	3.10	417	205	313
Kiên Giang					
Baseline climate	0.58	2.63	350	220	260
A2 Scenario	0.72	3.39	382	229	275
B2 Scenario	0.60	3.16	424	253	305
A2CC Scenario	0.58	2.71	382	229	275
B2CC Scenario	0.51	2.71	424	253	305

Figure 4: Average Yield for Different Irrigation Depths, and for Different Climate Scenarios, with a 10-Day Schedule

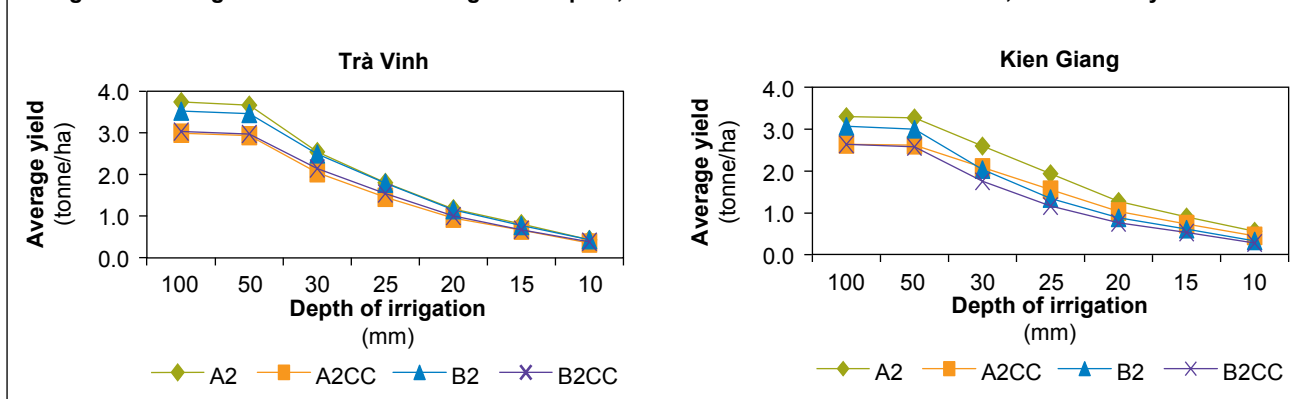


Figure 5: Average Water Productivity of Evapotranspiration for Different Irrigation Depths, and for Different Climate Scenarios, with a 10-Day Schedule

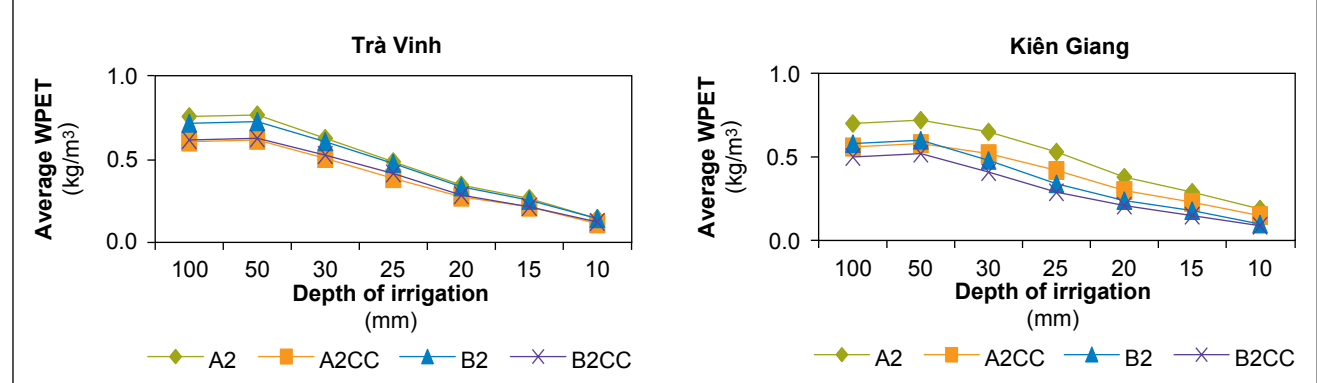


Figure 6: Average Water Productivity of Irrigation for Different Irrigation Depths, and for Different Climate Scenarios, with a 10-Day Schedule

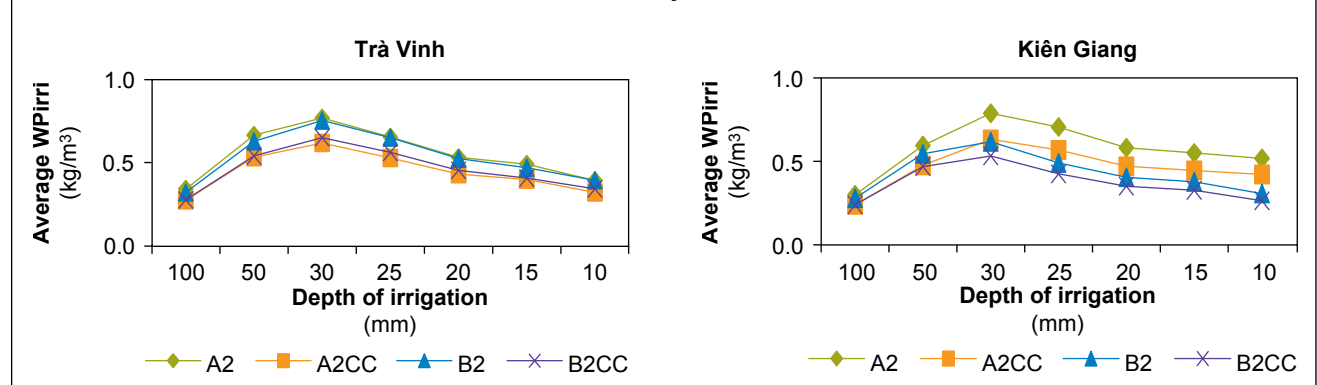


Figure 7: Average Yield for Different Irrigation Depths, and for Different Climate Scenarios, with a 5-Day Schedule

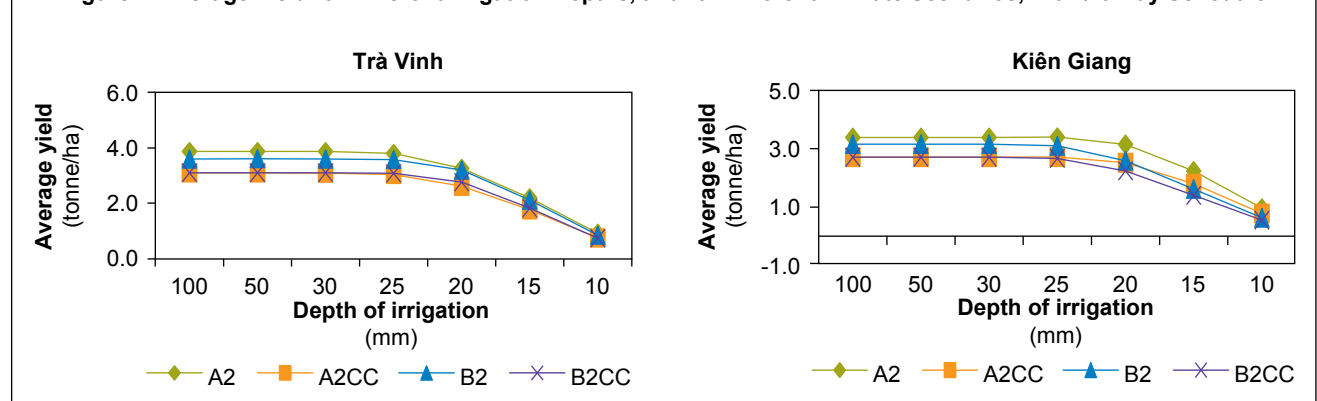


Figure 8: Average Water Productivity of Evapotranspiration for Different Irrigation Depths, and for Different Climate Scenarios, with a 5-Day Schedule

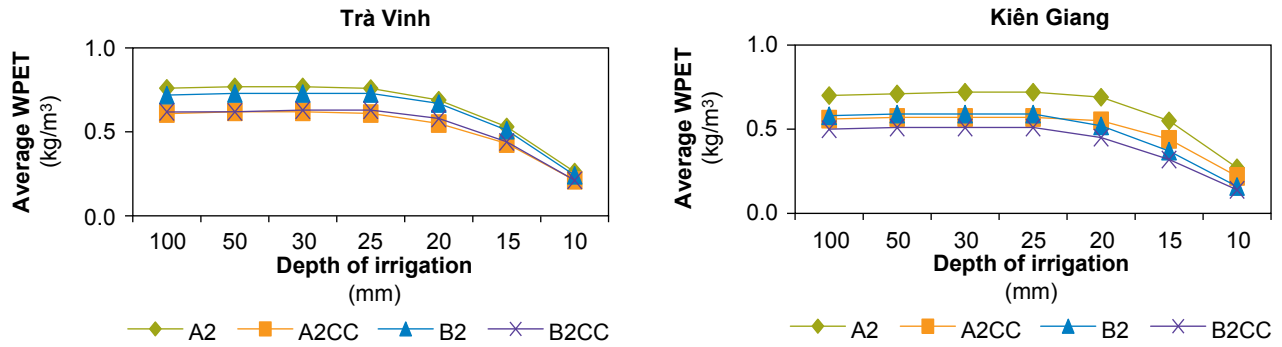


Figure 9: Average Water Productivity of Irrigation for Different Irrigation Depths, and for Different Climate Scenarios, with a 10-Day Schedule

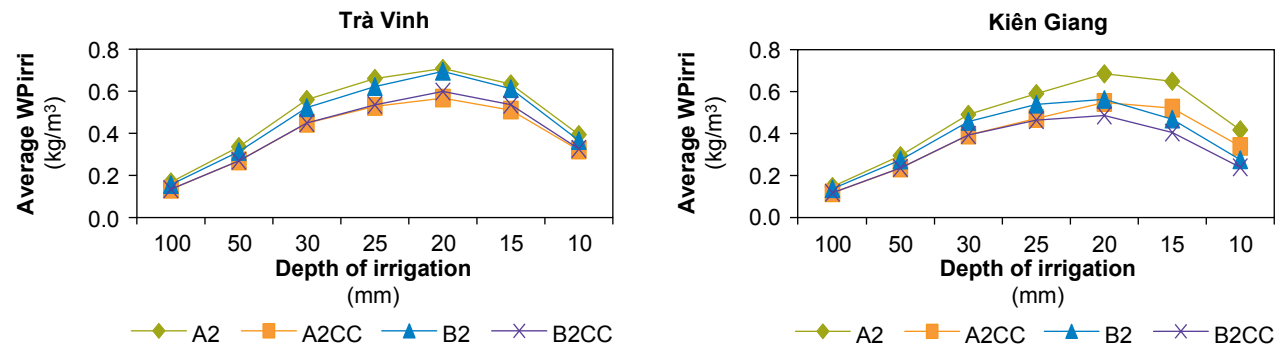


Table 7: Average Water Productivity, Yield, Amount of Water from Irrigation, Amount of Evaporation and Transpiration for the Alternate Wetting and Drying Schedule, under A2, B2, A2CC and B2CC Scenarios

	Average water productivity of evapotranspiration (kg/m³)	Average Yield (tonne/ha)	Average amount of irrigation (mm)	Average amount of evaporation (mm)	Average amount of transpiration (mm)
Trà Vinh					
Baseline case	0.63	2.96	853	208	295
A2	0.77	3.78	947	219	308
A2CC	0.62	3.02	947	219	308
B2	0.73	3.52	924	215	304
B2CC	0.63	3.02	924	215	304
Kiên Giang					
Baseline case	0.60	2.59	833	231	255
A2	0.73	3.31	882	241	266
A2CC	0.59	2.65	882	241	266
B2	0.61	3.06	922	263	294
B2CC	0.52	2.63	922	263	294

The increase in yield is more important than the increase of evapotranspiration and irrigation, as water productivity of evapotranspiration and irrigation are higher than for the baseline case. The increase of CO₂ concentration of climate change improves the results for water productivity and yield under an alternate wetting and drying irrigation management. But this irrigation management is still far from giving the best results, compared with scheduled irrigation at precise depths.

4. Conclusion

The study aimed at assessing the impact of different parameters on yield, water productivity of evapotranspiration and water productivity of irrigation. The major outcomes are that soil does not have any influence on water productivity of evapotranspiration and yield as long as standing water remains. The impact of fertility level on yield is very important, but in real conditions it is often not maximized. Concerning irrigation management, a small difference in the amount of water provided to the rice crop can have significant impact on yield and thus on water productivity. With regard to effects of climate change, the increase in yield and water productivity is due to the increase in carbon concentration, and not to the increase of temperature.

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REMOTE SENSING-BASED METHOD TO MAP IRRIGATED RICE CROPPING PATTERNS OF THE MEKONG DELTA, VIET NAM

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Abstract

Irrigated rice farming system plays an important role in the whole agroecological system of the Mekong Delta, Viet Nam. In this research, the hyper-temporal vegetation index (NDVI) derived from SPOT satellite imagery was used to map the spatial and temporal variation in regional rice cropping patterns. With support from interview data, 77 rice-cropping pattern classes were identified, of which 26 rice classes were validated using another field dataset. The validation result showed very good agreement between the mapped rice-cropping patterns and the reality, with an overall accuracy of 94%. The distribution of double and triple rice cropping patterns was related to flooding in the Hau and Tien rivers. The double rice cropping system was mostly found in the upper part of the rivers where rice fields were more vulnerable to flooding, while the triple rice cropping system was mainly found in the southeastern and central part of the delta. The duration of flooding strongly affected decisions made by farmers on what rice varieties they should grow. The overall spatial variability of the Mekong Delta mostly coincides with the administrative units, indicating that rice-cropping pattern choices and water control measurement were locally synchronized.

1. Introduction

Rice is the most important crop in Viet Nam. The total rice area of the country by 2000 was around 3 million hectares with an annual production of 32.5 million tons (Ministry of Agriculture and Rural Development, 2009a). This led to Viet Nam's emergence as the second largest rice exporting country in the world, with almost 5.8 million

tons of rice exported annually. In 2001, the Government adopted a 20-year plan for the agricultural sector to reach 3.7 million hectares of irrigated rice by 2020 and targeted a stable annual rice production of 41 million tons (Ministry of Agriculture and Rural Development, 2009a). However, as the Government's policies shifted toward industrialization, many productive rice areas were converted to industrial and urban uses. To worsen matters, many rice cultivation areas have recently been either less productive or completely abandoned due to the effects of climate change and saline intrusion.

To identify progress and prospects in meeting the Government's ambitious goal, annual assessment of national rice production is needed. This requires up-to-date and accurate information on where and when rice is grown in the Mekong Delta, the largest rice producing region of the country. This has become an extremely difficult task because rice cropping patterns vary by areas. Throughout the year, changes in the rice cropping patterns are driven by the availability of water supply, soil conditions, and crop management practices, leading to a variety of land cover patterns across the delta. This has created serious problems for the local authorities and the Ministry of Agriculture and Rural Development, and has resulted in inaccurate information on the area of rice cultivated and production achieved. As a consequence, published statistical data are unreliable; hence, planning to avoid food security issues suffers accordingly.

One solution for monitoring the change of rice cropping patterns in the region is to use remote sensed data. A common mapping approach is to use long time-series of the Normalized Difference Vegetation Index (NDVI) derived from optical satellite sensors. This approach assumes that the seasonal NDVI variability is related to the behavior of vegetation phenology. NDVI is numerically calculated as:

$$NDVI = \frac{(NIR-RED)}{(NIR+RED)} \quad (1)$$

where RED and NIR stand for the spectral reflectance measurements acquired in red and near-infrared regions, respectively.

NDVI indicates the greenness of vegetation cover (Sellers, 1985) and by using multi-temporal or hyper-temporal imagery, researchers have been able to provide useful information on LCLU and their changes over time (Townshend and Justice, 1986; Townshend *et al.*, 1987;

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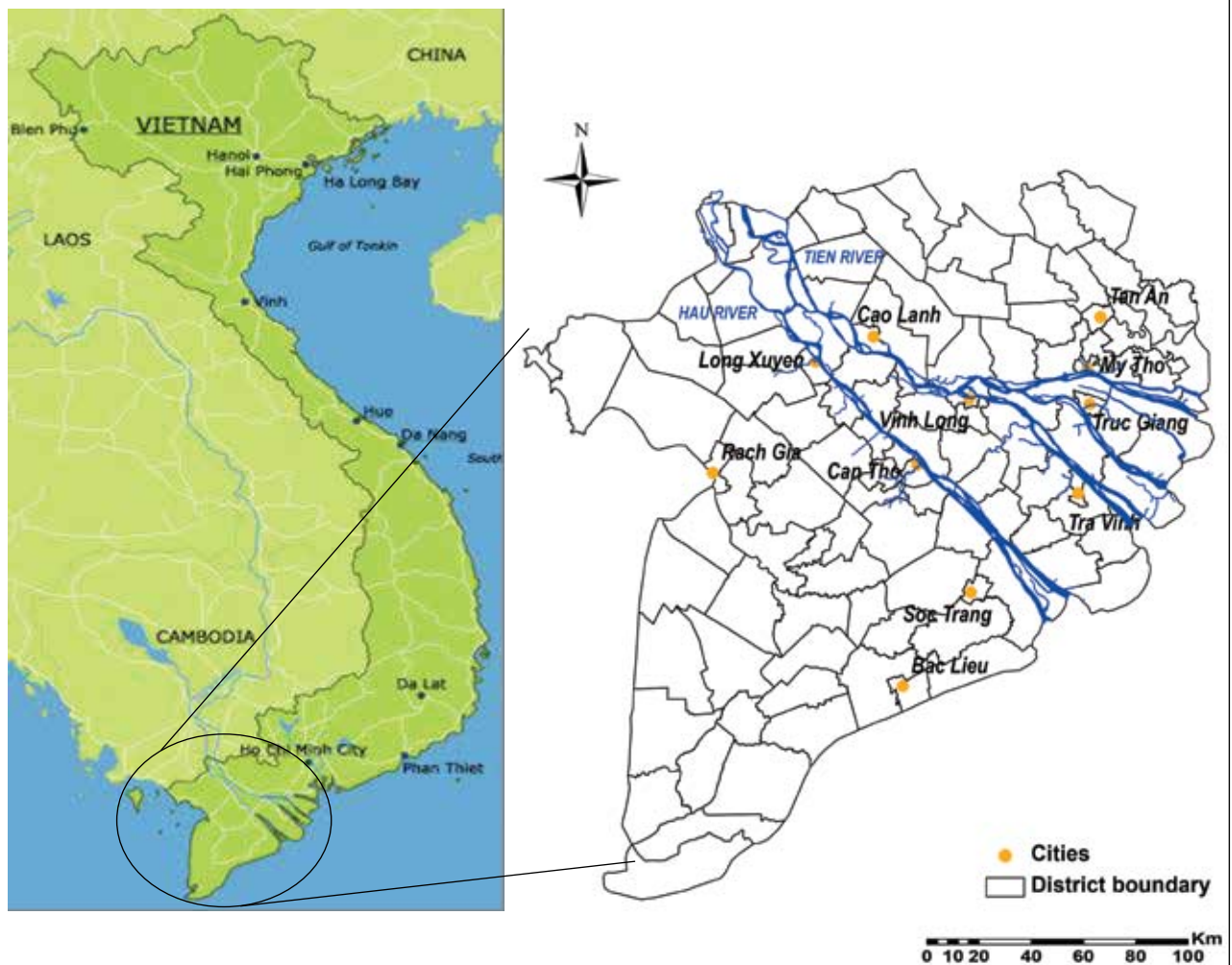
Lenney *et al.*, 1996). A number of studies have used optical remote sensing to map irrigated rice areas (Kamthonkiat *et al.*, 2005; Sakamoto *et al.*, 2006, 2009a, 2009b; Xiao *et al.*, 2002, 2005, 2006). However, these studies could not provide and describe all major temporal and spatial details of existing rice cropping patterns. Given the proven high potential of hyper-temporal NDVI image series for monitoring and mapping cropping patterns, our study aimed to investigate the use of SPOT VEGETATION (SPOT VGT), 10-day NDVI images to describe and map irrigated rice cropping patterns of the Mekong Delta. The specific aim was to differentiate and describe the spatial and temporal patterns of rice grown in the region and to develop an informative and user-friendly legend for the resulting map of the rice cropping systems.

2. Materials and Methods

2.1. Study area

The Mekong Delta is the southernmost region of Viet Nam. It is located between 8°30' to 11°00' N and 104°30' to 106°50' E and is bounded by the South China Sea in the east, the Gulf of Thailand in the southwest, and Cambodia in the northwest (see Figure 1). Its climatic conditions are characterized as savanna type according to the Koppen classification (Sakamoto *et al.*, 2006). The rainy and the dry seasons of the region are well defined; there are on average 145 overcast days. The delta is relatively flat with elevations ranging from 0 to 20 meters above sea level. The soils of the region are mostly alluvial.

Figure 1: Geographical Location of the Mekong Delta, Viet Nam



Rice is mostly cultivated as a monoculture using double or triple sequential cropping methods, although in some areas only a single crop of rice is grown in the year. The rice crops are winter-spring (W-S), spring-summer (S-S), and summer-autumn (S-A). The number of crops per year is strongly related to water availability and water management practices. Water originates from the two largest branches of the Mekong River: the Tiền and the Hậu rivers. In some flood-controlled areas, gates of dikes are opened during the flooding season every 3 or 4 years to flood the paddy fields. This is done for about a month, usually from September to October before the start of the W-S rice crop. It helps to deposit silt, increase soil fertility, and manage pests and diseases without affecting the cropping calendar.

2.2. Data

SPOT 4 and 5, 10-day NDVI 1 km resolution imagery was retrieved for the period April 1998 to March 2008 (VITO, 2008). These two systems have identical characteristics. Unlike the normal NDVI data ranging from -1 to 1, the SPOT NDVI images used in this study were unsigned-8-bit integers. The digital numbers (DN) were calculated by VITO using equation 2:

$$DN = \frac{NDVI + 0.1}{0.004} \quad (2)$$

All 354 images retrieved were stacked into a single image for subsequent classification.

Two field trips to the Mekong Delta were made. The first took place in September and October 2008. Through stratified clustered random sampling based on the initial map generated from the SPOT NDVI data of 26 preselected NDVI classes, 112 paddy fields were visited. All 26 classes were confirmed as rice, and their crop calendars were characterized based on interviews with farmers in their fields. The second field trip was made from December 2008 to May 2009. During this trip, 68 additional fields were surveyed to serve as validation data for the generated map of rice cropping patterns.

Several ancillary data sets were collected and used in this study: the official land-use map 2005 of the Mekong Delta (NIAPP, 2008) and the official districts, roads, rivers, and irrigation works maps. The official land-use map 2005 provides information on where rice is possibly grown, and helped in pre-selection the 26 NDVI classes for the first field work. This map was prepared using all possible cloud-free Landsat enhanced thematic mapper (ETM) images of the area.

2.3. Mapping the rice cropping patterns

The ISODATA clustering algorithm was employed to make a series of classification runs of the 10-year stacked NDVI images; the pre-defined number of classes was set from 10 to 100, making a total of 91 classification runs. For each run, the maximum number of iterations and the convergence threshold were set to 50 and 1, respectively. Selection of the best classification was based on cluster separability using the divergence statistic (Swain, 1978). The average and minimum divergences statistical indices calculated for all possible classified NDVI groups were all examined.

To construct the rice cropping pattern map legends, three steps were taken. The first step was to extract rice crop calendar information from interview data. These records were then grouped by NDVI classes on the basis of the number of crops grown sequentially within one year in association with the characters of the cultivated rice varieties. The second step was to examine the rice cropping calendars in relation to the flooding regime from the main rivers. The information on flood duration (full inundation) and extent was added to the map legend. Low NDVI values indicate flooding (Xiao *et al.*, 2002; de Bie *et al.*, 2008). A decadal mean NDVI DN value of 50, which is equal to 0.1 of a normal NDVI value (see equation 2), was set as the upper threshold for flooding detection. This value is lower than the value of 75 suggested by Xiao *et al.* (2002) because in our research, flooding refers to complete inundation of the area by sometimes up to 5 meters (m) of water, while in Xiao *et al.* (2008), flooding refers to irrigation associated with the rice transplanting period. The extent of flooding was recorded as either partial or extensive. The assessments on timing and extent of flooding were made by evaluating, by NDVI class, the spatial patterns over time of pixels having NDVI DN values lower than 50. These were based on the original 2004–2007 10-day NDVI images only. Areas with flood duration of less than one month were labeled as controlled, otherwise as uncontrolled. The last step was to describe all surveyed NDVI classes based on tabulated information on cropping patterns, flooding regime, and varieties grown. Additional information collected on soil type, soil salinity, and soil pH was added to the legend as notes.

Validation of the final rice cropping pattern map was done using the Kappa statistic, which shows the extent of agreement between the map legend and the second field trip data.

3. Results

Figure 2 shows the separability comparison for 10–100 separate NDVI classifications. The separability indices increase slowly until the number of classes reaches 77, where the average separability displays a unique peak; after 77 classes, the pattern is erratic. This indicates

that 77 is the most reasonable choice for correct pattern recognition while keeping the number of classes relatively low (less than 100).

Figure 3 provides an example of the temporal profiles of 3 different NDVI classes representing 3 rice cropping systems.

Figure 2: The Average and Minimum Separability Indices for NDVI Classes Classified from 10-Year Dataset.

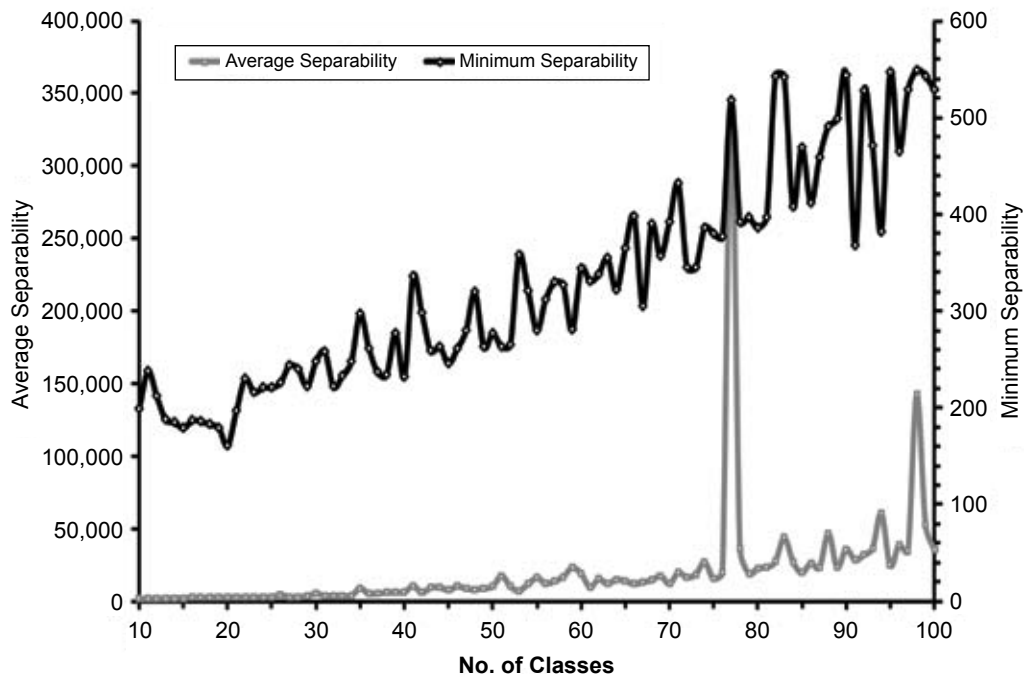


Figure 3: 10-Year NDVI Profiles of Three Rice Cropping Systems

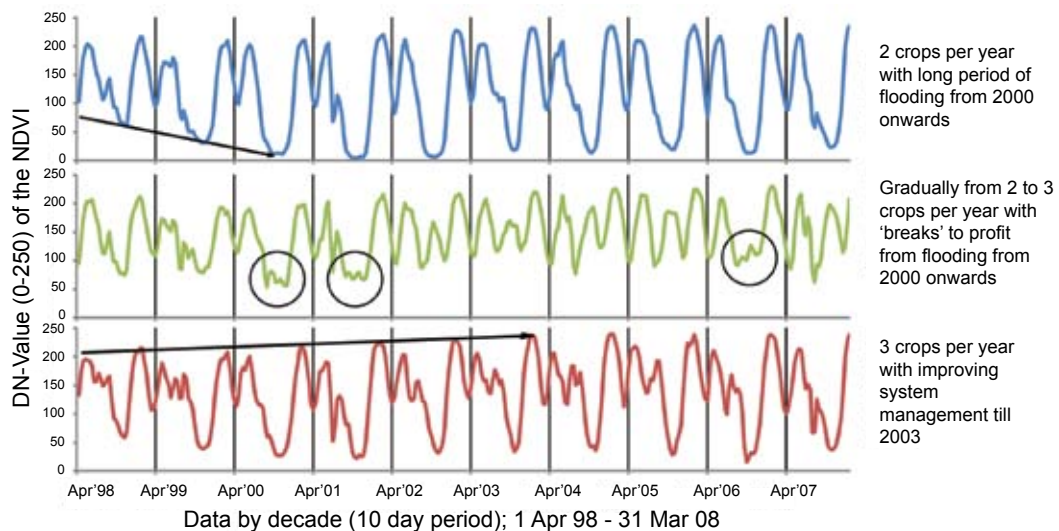


Figure 3 demonstrates clearly that past temporal land cover (NDVI) behavior can be examined and interpreted, subject to results of interview-based fieldwork. This serves to emphasize the point that NDVI datasets covering multiple years should not be merged into an annual representative data-stack, without considering whether inter-annual variability may be present. Furthermore,

applying a supervised classification to such time-series datasets would not allow a user to visually train time-series profiles as past land cover changes are difficult to incorporate into a supervised classification scheme.

Figure 4a shows the rice cropping pattern map and Figure 4b shows the detailed legend. The legend presents the rice

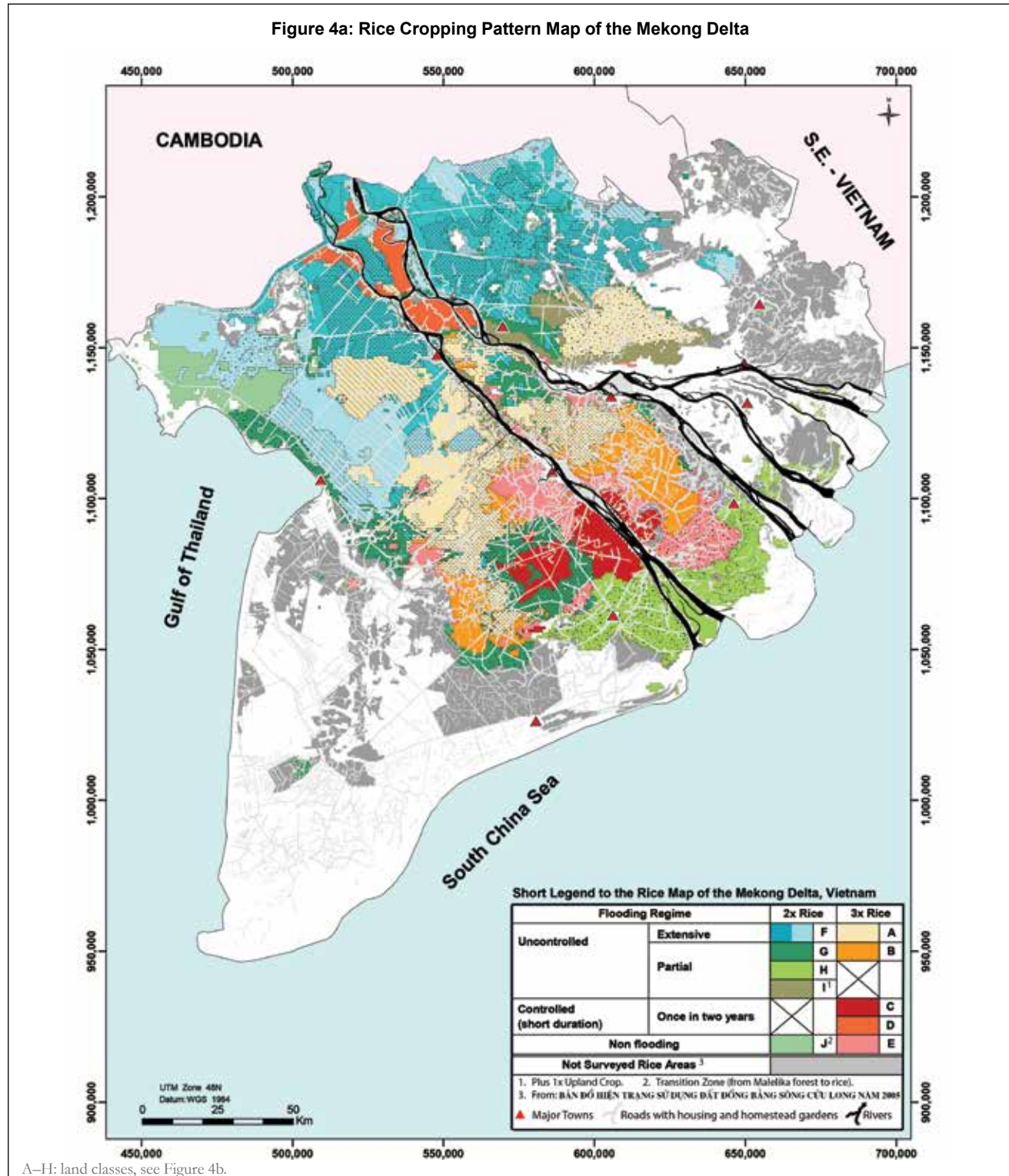
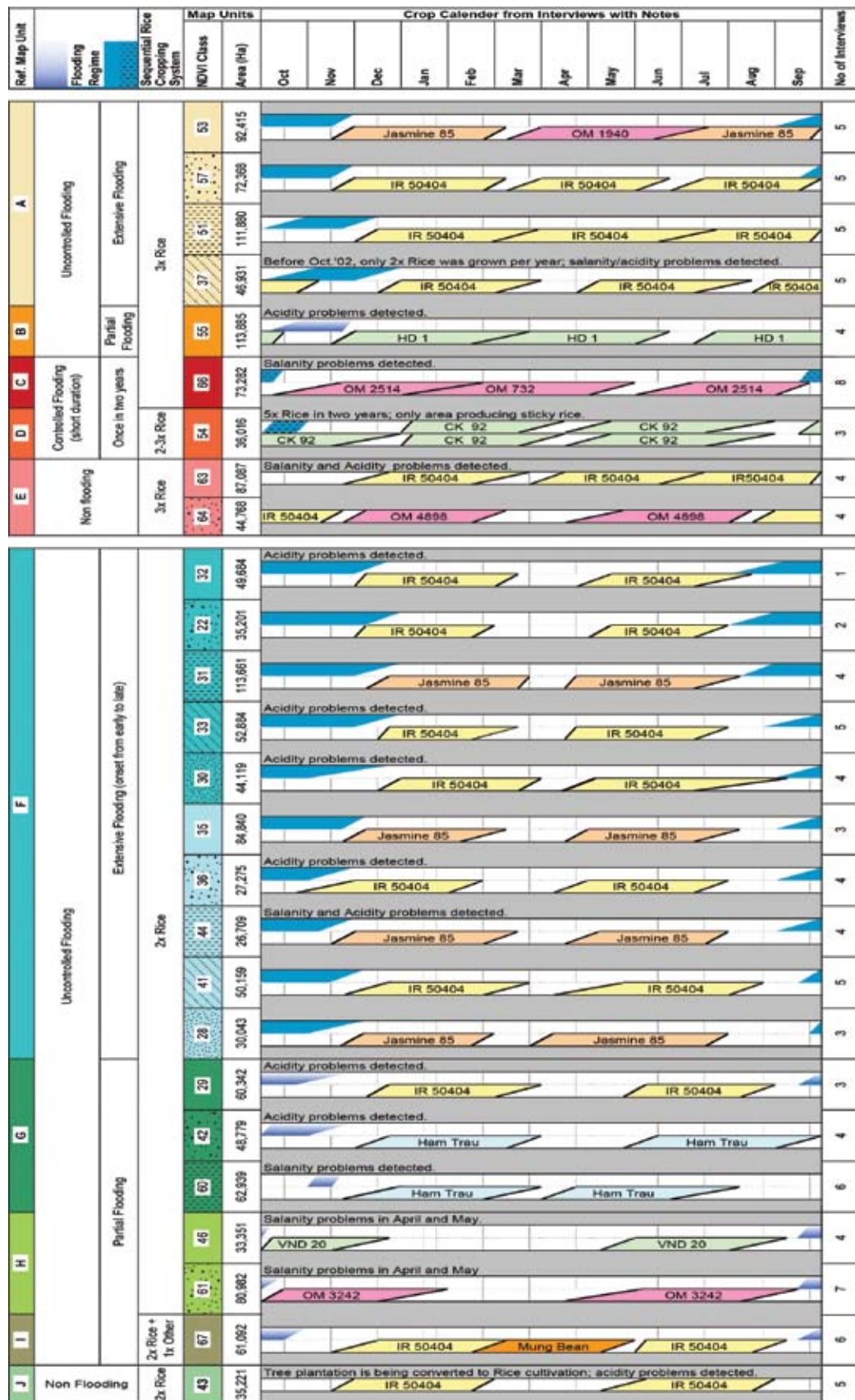


Figure 4b: Detailed Legend for the Rice Cropping Pattern Map, Showing the Rice Varieties Used



patterns in the delta and provides key information about the types of rice cropping in association with information about the flooding regime. The map also shows areas of rice that were not surveyed due to time limitations. In all surveyed areas, farmers practise either double rice cropping (2 x Rice) or triple rice cropping (3 x Rice) within a year.

The detailed legend (see Figure 4(b)) provides information about the variability in cropping patterns. Even within a class, overlap between two crops is found. For instance, in class 53, while the harvesting of the second crop had not totally been completed in some areas, sowing of the third crop already began elsewhere. This clearly indicates a high degree of temporal variability in cropping calendars. The legend also reveals that a variety of flooding conditions exists. Classes that are located in areas that are extensively flooded for long periods, such as classes 22, 31 and 33, only have two rice crops per year. Classes that are located in controlled flooding areas, and that are only flooded for a short period often have three crops. The flood regime affects the farmers' choices of which rice varieties to grow. To sustain the triple rice cropping pattern in controlled flooding areas, farmers tend to choose varieties with shorter growing periods (around 90 days), whereas in uncontrolled flooding areas, farmers prefer longer duration rice varieties. The legend also shows soil problems reported by farmers. Classes such as 42, 29 and 33 experience acidity problems whereas others, including classes 61, 46 and 66, suffer from salinization.

The validation (Table 1) shows very good agreement between our map and field data, with an overall accuracy of 94% and a Kappa of 0.93. Misclassifications based on site location occurred once for NDVI class 42 characterized by double rice cropping, and three times for class 53 mapped as triple cropping.

4. Discussion and conclusions

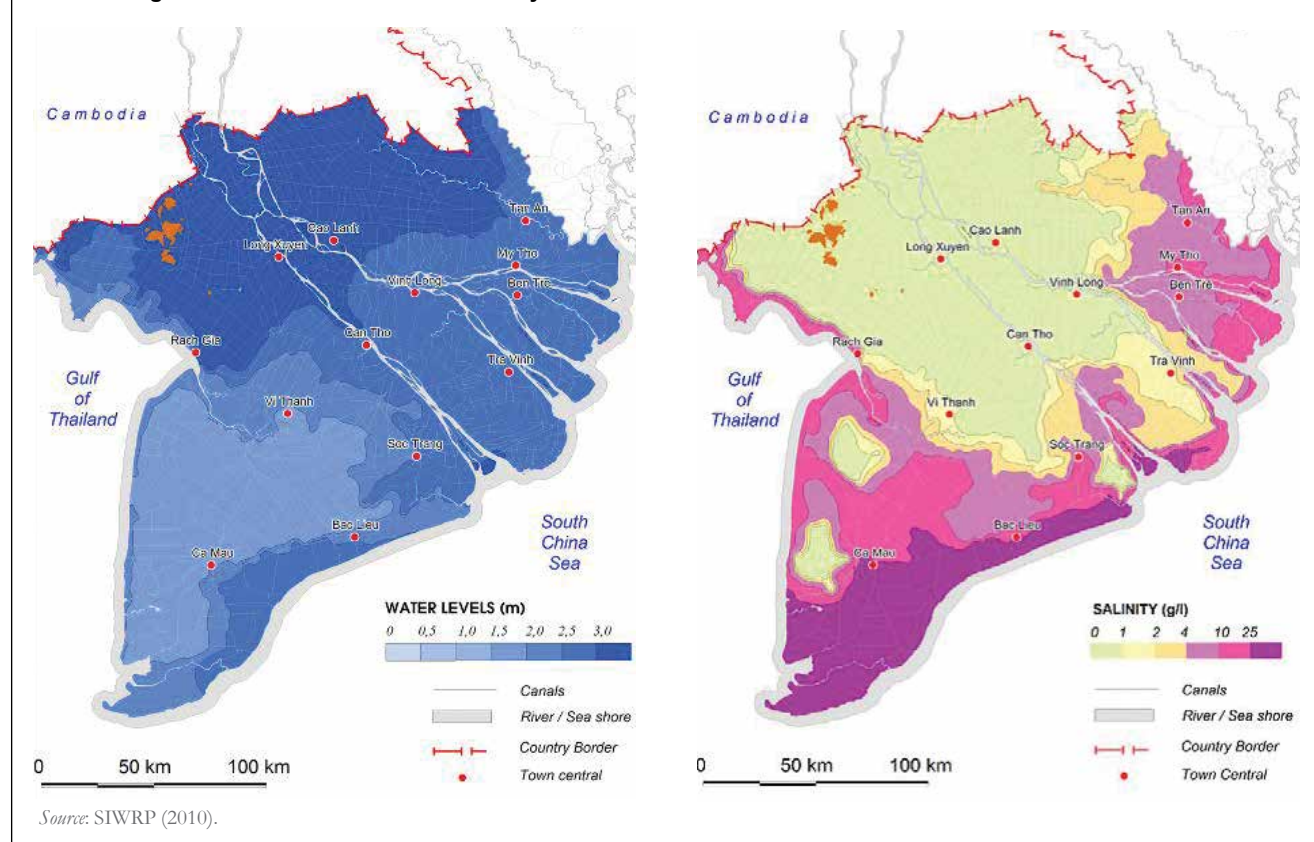
The results show that mapping irrigated rice cropping patterns in the Mekong Delta using hyper-temporal images was highly successful. The 10-year sequence of decadal images from the SPOT VGT sensor supported a very effective and detailed identification of complex cropping patterns of irrigated rice. Use of hyper-temporal NDVI data allows accurate and up-to-date information to be mapped when required, while the official land-use map is updated only once every 5 years.

The amount of detail about the rice crops is much higher in our map legend than in the official 2005 land-use map and reveals that the cropping patterns are closely associated with environmental conditions, especially prevailing flooding regimes.

Climate change may have a significant impact on rice production in the region. The number of days that have average daily temperature more than 35°C in the Mekong

Table 1: Accuracy of the Rice Cropping Patterns Map using the Detailed Legend

Sample site classes according to their location on map											Samples	User's accuracy (%)
Sample site classes according to the map legend	NDVI group	A			B		C	E	F	G		
	NDVI class	53	51	37	55	66	63	44	29	42	60	
	53	16	0	0	0	0	0	0	0	0	0	16
	51	2	5	0	0	0	0	0	0	0	0	7
	37	0	0	2	0	0	0	0	0	0	0	2
	55	0	0	0	10	0	0	0	0	0	0	10
	66	0	0	0	0	2	0	0	0	0	0	2
	63	1	0	0	0	0	4	0	0	0	0	5
	44	0	0	0	0	0	0	2	0	0	0	2
	29	0	0	0	0	0	0	0	4	0	0	4
	42	0	0	0	0	0	0	0	0	4	0	4
	60	0	0	0	0	0	0	0	0	1	15	16
Samples		19	5	2	10	2	4	2	4	5	15	68
Producer's accuracy (%)		84	100	100	100	100	100	100	100	80	100	Overall 94%.
												accuracy:
												Kappa: 0.93

Figure 5: Scenario of Sea-level Rise by 100 cm in 2100 with the Associated Effect of Saline Intrusion.

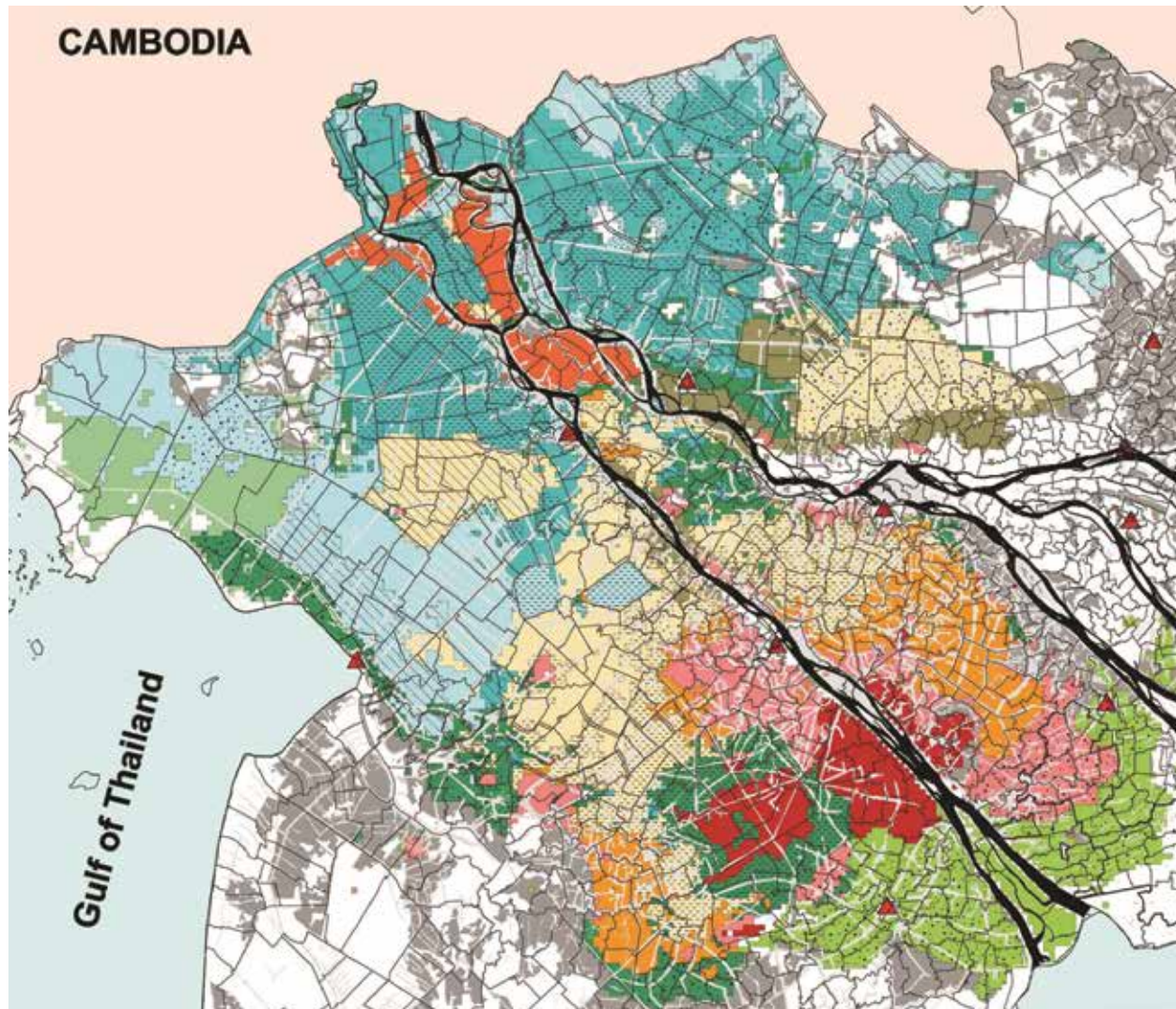
Delta could be more than 210 by the late 2090s (Jintrawet and Chinvarno, 2008), which would not be the most preferable growing condition for rice in the region. Sea-level rise will have a large impact on rice production in the delta. According to Viet Nam Sub Institute of Water Resources Planning (SIWRP) (2010), by 2100 most of the upper Mekong Delta would be covered under 3 m of water if the predicted sea-level rise of 100 cm occurs. In addition, most of the lower part of the region would be highly affected by saline intrusion. This would clearly lead to a shift in rice cropping calendars and many areas that are most suitable for rice production would probably disappear, resulting in a big decline in the region's rice production.

However, as our research reveals, the rice cropping patterns proved very homogeneous at the commune level; hence, strategies to mitigate any effects of climate change on rice cropping systems should consider inclusion of communes. By synchronizing seeding and harvesting time, damage to rice by pests and diseases remains limited; water management is also better controlled at the local level. The borders of our map units often coincide with administrative boundaries (Figure 6). This area-based homogeneity contributed to our mapping success; the

map-units, which are based on 1 km² pixels, are generally too small to contain a mix of cropping patterns, so that in the legend a 1:1 relationship between class and pattern was obtained.

We were not, however, able to include in the map legend pertinent information on rice varieties grown, due to the high annual variability in farmers' choice of varieties. Nevertheless, the lengths of rice growing seasons remain the same. They reflect the adaptation of the local farmers to the annual change of environmental conditions, especially the fluctuation of the flooding regime. By using hyper-temporal NDVI data, monitoring and mapping such changes in rice cropping patterns in the Mekong Delta has proven very successful.

Figure 6: Overlay of Mekong Commune Boundaries on the NDVI-based Rice Cropping Pattern Map



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HEALTH COST OF PESTICIDE USE PRACTICES IN MUNG BEAN (*VIGNA RADIATA* L) PRODUCTION IN MYANMAR

Seinn Seinn Mu¹ and Corazon T Aragon²

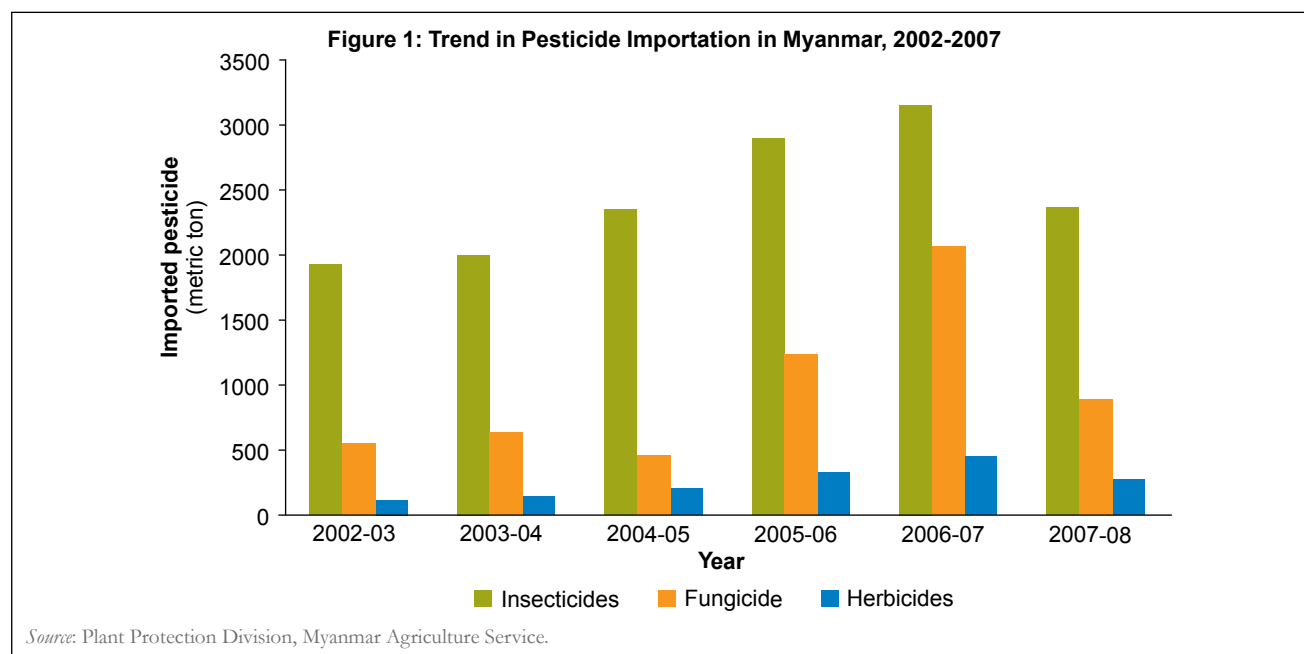
Abstract

The study assessed the effect of pesticide use practices in mung bean production on health cost in Khayan-Thongwa area, Yangon Division in Myanmar utilizing both primary and secondary data. Random sampling was used in selecting the sample respondents composed of 148 mung bean farmers and 58 hired farm workers. High dosage farmers who used 500 gm active ingredient (ai)/ha and above of pesticides, on the average, incurred the highest total health cost (26,378 Kyat), followed by moderate dosage farmers who used 250-500 gm ai/ha of pesticides (14,385 Kyat) and low dosage farmers who used less than 250 gm ai/ha of pesticides (3915 Kyat). To improve crop productivity and lessen the health risk of mung bean farmers and hired workers resulting from improper pesticide practices in the study areas, the following recommendations are suggested:

1) introduce alternative and safer pest control strategies (e.g., crop rotation, IPM, use of pest-resistant varieties, etc.); 2) conduct more training on proper pesticide use for farmers and hired farm workers; 3) monitor the pesticide importing companies, dealers, and retailers on the sale of banned pesticides in the market; 4) provide public health education to mung bean farmers on pesticide handling and safety practices.

1. Introduction

Being a developing country, Myanmar's goal of attaining food security in agricultural production partly depends on the use of pesticides. Since a market-oriented economy was first initiated in 1988, the country's exports of most agricultural products were opened to private trade. Likewise, the import and distribution of agricultural inputs such as seeds and agro-chemicals were also liberalized. In particular, subsidies for fertilizer and pesticides were greatly reduced, and the private sector was allowed to play a greater role in the distribution of such inputs (Oo, 2006). This has led to the rapid increase in the use of pesticides especially on pulses, cotton and vegetables rather than on rice. Insecticides comprised the largest share of imported pesticides and the rest are herbicides, fungicides and others (Figure 1).



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In recent years, yield-increasing measures and quality improvement of pulses through agricultural intensification such as the use of chemical fertilizers and pesticides, irrigation practices and crop management technologies have become an important issue in Myanmar's agriculture sector. Specifically, the use of pesticides rapidly increased and it became an indispensable production input among pulses growers to minimize yield losses and poor quality of the produce caused by pest and disease infestation. Most of the pulses growers in Myanmar seem to treat pesticides as substitutes for fertilizers. Owing to high input prices, farmers could not afford to apply the recommended rate of fertilizers. However, they want to minimize the risk of a very large crop failure caused by pest infestation by devoting much of their savings in pesticide application with great expectation of short-term benefits. Also, increases in pulse prices have a significant positive influence on pesticide use, indicating that a boost in pulses prices would also induce increased use of pesticides.

So far, an effective control measure has not been achieved practically (Morris and Waterhouse 1998 as cited by Oo, 2006) and use of chemical pesticides is the only control measure practiced at present due to its rapid action in controlling widespread pest infestation and the lack of other more reliable pest control practices. However, current practices of farmers based on prophylactic tactics have become increasingly questioned due to a number of reasons such as unsustainable crop production, inefficient pest control, damage to the environment and occupational health hazards to farmers and farm workers.

2. Objectives

The objective in this paper is to describe the pesticide use practices of mung bean farmers as well as to examine the effects of pesticide use on human health (i.e., incidence of diseases and pesticide poisoning and health cost) of farm workers and farmers engaged in mung bean production.

3. Study Design and Sampling

The study utilized both primary and secondary data. Secondary data were gathered from the Plant Protection Division, Myanmar Agriculture Service, Khayan, Thongwa township settlement offices, and the Settlement and Land Records Department. Clinical data on the incidence of pesticide poisoning were obtained from township hospitals of Khayan and Thongwa. Primary data were collected from

the farmers through personal interviews using a pre-tested interview schedule covering Crop Year (CY) 2008.

The study was conducted in Yangon Division in Myanmar. The townships of Khayan and Thongwa were purposively selected in this study because they are major mung bean growing areas in Yangon Division and pesticide use is widely practiced in these areas. Random sampling was employed in selecting the sample farmer- respondents. A total of 148 sample farmers and 58 hired pesticide applicators were included in the study.

In this study, descriptive statistics such as the mean, percentages, and frequencies were computed to describe the socio-economic characteristics (e.g., age, educational attainment, and income) of the sample mung bean farmers and their household members, current pesticide practices of the sample farmers such as: the number of years using pesticides, insecticide dosage, spraying frequency, timing of application, types of diseases caused by pesticide use, number of days the farmer/ laborer were sick/unable to work due to pesticide-related diseases, kinds of illness caused by pesticide use, cost of medication, and kind of self-medication.

4. Results and Discussion

Description of the Study Area

Khayan-Thongwa region is situated in the Southern part of the former capital, Yangon. The total area of Khayan-Thongwa is 143,186.6 hectares of basically flat land. The total agricultural land is 103,056.4 hectares and accounts for 72 percent of the total area. The proximity to the sea causes a salinity problem, especially in the dry season, and it is estimated that five percent of the land is already affected. Paddy land accounted for 98 percent of the total agricultural land, orchard, 1.8 percent, and toddy palm, 0.2 percent. There are 24 subdivisions, 115 village groups and 320 villages in Khayan-Thongwa area. Among the total population of 322,389, about 70 percent are farm households and the rest (30 %) are non-farm households.

Khayan-Thongwa has the largest pulses growing area among the nine townships of Yangon Southern District and is especially famous for mung bean production. The major cropping pattern in Khayan and Thongwa townships is rice followed by mung bean. Other crops such as groundnut, black gram, sunflower, vegetables, and cow peas are grown on a limited scale.

Characteristics of the Sample Mung Bean Farmer-Respondents and Their Mung Bean Farms

The socio-economic characteristics of the sample farmer-respondents are presented in Table 1. The sample mung bean farmer-respondents were classified into three groups according to pesticide usage. Group 1 are low dosage users who used less than 250 gm active ingredient (ai)/ha of pesticides. Group 2 are moderate dosage users or farmers who applied 250-500 gm ai/ha of pesticides while Group 3 are high dosage users or farmers who used 500 gm ai/ha and above of pesticides.

The mean age of the three groups of farmers was 47 years old. Most of the sample mung bean growing farmers (90%) were male, while only 10 percent were female. The average number of years of schooling of Groups 1, 2 and 3 farmers was 5.66, 5.96 and 6.6 years, respectively. The average household size of the three groups of farmers was approximately five persons.

Most of the farmers were engaged in rice-based farming system for several years already. The minimum recorded years of rice-mung bean farming experience of the sample farmers was two years and the maximum was 57 years. On the average, the 148 sample farmer-respondents had 22 years of experience in mung bean production. The average farm size of Groups 1, 2 and 3 farmers was 3.48, 4.01 and 4.53 hectares, respectively.

Majority of Group 1 (70%), Group 2 (67%) and Group 3 (74%) sample farmer-respondents accessed credit from both formal and informal sources (Table 1). The amount borrowed depended on the size of the land holding. Informal sources consisted of relatives, neighbors, and local money lenders while the formal source was the Agricultural Development Bank. On the other hand, about 30 percent of Group 1, 33 percent of Group 2 and 26 percent of Group 3 farmers borrowed from formal sources only such as the Myanmar Agricultural Development Bank and the Village Peace and Development Council at an interest rate of 1.5 percent per year. The maximum interest rate charged by informal money lenders was 20 percent while the minimum was three percent per year.

Pesticide Practices

The common types of pesticide used by the sample mung bean farmers were emulsifiable concentrate and soluble powder. Endosulfan and Monocrotophos were still used by the sample farmer-respondents, although they were included in the banned pesticide list in Myanmar. Some highly hazardous chemicals such as methomyl were illegally imported from border areas. It was highly demanded by mung bean farmers due to its stronger concentration and lower price in comparison with other pesticides sold in the market. Furthermore, mung bean farmers preferred Organophosphates such as Acephate, Dimethoate and Phenthoates to Organochlorines for wide-spectrum toxicity.

Table 1: Socio-economic characteristics of 148 sample mung bean farmer-respondents classified according to pesticide dosage, Khayan-Thongwa, Myanmar, 2008

Characteristics	Group 1 Farmers ^a	Group 2 Farmers ^b	Group 3 Farmers ^c	All Farmers
Number of respondents	41	49	58	148
Average age (years)	47	49	47	47
Gender :				
– Male (%)	90	84	93	90
– Female (%)	10	16	7	10
Average educational attainment (schooling years)	5.66	5.96	6.6	6.13
Average household size (person)	4.9	4.69	4.81	4.79
Average farming experience (years)	22.88	22.08	21.41	22.04
Average farm size (ha)	3.48	4.01	4.53	4.07
Source of credit:				
– Formal and informal sources (%)	70	67	74	71
– Only formal sources (%)	30	33	26	29
Source of income:				
– Mung bean (%)	61	57	58	59
– Paddy (%)	30	32	28	29
– Off-farm income (%)	3	7	7	6
– Non-farm income (%)	6	4	6	6

a Farmers' group using pesticides at less than 250 gm/ha of ai (low dosage)

b Farmers' group using pesticides at 251-500 gm/ha of ai (moderate dosage)

c Farmers' group using pesticides at more than 500 gm/ha of ai (high dosage)

Similarly, some farmers used Organophosphates together with pyrethroids such as cypermethrin and carbamates (e.g., Methomyl and Carbosulfan). Some farmers also used pesticides by mixing the same active ingredients with different trade names. However, the current sales promotion and advertising programs of pesticide companies have encouraged farmers to use more pesticides.

Frequency of pesticide application. Pesticide application patterns by the sample mung bean farmers do not reflect current pest situations. Even with no serious pest attack, farmers applied insecticides frequently with the maximum application frequency of 10 times and minimum application of two times. The average frequency of application was five times. The frequency of application per cropping is influenced by the interval of spraying. The less the number of days of interval, the more frequent the spraying would be. Thus, the most common spraying interval was seven to ten days as reported by 50 percent of all the sample respondents (Table 2).

Timing of insecticide application. The critical factors that farmers consider in determining the timing of pesticide application are crop age, presence of pest infestation, degree of pest infestation, past year's history of pest infestation, neighboring farmers' recommendation and pesticide salesmen's instruction. Majority (36%) of the 148 sample farmer-respondents reported that they sprayed according to crop age such as 14 days after sowing (DAS)

and 34 days after flowering (DAF) onwards. Crop age was the most important factor considered by the three groups of farmers in their decision on the timing of pesticide application. A larger proportion of Group 2 farmers (45%) cited crop age as the foremost factor compared to Group 3 (34%) and Group 1 (27%) farmers.

The second most important factor which influenced the farmers' decision on the timing of pesticide application was the presence of pests. Twenty-four percent of the 148 sample farmer-respondents stated that they sprayed when they saw the pests such as aphids, boll worms, army worms or jasssids attacking the plants. About four percent of the total respondents said that they sprayed 8 to 10 times when there was heavy pest infestation. All the three groups considered the pesticides salesmen's recommendations as the third most important factor which influenced their decision on the timing of pesticide application. However, some farmers sprayed pesticides as a protective or prophylactic measure regardless of whether there was pest infestation or not.

5. Health Cost Related to Pesticide Use

Medication

All the sample respondents composed of mung bean farmers and hired applicators practiced self-medication

Table 2: Frequency, spraying interval and timing of pesticide application by farmers' group, 148 sample mung bean farmer-respondents, Khayan-Thongwa, Myanmar, 2008

Pesticide Practices	No. of Farmers Reporting			
	Group 1 ^a (n = 41)	Group 2 ^b (n = 49)	Group 3 ^c (n = 58)	All (n = 148)
Frequency of pesticide application				
2-4 times	20 (49)	23 (47)	24 (41)	67 (45)
5-7 times	19 (46)	22 (45)	33 (57)	74 (50)
8-10 times	2 (5)	4 (8)	1 (2)	7 (5)
Spraying interval (days)				
5-6	3 (7)	6 (12)	2 (4)	11 (5)
7-10	25 (61)	19 (39)	35 (60)	79 (50)
14-25	13 (32)	24 (49)	21 (36)	58 (45)
Factors that Farmers Considered in their Decision on the Timing of Pesticide Application				
Crop age	11 (27)	22 (45)	20 (34)	53 (36)
Presence of pests	10 (24)	11 (22)	15 (26)	36 (24)
Degree of pest infestation	2 (5)	4 (8)	1 (2)	7 (5)
Salesmen's recommendations	8 (20)	10 (20)	14 (24)	32 (22)
Others ^d	10 (24)	2 (5)	8 (14)	20 (13)

Figures in parentheses are percentages

a Farmers' group using pesticides at less than 250 gm/ha of ai (low dosage)

b Farmers' group using pesticides at 251-500 gm/ha of ai (moderate dosage)

c Farmers' group using pesticides at more than 500 gm/ha of ai (high dosage)

d Others include neighboring farmers' recommendations, past year's experience, and as a protective or prophylactic measure

especially for less serious cases of pesticide poisoning and consulted professional doctors or assistant pharmacists for more serious cases. Almost half of the farmers just took a rest after applying insecticides and only 13 percent of them took cheaper traditional medicine such as analgesic pills. About 28 percent of the farmers reported that they immediately took a bath after pesticide application to remedy the skin or eye irritation.

Health Cost

Direct and indirect costs were determined to estimate the total health cost. Direct costs included the cost of medicines, doctor's fees, room charges, laboratory analysis, and transportation cost in going to and from the hospital. Indirect cost was measured in terms of the income forgone or opportunity cost of the farmers or farm workers for not working on the farm due to pest-related diseases (Rola and Pingali, 1993).

As shown in Table 3 and Appendix Table 1, the mean indirect health cost of Group 3 respondents (7,942 Kyat) was significantly higher than that of Group 2 respondents (5,099 Kyat) at five percent probability level and that of Group 1 respondents (2,187 Kyat) at one percent probability level. This could be attributed to the fact that Group 3 respondents or those who applied the highest dosage of pesticides and who also reported the highest proportion of those who did not use protective clothing and masks exhibited the highest opportunity cost of labor foregone due to more incidence of pesticide poisoning in this group. It was found that there was no hospitalized case among Group 1 farmers. They merely consulted an assistant pharmacist or did self-medication for their illness.

As Group 3 had the highest number of sick and rest days compared to Group 1 and Group 2 respondents, the mean indirect cost of Group 2 respondents was significantly higher than that of Group 1 respondents at one percent probability level. Again, this could be explained by the higher opportunity cost of labor foregone of Group 2 respondents as reflected from the higher number of sick and rest days in this Group as compared to Group 1 respondents.

This could be largely attributed to the significantly higher cost of medicines and consultation fees paid by Group 2 respondents considering that Group 1 respondents merely consulted assistant pharmacists instead of seeking professional treatment from medical doctors. Moreover, Group 1 respondents merely sought medical treatment as outpatients. None of them were hospitalized. Hence, they did not incur any hospital costs such as room charges and laboratory fees. Comparing the total health cost of the three groups of respondents who got ill from pesticide poisoning, Group 3 respondents, on the average, incurred the highest total health cost (26,378 Kyat), followed by Group 2 respondents (14,385 Kyat). Group 1 respondents spent the lowest total health cost (3,915 Kyat), on the average (Table 3).

The differences in the mean total health cost between Group 1 and Group 3 respondents and between Group 1 and Group 2 respondents were significant at one percent probability level. On the other hand, the difference in the mean total health cost between Group 2 and Group 3 respondents was only significant at 10 percent probability level. Twenty sample farmer-respondents who reported having been ill due to pesticide use were grouped according to pesticide dosage applied.

Table 3: Mean health cost of 20 mung bean farmers and 55 hired applicators by groups, Khayan-Thongwa, Myanmar, 2008

Item	Health Cost per Season (KYAT)			
	Group 1 ^a (n =19)	Group 2 ^b (n = 30)	Group 3 ^c (n= 26)	All (n=75)
Indirect cost	2,187	5,099	7,942	5,347
Opportunity cost of labor foregone	2,187	5,099	7,942	5,347
Direct cost	1,728	9,286	18,436	10,543
Medicine	913	3,188	6,423	3,733
Consultation fees	705	3,493	5,538	3,496
Room charges	0	1,033	3,096	1,487
Laboratory fees	0	800	2,323	1,125
Transportation cost	110	772	1,056	702
Total health cost	3,915	14,385	26,378	15,890

US\$ 1.00 = 1,000 KYAT

a Group using pesticides at less than 250 gm/ha of ai (low dosage)

b Group using pesticides at 251-500 gm/ha of ai (moderate dosage)

c Group using pesticides at more than 500 gm/ha of ai (high dosage)

Among the three groups, Group 3 farmers or those who applied high dosage of pesticides obtained the highest mean net income (219,852 Kyat) but they also spent the most on health cost (33,388 Kyat) compared to the moderate dosage users (Group 2) and the low dosage users (Group 1) (Table 4). Hence, the mean net benefit from pesticide use, which was computed by deducting mean health cost from mean net income, was lowest for Group 3 (186,464 Kyat).

Of the 55 hired farm workers who reported having been ill due to pesticide exposure during spraying of insecticides, Group 3 composed of those who applied the highest dosage of pesticides also incurred the highest total health cost (20,977 Kyat) compared to the moderate pesticide dosage users (Group 2) and low pesticide dosage users (Group 1) (Table 4). Despite their having received the highest income from wage employment (91,500 Kyat), they received the lowest net benefit from pesticide use (70,523 Kyat) because of the substantial amount of health cost that they incurred.

6. Recommendations

Based on the foregoing results of the study, some policy recommendations are suggested below to improve the crop productivity and lessen health risk of mung bean farmers and hired workers in their pesticide use in the study areas and in other major mung bean-producing regions with similar socio-economic and crop protection practices as the study sites.

1. Introduce alternative and safer pest control strategies: Aside from prophylactic chemical control, a number of pest control strategies could reduce the pest population at a lower social cost than chemical pesticides. Among the pest control measures, cultural practices are an integral

part of most pest control strategies and are effective in combination with other pest control measures. Crop rotation, timing of planting, and harvesting, use of farm yard manure or organic manure, choice of disease- or pest- resistant varieties, and proper soil management are simple cultural management practices to keep beneficial species active and populous enough to control pests. Although cultural methods alone are not likely to ensure adequate control of pest population, they often can reduce pest population pressures and enhance another control measure.

2. Provide more training to mung bean farmers and hired workers on proper pesticide usage: The common practice of high dosage users was under dosing in the first and second sprays and over dosing in the late sprays to control the pest outbreak level during the first and second sprays. Their preventive use of pesticides was found to be not very effective in controlling pest population. Therefore, a training on the proper usage of pesticides such as correct timing of application, type of pesticide, correct frequency, and dosage are essentially needed and will facilitate the farmers to correct their practice of misusing pesticides.

3. Monitor the pesticide importing companies, dealers and retailers: Owing to the continued sale of banned pesticides in the market, the Pesticide Registration Board (PRB) should closely monitor the activities of pesticide importing companies, pesticide salesmen and dealers and impose penalties (e.g., fines) to violators. Legislations on the formulation, repackaging, fumigation and the issuance of retailers' license should be strictly observed. Currently, most pesticide sales companies promote their products by employing different marketing strategies such as the provision of in-kind or cash credit to farmers before planting and giving of a sales incentive to big farmers who could sell pesticides to many small farmers through a profit sharing scheme. Hence, different trade names of pesticides with

Table 4: Comparison of the mean income earnings per season, health cost, net benefit from pesticide use among hired workers' groups, 55 sample mung bean hired laborers, Khayan-Thongwa, Myanmar, 2008

Item	Group 1 ^a (n=15)	Group 2 ^b (n=20)	Group 3 ^c (n= 20)
Wage income per season ^d (Kyat)	85,600	87,600	91,500
Mean health cost (Kyat)	3,760	14,633	20,977
Mean net benefit ^e (Kyat)	81,840	72,967	70,523

US\$ 1.00 = 1,000 KYAT

a Group using pesticides at less than 250 gm/ha of ai (low dosage)

b Group using pesticides at 251-500 gm/ha of ai (moderate dosage)

c Group using pesticides at more than 500 gm/ha of ai (high dosage)

d Computed by multiplying 60 working days per season times the daily wage rate of 1,500 Kyat

e Net income minus total health cost

the same active ingredients are being sold in the market. A policy on the imposition of a high import tax on pesticide categories I and II which are harmful and toxic to human health should be formulated to mitigate the health risks of farmers by using only cheaper and least harmful pesticides such as categories III and IV.

4. *Provide public health education to mung bean farmers on pesticide handling and safety practices.* Public health education is very important for the health safety of the farmers and their family members since most of the farmers in the study area were not careful in handling and storing pesticides. The cooperation of the regional public health centers and health workers such as trained nurses and village health assistants is deemed necessary in disseminating information on how to perform first aid treatment for pesticide poisoning and in distributing pamphlets on proper methods of pesticide handling in order to lessen the health cost of farmers resulting from pesticide related-symptoms and diseases.

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Appendix

Table 5: ANOVA results to test the significance of the differences in the mean health cost of selected variables among three groups of farmers, 148 sample farmers, Khayan-Thongwa, 2008

Variable	Anova Results/F-Value
Mean indirect cost (Kyat)	8.742***
Mean medicine cost (Kyat)	3.862**
Mean consultation fees (Kyat)	13.707***
Mean room charges (Kyat)	5.143***
Mean laboratory fees (Kyat)	2.808*
Mean transportation cost (Kyat)	5.465***
Mean direct cost (Kyat)	5.474***
Mean health cost (Kyat)	6.785***

***, **, * mean significant at 1%, 5% and 10% probability level

Session 2.2: Land, Water, and Climate Change

WATER FOR FOOD AND ENERGY IN THE GMS: ISSUES AND CHALLENGES TO 2020

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This paper is based on the IWMI research report “Climate change, water and agriculture in the Greater Mekong Sub-region” (Johnston *et al.*, 2010)

1. Introduction

The countries of the Greater Mekong Subregion (GMS) are experiencing rapid economic and population growth, with concomitant increases in demand for food and energy. The traditional rice-fish livelihood systems of the region, with their dependence on the annual flood pulse and natural aquatic ecosystems, still play an important role but are increasingly giving way to urban and industrial development. Demand for energy from hydropower, and irrigation for intensive commercial food production to meet the needs of urban populations are reshaping the way that water resources are used.

The region faces difficult decisions about how water resources will be managed to balance the requirements of different sectors. The three major water sectors in the GMS (hydropower, agriculture, and fisheries) are

inextricably interlinked, and management responses must take account of the interactions and inherent trade-offs between sectors to offset potential conflicts and capitalize on synergies. This paper explores the nexus between water, food, and energy in the GMS and the changing understanding of the issues and challenges driving water resource development in the next 10 years.

2. Water Resources in the GMS – Status and Trends

2.1. Water and Agriculture

Agriculture is by far the largest consumer of water in all GMS countries, estimated to account for 68% (in the People's Republic of China [PRC] and Viet Nam) to 98% (in Cambodia) of total withdrawals (WRI, 2009; Table 1). Despite this, the proportion of irrigated land in GMS countries is relatively low by world standards (ranging from 7% of total cropland in Cambodia to 31% in Viet Nam [World Bank, 2009a]), the availability of renewable freshwater in most countries is high and rainfed agriculture dominates production. While the overall availability of water resources in the GMS may not be affected significantly by climate change, agriculture is vulnerable to local climatic variability, with significant risk from both floods and droughts even under current climate conditions. Increasing and safeguarding production will require improvements in water management in both rainfed and irrigated systems.

Table 1: Water and Agriculture Indicators for GMS Countries

	Unit	Cambodia	PRC	Lao PDR	Myanmar	Thailand	Viet Nam
GDP from agriculture (%) (2008)		32.5	11.3	32.1	46.7	11.6	22.1
Agricultural population (%) (2006)		68	64	76	69	45	65
Arable land 2007	km ²	38,000	1,406,300	11,700	105,770	152,000	63,500
Arable land per capita (2007)	ha/person	0.26	0.11	0.20	0.22	0.24	0.07
Area equipped for irrigation as % of arable land 2007		8	41	26	21	33	47
Internal renewable water resource	km ³ /year	121	2,812	190	881	210	366
Total actual renewable water resource	km ³ /year	476	2,830	334	1,046	410	891
Per capita water resources, m ³ /person	2007	33,537	2,130	57,914	21,613	6,462	10,338
Total annual water withdrawal	km ³ /year	4.08	630	3.00	33.20	87.10	71.40
Per capita annual water withdrawals	m ³ /capita/year	308	486	555	711	1,412	877
% withdrawn for agriculture		98	68	90	98	95	68
% withdrawn for industry		1	26	6	1	2	24
% withdrawn for domestic use		2	7	4	1	2	8

km = kilometer

m – meter

Source: Adapted from Johnston *et al.* (2010).

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Agriculture in the GMS is in transition from traditional subsistence systems to modern commercial production of a wide range of commodities for both domestic consumption and export, with significant implications for water demand and water quality. Agricultural production in the GMS over the last 20 years has seen steady increases across all subsectors and all countries. Production in major commodity groups has more than doubled since 1990, outpacing the region's rapid population growth (FAOSTAT, 2009; see Johnston *et al.*, 2010 for a more detailed discussion of agricultural trends). Most of this remarkable increase has come from intensification and increases in yield, rather than expansion in agricultural area, which grew by less than 5% over the same period (FAOSTAT, 2009). Crop yield increases have resulted from the range of new technologies and approaches that underpinned the green revolution (IRRI, 2008): uptake of improved varieties, increasing use of fertilizers, improved farming practices, and the expansion and more efficient use of irrigation.

All national governments in the GMS see expansion of irrigation as an important priority, both to increase production and to reduce risk from climate change. FAO statistics indicate that irrigated areas in the region (excluding Yunnan Province, PRC) increased by at least 1 million hectares (ha) between 1990 and 2003 (World Bank, 2009a), but national figures suggest an even larger increase. UNDP (2006) reported that government programs in Myanmar doubled the area under irrigation over the last 20 years to 1.4 million ha; and the Cambodian Government estimates that over 0.73 million ha of land now have irrigation compared to less than 0.25 m ha in 1990 (MAFF and MOWRAM, 2007; FAOSTAT, 2009). In other words, while irrigated agriculture is not as dominant here as in other parts of Asia, the irrigated area is expanding relatively rapidly.

The largest irrigated areas are found in the mega-deltas and low-lying floodplains of the Red, Mekong, Chao Phraya, and Irrawaddy rivers, the "rice-bowls" of the region. Although they constitute only 10% of total land area, they produced almost 50 million (metric) tons of rice in 2005, half of the region's production (excluding Yunnan) and around 8% of the global crop (FAOSTAT, 2009; national government statistics). In these areas, complex systems of dykes, levees, and canals are also used to divert and retain the floodwater of the monsoon. Only the Red and Chao Phraya deltas have significant upstream storage to regulate supply (Water Resources e-Atlas, 2003). The importance of production from traditional wet season (May

to October) rice cultivation with supplementary irrigation is increasingly being diminished by fully or partially irrigated crops before and after the wet season, taking advantage of higher solar radiation and lower flood risk. For example, in the Mekong Delta, the contribution of (long duration) wet season rice crop has declined to only 10% of total annual, which is now dominated by two irrigated crops in winter-spring and summer-autumn (VN GSO, 2009). This trend has produced significant increases in both yield and total production, but places water resources under stress.

The extent and success of irrigation development in areas upstream of the deltas has been more variable. In Thailand, there has been substantial investment in irrigation storage for the inland plains, with large multi-purpose storages in both the Chao Phraya Basin and the Isan plateau, and thousands of small dams and reservoirs servicing small to medium schemes (Molle, 2004). Despite this, the area of dry season (November to April) irrigated crops planted is significantly lower than the total irrigable area. Similarly, in Cambodia the majority of irrigation schemes in the inland plains around Tonle Sap are used mainly for supplementary irrigation of wet season rice; only 13% of the total rice crop is grown in the dry season, most of this on the Mekong floodplains in the south (MAFF, 2009b). In Myanmar, programs begun in the 1980s have expanded irrigation to cover approximately 25% of crop area, with significant development in the inland plains, but irrigation intensity is generally suboptimal; for example, the Sedawgyi dam project runs at 61% of its total command area, with the remaining area utilized as rainfed (UNDP, 2006; FAO, 2008). Low uptake of dry season irrigation in the region is attributed to a mixture of factors, including inappropriate infrastructure designed to manage floods for wet season rice production and not dry season crops, a lack of farmer knowledge of dry season cultivation techniques, other labor opportunities in the dry season (seasonal migration to the cities), and operating and maintenance problems. Small- to medium-scale irrigation, mainly pumped directly from rivers, is common in the intensively farmed upland river valleys of northern Thailand and Yunnan for high-value horticultural produce and other cash crops. Groundwater irrigation in the Central Highlands of Viet Nam and the Bolavens Plateau of the Lao People's Democratic Republic (Lao PDR) has allowed establishment of large areas of coffee, but overexploitation has threatened the sustainability of groundwater resources in some areas.

Overall, withdrawals are only a small fraction of total renewable resources (maximum of 22% in Thailand; Table

1), but demand for agricultural water is increasing and the strongly seasonal patterns of rainfall and irrigation demand mean that seasonal shortages are common. Pech and Sunada (2008) estimate that more than 80% of flows from upstream are extracted for irrigation in the Mekong Delta during the critical dry season months of March - April, resulting in local shortages and intrusion of seawater. Both the Chao Phraya and the Red rivers are essentially “closed” basins (Molle, 2004), and further development of irrigation will result in water transfers from other sectors, whether planned or not. In the Isan Plateau in northeastern Thailand, seasonal water shortages have led to conflict between urban and agricultural users in the dry season (MRC-TNMC, 2004).

The current trend toward establishment of large commercial plantations (for rubber, oil palm, cassava, coffee, and other crops) is also likely to impact on agricultural water demand. Concessions to develop plantations have been granted over large areas of land, particularly in Cambodia and the Lao PDR (MPI, 2008; Rutherford *et al.*, 2008; MAFF, 2009a). It is not clear what the ultimate impact of these plantations will be on water availability and demand. Most of the current development is rainfed, but at least some of the investment deals have included funding to build irrigation infrastructure; for example, the Kuwaiti loan of \$546 million to Cambodia to build an irrigation dam on the Stung Sen (Economist, 2008); and Chinese loans to Myanmar to construct joint hydropower and irrigation infrastructure (International Rivers, 2009).

Widespread conversion of forest or grassland to agriculture may have significant impacts on run-off and water use, though these may operate in different directions at different scales. Clearing generally increases run-off, while reforestation (or establishment of tree crops) has been demonstrated to decrease overall water yield from catchments by up to 30% per year in tropical southern PRC (Sun *et al.*, 2006). Lacombe *et al.* (2010) have demonstrated measurable increases and decreases in runoff at large catchment scale due to deforestation and reforestation respectively.

Water quality in most of the region is generally not limiting for human use (MRC, 2010) but serious water quality issues associated with high population density and inadequate treatment of sewage and industrial effluent downstream of cities occur in all the major deltas. Fertilizer, pesticide and herbicide inputs from agriculture are significant in the Chao Phraya, Red and Mekong deltas; some aquaculture practices are highly

polluting; and intrusion of seawater in the dry season and acid sulphate drainage from poorly managed pyritic soils affects large areas in all the deltas (MRC-VNMC, 2004). Levels of agricultural pollutants in most other areas are presently low, although high concentrations may occur in some localized cases. Further intensification of agriculture will increase the threat of non-point source pollution. Irrigation-induced salinity affects parts of northeastern Thailand and the central Lao PDR, exacerbated by saline groundwater (Eastham *et al.*, 2008).

2.2. Water, Fisheries, and Aquatic Ecosystems

The region contains extensive and diverse wetlands ecosystems, comprising riverine floodplains, fresh- and brackishwater deltaic wetlands and major lake systems, including the Great Lake (Tonle Sap) system (Southeast Asia's largest freshwater lake), Lake Inle in Myanmar, and large upland lakes in Yunnan. Traditionally, wetlands have played an important role in livelihoods, providing fish and other aquatic animals, as well as reeds and a range of food and medicinal plants (MRC, 2010).

Food production in the GMS has a high degree of dependence on freshwater ecosystems, which must be seen as an integral part of agricultural production systems. Average per capita fish consumption is estimated at 23–45 kg/capita/year, and fish in some areas provide between 50% and 80% of total protein (Hortle *et al.*, 2004; Hortle, 2007; Soe, 2008). Studies on the socioeconomics of fish production in the GMS indicate a very high level of participation in fishing, and emphasize the importance of the inland capture fishery for small-scale livelihoods and food security (Phan *et al.*, 2003; van Zalinge *et al.*, 2004). Fisheries also make an important contribution to the regional economy. Estimates of the total value of the Mekong fishery alone are as high as \$3 billion per year (Barlow *et al.*, 2008; Friend, 2009). The fisheries industry accounts for between 4% (Thailand) and 11% (Cambodia) of GDP (Sugiyama *et al.*, 2004; Soe, 2008); in Cambodia, this places it ahead of rice production (Hortle *et al.*, 2004).

There is a common perception that the region's inland fish catch is declining, and there is a high degree of concern regarding the sustainability of the capture fishery. The perception of decline is related mainly to a significant (40%–50%) decrease in catch per fisher as the total population and the number of people engaged in fishing has increased (Baran, 2005). Official statistics indicate that the overall freshwater catch in the region increased between 1990 and 2000 (FAOSTAT, 2009), and there

is no evidence of a decline since then. Concerns about sustainability remain, as there is evidence that large and medium migratory species have declined, and the average size of fish has also declined, a pattern typical of overfishing (Hortle *et al.*, 2004). There have been dramatic increases in both freshwater and brackishwater aquaculture production since the turn of this decade, with official increases of over 300% in brackishwater and over 500% in freshwater systems (FAOSTAT, 2009; Department of Fisheries Thailand, 2009). However, in the case of the Mekong, aquaculture represents less than 10% of total production, and while it can complement the capture fishery it cannot replace it in terms of food security (ICEM, 2010). In addition, aquaculture depends heavily on the capture fishery for stocks and feed.

Changes to river flow regimes, loss of habitat and disruption of migratory paths pose significant risks to inland fisheries in the GMS. The fish catch is strongly dependent on the extent, duration, and timing of flooding, and access to productive floodplain and wetland habitats for feeding (van Zalinge *et al.*, 2004; Krittasudthacheewa and Apirumanekul, 2008). Increasing areas of floodplain are being cleared or converted to agricultural use; for example, the area of flooded forest around Tonle Sap fell from over 1 million ha in the early 1970s to 0.45 million ha by 1997 (Evans *et al.*, 2004). Infrastructure, such as dykes and roads, disrupt access by fish to the floodplain for spawning and feeding. Proposed development of large-scale hydropower facilities will modify river flows and flooding regimes and block migration routes.

2.3. Hydropower

The GMS has estimated potential hydropower resources of over 200,000 megawatts (MW). However, in the near future only 6,000 MW will be developed and over the long run approximately 26,000 MW is foreseen as the maximum installed capacity. Demand for energy within the region is growing rapidly, and all governments are considering major hydropower developments to meet part of that demand. A review of hydropower in the GMS (King *et al.*, 2006) compiled an inventory of 82 projects existing or under construction and a further 179 planned and proposed projects. Figure 1 indicates the main planned developments within each of the major basins in the region. Hydropower development is considered as a relatively cheap, independent solution for energy demand, and also contributes less GHG emissions than alternatives such as charcoal, oil, and biofuel. However, existing and proposed major hydropower development will result in changes to

flow regimes and river ecology with significant implications for both agriculture and fisheries.

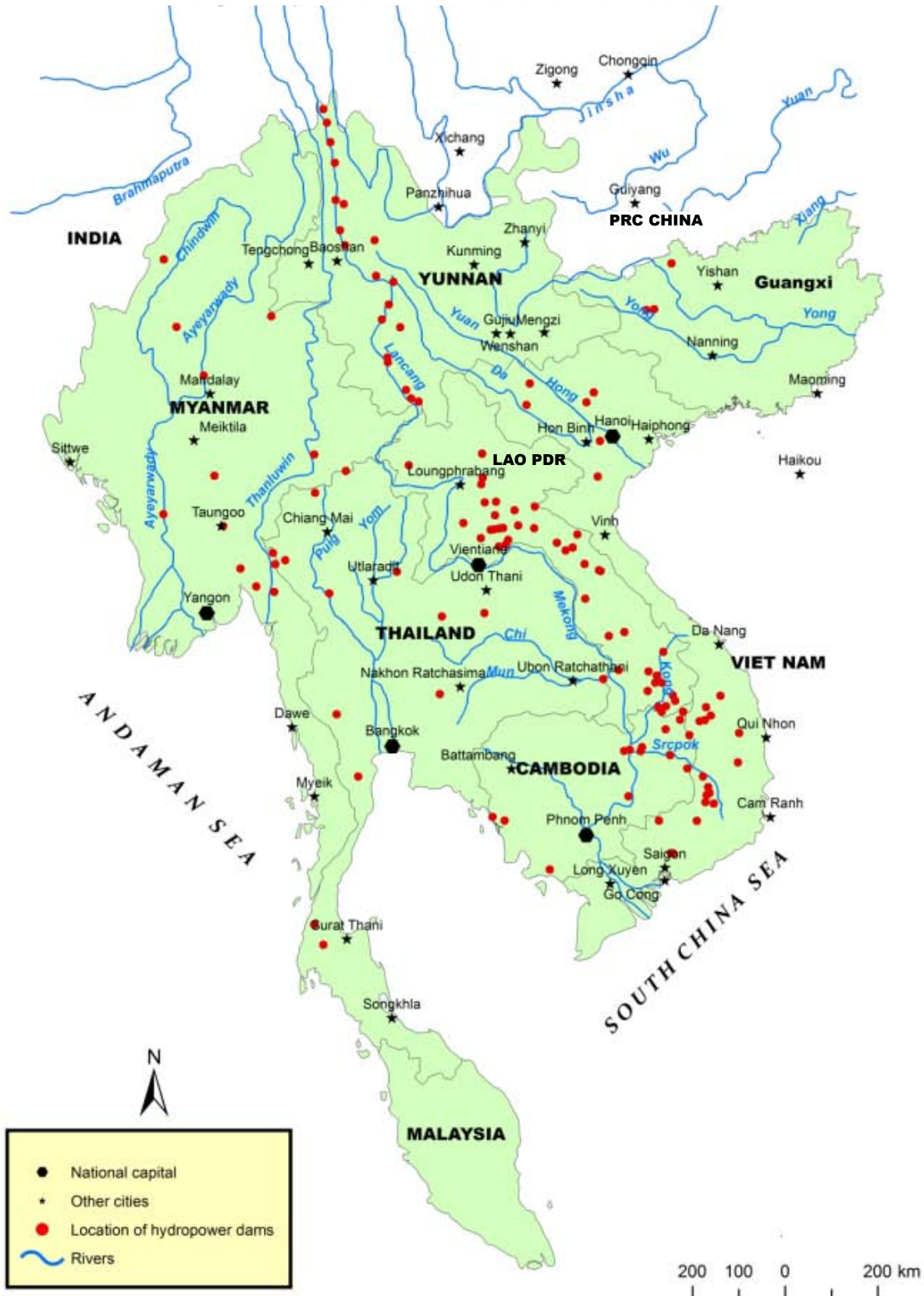
While mainstream developments in the lower Mekong are in most cases proposing run-of-the-river facilities, many of the envisioned tributary projects include considerable storage and will drive significant and immediate change in seasonal distribution of flows (MRC, 2010). For example, current development in the Mekong provides around 10 km³ storage (2.5% of mean annual runoff [MAR]); under a “definite future” scenario, MRC (2011) estimate this will increase to 46 km³ and under a range of 20-year “full development” scenarios to more than 73 km³ (15% of MAR).

Assessment of the hydrological impacts of the “definite future” scenario predicts an increase in dry season discharge of around 20% at Kratie, with accompanying reduction in wet season flows averaging 7%. Under the 20-year scenarios, dry season flows would be expected to increase 30%–100% above baseline conditions; and wet season flows to decrease by 4%–15%, depending on location on the river and the details of the scenarios considered.

The projected increase in dry season discharge is larger than projected irrigation demands from all Lower Mekong countries and could provide significant opportunities for irrigation development and for mitigation of current dry season shortages and saline intrusion in the Delta. There are concerns that at lower scales the availability of increased water supply from the hydropower dams may not coincide with increased irrigation demands. One such area of concern is the Vientiane Plain, but recent research results demonstrate that the increase in dry season flows will be greater than the likely demand.

Proposed dams on the Mekong mainstream (ICEM, 2010), including the currently controversial Xayaburi dam in the Lao PDR, are run-of-river dams with only small storages, but will form a barrier to fish migration. Blockage of migration paths by dams has serious impacts on recruitment and spawning (Thanh *et al.*, 2004; van Zalinge *et al.*, 2004). A high proportion of fish species in Southeast Asian Rivers are migratory, with seasonal movements over large distances to access spawning and feeding grounds (Baran, 2006). Dugan (2008) reports that up to 70% of the Mekong fishery depends on long-distance migrant species. Halls and Kshytriya (2009) investigated the impact of barrier effects of Mekong mainstream dams on fish populations using population dynamic models,

Figure 1: Current and proposed hydropower development in the Greater Mekong Subregion
(Johnston *et al.*, 2010; data from ADB, 2009b)



and concluded that structures would need to pass at least 60%–87% of upstream migrating adults to maintain viable exploited populations. Passage success rates at this level have never been achieved elsewhere; and even higher levels were needed for larger species, or if multiple dams were included in the analysis. Mainstream dams thus pose a significant threat to the viability of migratory fisheries (Ferguson *et al.*, 2010), and it is essential that these impacts—and their economic and social consequences—are taken into account in feasibility and impact studies.

Large dams trap sediment carried by rivers and can significantly reduce suspended sediment load and delivery of sediment to downstream areas. Removal of sediments results in geomorphological changes in the river (increased bed scour, channel and bank erosion) and decreased ecosystem productivity in the floodplain (because nutrients are carried with sediments). Kumm and Varis (2007) estimated that the major Chinese reservoirs on the upper Mekong (Lancang) will have sediment trapping efficiencies between 66% and 92%, with large potential impacts for downstream areas.

2.4. Climate Change

Anticipated climate changes in the GMS to 2050 (Johnston *et al.*, 2010; TKK and SEA-START, 2009; Kistin and McCornick, 2010; Lacombe *et al.*, 2011) can be summarized as:

- **Temperature** will increase by 0.02–0.03°C per year across the entire region in both warm (March to October) and cool (November to February) season, with higher rates of warming in Yunnan and northern Myanmar, especially during the cool season. Higher temperatures will increase evapotranspiration, increasing the water demand of crops and pastures in both rainfed and irrigated systems. Irrigation demand in semi-arid regions of Asia is estimated to increase by 10% for each 1°C temperature rise, but this expected to be less in the GMS (Fischer *et al.*, 2002).
- **Rainfall.** Projected changes in rainfall across the region vary from decreases of a few millimeters (mm) per year to increases of up to 30 mm with a high degree of uncertainty. Some (small) seasonal shift in rainfall, with drier dry seasons, and in some studies shorter, more intense wet seasons will occur, so that even if total annual rainfall does not change significantly, it is possible that the availability of water for agriculture may change, with increases in the incidence of both droughts and floods.

- **Sea level** is expected to rise 33 cm by 2050 (MONRE, 2008) in addition to observed rise of 20 cm over the last 50 years (Hien, 2008)
- **Typhoons.** Increase in sea surface temperature may increase the intensity and incidence of typhoons during El Niño years (MRC, 2009).
- **Glacier melt.** The impact of the glacier melting is negligible in the two main catchments of the GMS (Mekong and Irrawaddy). The situation may slightly differ in the Salween catchment where the ice melting contribution to total runoff is higher, but the population that would potentially be impacted by such changes represents only 2% of the total population of the GMS (Johnston *et al.*, 2010). The effects of temperature rise in the upper Mekong Basin will induce earlier snow melting, thus causing higher flow in springtime (April–May) and lower flow in Summer (July–August) (Kingston *et al.*, 2011; and Hoanh *et al.*, 2010).

Sea level rise is a significant threat in the GMS, since low-lying deltas host five of the region's major cities and a large area of highly productive land. Sea level rise in the deltas is exacerbated by land subsidence due to groundwater extraction and sediment loss. Syvitski *et al.* (2009) report relative sea level rises of 6 mm per year in the Mekong Delta and, due in part to subsidence caused by groundwater over-abstraction, higher levels in the Chao Phraya Delta (Wada *et al.*, 2010), much higher than the global mean of 1.7 mm per year over the last century. For an extreme scenario of 1 meter rise in sea level, Dasgupta *et al.* (2007) estimate that more than 5% of Viet Nam's total land area and 10% of its population would be affected, with 5,000 km² of the Red River Delta and 15,000–20,000 km² of the Mekong Delta being flooded. The Red, Chao Phraya and Irrawaddy are steeper deltas, and so less prone to sea level rise; Dasgupta *et al.* (2007) estimate that a 1 meter rise in sea-level would have smaller but still significant impacts, affecting 1%–2% of both total land area and population.

These conclusions are only from a simple comparison of sea level with ground elevation (Digital Terrain Model) without considering the hydrodynamics in the river system influenced by tide in the sea. Currently many locations in the Mekong Delta are lower than mean sea level but are not inundated because of river banks, and because there is insufficient time for the seawater to reach some locations. That said, and while the more severe impacts of sea level rise will not be felt until after 2050, it is essential to take longer-term impacts into consideration in planning and investment.

To date, only increases in temperature and sea level have been observed. Analysis of historical rainfall records indicates a high degree of variability, but no trend in either overall amount or seasonality of rainfall. This contrasts with the widespread perception, reflected in published reports (e.g., ADB, 2009a; WWF, 2009), that climate change is already being felt in the region as increases in the incidence and severity of extreme climate events. This perception is a result of confounding climate change with climate variability (or sometimes even with land-use change). For example, ADB (2009a) quotes Mekong floods in 2000 and droughts in the Lao PDR and Viet Nam in 1997 and 1998 as examples of extreme events attributed to climate change, but there is no convincing evidence that these events are outside of the range of normal climate variability, or that the frequency of such events has increased, at least in the mainland Southeast Asia (MRC, 2005; Johnston *et al.*, 2010). In the Mekong Delta, the reported increase in flood damage can be attributed to demographic and land-use changes, as increasing population resulted in settlement of areas previously not used precisely because of their vulnerability to floods (Lacombe, *et al.*, 2011). However, the rise in carbon dioxide emission during 2000–2007 was higher than levels in the worst-case scenario analyzed by the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2007), and global warming may accelerate much more quickly than current models indicate (GCP, 2008). Global studies (IPCC, 2007) suggest that temperature rise may become non-linear and much more rapid. Longer-term impacts of climate change may be correspondingly much more severe (ADB, 2009a).

Given the high degree of uncertainty around projections of rainfall and runoff, it is counterproductive to use them as the basis for adaptation planning until more consistent estimates are available. It is more useful to characterize likely change as an increase in the variability and uncertainty of water availability and to take a “no regrets” approach to water management, with actions to improve water-use productivity, improve access to on-farm and off-farm storage, and reduce water-related risks.

2.5. Other Drivers of Change

A combination of population growth and rising living standards is posing a new set of challenges in meeting future food demand in the GMS, and economic development is placing increasing pressure on land and water resources. Global markets are driving changes in agricultural production to meet export demands, and have opened up external sources of capital for investment in agriculture

and infrastructure. The PRC’s economic growth and re-emergence as a major trading partner is placing an ever-increasing demand on the natural resources of the region (Rutherford *et al.*, 2008). Increased energy requirements are driving large hydropower developments, which will impact on freshwater ecosystems and water availability for agriculture. All these trends have implications for water management, but two forces are currently reshaping water and land management in the GMS at an unprecedented rate: population growth and foreign investment and trade.

The population in the GMS is projected to grow from its current level of 275 million to over 340 million by 2050 (World Bank, 2009a; World Gazetteer, 2009). Based simply on population growth, if no new land is brought into production, a 25% increase in average per hectare productivity will be needed simply to maintain current levels of per capita food production. This could only be achieved with significant increases in irrigation, placing heavy additional demands on water resources. Alternatively, to hold the current ratio of agricultural land per capita constant would require an additional 7.2 million ha of arable land—again, inducing large increase in water demand. Such increases in agricultural water demand are likely to come at the expense of flows for the environment, and will place significant pressure on ecosystems and biodiversity.

Changes in diet and globalization of food markets mean that the picture is much more complex. As incomes increase, there is a general trend common across the world to more diversified diets with a higher proportion of food from animal sources and high value fish, a shift from cereals to non-cereals, and an increase in consumption of high-value foods, such as fruit, sugar, and edible oils (Pingali, 2004). These trends are observed across Southeast Asia, although cultural and regional differences are pronounced; for example, Thailand consumes significantly less animal products than does the PRC, even with much higher GDP. Changes in dietary preferences have significant implications for food production systems: a more meat-based diet requires a much higher level of resource inputs, including water (CA, 2007).

Agriculture in the GMS is transforming in response to global markets, directly through investment in agribusiness and indirectly, as export markets (particularly in the PRC) influence production trends. International demand for such commodities as rubber, cassava, sugarcane, corn, palm oil, cashews, coffee, pepper, and eucalyptus has driven a large shift in production,

with an increase in commercial plantations and contract cropping. Governments in Cambodia and the Lao PDR are promoting commercialization and industrialization of agriculture, and seeking private investment (foreign and domestic) to fund the transition. This has resulted in an upsurge of investment in plantation agriculture which is profoundly altering agricultural production, with a rapid rise in plantings of commercial (often non-food) crops such as rubber, oil palm, grains, and legumes for feed stocks.

Investment is also driving rapid expansion in the mining and energy sectors. Most activity in hydropower in the GMS is funded through foreign investment, except in Viet Nam and Yunnan, where domestic and government companies dominate. For example, in Cambodia and the Lao PDR, the PRC is currently involved in over 20 hydropower projects either as an investor or developer (Rutherford *et al.*, 2008), with a large number of potential projects in the pipeline (King *et al.*, 2006); International Rivers (2009) lists over 50 current and proposed hydropower projects in Myanmar funded or built by PRC companies. International investment has financed the development of large-scale mines in the region; for example, in the Lao PDR, the gold and copper mines at Phu Bia and Sepon (Australian/Chinese investors), and coal mines in Xayabury (Thai investors).

Recently, extensive deposits of bauxite have been identified in northeastern Cambodia, the southern Lao PDR, and the Central Highlands of Viet Nam. Chinese, Vietnamese, and Australian companies, among others, have put forward proposals for large-scale extraction and processing. Development of these deposits, started in Viet Nam in 2009, could have significant impacts on water resources and the environment locally. In addition to water demand for mining and processing, and questions of disposal of the large volumes of “red muds” produced as wastes from processing bauxite, smelting of alumina requires enormous amounts of energy, and the viability of bauxite extraction may ultimately depend on concomitant development of hydropower as an energy source (Lazarus, 2009).

3. Discussion

Over the next 10–20 years, water resources will be shaped by a complex mixture of social, economic, and environmental factors. Some, like climate change and population growth, are cumulative while others, such

as food prices, oil prices, financial crises, and political fluctuations, can have immediate and severe effects, but these effects fluctuate over time and tend to even out. Efficient use of water is fundamental to future food security and sustainable economic growth in the region.

The most controversial aspect of Mekong water management is the debate surrounding hydropower development. Potential impacts of hydropower development in the Mekong have been extensively reviewed by the Mekong River Commission (ICEM, 2010; MRC, 2011), and identify inherent trade-offs between hydropower development and fisheries production; potential benefits to irrigation through augmentation of dry season flows by hydropower dams; and significant variance in distribution of benefits between countries. These analyses highlight the difficult decisions that governments of the region will face. ICEM (2010) recommends a 10-year moratorium on mainstream dam development until impacts are better understood, given the importance of the Mekong system and the far-reaching and irreversible nature of the impacts of development. However, whether the impacts and alternatives can be fully understood in this time period, or whether it is too long of a delay for the benefits from the hydropower development to be realized is actively debated.

Instead, they recommend fast-tracking of tributary projects, since the impacts tend to be less extreme and more localized. Comparable studies have not been undertaken for the Salween and Irrawaddy, although large-scale developments are also proposed for these rivers.

Rising food prices and growing populations are driving renewed interest in investment in irrigation in Mekong countries (Hoanh *et al.*, 2009); for example, the Cambodian Government has proposed over \$1 billion in irrigation investments over the next 15 years (Thuon and Baskoti, 2010). Recent FAO studies found that large-to medium-scale public irrigation systems in Asia are generally performing well below their potential (Facon, 2007; Mukherji *et al.*, 2009). Problems stem mainly from inappropriate design, operation, and maintenance. Given the high level of existing and planned investment in irrigation infrastructure, improving the performance of these systems must be a high priority. In many older irrigation systems in the GMS, water use is highly inefficient due to poor design of conveyance and application systems combined with a tendency to over-irrigation. Increased water-use efficiencies can be achieved through upgrade of distribution systems (channel lining, use of pipes) and the adoption of improved technologies, such as drip and

pivot irrigation, deficit irrigation, and the production of wet-dry (aerobic) rice.

Intensification of cropping systems through both full and supplementary irrigation in the dry season is needed to realize the full value of irrigation infrastructure. Many systems were initially designed around rice production (e.g., low drainage requirements, inflexible scheduling), making it difficult for farmers to diversify into higher value dry season crops. More flexible systems are needed to allow farmers greater control and autonomy of irrigation scheduling, thereby encouraging diversification of farming activities. In South Asia and the PRC there has been a massive shift to farmer managed small-scale pumping, even in areas where public irrigation previously dominated—the “atomization” of irrigation (Mukherji *et al.*, 2009). There is evidence of a similar shift in Southeast Asia with a rapid increase in the number of small pumps installed in Viet Nam (>800,000 by 1999), Thailand (> 3 million by 1999), and more recently in Cambodia (120,000 in 2006) (MAFF, 2009b; Mukherji *et al.*, 2009). Viability of pumped irrigation depends on energy costs; access to cheap electricity has been used as both an incentive and a control on overuse of pumping in India (Shah, 2009). Small-scale options and opportunities to adapt existing large-scale systems should be evaluated more thoroughly, including considering the energy requirements, before major new investments are made in large irrigation systems.

With rapid urbanization in GMS countries, the role of urban waste water within the agricultural sector in the region presents both a challenge and a potential opportunity to increase water-use efficiencies. This is an area that has not been promoted and one that holds significant implications for closing the nutrient cycle, reducing the costs associated with waste water treatment plants, and increasing water-use efficiencies.

Groundwater currently accounts for only a small proportion of irrigation in the GMS, but use is increasing. In many parts of Asia, there has been a substantial move to the use of groundwater for irrigation, often even where surface water is available (Mukherji *et al.*, 2009; Shah, 2009) and this trend is also emerging within the GMS. Where conditions allow, managed aquifer recharge, storage, transfer, and recovery can be used to enhance water supplies, reduce the need for infrastructure, decrease evaporative losses, and improve groundwater quality through dilution. For example, flood waters can be pumped to aquifers for later recovery and use; and in highly connected floodplain systems, shallow aquifers can act as delivery systems for

river water to the floodplain (NWC, 2009). Groundwater resources are thus of emerging importance, but little is known about their size and sustainability in the GMS. A comprehensive assessment of groundwater resources, use, and potential in the region is urgently needed, as the basis for management plans for the conjunctive use of surface and groundwater.

Despite the recent expansion of irrigation, rainfed agriculture dominates production in the GMS; the majority of the wet season rice crop is either rainfed or has only limited supplementary irrigation. Significant areas of the plains and uplands may never be irrigable because of topographic, hydrologic, or soil constraints; for example, FAO estimates that only 20% of total potential cropland in Cambodia is irrigable (MAFF and MOWRAM, 2007). Thus, a large proportion of cropland is likely to remain rainfed, and it is essential that water management options for rainfed agriculture are not neglected. Drought is the major risk in the plains and uplands, but rainfed production in the deltas and floodplains is prone to risks from both flood and drought. Technologies and practices for improving water management at the farm scale range from traditional techniques to modern innovations, including conservation agriculture, rainwater harvesting and storage, technologies for efficient application of water to plants (e.g., drip and trickle systems, clay pot sub-surface irrigation, bucket irrigation, direct application by hose) and breeding of crop varieties that are tolerant to drought and submergence (IWMI, 2006; CURE, 2009; IRRI, 2009).

The significance of freshwater fisheries and aquaculture to both food security and the economies of the GMS countries means that maintaining the health of freshwater ecosystems is a very important priority (Mainuddin *et al.*, 2011). In addition to the valuable freshwater fishery, aquatic ecosystems also provide a range of ecosystem services—wetlands and lakes provide flood attenuation, ground water recharge, and water purification (Foley *et al.*, 2005; CA, 2007); and wetlands are important agricultural systems for deepwater and recession rice (McCartney *et al.*, 2011). Definition of the magnitude and timing of flows needed to maintain rivers, lakes, and wetlands in an ecologically acceptable condition (environmental flows) has been the subject of extensive debate and study internationally (Arthington *et al.*, 2006; Richter *et al.*, 2006). There is an urgent need to incorporate these approaches into water resources planning in the GMS before extensive developments are undertaken, to prevent degradation of fisheries and other environmental services observed in other parts of the world (World Commission on Dams, 2000b).

However, water infrastructure projects are an important component of national development plans and in this context, it is often difficult for decision makers to prioritize reserving flow for the environment over the more urgent requirements of income generation and poverty reduction. However, there is increasing recognition of the much broader economic and social importance of environmental flows, and of their role both in alleviating current poverty and in maintaining options for the future (SWH, 2009). To gain more policy traction in a development context, the definition of environmental flows needs to be broadened to explicitly include subsistence uses and be directly connected to the viability of freshwater fisheries.

4. Conclusions

In the next 10 years, the countries of the GMS face decisions about water resource development that will have far-reaching consequences. The relatively low level of water resource development in the region to date and high levels of dependence on natural aquatic ecosystems as a major source of food, means that there are both great opportunities and great risks. Increasing infrastructure and withdrawals will inevitably—and possibly irrevocably—change the way that river systems function. The dilemma facing the region's water resource managers is how to weigh benefits that rivers provide in their natural state (fisheries, other aquatic products, flood pulse agriculture) against benefits provided by regulated rivers (hydropower, irrigation, flood control).

Over the past 20 years, research has greatly improved understanding of the functioning and importance of rivers systems in the region, and the hydrological consequences and economic benefits of river regulation are now relatively well understood. Unfortunately, the ecological consequences and economic costs are not nearly as well defined. As a result, the debates on water resource development are skewed by both overly optimistic projections of development outcomes, and by alarmist predictions of ecological catastrophe. Economic and demographic change in the region is progressing at a rapid pace and water resource development will not wait on a full exploration of the research issues. Decisions must be made using the best available information, and with recognition of the risks involved. There is a critical need for an improved policy analysis to inform decision makers about the enormous trade-offs that are at play, particularly in view of the current emphasis on large-scale water infrastructure for both hydropower and irrigation.

Meeting the region's food requirements over the coming decades will require significant increases in productivity in both irrigated and rainfed production systems. It is increasingly clear that rice production alone can deliver neither food security nor poverty reduction, and diversified agricultural systems are essential to increase productivity and reduce agricultural risk. Rainfed agriculture is likely to continue as the dominant production mode in the GMS for the foreseeable future, and agricultural water management approaches are needed to reduce water-related risks and support diversified production. The focus for investment in agricultural water management must shift from large-scale irrigation systems designed for rice to more flexible approaches, including small-scale, on-farm systems and groundwater irrigation, particularly in the large alluvial floodplains where aquifers are recharged by annual floods. A comprehensive assessment of groundwater resources (including surface and groundwater connectivity) is needed as the basis for coordinated water resources planning.

Proposed hydropower development in the major river basins of the GMS will result in changes to river flows at a previously unprecedented scale and rate. The importance of freshwater fisheries to food security in the region underscores the importance of protecting the productive capacity of freshwater ecosystems from the impacts of these changes. This requires attention not only to environmental flows, but also to habitat coherence and connectivity at the landscape scale. Given the importance of migratory fisheries to regional food security, a precautionary approach to development is warranted until a clearer picture emerges of the risks involved. Research to date indicates that the adverse consequences of dams on tributaries are both more localized and better understood than those of developments on the mainstream: the advice of ICEM (2010) for a moratorium on Mekong mainstream development, compensated by fast-tracking tributary dams, appears to offer a lower-risk development path.

A high proportion of the research effort in the region has focused on the Mekong: hydrological and ecological information for the region's other major river basins is limited, and this lack will severely constrain planning and monitoring of water resources. Compilation of consistent hydrological data and models across the GMS and assessments of flow requirements to protect ecological functioning of all major rivers in the basin should be an urgent priority.

Much of the investment in agriculture, mining, and hydropower that will define water resource use in the

GMS over the next 10 years will be driven by the private sector. Even when standards for impact assessment of individual projects are met, there is rarely adequate analysis of the cumulative benefits and impacts of multiple projects at the basin, catchment, or national scale. It is the role of national governments to retain a strong focus on strategic assessments of the overall economic, social, and environmental sustainability in planning infrastructure development, but such approaches will only be successful if ways can be found to involve private sector investors and local communities (Campbell *et al.*, 2011) in planning at the early stages.

Projections indicate that the impacts of climate change on water resources in the GMS over the next 20–30 years are likely to be small compared to the impact of economic, demographic, and environmental changes. This “breathing space” provides an opportunity for countries and communities to reshape their water management systems and to deal with the more extreme changes expected after 2050. The most effective strategies for adaptation will be those that promote more productive water use, reduce water-related risk and vulnerability, and build the overall resilience of rural and urban communities.

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DEVELOPMENT AND APPLICATION OF A LAND-USE PREDICTION MODEL FOR FUTURE WATER RESOURCES MANAGEMENT IN THE GREATER MEKONG SUBREGION

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and Peter Rogers³

Abstract

Land-use prediction is one of the biggest planning challenges in the Greater Mekong Subregion (GMS) because of the rapid and dynamic changes in its economy, society, and environment. At various sites in the GMS, there are major processes affecting land-use change, including (i) deforestation of the native rain forest, (ii) expansion of agricultural areas, and (iii) development of plantation forests, such as rubber-tree planting for commercial purposes. We developed a land-use prediction model to reflect these major processes, using as the study area the 3S sub-basins (Sekong, Sesan, and Srepok)—a part of the Lower Mekong River Basin, including land in Cambodia, the Lao People's Democratic Republic, and Viet Nam. We then used this model to predict land-use change and water demand increase over the next 20 years due to agricultural area growth.

Two scenarios were considered for agricultural area growth: Scenario 1 for aggressive agricultural growth and Scenario 2 for moderate agricultural growth. The major difference between the two scenarios is whether we consider abandonment of agricultural area a major land-use change process (Scenario 2) or not (Scenario 1). Both scenarios show that agricultural area would grow in Srepok sub-basin. However, in Sekong and Sesan, Scenario 2 shows that agricultural area may shrink over time, while Scenario 1 shows positive agricultural area growth. From the available information, it is hard to decide which prediction is the more likely one. However the model was developed as a tool so that the user can modify model

parameters at any time. Future agricultural water demand projections showed that water demand in Viet Nam would keep increasing and the demand would become intensive, especially upstream of the Srepok River basin.

1. Introduction

As a direct driver of environmental change, changes in local land use affect not only the welfare of human beings but also ecosystem services (Millennium Ecosystem Assessment, 2005). In the field of hydrology, the impact of land-use change on water resources is considered as potentially large, but quantifying these impacts remains one of the more challenging issues (Stonestrom *et al.*, 2009). Land use is an important factor in hydrology, because its changes can affect key atmospheric elements of the hydrologic cycle, including evapotranspiration, precipitation, and land-surface temperatures (Feddema *et al.*, 2005; Turner *et al.*, 2007). And large-scale land-use change can modify regional weather patterns and future climate (Foley *et al.*, 2005; Schilling *et al.*, 2008; Zheng *et al.*, 2009). Also, land-use changes can have impacts on water quality by altering sediment budgets; salinizing soil water, groundwater, and surface water; and introducing chemical compounds, such as nitrogen and phosphorus (Schlesinger *et al.*, 2006). Land-use impacts are not limited to irrigated areas by releasing fertilizer; urbanizations also affect water resources locally, impacting water quality, storm discharge, and groundwater recharge.

Substantial scientific investigations are being conducted to understand the impact of land-use change on water resources, and this relationship is being explained in steadily more advanced ways. On a parallel with these scientific inquiries, a method is needed to assess the impact of land-use change on water resources to support decision makers in city and regional planning dealing with climate change and water resources adaptation and policy. Advanced analytical techniques and precise data are required for making such plans and policy, but this is often difficult for underdeveloped countries due to shortages of technology, funding, and human resources. In order to address this issue, a reliable and easy-to-handle method for modeling land use for water resources assessment must be developed that can be applied by decision makers and planners using available data in developing regions, such as the Greater Mekong Subregion (GMS). This paper describes the development of such a tool and its application in the 3S sub-basins, and discusses the implications for future water demand and availability.

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2. The 3S Sub-Basins

2.1. Outline

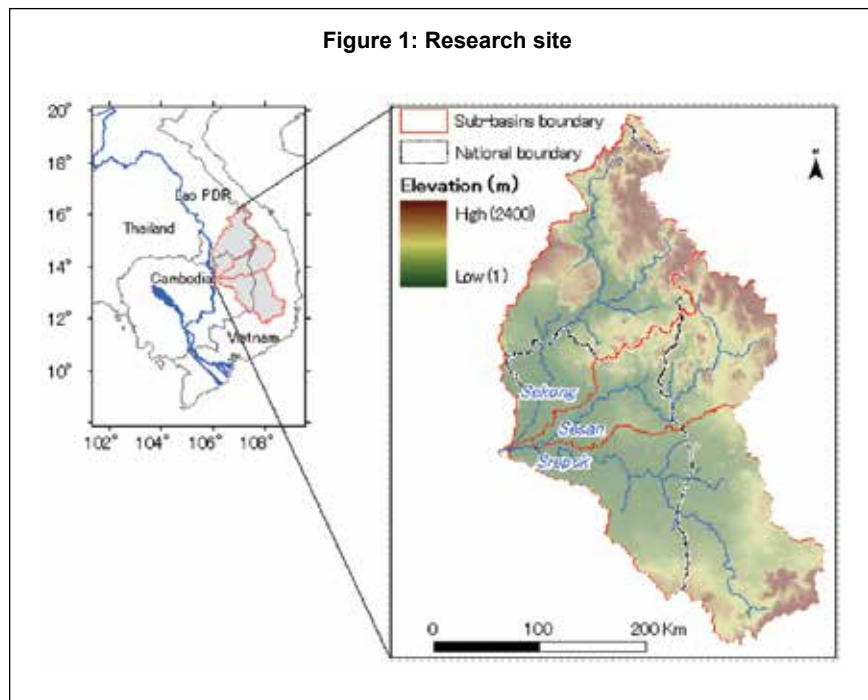
The study area was the 3S sub-basins, named for the three sub-basins it contains (Sekong, Sesan, and Srepok), in the Lower Mekong River Basin on the Indochinese Peninsula, including land in Cambodia, Lao People's Democratic Republic (Lao PDR), and Viet Nam (Figure 1). The 3S area of 78,650 km² is the largest tributary system of the Mekong River Basin (Mekong River Commission, 2007), which is divided between the three countries, with 33% of the area in Cambodia, 29% in the Lao PDR, and 38% in Viet Nam. It covers about 10% of the area of the entire Mekong Basin and contributes 17% of the total run-off (World Bank, 2006). The Mekong River Commission (MRC) Basin Development Planning project (2009) identified the area as a region where considerable development potential exists and as a result, multilateral development banks have been investigating it. The World Bank (2006) studied the water resources assistance strategy for integrated development and management from the 1990s. The Asian Development Bank (ADB, 2009) has been supporting arrangements to strengthen regional cross-border collaboration at the request of the national Mekong committees of the governments of Cambodia, Lao PDR, and Viet Nam since April 2006.

In relation to its large area, the total population is low, about 2,900,000 in 2004, but the population growth rate is much higher than the national average in each country. The social

and economic development and resulting environmental pressures are higher in the upstream than the downstream regions. Precipitation varies across the 3S, ranging from about 1,500 mm in the downstream areas and middle reaches of the Srepok to greater than 3,000 mm in the upstream portions of the Sekong and Sesan sub-basins.

2.2. Land-Use Change in the GMS

The deforestation and clearing of land for permanent cultivation and increased cultivation of annual crops have already led to a measurable increase in the frequency of flash floods in the upper catchments and there are indications of declining low flows during the dry season (Qiu, 2009; Ziegler *et al.*, 2009). The Mekong Water Resources Assistance Strategy report (World Bank, 2006) described the impact of land-use change to water resources as follows: "The stability of the hydrological systems and local climate, however, is threatened by degradation of critical watersheds, most significantly by deforestation in the upper catchments, but also by increasing cultivation of annual crops and abstraction of groundwater for irrigation on the plateaus." Change in land use is one of the critical factors impacting water resources in the Mekong watershed, including the 3S watershed, and potential change in land use in the future is critical for water resources planning and management. The growing number of hydropower dams should be also addressed. As of February 2009, 9 hydropower plants were in operation, 8 were under construction, and 24 were still in design or planning



stages (ADB, 2009). With development proceeding in the region's countries, power demands are expected to rise 7% per year over the next 20 years (MRC, 2010), yielding a substantial—and potentially lucrative—energy market.

2.3. Data Availability

In the 3S sub-basins, the most prominent land-use change processes are deforestation, agricultural expansion, and regrowth using commercial trees (Qiu, 2009; Ziegler *et al.*, 2009). The developed land-use model included these processes. The model was developed based on available literature, field visits, and land-use change trends captured from available data sets. It was challenging to prepare land-use data for various periods across 3 countries. We used land-use data at three points of time (1993, 1997, and 2002–2005). For 1993 and 1997, the integrated land-use data edited by the MRC were available with consistent land-use categories in the entire region. For the latest land-use data, however, only official individual national land-use data were available (Save Cambodia's Wildlife, 2006; Messerli *et al.*, 2008; FAO, 2009). Therefore, we combined these data into an integrated land-use data set for the entire basin.

Combining the three 2002–2005 land-use data from different sources was difficult as the categorization was largely different. In this study, MRC 1993 and 1997 data were primarily used and the latest 2002–2005 combined land-use data were supplementary and used to understand more recent trends in land-use change in the region. Figure 2 shows the MRC 1993, MRC 1997, and combined 2002–2005 land-use data.

To understand the trends of land-use change in the 3S sub-basins, first the MRC 1993 and 1997 land-use data were simplified into 5 major categories: forest, agriculture, mosaic, regrowth, and inactive. Inactive refers to the areas where land-use change may not be significant, such as water and wetlands. Urban area was also included in

the inactive category because urban expansion was not considered in this study. Table 1 shows the original and simplified major land-use categories in the MRC data. A variety of studies in the forestry sector indicate that trends in forest changes accelerated during 1997–2002 and further increased between 2002 and 2005 (Save Cambodia's Wildlife, 2006). Regarding population density in 1995 and 2005, the Gridded Population of the World data with grid resolution of 2.5 arc-minute were used (CIESIN, 2008).

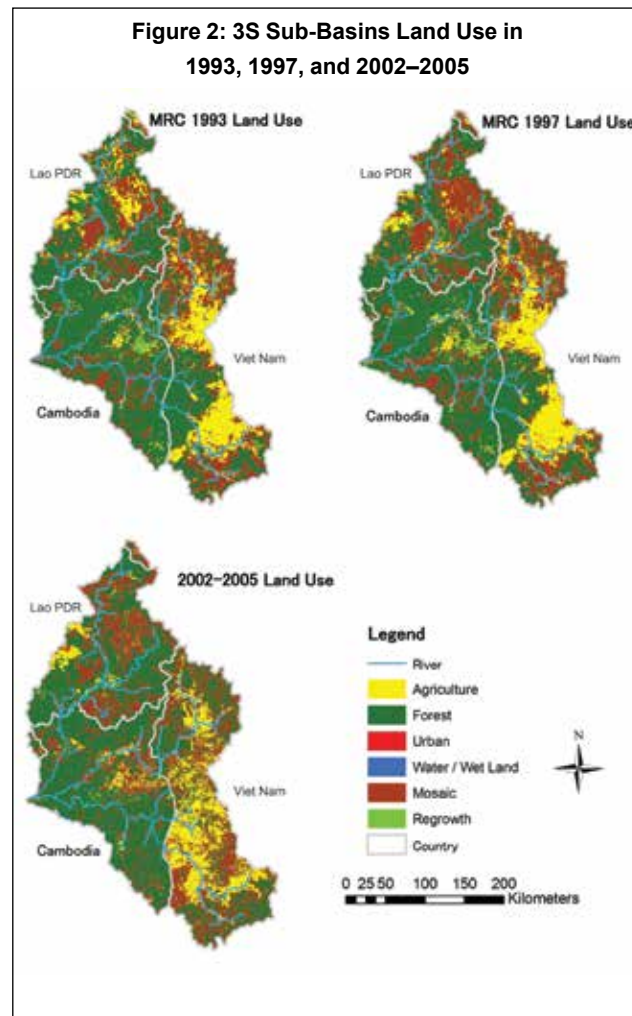


Table 1: Re-categorized Mekong River Commission Land-Use Classes

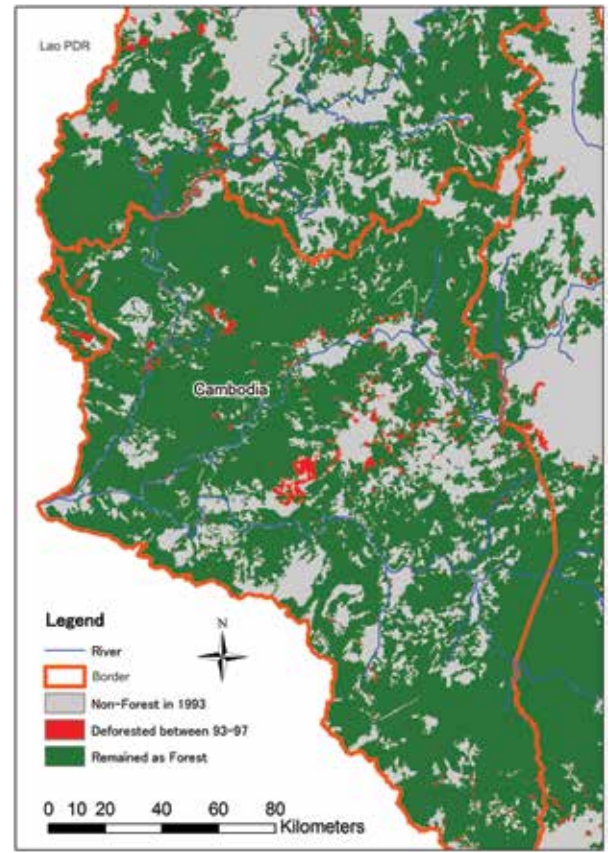
Simplified Major Category	MRC Original Category
Forest	Evergreen, high cover density; evergreen, medium-low cover density; mixed (evergreen and deciduous), high cover density; mixed (evergreen and deciduous) medium-low cover density; and deciduous
Agriculture	Plantations; Cropping mosaic, cropping area < 30%; cropping mosaic, cropping area > 30%; and agricultural land
Mosaic	Evergreen mosaic; mixed mosaic; deciduous mosaic; wood- and shrub land, evergreen; grassland; bamboo; wood- and shrub land; and barren land
Regrowth	Regrowth
Inactive	Urban or built-over area; water; other; wetland; and clouds

3. Analyzing Land-Use Change Trend

Table 2 shows area change for each land use from 1993 to 1997. Forest area was reduced by 974 km² or 2.2% in 4 years. Agricultural area was increased by 42 km² or 0.3%, while mosaic area increased by 1,339 km² or 8%. The total agricultural area did not change much; however, there was active expansion and shrinkage of agricultural area during the period: 17% of the 1993 agricultural area became mosaic by 1997 and 17% of the 1997 agricultural area was not agricultural area in 1993. The active change in agricultural area may include the slash-and-burn short-term agriculture, including rubber tree plantations in mountainous areas on the east side of the 3S basin. In these areas, forest area becomes agricultural land for several years, then becomes barren, grass land or different types of agriculture after the land is abandoned.

Figure 3 shows deforestation areas during 1993–1997. Among the deforested areas about 60% became agricultural and 40% became mosaic. As Figure 3 shows, deforestation tends to occur from the outer edge of the forest area because of accessibility from villages and roads. After deforestation, the land would have a new land use depending on the ambient land use. The 2002 land-use data show this trend well. A large agricultural area, next to forest area in the south of Viet Nam in 1997, significantly expanded in the northeast toward the border with Cambodia in 2002–2005.

**Figure 3: Deforested Area in 3S Sub-Basins
between 1993 and 1997**



made the model flexible and kept model parameters as variables so that the user can give target values for future land-use prediction.

Based on the observed trend in land-use change and available literature statistics, assumptions for land-use prediction were set as follows:

- 1) Deforestation rate per every 5 years was fixed as $C_{DF} = 3\%$ until 2032.
- 2) Regrowth rate in Viet Nam was about 1/3 while those in Cambodia and the Lao PDR were only 6% (Tanji,

4. Land-Use Prediction Model

4.1. Model Development

One of the most frequently used approaches in land-use prediction is logistic regression (Ty, 2011). However, instead of relying on statistics, we chose to develop a model that can reflect the trend qualitatively observed from the historical land-use data. Also, to use the model as a planning tool as well as a land-use prediction tool, we

Table 2: Land-Use Change from 1993 to 1997

	MRC 93 (km ²)	MRC 97 (km ²)	Change (km ²)	Change (%)
Forest	43,855	42,881	-974	-2.2
Agriculture	12,269	12,311	42	0.3
Mosaic	17,064	18,403	1,339	7.8
Regrowth	1,339	1,164	-175	-13.1
Inactive	3,910	3,677	-232	-5.9
Total	78,436	78,436	-	-

2005). For simplicity, a uniform forest regrowth rate of 25% was used within the 3S sub-basins ($C_{RG} = 0.25$).

3) Among the deforested area, 75% was assumed to become agricultural area.

4) The deforestation process was considered as nonreversible, starting from forest, going through agriculture, mosaic, then ending as regrowth. Table 3 shows the possible next land use after every 5 years. As shown in the table, direct changes from forest to regrowth and agriculture to regrowth were ignored.

5) Density was primarily used to prioritize the cells subject to change. This is based on the trend that deforestation and agricultural area growth tends to occur from the edges of the existing and next land use. For example to predict cells where forest becomes agriculture, density of agricultural area was calculated for each forest cell within a radius of 30 cells and these were ranked based on the density. The highly ranked cells within the pre-fixed number of changing cells were transformed into agriculture.

With these assumptions, two scenarios were developed; the direction of land-use change is illustrated in Table 3:

Scenario 1: Aggressive agricultural growth. This scenario assumes no agricultural area will become mosaic land-use type. This assumption implies that no agricultural area is abandoned (i.e., $C_{AB} = 0$).

Scenario 2: Moderate agricultural growth. This scenario suppresses the rate of agricultural area growth. While new agricultural area is created from 75% of deforested area, existing agricultural area decreases at the rate of 2/3 of the new agricultural area generated. (i.e., $C_{AB} = 0.5C_{DF}$).

With the current area ratio of forest (X_F^0), agriculture (X_A^0), mosaic (X_B^0), regrowth (X_R^0), and inactive (X_I^0) as initial conditions, the future area ratio (X^1) for each land use can be predicted with the assumptions described above.

$$X_F^0 + X_A^0 + X_B^0 + X_R^0 = X_F^1 + X_A^1 + X_B^1 + X_R^1 = 1 - X_{LI}^1$$

(Total balance)

$$X_F^1 = (1 - C_{DF}) X_F^0 \text{ (Forest)}$$

$$X_R^1 = X_R^0 + C_{BR} X_B^0 \text{ where } C_{BR} = C_{RC} C_{DF} X_F^0 \text{ (Regrowth)}$$

$$X_A^1 = (1 - C_{AB}) X_A^0 + C_{FA} C_{DF} X_F^0 \text{ (Agriculture)}$$

The process was integrated into a model using the ArcGIS Model Builder function. Figure 4 shows the entire model procedure for Scenario 2. The model represents the complete process needed to predict the next 5 years of land-use change. The model first calculates the probability of change based on the density of potential next land use; then ranks changes based on their probability, and allocates the next land use based on the rank and pre-fixed total number of cells subject to change. Putting all single processes together as a single tool helps the user reduce errors because the user does not need to deal with intermediate files and it is easy to test different scenarios.

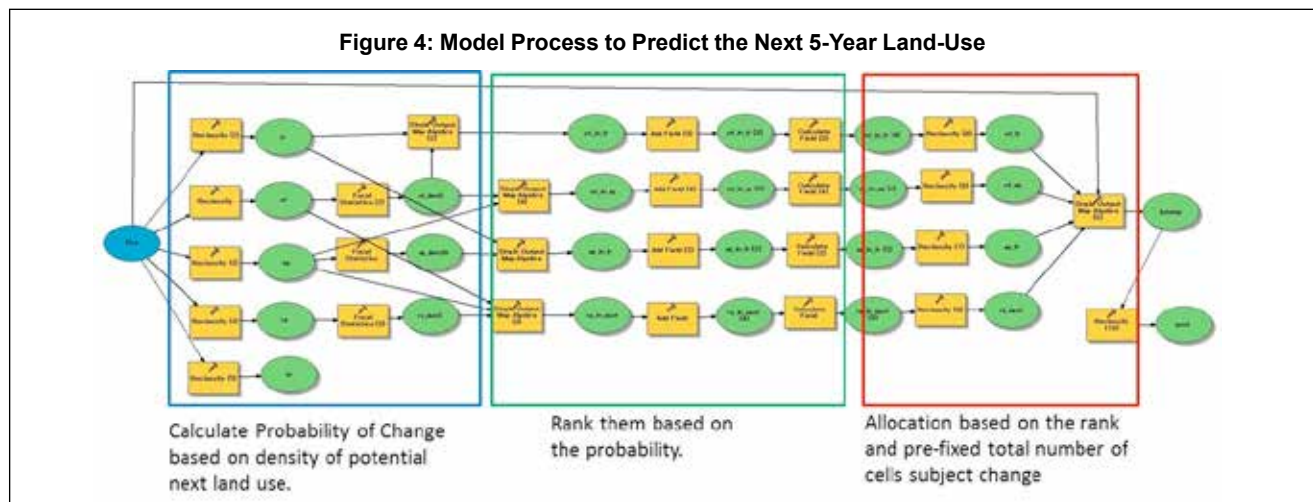


Table 3: Assumed Rule for Land-Use Change

		Future Land Use ^a			
		Forest	Agriculture	Mosaic	Regrowth
Existing land use	Forest	XX	XX	X	
	Agriculture		XX	X	
	Mosaic			XX	X
	Regrowth				XX

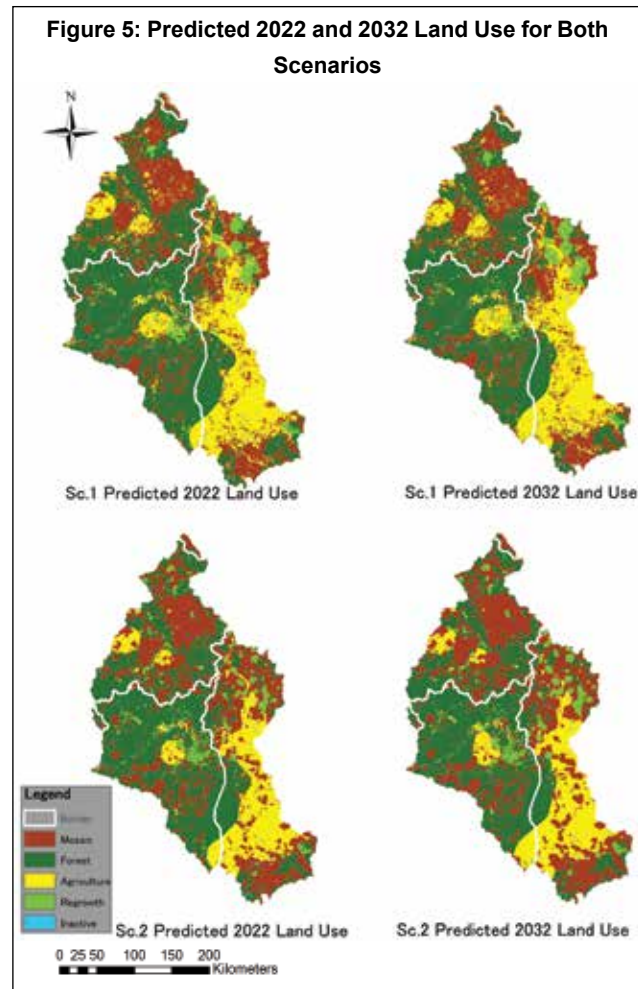
Note: a Values are XX for both scenario 1 and 2, X for scenario 2 only.

4.2. Predicted Future Land Use

Figure 5 shows predicted 2022 and 2032 land-use maps for the two scenarios. In Viet Nam forest area would become very small due to intensive expansion of agricultural and mosaic areas. In Cambodia and the Lao PDR, forest area would be diminishing due to expansion of sporadic growth of agriculture and mosaic areas. Figure 6 shows the predicted agricultural area change for both scenarios. Both scenarios predict that the Srepok basin will experience strong growth of agricultural area whereas it was not clear whether Sesan and Sekong will have growth in agricultural area. The land-use change trend and prediction are worth checking after the next MRC land-use data are published.

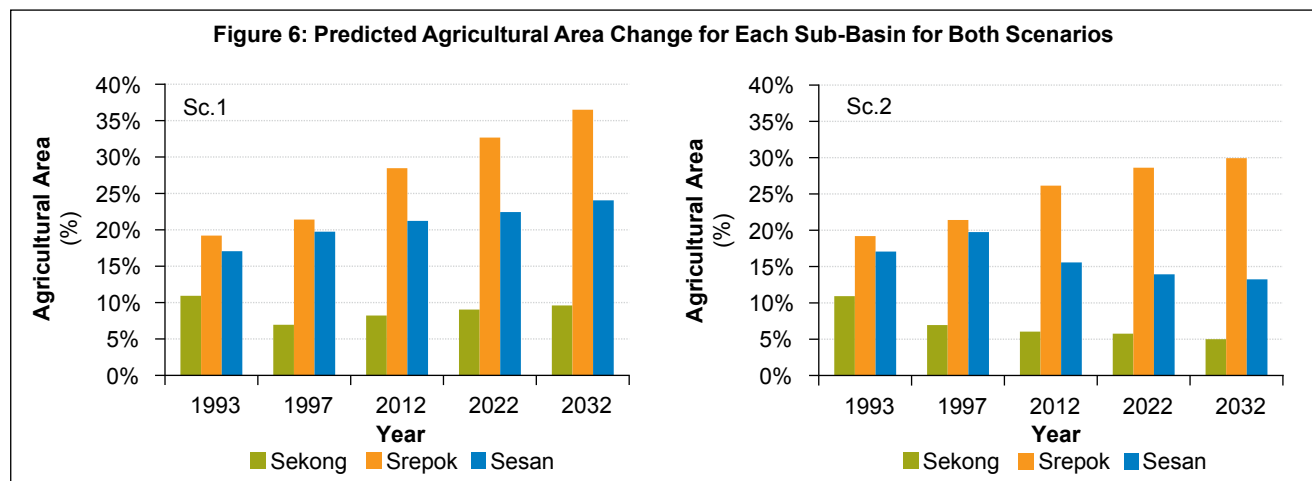
There are several limitations of model: (i) Urban area: In this research, urban area expansion was not considered. (ii) Thick vs. thin forest was not considered; however, the MRC's 1997 vegetation cover inventory reported that thickness of forest is different depending on the level of deforestation while runoff pattern can be different as well. (iii) Preserved area: There are some protected areas in the 3S sub-basins. However, such data were not available throughout the sub-basin expanse. Thus, this aspect was not considered in the prediction.

It should be noted that the land-use prediction model was also developed as a tool. Users can change or modify parameters globally and locally to improve prediction. The model can be used as a planning tool by setting a goal, such as lower deforestation rate than existing, and visualizing the difference in prediction maps.

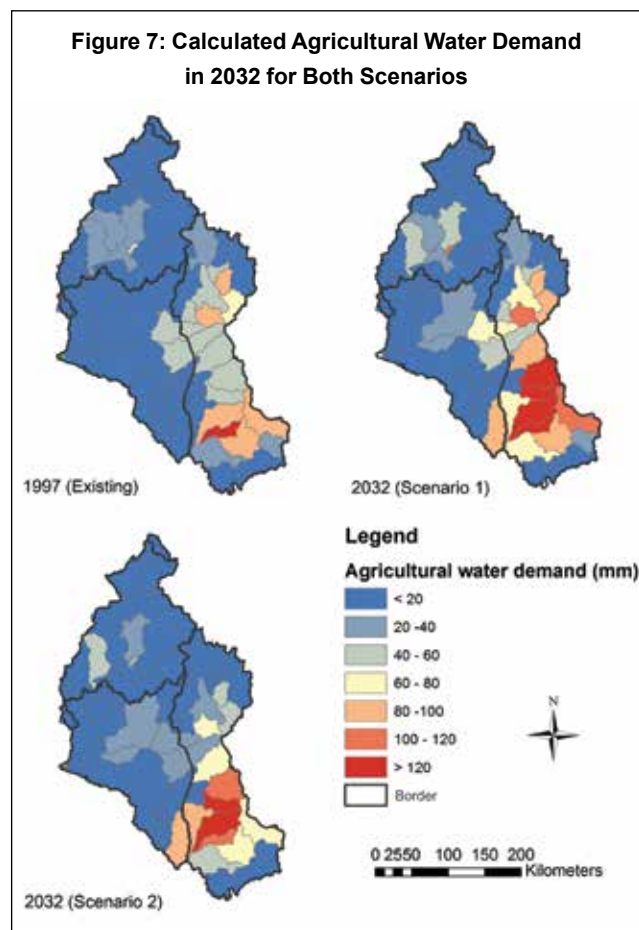


4.3. Impact of Agricultural Area Growth on Water Demand

The predicted land-use map was used to evaluate the impact of land-use change on water demand at the sub-watershed scale. For each sub-delineated sub-watershed, existing and future water demands were calculated.



Agricultural water demand calculation was done separately for wet and dry seasons. During wet months (April–September), a value of 0.27 million cubic meters per square kilometer per year (MCM/km²/yr) was used (Kawasaki, *et al.*, 2010) and for dry months (October–March), 0.54 MCM/km²/yr. During dry months more water is needed for agriculture, but only for areas where irrigation is available. In the 3S sub-basins, total available dry irrigation is about 0.8% in Cambodia, 2.2% in the Lao PDR, and 7.8% in Viet Nam, (3Ss Basins, 2011). The ratio was uniformly applied in each country to calculate dry-season agricultural water demand. Figure 7 shows existing and predicted 2032 agricultural annual water demand for the two scenarios. The prediction shows water demand in Viet Nam would keep increasing and the demand would become intensive, especially upstream of the Srepok River basin.



5. Conclusion

In this study, a land-use prediction model was developed for predicting future agricultural water demand. Two scenarios were considered for agricultural area growth: Scenario 1 for aggressive agricultural growth and Scenario 2 for moderate agricultural growth. The major difference between the two scenarios is whether we consider abandonment of agricultural area a major land-use change process (Scenario 2) or not (Scenario 1). Both scenarios show that agricultural area would grow in Srepok sub-basin. However, in Sekong and Sesan, Scenario 2 shows that agricultural area may shrink over time, while Scenario 1 shows positive agricultural area growth. From the available information, it is hard to decide which prediction is the more likely one. However the model was developed as a tool so that the user can modify model parameters at any time.

Based on the two 2032 land-use predictions, future agricultural water demand was calculated for each sub-catchment. The prediction shows water demand in Viet Nam would keep increasing and the demand would become intensive, especially upstream of the Srepok River basin.

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CHALLENGES FACING COOPERATION AND SUSTAINABILITY ON WATER SECURITY AND HYDROPOWER DEVELOPMENT IN THE MEKONG RIVER BASIN: THE GMS RESPONSE

Suzanne Ogden¹

Abstract

The GMS faces many challenges as it tries to establish a framework for poverty alleviation and sustainable development in the GMS. This paper examines why the “science” of development has been secondary to the politics of development in the GMS, and especially within the Mekong River Basin (MRB) itself. It highlights the relationship of Yunnan Province to the Central Government of the People’s Republic of China (PRC), and contrasts the role of Yunnan Province as China’s “Gateway to the South” with the role of Guangxi Zhuang Autonomous Region in the GMS. The paper points out the conflicting viewpoints and objectives, not only among the MRB/GMS states, but also among the ministries within these states, within the Mekong River Commission (MRC), within the donor community, and among all these and the investors in the MRB/GMS. As the uppermost riparian country on the Mekong River (known as the Lancang River in the PRC² the PRC has had few incentives to share in the costs that hydropower and natural resource development can impose on downstream riparian countries; but the PRC’s approach to natural resource and hydropower development has not necessarily differed from that of the lower MRB countries. Nor has the impact of the PRC’s development necessarily been detrimental to the Lower MRB countries. However, with the creation of the GMS, which is conceptually, geographically, and economically broader than just the MRB, the PRC has far more reasons to share in the costs and benefits of development for all states in the subregion. This may, in turn, result in agreements concerning the sustainable development and security (national, food, energy, water) of the MRB/GMS countries.

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² Mekong (湄公河) or Lancang River (Lancang Jiang, 澜沧江)

Introduction

In a zero-sum situation, countries try to get absolute gains, forcing others to accept absolute losses. Upstream riparian countries often seem to take this approach to their control of water as it flows through their sovereign territory. If we construct a scenario in which one or more countries are “losers,” their food and water security is endangered, and their natural resources are exploited in an unsustainable way, ultimately all lose. Indeed, it can be quite costly for the “winners,” who often must respond to disruptive and costly protests in response to their development projects. This has been an issue for the stakeholders in the Mekong River Basin (MRB).

If a non zero-sum strategy is pursued, actors share in costs as part of the package of expanding the benefits. A non-zero sum approach is essential for cooperation on national, food, water, and energy security as well as for sustainable development, because all countries will feel that they will gain—even if they have to bear some costs. The Greater Mekong Subregion (GMS), by facilitating a framework for increasing the benefits to all member states, has somewhat improved cooperation and benefit sharing on the difficult issues of water, energy, and natural resource sustainability and development in the MRB and GMS. Thus far, most of the investment in the GMS has been in transportation and energy infrastructure. This is vital for developing tourism and the extraction of natural resources—and to poverty alleviation.

This paper looks at the challenges facing the GMS as it tries to establish a framework for poverty alleviation and sustainable development. However, it should be noted that there are some problems facing the region that are beyond the control of the GMS and sometimes beyond the power of its member states acting individually. For example, fluctuations in the global price of crops, such as rice, fish, coffee, rubber, or oil, may have much more impact on the poverty of farmers and fishers than does the construction of a dam. These global prices may be dramatically affected by weather (including climate change) or wars, or by subsidies given to major producers or exporters of these products elsewhere, such as in Europe and the United States. On the other side, a GMS government’s own policies that tax or subsidize farmers and fishers, or which carry out rural electrification, may make or break their livelihoods.

The second major factor that makes poverty alleviation and sustainable development such a challenge for the

GMS is the rapid and uncontrolled population growth in the subregion. The population of the five GMS countries and the two provinces of the People's Republic of China (PRC) (Yunnan and Guangxi) in the GMS is projected to increase by about 17%, from 318.43 million in 2010 to 371 million by 2030. (Most of the growth is in Cambodia, where population is projected to grow 22% by 2030, with 25% growth in the Lao People's Democratic Republic (Lao PDR). Myanmar's population is projected to grow at 15%, while Thailand's will only grow 5%. The demand for energy, water, natural resources, and food will, given continued population growth rates, greatly outstrip their current supply by 2030 (Rogers, 2012).³ As long as governments lack the political will to address population issues, GMS efforts to bring about poverty alleviation and sustainable development will be thwarted. Within this difficult context, there are still further challenges for the GMS.

This paper is based on research on the MRB and GMS, including findings from a field trip to Yunnan Province of the PRC, Cambodia, the Lao People's Democratic Republic, and Thailand. During this trip, a team (Professors Peter Rogers, Akiyuki Kawasaki, and the author) met with government and institution officials, academics, nongovernment organizations, farmers, and fishers. Annex 1 gives a list of the persons and institutions visited.

1. Toward Sustainable Development in the GMS

The “science” of development—for example, the impact of irrigation and dams on hydrology, the environment, fishing, forestry, and people's livelihoods—has really been secondary to the politics of development in the GMS (Molle *et al.*, 2009). This is to some degree because there are enough “facts” available for everyone to choose the facts most appropriate to their own position. The interests of virtually every sector, group, institution, ministry, and country in the GMS can easily rely on facts that reflect their preferences. Perhaps the overriding problem is that the largest stakeholders (such as construction companies, fisheries, developers, governments, politicians, and investors) have a huge amount at stake in the development of the MRB and GMS.

There are conflicting viewpoints and objectives, not only among the MRB/GMS states, but also among the ministries within these states, within the Mekong River

Commission (MRC), within the donor community, and among all these and the investors in the MRB/GMS. Indeed, there is disagreement even among the various states' own ministries that are concerned with matters related to the MRB/GMS environment, natural resources, water, and economic development.

There are, of course, many stakeholders in the GMS who suffer from the decisions made by state actors, construction companies, investors, and others. The support or opposition from those affected by development, such as farmers and fishers in certain areas, vary widely depending on the type of development project, the state in which it occurs, and where they live. Even the poorest fishing communities do not necessarily agree on whether they want their livelihoods protected, or whether they would prefer, given the option, to leave behind their traditional livelihoods if they were adequately compensated or could find alternative livelihoods—especially for their children.⁴

An additional problem for sustainable development in the GMS is that national governments do not make decisions based on environmental impact assessments. This is because ministries of the environment tend to be weak vis-à-vis ministries that are involved with energy, water, and construction. The more they build, the better, because these ministries get more power (and dollars for themselves) from such things as building dams. Ministries get nothing from protecting fish, communities, livelihoods, or the environment. Speaking for the poor gives no power to a ministry.

There is no disinterested national actor in the GMS who puts the interests of the region as a whole ahead of its own national interests. Thus, there is little agreement on many issues that concern water, natural resource exploitation, and development among the national actors in the GMS. As a result, each GMS state tries to act in its own national interests. Because national interests take precedence, GMS states tend to resist regulation from international or regional bodies. Further, because there are many international agencies and donor states involved, it gives the individual states of the GMS a chance to maneuver among them and to choose their best options from among those offered.

³ This would be a 1.7% annualized growth rate for the GMS.

⁴ National and international nongovernment organizations often try to protect the livelihoods of fishers and farmer-fishers, regardless—or even especially—if they are at subsistence level, whether they want it or not. A frequent criticism is that they appear to speak on behalf of protecting the fish, wild life, and the trees, rather than for the people.

Almost all the GMS actors belong to more than one development cooperation network (such as the GMS, the MRB and the Greater Bei Bu Gulf Regional Economic Cooperation Organization), so each of the states is paying attention to its interests in more than just the GMS. (Binh, 2006, p. 81) Thus, within the MRB, as within the GMS, states tend to make bilateral or multilateral deals with each other, rather than cooperating with the MRC and adhering to its recommendations concerning water, natural resources, and the environment. Nevertheless, within the GMS framework, these countries are making important investments in infrastructure, notably in roads, railroads, port facilities, tourism, and trade.

Further, there is little agreement among the various stakeholders within a state. Stakeholders include construction companies, ministries, the public, nongovernment organizations (NGOs) (some of which are called international NGOs because of international sponsorship), banks, and affected communities. Those stakeholders who benefit the most from dams, such as urban communities that get more electricity and better control of flooding, are not necessarily the stakeholders who have to pay the costs of (or suffer from) development.

2. Role of the PRC

2.1 Water Resources Management

In 2002, the World Bank concluded that the PRC generally had been quite successful, even too successful in some cases, “in constructing infrastructure to develop and control water resources;” but it had been less successful in “establishing the institutional framework and systems needed for efficient management of water resources” (World Bank, 2003).

Seven years later, in 2009, the World Bank issued another report that pointed out virtually the same problems of fragmentation in the PRC’s water resource management system: “Horizontally, at every level of government, several institutions are involved in water management, with frequent overlaps and conflicts of responsibilities....The water management system is also vertically fragmented. It is mainly built upon the administrative boundaries of different levels of government rather than at the river basin level. Each level of government has its own focal points and priorities. This makes the management of trans boundary rivers—most of the PRC’s rivers—very difficult” (World Bank, 2009).

Perhaps worse as far as the MRB/GMS is concerned, although the PRC has established river basin management commissions (RBMCs) for seven of its large rivers (under the Ministry of Water Resources), they “have limited power and *have no representatives from the affected local governments in the basin*” (World Bank, 2009). Further, the Lancang/Mekong River is managed by the Yangtse River commission, not by its own RBMC.⁵ Possible solutions that would lead to more integrated water resource management have not been tried.

One of the primary emphases of the PRC’s 12th Five-Year Plan (2011–2015) is sustainable growth in the development of clean energy, energy conservation (which entails reducing the intensity of energy use per unit of production), and diminishing the negative effects of energy development on the environment. Hydropower is one of the sustainable sources to be tapped, with its role potentially expanding because of the Japanese earthquake and tsunami in March 2011 that led to a crisis for its nuclear power plants. This has resulted in a rethinking of the vast planned expansion of nuclear power announced in the 12th 5-year plan and perhaps more emphasis on hydropower. It remains to be seen whether the PRC can take into account sustainability, as well as the costs and benefits to its own citizens in Yunnan Province and those of the citizens of the MRB as it develops dams on the Lancang/Mekong, extracts natural resources, and builds infrastructure.

2.2 Role of Yunnan Province

In Yunnan Province, there is considerable discord among stakeholders as well as academics and local and international NGOs over the issue of whether hydropower should be developed in order to address the grinding poverty of many of the people living in the Nu and Upper Mekong River Basins (about 10 million people), or whether the priority should be protecting the environment—especially the “Grand Canyon” of the PRC formed by the three rivers—the Nu, the Mekong/Lancang, and the Yangtse (Sun and Zhao, 2008).

The debate is framed to reflect the interests of each side. To the Chinese “anti-dam” (and perhaps anti-development) groups, “protecting the environment” means keeping it in its pristine state (which they insist still exists). They argue

⁵ Within Yunnan, the river is managed by the Suili Bu (Water Power Agency).

that the damage done by dams to fisheries, wildlife, and forests is unacceptable. For the Chinese pro-dam groups, the only issue of “environmental protection” is stopping pollution of the environment. There is, in their view, no pristine environment to protect. They argue that building dams for hydropower, regardless of the damage it does to fisheries, wildlife, or forests, aids poverty alleviation without polluting the air or adding to the greenhouse gases that are contributing to climate change. (Mertha, 2008: 110–149) The alternative, building coal-fired plants, may help development, but at enormous costs to the environment. Apart from emitting greenhouse gases, the production (mining and processing) and consumption of coal power, is the largest industrial use of water in the PRC. (Liu, 2011; Circle of Blue, 2011) Thus, building more coal-fired plants for electricity affects both the quality of the air and water, and itself puts strains on the supply of water.

So for Yunnan, there will be significant costs to one stakeholder group or another, regardless of what choice is made—even if the choice is to protect the environment by keeping it “pristine.” This same dilemma confronts other GMS states as well—a dilemma exacerbated by yet other concerns over building nuclear power.

The PRC’s central Government considers that Yunnan’s policies are not in line with the *da qu* (big community) national viewpoint. That is, Yunnan has done things in its relationships with GMS/ASEAN countries that cross the line between “foreign policy” (which the central Government’s Ministry of Foreign Affairs reserves for itself) and “external relations” (which Yunnan as a province is permitted to do). Yunnan may be undertaking “foreign policy” that serves its narrow local interests, rather than approved “external relations” that serve the needs of the “big community.” (In Yunnan, as in other provinces, there is a *waiban* in charge of “external relations”—but any decisions it makes must be approved by the Ministry of Foreign Affairs.)

One example is Yunnan working with a Malaysian multinational rubber company, which has a branch office in Yunnan. In recent years, this company has been replacing Yunnan’s local vegetation with rubber plantations. When the drought hit Yunnan in 2010, its farmers did not even have enough water to drink, much less grow crops. The central Government considers that the rubber trees, which need a lot of water, contributed to the drought. Also, since rubber trees do not have deep roots and do not hold water well, they do not hold down the soil and can contribute to erosion. As a result, the local people suffered, while the rubber plantation operators profited.⁶ Further, the

central Government’s view is that rubber plantations are undercutting Yunnan’s biodiversity and wants to limit the policies Yunnan pursues with MRB/GMS and Association of Southeast Asian (ASEAN) countries and companies.

Judging from this type of conflict between Beijing and Yunnan, it appears that sometimes the PRC’s central Government is more concerned than Yunnan’s provincial government about the impacts of provincial policies on poverty, the environment, and biodiversity. (Note, however, that Chinese companies are likewise buying concessions and contracting farmers to grow rubber in the Lao PDR [Asia Times online, 2011]) In other situations, however, it may well be that the provincial government wants to cooperate with the GMS and the MRC in a way that improves the governance of the region—but is not permitted to do so by the PRC’s central Government. For example, because the latter considers information about any transnational river, such as the Mekong, a “state secret,” and, since transnational rivers are considered issues of “foreign policy” in the PRC, Yunnan is essentially powerless to give information to the MRC about the Lancang/Mekong River’s flow, sedimentation rates, plans for building dams, and anything else that would affect the ecology of the lower MRB—unless the central Government is convinced it is in the PRC’s national interest to do so.

Although Yunnan has become the best “gateway” to ASEAN and GMS countries, Guangxi Zhuang Autonomous Region’s trade with the GMS was actually higher than Yunnan’s in 2005–2009.⁷ GMS/ASEAN states benefit from the competition between these two Chinese provinces because each tries to offer greater economic and commercial benefits to them in order to get their business (Lu and Chong, 2010, pp. 11–12).

Because Yunnan is just a poor province, it has limited economic power. Other GMS members can make decisions as national governments; Yunnan has to follow the central Government to get the relationship it wants with the GMS.

He Shengda, a leading academic in Yunnan, suggests that the “central Government should act as the decision maker

⁶ According to one Chinese scholar, those who have looked at the history of Yunnan cannot find a drought with such serious consequences anywhere in the historical documents. The scholar concluded that the rubber plantations exacerbated the normal damage from drought. (Interview, 25 March 2011).

⁷ This is partly because 80% of Guangxi’s trade with ASEAN/GMS countries was with Viet Nam (Wong and Chong 2010), a much better developed economy than most of the countries with which Yunnan trades.

with respect to the counterpart governments of the GMS while Yunnan plays its role as the implementer of projects approved by the central Government.” The Yunnan provincial government “needs the central Government’s leadership, institutional and financial support, and backing for research and development on potential cooperation projects.” He’s 2006 suggestion that the PRC should make Kunming “the liaison center between [the PRC] and ASEAN countries;” and that the transportation networks that connect Yunnan with them should be incorporated “into the China-ASEAN Free Trade Association framework as an essential element of bilateral economic and technological cooperation...” (He, 2006, pp. 113–114) has become a reality. But perhaps his most important point is that “the PRC’s interest in GMS is marginal compared to its interest in the rest of the world; whereas for Yunnan, integration, development, and trade with GMS countries is central” (He, 2006).

Since the PRC’s “Develop the West” program to reduce economic and social disparities between its east coast and the western hinterland began in 2000, it has benefited Yunnan Province significantly; and the PRC’s national strategy has now embraced Yunnan Province’s “Gateway Project”—a reformulation of Premier Hu Jintao’s statement in 2009 that Yunnan should be the “bridgehead” for the southwestern region of the PRC.⁸ This strategy, originally conceived as one way to lessen conflicts along the borders with Yunnan’s neighbors, has become a far more expansive economic development strategy (Lu and Chong, 2010). Further, by making Yunnan the center for the transit of goods to and from the PRC to a substantial part of the GMS, as well as to South Asia and beyond to West Asia and East Africa, Yunnan is freed from its landlocked position to become the PRC’s southwestern “gateway” to the world.

Initially, however, the key components of Yunnan’s “Gateway Project” are to expand regional tourism and cross-border trade while curbing illegal trade as well as human and drug trafficking; and to enhance the PRC’s energy and natural resource security by making Yunnan a transportation and communication hub of the GMS area—especially to the port of Haiphong to the east, and Bangkok⁹ and the Port of Mawlamyaing (formerly

Moulmein, in Myanmar) to the south, giving it access to the Indian Ocean’s Bay of Bengal and Andaman Sea—the southern ports being of particular importance to avoid the maritime security issues of shipping from the PRC’s east coast ports to the south and west through the Straits of Malacca.¹⁰ Expanding the transportation and commercial infrastructure is central to the PRC’s effort to increase trade in the region and beyond, and to exploit the natural resources in the GMS area.¹¹ Almost every major infrastructure project—the railroad and road corridors, dams, and waterways that link the GMS countries and provide hydropower—has Yunnan in a key transit (and construction) role.¹² The PRC-ASEAN Free Trade Area Agreement (2002) is fundamental to Yunnan’s cooperation with the GMS (He, 2006, pp. 90–92, 105)

While these are clear benefits for the PRC, the other GMS countries also benefit from these investments in trade and tourism; the PRC’s cooperation in addressing a variety of cross-border issues, such as human trafficking, regional stability, and development; and increased revenue from the export of their natural resources.¹³ For example, from Thailand’s perspective, the planned super express rail routes will “turn Thailand into the PRC’s gateway to trade with India and Europe.... Beijing has long planned to

¹⁰ Note that the city of Nanning in Guangxi Zhuang Autonomous Region is also very much connected to the GMS by the transportation infrastructure.

¹¹ Qin Guangrong, Yunnan’s governor stated “the gateway idea has five different forms— as a channel, window, platform, base, and barrier. The channel...means building an international thoroughfare to Southeast and South Asia. The window refers to making Yunnan a showcase of Chinese culture and friendship. The platform means that Yunnan should have an economic and trade cooperation role. The base refers to Yunnan as a manufacture and processing base, while the barrier refers to its role as an ecological barrier.” As Qin explained it, “We’re going to build international highways, railways, water routes and oil and gas channels and make the city of Ruili a pilot in opening and exploring. It will accelerate economic cooperation as a cross-border economic zone, and take part in building trade and economic cooperation zones beyond the border.” Indeed, in 2010, Yunnan’s foreign trade increased by a remarkable 69% over 2009 (Li *et al.*, 2011).

¹² The Kunming-Bangkok Highway, completed in April 2008, cut travel time between the two cities from 48 hours to 20 hours. Cooperating with the GMS, the PRC plans to connect to the ASEAN states by way of three rail lines from Kunming through Thailand. Currently, two rail routes—Kunming-Kehou-Hanoi, and Nanning-Ping Xiang-Hanoi—connect the PRC with ASEAN via Viet Nam, but they do not yet connect directly to Thailand. “[T]he PRC’s Western Railroad Line will link the PRC with Myanmar, India, and Bangladesh.The Nanning-Bangkok Highway via R6, which is under construction, will be the shortest route linking Thailand with the PRC, Viet Nam, the Lao PDR, Malaysia, and Singapore in the near future.” As a result, the trade route, which now takes from 8–9 days by sea from the Port of Bangkok to Shanghai, will be shortened to 3–4 days... (*The Nation* (Bangkok), 2011; Lu and Chong, 2010, p. 13).

¹³ Others would include sharing benefits (and costs) of water resource development for hydropower, irrigation, and urban use; protection and development of fisheries; environmental protection; protection of water quality; and navigation.

⁸ The PRC’s Minister of Foreign Affairs thought this term, with its military origins, would offend southern neighbors of Yunnan, and wanted to drop it, but it appears in the 12th 5 Year Plan (2011–2015), which was approved by the PRC National People’s Congress on 14 March 2011.

⁹ In early 2011, Thailand announced that the PRC would construct a major transfer center (warehouses) close to Bangkok’s port so the PRC’s goods can flow, without tax, into Thailand and out through the port to South Asia and beyond. Kunming is at the north of this North-South Corridor, and Bangkok is at its south. As of 2012, it appears that for the time being, this project has been suspended, if not terminated.

position Thailand as the route linking southern PRC to the Andaman Sea and beyond to South Asia and Europe.”¹⁴ Although many Thais have voiced concern about this, the Thailand Government sees significant potential benefits for Bangkok. The planned GMS transport corridors (Figure 1) make clear their benefits to Yunnan Province and Bangkok—and to the entire GMS. Perhaps most important is that water security is itself significantly benefitted by preventing conflict, and China’s involvement in the GMS and ASEAN Free Trade Area has contributed to this important aspect of water security.

2.3 Role of Guangxi Zhuang Autonomous Region

Guangxi Zhuang Autonomous Region’s relationship with the GMS is different from that of Yunnan, in large part because it is not part of the MRB; so cooperation on issues of water and natural resource sustainability in the MRB are not issues for Guangxi. Originally, Guangxi wanted to join GMS in order to help itself develop. However, the only Southeast Asian country that Guangxi borders is Viet Nam, whereas Yunnan has borders with the Lao PDR,

Figure 1: Planned GMS Transport Corridors



Source: Thailand Ministry of Foreign Affairs, Bangkok, December 2010.

¹⁴ Thailand’s Ministry of Finance, as referenced in (Watcharapong, 2011).

Myanmar, and Viet Nam, and is connected by the MRB to Cambodia and Thailand. By 2006, Guangxi decided to pursue development through participation in the Greater (Pan-) Bei Bu Gulf Regional Economic Cooperation [Organization]¹⁵ rather than the GMS. This is because, like every Chinese province, it wants a “cooperation” mechanism in which it can play a leading role, in part so that it can get more money for development from the PRC’s central Government.

Guangxi desires a leading role in Greater Bei Bu, a role it cannot play in the GMS because Yunnan is much better positioned to lead. As a result, Guangxi’s interest in the GMS has diminished, even though it remains a member. There is now considerable overlap in membership of the two groups;¹⁶ but Greater Bei Bu is involved in different projects and engages in trade and commerce along routes that use Guangxi, rather than Yunnan, as the hub (Wong and Chong, 2010).

3. Expanding the Benefits

Geographically, the GMS is larger than the MRB, and the interests of the former are far more comprehensive than just managing the Mekong River system and the natural resources of the MRB. Many of the present benefits in the GMS are the result of bilateral and multilateral deal-making, with the PRC often the primary dealer. Nevertheless, it is the GMS structure, with the institutional support of ADB, that may well prove essential in expanding benefits to all countries in the GMS, and for enhancing cooperation on the very difficult issue of sharing the benefits and costs relating to water, energy, and natural resources development within the MRB.

Inevitably, there are costs associated with the rapid development of the GMS: sustainability, threats to livelihoods, and degradation of the environment. Environmental impact assessments are not often high priority for governments of GMS countries when they make joint or bilateral agreements for investment. In the case of the PRC, this has resulted in complaints and protests from various stakeholders in other GMS countries over Chinese long-term objectives, though rarely from the GMS

governments themselves, which are busy making lucrative deals with the Chinese (Asia Times online, 2011). In the MRB, there is a consultative and regulatory role played by the MRC and many stakeholders have been successful in holding up development projects because of the regional nature of this regulatory body. The MRC has helped create peace and stability by developing trust among the MRB countries—trust that other MRB countries cannot act in a way that damages their own state’s interests because the MRC will do its best to prevent it.¹⁷

As mentioned above, almost all development projects in the GMS are bilateral or multilateral and no regional regulatory body is empowered to require consultations concerning the exercise of sovereign rights by its members. Only investors outside the GMS, such as the ADB, which set up the GMS and wants it to succeed, can hold up (or discourage) projects because of sustainability and environmental issues.¹⁸

4. Conclusions

First, each of the GMS/MRB countries, particularly the larger, wealthier countries in the GMS that are the main investors (PRC, Thailand, and Viet Nam) should consider the whole area not as someone else’s land that they can exploit, but rather as their own “backyard”—a place that they actually need and want to protect for everyone’s benefit. For example, the Lao PDR and Cambodia already provide outstanding tourism opportunities—with tourists increasingly coming from the PRC, Thailand, and Viet Nam—the three GMS countries that invest most in the GMS. Cambodia and the Lao PDR provide fascinating and beautiful places for citizens of these countries to visit, especially for ecotourism. Outdoor activities—boating, mountain climbing, biking, sight-seeing, and cultural heritage sites are plentiful. So, why do anything that would destroy this natural resource located nearby in another country that their own people would like to enjoy? And, as

¹⁵ (*Fan Bei Bu Wan Qu Jingji Hezhan*—hereafter cited as “Greater Bei Bu”)

¹⁶ Greater Bei Bu originally consisted of Guangxi, Hainan Island, Guangdong, and Viet Nam, all places close to or bordering on the Beibu Gulf or South China Sea. Later, it added 8 of the 10 countries in ASEAN (all but Myanmar and the Lao PDR).

¹⁷ The United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) in Bangkok supports the MRC because it helps stabilize the whole region by requiring consultation on all projects that affect energy, water, food, and natural resource security and sustainability. (Interview, January 2011) Discussions with other members of the MRC in Vientiane and Phnom Penh suggest, however, that the four countries already in the MRC (Cambodia, the Lao PDR, Thailand, and Viet Nam) are quite hypocritical about their willingness to negotiate or to compromise on issues of national interest.

¹⁸ For example, ADB funds GMS flood management projects that affect MRC work in the MRB; ADB tries to have GMS and MRC cooperate on these issues.

with any non-zero sum game, anything that undercuts the appeal of tourism in one country will impede its growth in the entire region.

Second, the GMS has been successful because it is, in many ways, not addressing the central element of benefit sharing in the MRB, namely, the Mekong River's water. When it comes to sharing or protecting that water as a resource, or sustainably developing water, scientific calculation has in some respects become almost irrelevant, and politics has taken over. As demonstrated in the dispute in 2011 over a small piece of territory on the border of Thailand and Cambodia, where little is at stake compared to control over the Mekong River Basin's flow and natural resources, control over territory and its resources is not something easily settled by a rational cost-benefit analysis.

Third, it is difficult to imagine how there can be poverty reduction without some change, if not damage, to the ecology/environment of the GMS. The MRC and the GMS, with the institutional support of ADB, must find a way to minimize this damage by gaining a more cooperative spirit among the GMS governments. But if nothing is done to control population growth in some of the GMS states, the goal of sustainable development would seem unattainable.

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Annex 1: Discussions and Interviews

Institution	Person	Title
Lao PDR (5–7 January 2011)		
Mekong River Commission	Mr. Jeremy Bird	Chief Executive Officer
	Mr. Ton Lennaerts	Chief Technical Adviser
	Mr. Phetsamone Southalack	Natural Res. Planner/Env. Specialist
	Mr. Voradeth Phonekeo	Project Manager
Lao Ministry of Agriculture and Forestry	Mr. Khamhou Phanthavong	Deputy Director
GHK International	Mr. Victoriano B. Macasaquit	Social and Resettlement Specialist
Cambodia (8–13 January 2011)		
Royal University of Phnom Penh, Department of Environmental Science	Mr. Ham Kimkong	Senior Researcher / Lecturer, Natural Resource Specialist
	Mr. Spoann Vin	Researcher / Lecturer, Urban Environment Management
	Mr. Chann Sopheak	Researcher / Lecturer, Geographic Information System
Virachey National Park	Mr. Chou Sophark	Director
3S Rivers Protection Network (3SPN)	Mr. Paul Humphrey	Information and Advocacy Advisor
Mekong River Commission Cambodia	Mr. Erland D Jensen	Chief Technical Advisor
World Bank	Mr. Veasna Bun	Infrastructure Operations Officer
Thailand (24–29 December 2010)		
Ministry of Natural Resources and Environment	Mr. Suwit Khunkitti	Minister
	Mr. Chaiporn Siripornpibul	Deputy Director General, Department of Water Resources
	Ms. Janya Trairat	Water Use Efficiency Division
Ministry of Energy	Ms. Asdaporn Krairapanond	Director, Office of International Cooperation
	Ms. Wilailak Suraphruk	Environmentalism, Office of International Cooperation
	Mr. Suthep Liumsirjarern	Deputy Director-General
United Nations	Mr. Rangsan Sarochawikasil	Department of Alternative Energy Development and Efficiency, Energy Research Bureau
	Ms. Hang Thi Thanh Pham	Regional Programme Officer, International Strategy for Disaster Reduction (ISDR)
	Mr. Kasit Piromya	Minister
Ministry of Foreign Affairs	Mr. Chavanond Intarakomalyasut	Secretary to the Minister
	Mr. Surasak Suparat	Director, Department of International Organizations, Development Affairs Division
	Ms. Kesarin Phanarangsarn	Second Secretary, Department of International Organizations, Development Affairs Division
	Ms. Nitivadee Manitkul	Director, Department of International Economic Affairs, Division of Economic Relations and Cooperation
	Mr. Pornsith Pibulnakarintr	First Secretary, Department of International Economic Affairs, Division of Economic Relations and Cooperation
	Dr. Nob Satyasai	President
N-POWER CO., LTD		
Thai Oil Public Company Limited (PTT Group)		
People's Republic of China (30 December 2010–4 January 2011)		
Yunnan University	Dr. He Daming	Director/Professor, Asian International Rivers Center
	Dr. Kang Bin	Professor, Asian International Rivers Center

World Wide Fund (WWF) for Nature Beijing Office	Ms. Wu Yusong	Head/Coordinator of UMB Program
Bangkok and Singapore (25 January–15 April 2011)		
USAID office	Bradford Phillips	Regional Climate Change Adaptation Advisor, Regional Environment Office, Asia
	Saengroaj Srisawaskraisoen	Program Development Specialist, Regional Environment Office, Asia
United Nations, ESCAP	Le-Huu Ti	Chief, Water Security Section, Environment and Development Division
Thammasat University, Rangsit Campus, Pathunthani, Thailand.	Stephen J. Atwood	Director, Center for Global Health and Development. Assoc Prof, Faculty of Public Health
Renmin University, Beijing	Pang Zhongying	Professor of International Relations and director of Global Governance Studies
Yunnan University, Kunming	Li Chenyang	Director, Institute of Southeast Asian Studies
Institute of Southeast Asian Studies, Singapore	Sothirak POU	Visiting Senior Research Fellow; Former Ambassador of Kingdom of Cambodia to Japan
Institute of Southeast Asian Studies, Singapore	Thaung Tun	Visiting Senior Research Fellow; Ambassador to Brussels Ministry of Foreign Affairs, Myanmar

DROUGHT RISK MANAGEMENT AS CLIMATE CHANGE ADAPTATION AND DISASTER RISK REDUCTION LINKAGES IN LOWER MEKONG REGION: ISSUES, CHALLENGES, AND POTENTIAL

Rajib Shaw¹

1. Introduction

Climate change has brought new risks to humanity. It is important to understand the nature of these risks, where natural and human systems are most vulnerable, and what may be achieved by adaptive responses. Adaptation to climate change has the potential to substantially reduce many of its adverse impacts by enhancing the capacity of governments and communities to withstand these impacts. While climate change adaptation has been discussed over recent years, including organizational response, little attention has been focused on community adaptation, and integrating community adaptation methods into government policies (Shaw *et al.*, 2010a).

Since some of the worst sufferers of climate change are rural communities (Shaw, 2006) whose livelihoods are dependent on agriculture, it is important to focus on the impacts of climate change on their livelihoods and re-establish the links among poverty—defined as stable purchasing power to maintain decent living—livelihood, and environment. However, focusing on communities is not enough; so long as community initiatives do not become part of government policies it is difficult to sustain their efforts, which means that the emphasis should be from both ends. Perhaps the most important prerequisite for creating sustainable livelihoods and for achieving sustainable development is good and accessible government. Thus, the link between local, state, and national governments to the community is of utmost importance.

1.1 Context: Climate Change Adaptation and Disaster Risk Reduction

Schipper and Burton (2009) made an excellent review of the evolution of the term adaptation, from its inception by UNFCCC in 1992. They emphasized that adaptation has a long history in the ecosystem and human sciences,

however, it is only recently that, the scientists and growing number of policy makers have begun to grapple with how humanity can actually adapt in a planned and strategic way as climate changes. Schipper and Burton (2009) gave a logical flow between theory, definitions of vulnerability, resilience, relation to disaster risks, development, and linkage to climate change policy.

Leary *et al.* (2008) stated that adaptation can be a specific action (e.g., a farmer switching one crop to another), systematic change (e.g., diversifying rural livelihoods), or an institutional reform (revisiting water reform and land ownership). Adaptation can be product as well as process. Leary *et al.* (2008) argued adaptation to be a process, which includes learning about risk, evaluating response options, creating the conditions that enhance adaption, mobilizing resources, implementation, and reviewing choices with new learning.

Climate change adaptation (CCA) and disaster risk reduction (DRR), though broadly understood to be linked in some ways, have not yet been taken as a holistic set of actions that require collaborative and coordinated action by all concerned stakeholders (Shaw *et al.*, 2010a). The significance of CCA-DRR synergy is felt most by vulnerable communities who do not feel the impact of climate change or natural disasters sectorally, but as a combined whole with devastating effects. Thus, a sectorally split approach to this complex set of problems will not bear fruit. Recent work by researchers and policy makers has thrown light on the intricate linkages between cross-sectoral development activities, their impact on the environment, subsequent detrimental impacts of a deteriorating environment on human life, and the integrated approach needed to address this combined threat of climate change and disasters (AUEDM, 2010). Such an understanding can be very meaningfully deployed at various levels from governance to voluntary action to education, and can go a long way in developing community-based and environment-based resilience to climate change as well as disasters. CCA began to receive attention in 2005 in COP 11, which prepared the Nairobi Action Plan (Shaw *et al.*, 2010a). Further attention and commitments were gained in 2007 in the Bali Road Map and Action Plan, followed by COP 15 in 2009, but a consensus exists that CCA is more talk than action. Local implementation of adaptation policy is considered to be the core of success of adaptation.

DRR evolution showed a similar trend. In the 1960s and 1970s, disasters were generally thought to be extreme events and the focus was more on relief and

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rescue, dominated by civil defense and the Red Cross. Due to strong lobbying of professional societies like the International Association of Earthquake Engineering, the United Nations (UN) designated 1990 to 1999 as the International Decade of Natural Disaster Reduction. Two major events brought DRR into prominence: the 1994 Yokohama World Conference on Disaster Reduction and the 1995 Hanshin Awaji earthquake of Kobe, Japan. A strong need for a multidisciplinary approach was felt, which emphasized the focus on local rather than national approaches. In 2000, the UN International Strategy for Disaster Reduction (ISDR) took the charge of international advocacy and negotiations in this field. The 2004 Indian Ocean tsunami brought the disaster issue into high political profile and in 2005, the UN member states signed the Hyogo Framework for Action (HFA: 2005–2015). Development agencies also expressed their commitments by establishing the Global Facility for Disaster Reduction and Recovery with its secretariat at the World Bank, and incorporating disaster-related issues in development activities.

A recent compilation demonstrated the linkages between climate change adaptation and disaster risk reduction in two volumes that describe the issues and challenges and Asian experiences, respectively (Shaw *et al.*, 2010b).

1.2 Common Issues and Challenges of CCA and DRR

Three common issues of CCA and DRR development are: increasing focus on local governments, emphasis on multidisciplinary approaches, and emphasis on theory to practice. The key challenge is how to incorporate CCA and DRR in local practices (Shaw *et al.*, 2010a).

CCA and DRR do not fully overlap. However, there is scope to bring the two sectors together. One of the key differences is that DRR approaches are mainly based on past experiences, while CCA is based more on future projections. For example, when a river dyke is made as a DRR measure, the deciding factors for the height of the dyke are past flood levels or rainfall data, and importance of the area (commercial, residential, industrial, or agriculture). This has been a traditional approach of DRR. However, the current DRR approach incorporates possible future rainfall in the area (with different levels of uncertainty), in addition to the above factors. This is an example where CCA and DRR come together. Adaptation can be planned (with information on future uncertainty) or autonomous (without focusing on long-term future). Understanding adaptation

depends on two key parameters: clarity or uncertainty of existing climate predictions and the vulnerability of a community or household to a given climate-related hazard. After examining uncertainty and vulnerability in more detail, the elements of adaptation are considered, with particular emphasis given to the role played by social networks in enabling knowledge sharing, access to resources and influence over policy. The principal adaptation activities are identified as vulnerability reduction, building adaptive capacity and strengthening resilience (Ensor and Berger, 2009).

Several activities are considered useful to contribute to resilience and adaptive capacity of communities (UNDP, 2002): diversification of livelihood activities, assets, and financial resources; mobility and communication (ability of goods, people, information and services); ecosystem maintenance (with basic services like water); organization (social networks, organizations, institutional systems); adapted infrastructure (physical structures for basic services); skills and knowledge (ability to learn and basic educational skills); asset convertibility (development of assets or markets); and hazard-specific risk reduction (early warning, spatial planning, building codes, etc.). UNDP (2002) also noted that governance plays an important role in bringing CCA and DRR closer together. Social, political, and economic systems that deny groups access to key decision making are also considered important. Adger *et al.* (2009) emphasized three challenges of adaptation: ecosystem and sociological systems absorbing the perturbation as adaptation, values of adaptation (from different perspective) to be included properly in decision making, and the governance dimension of adaptation.

Leary *et al.* (2008) listed nine adaptation lessons: need for adaptation action now, create conditions to enable adaptation, integrate adaptation with development, increase awareness and knowledge, strengthen institutions, protect natural resources, provide financial assistance, involve those at risk, and use place-specific strategies. The same lessons are equally applicable to the DRR field, when it is seen through the lens of Hyogo Framework for Action (HFA, 2005): ensure that DRR is a national and a local priority with a strong institutional basis for implementation (institutional issue); identify, assess, and monitor disaster risks and enhance early warning (risk assessment); use knowledge, innovation, and education to build a culture of safety and resilience at all levels (education); reduce the underlying risk factors (links to development); and strengthen disaster preparedness for effective response at all levels (emergency response).

1.3. The Context: Lower Mekong Basin

The lower Mekong River Basin (MRB) is located in the East Asian Monsoon region, which affects large parts of the People's Republic of China (PRC), Indo-China, Japan, Republic of Korea, and the Philippines. It is characterized by a warm, rainy summer monsoon and a cold, dry winter monsoon. The rain occurs in a concentrated belt that stretches east-west except in the eastern PRC where it is tilted east-northeast over Japan and the Republic of Korea. The onset of the summer monsoon is marked by a period of pre-monsoonal rain over the southern PRC and Taipei, China in early May. From May through August, the summer monsoon shifts through a series of dry and rainy phases as the rain belt moves northward, beginning over Indochina and the South China Sea (May), to the Yangtze River Basin and Japan (June) and finally to northern PRC and the Republic of Korea (July). When the monsoon ends in August, the rain belt moves back to the southern PRC (Shaw *et al.*, 2010).

The lower MRB plays an important role in the well-being of Cambodia, PRC, Lao PDR, Myanmar, Thailand, and Viet Nam as the Mekong is the major river supporting agriculture and many other economic activities in the region (Figure 1). The lower MRB is also a cause of concern due to the regular floods it brings, which have a significant impact on the lives of many people in the river basin. However, in recent times, the MRB has become increasingly vulnerable to drought. A notable example was the drought of 2004, which began two years earlier and grew to serious proportions. Dealing with drought requires strategies different from those for dealing with floods and typhoons, which have plagued the Mekong region for years. Local communities, governments, and nongovernment organizations (NGOs) know how to deal with these age-old problems but drought, being a slow-onset disaster with crippling impacts, needs to be looked at from a different perspective.

2. Droughts in the Lower Mekong Region: an Interplay of Climate Change and Disasters

Drought is a slow onset disaster and it is not an unusual occurrence (Wilhite, 2000). For several years, the Asian monsoon countries suffered under a long-lasting severe drought, until the wet 2010 El Niño-driven winter and spring. The impacts of drought are non-structural—unlike other hydro-meteorological extremes, such as floods and typhoons—and they tend to be much more widespread

Figure 1: Map of Lower Mekong River Basin



Source: http://www.mekongboat.com/mekong_map.htm

geographically. The severity of a drought is dependent not only on its duration, intensity, and spatial extent, but also on the specific environmental and economic activities carried out within it. Once a drought is established, economic, social, and environmental consequences pose a serious threat to those who rely on secure water availability and supplies, including farmers, fishers, and households. Vulnerability is further aggravated by population growth and migration, urbanization, land-use changes, government policies, water use patterns, the diversity of income generating activities, changing cultural practices, etc. Therefore, it is useful to discuss and agree on definitions and indicators.

The Asian monsoon region has rice farming as a basis for food production. Agriculture is very diverse from north to south, and the countries are characterized by high biodiversity around rice fields. Drought affects mainly rural livelihoods and causes rural migration (Shaw *et al.*, 2007). For example, millions of farmers and low-income earners were affected by the drought of 2004, which

caused considerable agricultural losses in Cambodia and northeastern Thailand, significant reduction in the second rice crop in the Lao PDR, and critical levels of saline intrusion in the Mekong Delta (Navuth, 2007). There are four main types of droughts, described in Table 1.

2.1. Meteorological Droughts

Drought events in the Mekong Basin have occurred several times in recent years (to 2004)—in 1992, 1993, 1998, and 1999 (MRC, 2005). The 1993 and 1999 events extended across every region of Thailand and caused water shortages within the agriculture, industrial, and domestic sectors. The 1998 drought was also severe, especially in the Mekong Delta of Cambodia and Viet Nam. Flood season flows were low, with critically reduced flood plain inundation. Tonle Sap, the Great Lake, recorded a maximum level of only 6.85 meters (m) and a flooded area 7,000 square kilometers (km²), compared to typical seasonal maxima of 8–9 m and 15,000 km². In six provinces of the central highlands in Viet Nam stretching 400 km south from Hue, severe meteorological and agricultural drought was reported.

The most recent drought event began in 2003 and generally lasted into 2005, although there are some areas where lower than normal water levels and flows are still being observed. Close and routine monitoring in these areas is being carried out by concerned national line agencies and the Mekong River Commission (MRC) Secretariat. The most recent regional drought episode emphasized

the point drought is not just about accumulated rainfall deficits, but also about unexpected patterns of rainfall occurrence.

Regionally, total rainfall in 2004 was average, but it all occurred early in the monsoon season, which ended very early in the first weeks of September, after which rainfall was only a fraction of normal. Mean regional rainfall over the lower MRB during the last quarter of 2004 was only +/- 47% of normal. Among the four countries, Thailand received only 13% of the normal amount 29%, 65%, and 68% were the equivalent figures in Lao PDR, Viet Nam, and Cambodia, respectively (Nguyen, 2010).

The current water level on the mainstream Mekong River is significantly below average in northern Lao PDR and Thailand. Levels at mainstream measuring stations at Chiang Saen, Chiang Khan, Luang Prabang, Vientiane, and Nong Khai are below those that occurred in the low flow season of 1993, which followed the most extreme regional drought on record in 1992. All mainstream water levels measured north of Stung Treng are significantly below the average for this time of year and are expected to decrease further for another month. Starting from that low base, analysis of the rainfall at selected hydrological stations in Yunnan, Chiang Saen, and Luang Prabang has shown a consistent pattern of monthly precipitation significantly below average amounts since September 2009. For example the rainfall recorded at Chiang Saen in November and December 2009 was only 20 mm compared to the long-term average of 52 mm for the same

Table 1: Characteristics of Four Types of Drought

Type of drought	Characteristics
Meteorological	Meteorological drought is the amount of dryness and the duration of the dry period. Atmospheric conditions that result in deficiencies of precipitation change from area to area.
Hydrological	Hydrological drought is associated with the effects of low rainfall on water supply. Water in hydrologic storage systems, such as reservoirs and rivers, are often used for multiple purposes, such as flood control, irrigation, recreation, navigation, hydropower, and wildlife habitat. Competition for water in these storage systems escalates during drought and conflicts between water users increase significantly.
Agricultural	Agricultural drought mainly effects food production and farming through soil water deficits, reduced groundwater or reservoir levels, etc. Deficient topsoil moisture at planting may stop germination, leading to low plant populations.
Socioeconomic	Socioeconomic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply. The supply of many economic goods, such as water, forage, food grains, fish, and hydroelectric power, depends on weather. Due to variability of climate, water supply is not satisfactory to meet human and environmental needs in some years. The demand for economic goods is increasing as a result of increasing population. Supply may also increase because of improved production efficiency and technology.

Source: Shaw et al. (2011).

period and this has contributed to the low river flow. The very low water levels recorded at monitoring stations in the mainstream between Chiang Saen and Nong Khai show that tributaries in the Lao PDR and Thailand are not feeding as much water into the mainstream as would be expected. This can be seen with the Nam Khan River that flows into the Mekong at Luang Prabang. Water levels in the Nam Khan are the lowest for 50 years.

The implications of these low water levels are serious for the people of the northern Lao PDR and Thailand. Severe drought will have an impact on agriculture, food security, access to clean water, and river transport and will affect the economic development of people already facing serious poverty. The northern provinces are amongst the poorest areas for both the Lao PDR and Thailand. River tour operators have stopped offering services on the stretch of river between Houiesay and Luang Prabang and it has been reported that Yunnan provincial authorities have halted the operation of Chinese cargo boats, which will affect regional trade. The National Centre for Environmental Health and Water Supply in the Lao PDR has started advising people to counter the effects of drought by reducing water consumption. The MRC is undertaking more detailed assessments of the low flow conditions and is working with its member countries to closely monitor the drought situation as well as integrating drought management considerations into its climate change adaptation initiative.

The drought vulnerability of a region can be assessed using the Standard Precipitation Index (SPI). The SPI is the difference of precipitation from the mean for a specified time period divided by the standard deviation where the mean and standard deviation are determined from past records. However, as the precipitation will not be normally distributed over the time scale considered, a transformation is applied to the distribution. The SPI is simply the transformation of the precipitation time series into a standardized normal distribution. Following are examples from countries in the region:

Viet Nam. According to the data from national drought research (Hoc, 2002), drought events were identified based on the drought index, which uses hydro-meteorological data in order to indicate meteorological drought. The evidence of climatic data shows that rainfall and temperature are increasing in the lower Mekong region in recent decades. This provides more evidence the change of global climate (IPCC, 2001) and the prediction of the Viet Nam Hydro-Meteorological Institute (1999). The climate is changing

in south central Viet Nam with variations of rainfall and temperature. Droughts occur because of the change in rainfall pattern and very low precipitation in this area. The analysis of available meteorological data through SPI indicated high variability in rainfall, which is the reason for prolonged meteorological droughts. It is recorded that there were 19 drought years in Phan Rang and 17 drought years in Ba Thap within 26 years.

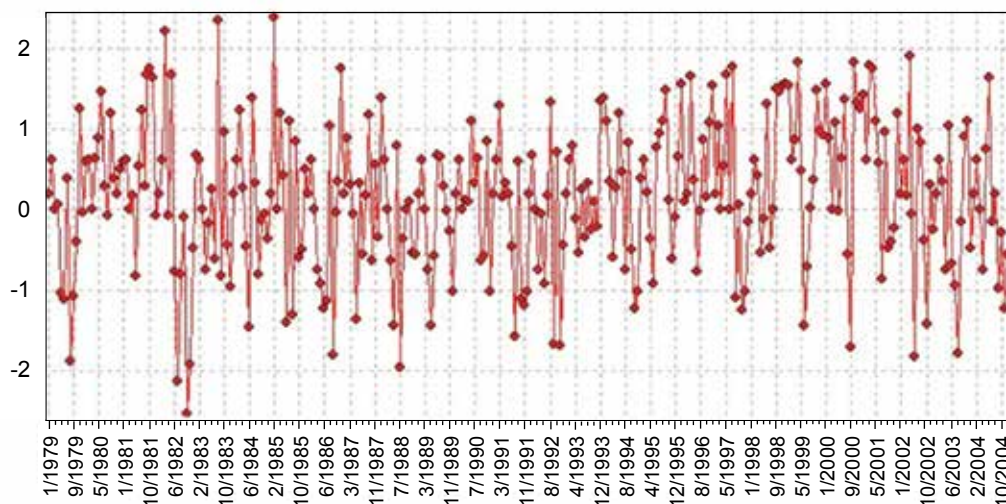
Here, the SPI was calculated using average monthly precipitation in 2 stations in Ninh Thuan Province. The SPI time series spanning January 1979 to December 2004 in the 2 catchments Phan-Rang and Ba-Thap are presented in Figure 2, which shows that SPI values vary significantly, temporally and spatially, reflecting the fact that rainfall in Ninh Thuan Province is not only influenced by large-scale atmospheric circulation but also by local weather regimes. The SPI values illustrate dry and wet conditions well. They correspond well to statistical records of drought occurrence in 19 years during 1979 to 2004 in Phan Rang. Severe drought events occurred in 1979, 1982, 1986, 1988, 1991, 1992, 2000, 2002, 2003, and 2004. The data recorded in Ba Thap station show that there have been 17 drought years with 10 severe drought years, namely, 1979, 1984, 1985, 1986, 1988, 1992, 1993, 2001, 2003, and 2004.

Figure 2 includes SPI values during some severe drought years in Ninh Thuan Province. Most SPI values are negative during these years. A large-scale drought occurred from early spring to end of summer in 1998 corresponding to highly negative SPI values, and it had severe impacts on socioeconomic conditions. Thus, the SPI is a good indicator of occurrence, intensity, and magnitude of meteorological droughts based on precipitation records. Therefore, it can be used for drought monitoring and assessment in the south central coast of Viet Nam.

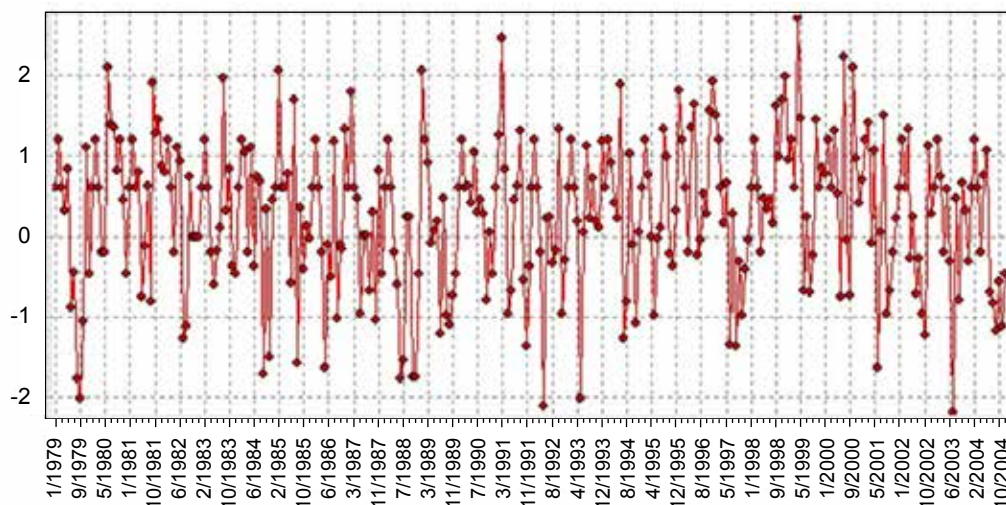
Cambodia. The rainfall data obtained from Svay Rieng Province was subjected to SPI analysis and results as presented in Figure 3. The figure indicates that there has been a large deviation of rainfall over the study period. Out of 282 rainfall events (monthly rainfall data), 126 (42%) events were negative (lower than the normal), and 172 were higher than normal. We counted the maximum consecutive negative months between January 1982 and November 2006. Six consecutive negative SPI values occurred during the 50 months of January 1982–January 1986 followed by 5 consecutive negative SPI values during May 1998 to May 2002. During the study period, a maximum SPI value of 2.78 and a minimum SPI value

Figure 2: Time Series of Monthly Standard Precipitation Index (SPI) Values in Two Stations in Ninh Thuan Province, January 1979–December 2004

A: SPI in Phan Rang Station



B: SPI in Ba Thap Station



Source: Nguyen (2010).

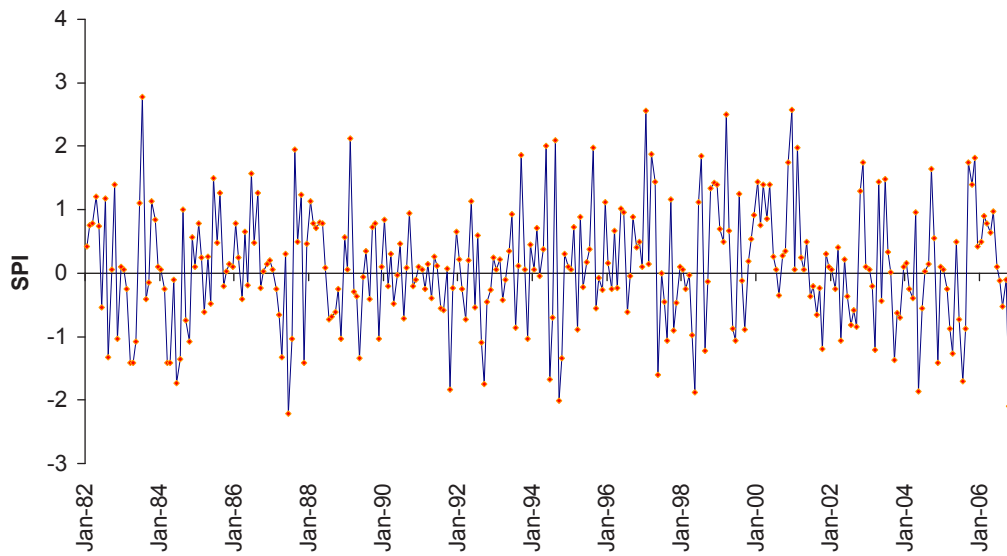
of -2.21 were recorded. In 2002, the year of drought in Cambodia, six negative SPI months were recorded (Figure 3). The months of June, July, August and September—the months of the southwest monsoon—had negative SPI values; the monsoon revival in October and November was indicated by positive SPI values.

From the above observed behavior of drought in Cambodia, it can be recognized that rainfall in Svay Rieng is erratic with detrimentally long dry spells spanning 6 months at times. This necessitates dependable irrigation, water harvesting, and storage systems so that crop production is not severely hampered due to water scarcity.

Thailand. Northeastern Thailand has been frequently subjected to drought, although the amount of rainfall is relatively high. The major causes are erratic distribution of rainfall—dry spells in the rainy season from June to July and also in last two weeks of September, and low water-holding capacity of soil. The most serious negative result from drought is water deficiency for agriculture, the major economic sector in the region, which impacts human life, property, and agricultural production in the region and the country as a whole (Wattanakit *et al.*, 2007).

Annual rainfall of the region ranged from a minimum of 778.25 mm in the southwest to a maximum of 3,021.50

Figure 3: Standard Precipitation Index of Rainfall Events in Svay Rieng during 1982–2006



Source: Nguyen *et al.* (2009).

mm in the northeast. Rainfall in September and October in the northeast comes from the northeast monsoon and the amount of rainfall is higher than in the southwest. Over 70% of the northeast receives annually 983–1,437 mm. of rainfall, while the areas along the Mekong River receive 1,437–2,345 mm. The spatial autocorrelation of rainfall in the study area was examined from a semivariogram and covariance cloud (Wattanakij *et al.*, 2007).

Analysis of spatial pattern of drought using spatial SPI and temporal SPI from rainfall data was used to determine the spatial distribution of drought and evaluate drought affected areas and drought frequency in northeastern Thailand. The spatial pattern of mean annual rainfall over 29 years was confirmed to increase from the southwest to the northeast. A measurement of reliability of rainfall at each station for the study periods using covariant analysis indicated high values at 6 months and 12 months in the western part of the region. Multi-temporal SPI analysis at various time scales was used to indicate drought occurrences at the station and their severity. From the observation of decadal variation of rainfall since 1976, shown by values of $SPI < -1$, it was indicated that drought in the region was more severe during 1988 to 1999. The most affected areas were the western and southern parts and its severity, which is associated with the pattern of rainfall, decreased from southwest to northeast. The worst dry years from spatial SPI were 1979, 1981, 1986, 1997, and 2001. The frequency, area extent, and severity of drought as assessed from SPI could benefit sustainable

water resources management and the development of mitigation strategies of drought events in the region (Wattanakij *et al.*, 2007).

The Lao PDR. In the upper part of the lower Mekong Basin, the rainfall from July 2009 to February 2010 was comparable to the long-term average. However, from September onwards rainfall was considerably less than normal.

From these preliminary rainfall data, the indications are that the 2009 monsoon in Southeast Asia ended early. The average date for monsoon withdrawal at Chiang Saen is the first week of November and at Vientiane the first week of October. The early withdrawal of the monsoon in 2009 meant that the discharges on the Mekong and its northern tributaries started to recede early in the season, drawing on the available natural catchment and groundwater resources. Catchment and groundwater storage in the northern parts of the basin is not large, so a deficit situation would have arisen relatively quickly, particularly in the large tributaries in the northern Lao PDR, leading to considerably reduced flow contributions to the mainstream.

2.2. Agricultural and Hydrological Drought

In the lower MRB, the definition of drought is based on its impact on water resources (hydrological drought) and agriculture (agricultural drought). Agricultural drought is effectively just a concept, which reflects the perspective

of the agricultural sector on water shortages. This concept links the lack of precipitation (or river flow or groundwater) to agricultural impacts. Crop water requirements depend on local weather conditions, soil and plant characteristics, and plant stage of growth. The extent of an agricultural drought should ideally be defined in terms of its impact on a specific plant on a specific soil in a specific area, which makes it a difficult task to accomplish. In more general terms, agricultural drought exists when root-zone soil moisture is insufficient to sustain crops between rainfall events. In this context, the status of soil water deficit in the top meter of a soil profile may be used as a drought measure. In practical terms, some of the indices referred to above are used to monitor the developing deficits of water availability to crops. Hydrological (flow and groundwater) drought is the effect of low precipitation on hydrological systems. In some cases, the impact on both rivers and aquifers is included under this “type”. In other cases “a flow drought” is distinguished from “groundwater drought”. In both cases, a hydrological drought usually lags behind the deficient precipitation. It takes longer for precipitation deficiencies to manifest themselves through the river flow or through the groundwater level.

The history of drought events in MRB indicates that drought has occurred throughout Viet Nam, in southern Thailand, the central region of the Lao PDR, and in southern Cambodia. Observations have also indicated that the frequency of drought in the region has been increasing in recent years. A deficit of rainfall over a certain period in combination with high temperature and high potential evaporation may lead to huge deficiencies in water supply over the region, which subsequently may turn into a large-scale drought with impacts on the water-using sectors, e.g., losses in agricultural production, emerging forest fires, and reservoir depletion, as well as on related sectors causing, e.g., famine, diseases, and conflicts.

This decrease in upstream water levels is reflected at Luang Prabang and Vientiane from late January onwards. Clearly, the contributions from the large northern Lao PDR tributaries, such as the Nam Ou and Nam Khan, were already low due to the drought conditions; observations confirm that these rivers are currently very low.

Further downstream at Kratie, the decrease in water levels during February remains quite apparent, with those of 2010 being half a meter higher than those of 1993 during late February. Water levels in the Mekong River at Chiang Saen from November 2009 onwards were higher than those in 1992-93. At Luang Prabang and Vientiane, the

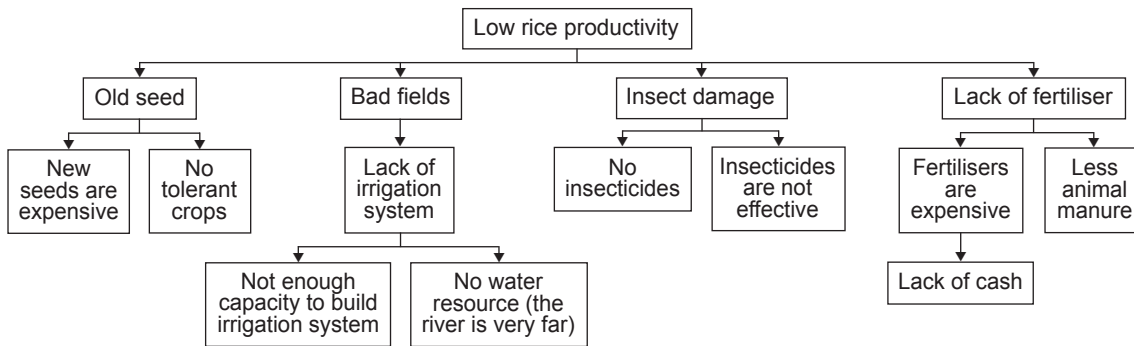
opposite is the case. This suggests that the water levels at Chiang Saen were kept artificially high by upstream reservoir releases until late January when they receded. The levels at Luang Prabang and Vientiane being lower than 1992-93 reflect the regional drought conditions from September 2009 onwards and the very low contributions to the mainstream by the large tributaries in the northern Lao PDR. The situation represents serious regional hydrological drought conditions.

3. Drought Risk Reduction Approaches

As vulnerability to drought has increased globally, greater attention has been directed to reducing risks associated with its occurrence through the introduction of planning to improve operational capabilities (i.e., climate and water supply monitoring, building institutional capacity) and mitigation measures that are aimed at reducing drought impacts. This change in emphasis is long overdue. Reducing the effects of drought requires the use of all components of the cycle of disaster management, rather than only the crisis management portion of this cycle. In the past, when a natural hazard event and resultant disaster has occurred, governments have followed with impact assessment, response, recovery, and reconstruction activities to return the region or locality to its pre-disaster state (Wilhite *et al.*, 2002, 2005). Little attention has been given to preparedness, mitigation, and prediction/early warning actions that could reduce future impacts and lessen the need for government intervention in the future. Because of this emphasis on crisis management, society has generally moved from one disaster to another with little, if any, reduction in risk. In fact, many response measures instituted by governments, international organizations, and donors have actually increased vulnerability by increasing dependency on internal or external assistance. All components of the cycle of disaster management should be addressed in a comprehensive hazard mitigation plan, but greater attention than in the past needs to be placed on pre-disaster activities.

In this section, one example is brought from Viet Nam, introducing a policy for drought risk management at national and community levels. The root causes of drought problems were identified at the local level. Impact tree diagrams were constructed and root causes were uncovered through probing questions, such as ‘why lack of water?’ Local communities were asked to provide their problems during the drought events and the main problems were chosen to identify the root-causes (Figure 4).

Figure 4: An Impact Tree Diagram for Agriculture



Source: Nguyen (2010).

Based on the root causes, policy options were identified for DRR that could be implemented by governments, NGOs, and communities. Emphasis was given to identify a mix of policy options containing mitigation and response strategies. For example, provision of more microfinance to provide financial capital, enhancing weather monitoring and forecasting for better drought preparedness, and regulations to restrict water use through strict irrigation scheduling and water distribution to solve the problem of bad practice on water use and water management. The actions taken will depend on needs, local conditions, and other resources.

3.1. National Drought Strategy

A drought policy should encompass responsibilities and obligations from the government to the local level and especially citizens affected by droughts. Promulgating a drought policy is fundamental to determining technical norms and assistance to reduce the impacts of droughts through relevant and legal actions, e.g., aid programs, healthcare, low interest loans, and subsidies. A set of generic responses to drought was developed by Wilhite (1991):

- Establish a specialized drought task force.
- Organize stakeholders to participate in the preparation and implementation of measures and resolution of conflicts.
- Unify techniques and policy at all levels.
- Determine the drought risk in order to prepare actions for risk mitigation, and minimize difficulties after a drought occurrence.
- Monitor and assess the implementation of drought mitigation and response measures, including mistakes and successes to meet the demand of social and economic development.
- Promulgate drought plans and carry out timely public awareness campaigns.

- Enhance participation in actions for drought mitigation and response processes.

Crucially, those most at risk from drought risk and climate change, the rural poor, have limited information or financial and technical support to adapt to their changing world, despite some localized successes. Their direct experience of drought risk and climate change impacts should be incorporated into future responses, and solutions sought that build on existing local adaptation practices, where appropriate. The people who are directly affected by drought and other disasters and climate change should also be key participants in the planning and implementation of future climate change adaptation measures, particularly where these require relocation or significant dislocation of existing livelihood practices.

A national drought committee is needed to supervise and coordinate development of drought planning corresponding to the multidisciplinary nature of drought and its impacts. During drought occurrence, the drought committee should work closely with public media to keep the public well informed of the water supply status and drought condition that may lead to requests for voluntary or mandatory use restrictions. The committee should have access to assistance from other government agencies and organizations, including international organizations and NGOs.

3.2. Drought Strategy at Local Government Level

Local governments also include entities other than the drought community, e.g., county government offices. Local governments may assist in drought management in the following ways:

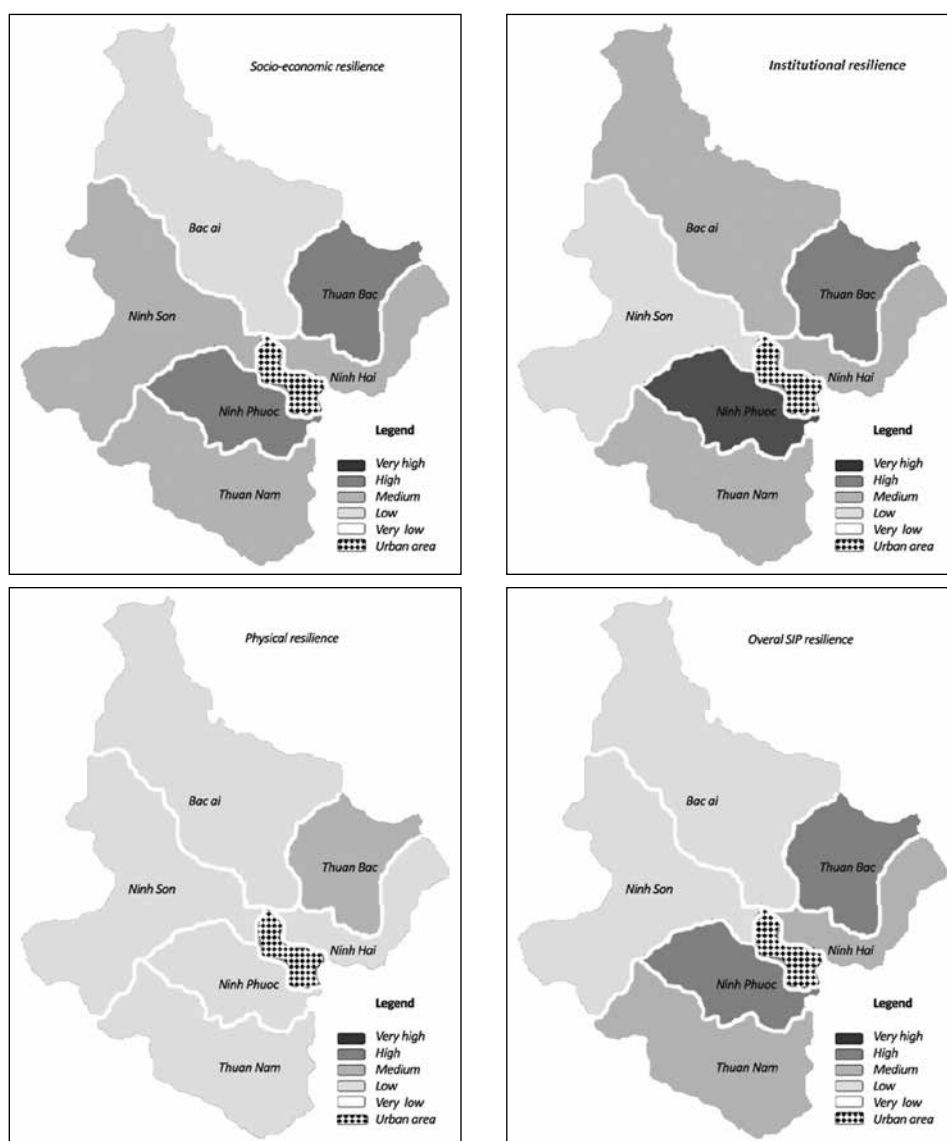
Assist With Planning. Assist the drought community within their jurisdictions to plan and coordinate the development of water supplies, extension of infrastructure, and the coordination of resources, manpower, and technical expertise. Assist the community water system in the development of the drought management plan.

Implement Drought Responses. Local government officials involved in the development of the drought management plan will be informed about the trigger-points for the various drought phases and the planned responses. The local government may be able to assist in the implementation of some of those responses, especially those associated with emergency conditions. For instance, in certain phases

of drought, local governments may be tasked to haul water for domestic and livestock.

Mainstream Sustainable Land Management into Provincial Frameworks. Mainstreaming is a two-pronged approach of embedding development concepts into the provincial plans while also effecting changes in the way of doing business, e.g., policy reforms, changes in planning, institutional structures, and coordination arrangements. It leads to increased recognition of the importance of land management in development and could increase investments by the public budget and international financial contributions.

Figure 5: Socioeconomic, Institutional, and Physical aspects (SIP) Resilience Mapping of Ninh Thuan Province



Source: Nguyen and Shaw (2011).

Resilience Mapping. Resilience against droughts and dry spells is fundamental for water security. Resilience (as it applies to integrated systems of people and nature) is the amount of change a system can undergo (e.g., land degradation) and still remain within the same state (e.g., avoid desertification by continuing to produce essentially the same ecosystem services). With regard to drought resilience issue, the socioeconomic, institutional, and physical aspects (SIP) approach was developed to determine different SIP aspects of a targeted area and provide an overview of drought resilience of that area. The approach helps to find out the strength and weakness of the three dimensions for drought resilience. Government and different organizations can prioritize a sector and provide inputs for the formulation of policy that will help to minimize the drought risk (Habiba *et al.*, 2011).

Each SIP dimension has several primary indicators and each primary indicator has five secondary indicators. A questionnaire survey is the primary tool for data collection. The quality of the results is very much dependent on proper understanding of the questionnaire. The results are qualitative and serve mainly to give better understanding of drought resilience of the study area. Figure 5 shows resilience mapping of Ninh Thuan Province, which can be used as a decision tool at the local level.

3.3. Implementation at the Community Level

The local community should be involved in the process of drought risk management by establishing a “drought community” in each commune where drought frequently occurs.

Role of the Drought Community. The drought community can contribute to the process of drought early warning and forecasting. Local people can observe and predict weather by their traditional knowledge of changes in plants and animals, influence of the moon and sun, the dryness of their fields, etc. Their information can be combined with climate data for drought early warning analysis. The

local community, via its associations, then receives the drought early warning information directly from a provincial hydro-meteorological center. The drought management plan should provide equitable drought protection to the community. Development of the plan may provide the community water system with an opportunity to establish their priorities and identify the means to meet this priority.

For these reasons, a drought management plan is often a companion to a regional water supply plan. Communities that conduct effective regional supply planning find that there is less need for drought management planning. In assessing their risk, a drought community often finds that the best drought preparation is developing interconnections with other facilities to form a regional water system and improve the adequacy of their sources.

Drought Proofing. For practical measures, some appropriate approaches, as shown in Table 2, should be considered for drought risk management. Some of these measures are outlined below.

Fodder Banks. Farmers need to provide their animals with quality feeds to augment dry season forages, especially if there is the prospect of coming drought. One option is to supply expensive concentrates or supplemental feeding. For most small-scale farmers this is not possible due to the high cost and limited availability of supplements. A more practical option is for farmers to establish fodder banks, plantings of high-quality fodder species. These can be utilized all year, but are designed to bridge the forage scarcity of annual dry seasons.

Microcredit. The rural poor generally do not have the capacity to start income-generating activities due to lack of financial capital (Ahmed, 2004). They also have very limited access to the formal financial institutions because of the inability to fulfill the collateral requirements. Thus, microcredit programs have been launched which require no collateral to obtain loans. Their major goal is to provide financial capital to the rural poor in order to engage them

Table 2: Drought-Proofing Measures at Individual, Community, and Local Government Levels

Dimension	Individual	Community	Local government
Environmental impact	- Water use management	- Community-based forest management - Community-based water management	- Reforestation - Land-use management
Social impact	- Lifestyles	- Lifestyles	- Health care service - Education
Economic impact	- Livelihood diversification	- Fodder bank - Microcredit - Livelihood diversification	- Irrigation system - Water management - Livelihood diversification

Rice Straw for Cattle and Sheep at a Household in Ninh Thuan Province, Viet Nam

in income-generating activities for alleviating their poverty (Mahmud, 2006). Microcredit can help them to recover from drought and perhaps diversify into enterprises less likely to be affected by drought.

Ecological Planning. The target of ecological planning is to set up a sustainable system of local practices for DRR in drought-prone areas. This brings benefit not only for local people but also for the environment. In the lower MRB, agricultural systems concentrate on a limited number of crops, such as rice, maize, cassava, sugar cane, onion, garlic, and soy beans, as well as raising sheep, goats and cattle. Most farms use monoculture, but some use multicropping or agroforestry systems.

With relation to temperature, it is predicted that an increase of 1.6 degree C will be experienced in the next 50 years and average annual rainfall will increase by 2.7% in the region. Although annual rainfall is increasing there is no corresponding increase in water availability due to high run off, low infiltration and high evaporation. The impacts of climate variability are taking their toll on local communities as they are experiencing reduced income due to increased mortality of crops from heat and water stress; reduced productivity of livestock due to declining fodder availability and heat stress; ground water subsidence due to over extraction and saline intrusion in coastal areas (contamination of wells); and increased “natural” disasters such as droughts and floods.

The farm households better adapted to the natural ecological constraints of the region and increasing climate variability are those who pursue an agro-silvopastoral system supplemented with small water harvesting structures. This system combines the following: a blend of annual subsistence and market crops both shade grown and under sunlight; fruit, fodder, leguminous and high value trees (perennials); citrus and other medium height bushes or shrubs; stall-fed livestock; and small-scale rainwater harvesting structures. From an adaptation to climate change perspective, the main challenge to be overcome in reducing the vulnerability of local communities is to be able to facilitate a shift from a high water-use mono-crop production system to the adoption of integrated eco-farming models that generate a diversity of products. The key constraints identified in making this shift are the following: i) Inadequate institutional responses with regard to land-use planning and management, ii) an effective regulatory framework that protects investments, and incentive frameworks to support integrated eco-farming systems; iii) Focus on short-term gains over longer term sustained benefits; iv) Cultural norms and values associated with existing cultivation practices (in many cases highly unsustainable) and a lack of knowledge and skills for adopting alternative integrated eco-farming models; v) Insufficient inventory of crop, shrub, bush, tree and livestock varieties suitable for the ecological conditions of the region that have market value; and vi) Insufficient capture of value addition and market access.

For the drought prone areas, it is evident that tree and vegetative cover on farm lands need to be increased considering the multiple characteristics trees exhibit and benefits that they provide, such as, ability to tap ground water; low maintenance after the first few years; produce high value products for the market and subsidiary products like fodder, fuel wood and small construction material; increase leaf litter and soil fertility; decrease soil erosion by forming wind breaks and mitigating rainfall intensity; moderating heat stress by increasing shade cover; and increasing biodiversity. The adaptive agriculture program integrated with other programs such as community-based reforestation, livelihoods diversification and microcredit program can help the local community's resilience to drought by reducing impacts of drought on social aspects and improving environment condition even with the changing climate.

4. Challenges and Potential

Promoting meaningful participation of stakeholders at various levels of governance is a major challenge in many countries in the lower MRB. In Cambodia, Thailand, and Viet Nam, meaningful community participation is indispensable in various levels of decision making from planning to implementation as well as in monitoring changes in climate and its impacts as drought. An important issue is to ensure the full engagement of the more vulnerable groups, whose lives and livelihoods will be affected by certain adaptation options like relocation, by involving them in exploring alternative response options (Pulhin *et al.*, 2010). Based on the current and previous analysis, the following key issues should be considered for better drought risk management in the lower MRB.

Facilitate CCA and DRR Integration at Various Levels. Integration of CCA and DRR concerns at various levels of DRR from national to local should be a major priority for immediate implementation in many countries. An appropriate platform should be established to facilitate the functional integration among the different agencies and sectors concerned with climate change and DRR.

Strengthen the governance system. To strengthen governance and improve the outcomes of integrated drought risk management, enabling policies should be formulated and effective implementation mechanisms developed from the national down the local level in many Asian countries. Such policies and implementation mechanisms should be directed toward mainstreaming

of CCA and DRR in all levels of development planning as already pointed out.

Improve information systems and knowledge management. The value of a well informed public to minimize and avoid risks associated with disasters cannot be overemphasized. More reliable and timely information is needed by the public to forewarn them of a forthcoming drought, so they can act more responsively. Equipment, facilities, and trained staff are required to develop a reliable early warning and forecasting system and effectively communicate information to the public in a timely manner.

Apply integrated assessment methods and tools. The application of existing methods and such tools as the sustainable livelihood framework, the SIP approach, and community-based drought risk management methodologies should be encouraged for more robust assessments of climate change impacts, vulnerability, and adaptation including DRR concerns. These tools should be further developed to incorporate future climate change scenarios using downscaled local data.

Ensure natural resources sustainability and resource rights. Countries in the lower MRB are typically dependent on climate-sensitive natural resources for their livelihoods, economic activities, and national income. As mentioned earlier, most of these resources are degraded, making them and the people dependent on them highly vulnerable to damage from drought and climate change.

Build local resilience and reduce vulnerability. The success of integrating drought in the CCA-DRR can be only effectively measured in terms of its local outcomes. Collective efforts by the governments and other stakeholders should therefore be focused on building local resilience of both people and the environment to climatic threats and reduce social vulnerability of communities, particularly the poor.

Advance innovative education and research and development initiatives. Innovative higher education and research and development initiatives that integrate CCA and DRR should be supported and promoted. These should include both formal and non-formal educational systems and go beyond the more conventional classroom-type (or lecture-type) of learning to allow the engagement of the learners in actual field conditions for meaningful learning to take place.

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WATER AND DEVELOPMENT IN THE LOWER MEKONG BASIN

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Abstract

The Mekong is one of the world's great rivers. The Mekong Basin contains the second most biodiverse river in the world after the Amazon, and supports the world's largest freshwater capture fishery of about 2.3 million tons per year. A considerable part of the 60 million people in the lower Mekong Basin (LMB) rely on the goods and services provided by the Mekong River system for their food and livelihood.

Despite impressive economic growth over the past decade within the basin countries, much of the Mekong Basin itself remains among the world's poorest areas. Food security and malnutrition pose great challenges. Half of all households in Cambodia and the Lao People's Democratic Republic have no safe water supply. In a major part of the Mekong Basin, per capita electricity consumption is less than 1% of average electricity consumption in the industrialized world.

Governments realize that developing water resources can stimulate economic growth, reduce poverty, and improve food security. Currently, all LMB countries have poverty reduction strategies and sector plans in place that include water supply for drinking and irrigation, flood management, hydropower generation, fisheries, and other uses of Mekong water. Hydropower is projected to provide an important source of revenue and contribute to the reduction of climate change impacts.

Recent basin-wide assessments by the Basin Development Plan Programme of these strategies and plans on a range of environmental, social, and economic criteria, provided, for the first time, the information the LMB countries need to address each other's concerns and developing a shared understanding of the opportunities and risks of further water resources development. The resulting Integrated Water Resources Management (IWRM)-based Basin

Development Strategy, facilitated by the Mekong River Commission (MRC), shows that there is considerable scope for further basin development that can improve water, energy, and food security in the region.

The Strategy also identifies the risks associated with some of these opportunities, including the blockage of migratory fish by dams, which must be managed and mitigated, both at the national level, and where relevant, through cooperation at the transboundary level. The Strategy defines 12 priorities for basin development and basin management in order to move development opportunities to sustainable development.

The Strategy was adopted by the MRC Council in January 2011. Its implementation is now being aligned, to every extent possible, with MRC programmes and national planning and management cycles in order to capture the mutual benefits that can be created by cooperation under the 1995 Mekong Agreement.

1. Introduction

The preparation and adoption in January 2011 of the Integrated Water Resources Management (IWRM)-based Basin Development Strategy by the lower Mekong Basin (LMB) Countries was an important milestone in the history of cooperation under the 1995 Mekong Agreement that established the Mekong River Commission (MRC). The Strategy was prepared at a time when the Basin and the Mekong River itself are seeing significant changes. It has been owned and driven by the LMB countries and facilitated by MRC's Basin Development Plan (BDP) Programme.

This paper aims to inform a wide audience about the implementation of the Strategy. The paper first summarizes the unique characteristics of the Mekong Basin, the peoples' development needs, and government plans. It then outlines the assessment of basin-wide development scenarios that have supported basin-wide discussions on balanced basin development. Finally, the paper highlights the resulting IWRM-based Basin Development Strategy.

2. The River and its Environment

The Mekong is one of the world's great rivers. The Mekong flows for almost 4,800 km from its source in Tibet through the People's Republic of PRC, Myanmar, the Lao People's Democratic Republic (Lao PDR), Thailand, Cambodia, and

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Figure 1: The Mekong River Basin



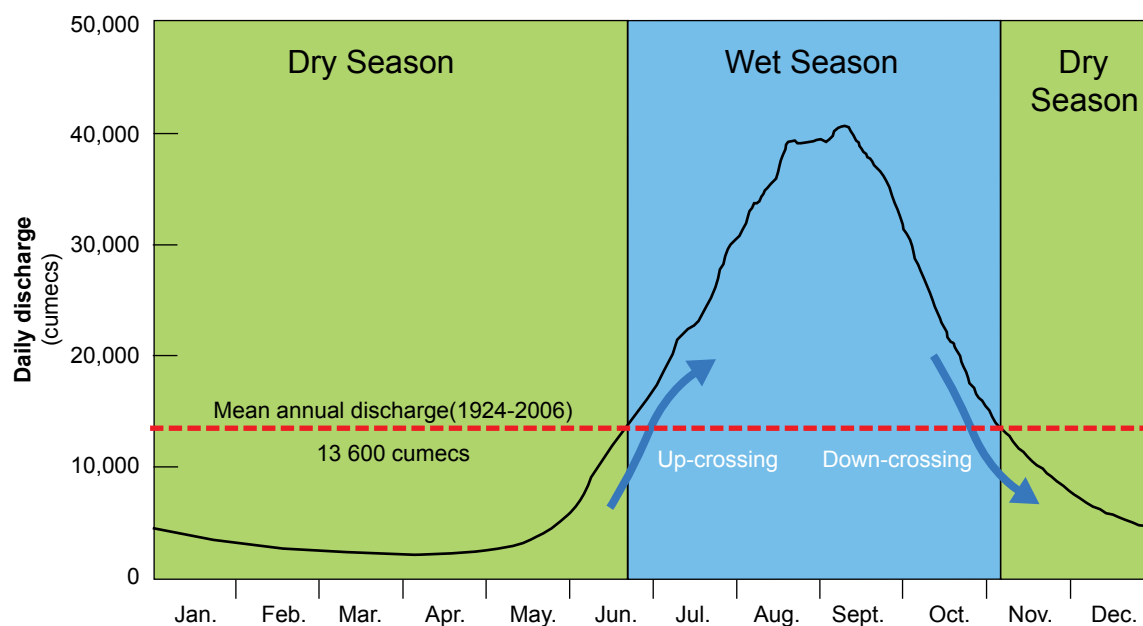
Viet Nam via a delta into the South China Sea, draining a basin area of 795,000 square kilometers (km^2) (the Mekong Basin, Figure 1). The mean annual flow of the Mekong is approximately 475 cubic kilometers (km^3). Per capita water resources amount to 8,500 cubic meters (m^3)/person/year, which is high relative to other international river basins.

The little understood and therefore unpredictable southwest monsoon creates exceptional large seasonal differences in river flows (Figure 2). At Pakse in the southern Lao PDR, mainstream river flows can vary fifty-fold between wet and dry season. The seasonal cycling of water levels at Phnom Penh causes the large “flow reversal” to and from the Great Lake via the Tonle Sap River.

The annual flood pulse and the associated flooding and drying create a rich ecology. The Mekong Basin is the second most biodiverse in the world after the Amazon, and supports the world’s largest freshwater capture fishery of about 2.3 million tonnes per year, although, there are reports of declining catches. The outlook for the basin’s forests is not positive, with increasing demand for timber and land causing deforestation and soil degradation (MRC, April 2010).

Wet season flooding, although bringing many benefits, can also be very destructive; in contrast drought is common in the dry season, impacting crop production, restricting

Figure 2: Monthly Distribution of Flow in the Mekong Mainstream at Kratie



Cumecs (m^3/s) = cubic meter/second.

navigation, and causing saline water intrusion in the delta. Highly variable rainfall and runoff is 'difficult hydrology' which, without significant investments, often correlates with widespread poverty and restricted economic growth around the world.

3. Socioeconomic Development Needs

Despite impressive economic growth over the past decade in the LMB countries, much of the Mekong Basin itself remains among the world's poorest areas. The total population living in the LMB is about 60 million, with 80% living in rural areas. Many are farmers, who supplement what they grow with the fish they catch and the food and other materials they gather from forests and wetlands. This makes the rich ecology of the basin unique in terms of its contribution to livelihoods, particularly of the poor.

Despite the rich water and related resources, water, energy, and food security and malnutrition pose great challenges. Half of all households in Cambodia and the Lao PDR have no safe water supply and half of all villages are inaccessible by all-weather roads (MRC, April 2010). In a major part of the Mekong Basin, electricity consumption is less than 100 kilowatt hours (kWh) per person per year, which is only 1% of average electricity consumption in the industrialized world. The occasional severe floods claim lives and cause substantial economic losses. Climate change could increase the frequency and intensity of floods and droughts.

Economic growth across the LMB is expected to continue, supported by economic diversification, regional economic integration, and investments in infrastructure and human resource development. Cambodia and the Lao PDR seek to graduate from least developed country status, while Viet Nam seeks middle-income status by 2030 (MRC, March 2011). Increasing populations and living standards and growing economies will accelerate food and electricity demand.

The countries' policies demonstrate that governments recognize that developing the economic potential of the water resources in the Mekong Basin can contribute to increased economic growth, alleviate poverty, and improve food security and malnutrition, as demonstrated in the Viet Nam Delta and Thailand where millions of people have been lifted out of poverty and capture fisheries remain among the highest in the basin (MRC, March 2011).

Currently, all LMB countries have poverty reduction strategies and sector plans in place that include water supply for drinking and irrigation, flood management, hydropower generation, fisheries, and other uses of Mekong water to produce benefits for the many millions who live in poverty, especially in rural areas. Hydropower is projected to provide an important source of foreign exchange earnings and revenues and contribute to the reduction of climate change impacts.

4. Basin Development

Current water resources development in the Mekong Basin is limited relative to most other international river basins. Average annual withdrawals for agricultural and other consumptive uses in the LMB are estimated at 12% of the Mekong's average annual discharge. Diversions from the Mekong mainstream upstream of the delta are so far negligible. Existing storage of water resources behind dams corresponds to 5% of the average annual flow, and does not significantly redistribute water between seasons. As a result, the flow regime in the Mekong mainstream is close to its natural state.

However, this will change during the coming years as a result of accelerated development of water resources, in particular for the generation of hydroelectricity. In the upper Mekong Basin, the PRC is completing its hydropower cascade on the Lancang (Mekong) River. In particular, the Xiaowan dam (currently operational) and the Nuozhadu Dam (to be completed in 2015) with 9.8 and 12.4 billion m³ of active storage, will cause significant seasonal redistribution of flow from the wet season to the dry season, and further reduce sediment transport in the Mekong mainstream (MRC, April 2011).

In the LMB, 26 hydropower projects (>10 megawatts [Mw]) are under construction on tributaries, creating, together with the dams in the PRC, 36 billion m³ of additional active storage. Over the next 20 years, further LMB dams are planned, including 12 mainstream projects and 30 tributary dams, mostly in the Lao PDR. Many tributary dams include significant reservoirs, adding 21 billion m³ of storage.

There are plans to increase dry season irrigation by 50% (from 1.2 to 1.8 million hectares) in the next 20 years, with the Lao PDR planning to expand irrigation from about 100,000 to over 300,000 hectares. Major irrigation expansion is being studied in Cambodia, linked to investments in flood control in the undeveloped Cambodian delta, and elsewhere linked to hydropower development.

Table 1: indicative Management Arrangements for IWRM

Management Level and Strategy	Purpose of Strategy or Plan	Coordination or Management Body	Partner, Supporting or Implementing Bodies.
Basin Scale: IWRM-based Basin Development Strategy	Guides the water related development and management in the LMB.	MRC	NMCs, national water resources management agencies
National: National water policy and strategy (linked to basin-scale strategy)	Plans the actions to achieve national objectives, follows an IWRM approach. Takes account of the basin scale strategy.	MOWRAM, Cambodia MONRE, Lao PDR MNRE, Thailand MONRE, Viet Nam	NMCs, national planning and sector agencies, private and nongovernment stakeholders
Sub-basin: Sub-basin IWRM Strategy	Plans the actions for local level socio-economic development and resource protection, in accordance with the national IWRM strategy.	RBOs, Province level coordinating mechanism	NMCs, national sector agencies (province level)
Watershed: Watershed Plan of Action	Provides information into sub-basin level plans	Watershed Committees	Districts and commune agencies, local communities.

MNRE = Ministry of Natural Resources and Environment, MONRE = Ministry of Natural Resources and Environment, MOWRAM = Ministry of Water Resources and Meteorology, NMC = National Mekong Committee, RBO = River Basin Organization.

Mainstream water transfers have long been considered by Thailand, to complement national approaches to alleviate droughts in the northeast (MRC, March 2011).

LMB countries also plan to further develop aquaculture and improve fisheries management, navigation, flood and drought management, and tourism development. Aquaculture growth is forecast to double to 4 million tonnes/year in the next 20 years, so that total basin-wide fish yield (capture and aquaculture) is likely to increase, despite development impacts (MRC, April 2011).

In many of these areas, investment from the private sector now outweighs public sector investments. When private sector projects begin to dominate, the government will require strong government regulatory systems and enforcement capacity, and the readiness to interpret national policies to include emerging good practice. This means a more strategic set of skills and capacities for the central regulating and resource management agencies, (see Table 1) and stronger supporting laws and regulations.

5. Water Resources Management

Water resources management in the LMB is a mix of a “cooperative and coordinating model” at the basin scale (facilitated through the MRC) and four national models, where individual sovereignty, customs, and administrative systems dominate. MRC, through the 1995 Mekong Agreement, acts as a focal point for the cooperation, and assists the member countries in achieving their basin-scale aims through provision of shared information, technical guidance, and mediation.

Since 1995, the MRC has made slow but sure progress, with member country agreement to a procedural framework for cooperation and the development of a regionally recognized knowledge base. It also established a participatory process for basin planning and commenced an effective dialogue with the PRC and Myanmar. Most of MRC’s activities are now implemented through sector or thematic programmes. In 2009, core functions were defined. Some of the core function activities will be gradually decentralized to the member countries.

Each country is implementing IWRM in a way that suits its particular circumstances. There have been large changes in all countries, particularly relating to developing clear statements of national water-related policy and Strategy. An improving institutional and regulatory framework increasingly supports these policies, and removes uncertainty as to which agency has the role of the “water resources manager” (Table 1).

All countries are strengthening participatory approaches to river basin and sub-basin planning and management. Thailand has a well structured framework for River Basin Organizations (RBOs) covering all major sub-basins in the country, while the Lao PDR Viet Nam and are now commencing an RBO approach in critical river basins.⁴ New decentralization policies that will enable water related decisions to be taken at the provincial levels.

⁴ Critical sub-basins need a more holistic and integrated approach in water resources planning, development and management. In such basins, RBOs or provincial departments of the national water and environment agencies (MNRE, MONRE, MOWRAM, MONRE) would need to play their most prominent role in engaging stakeholders and steering and coordinating the planning and implementing activities of Sector agencies (agriculture, hydropower, etc.) and Provinces.

All countries are supporting capacity building programmes for IWRM and introducing new technical, modelling and analytical tools and approaches to support water planning and management. Environmental protection objectives are prominent in the National Socio-economic Development Strategies of all countries. Approaches to stakeholder participation and consultation are being strengthened, building on each country's systems, approaches and cultures relating to community or mass participation.

6. Balancing Development and Protection

The LMB countries' ambitious development plans will bring with them both synergies between water resources developments, and trade-offs, where benefits in one area or activity create detriments for another. For example there can be synergies between hydropower, irrigation, and upland watershed management, with some benefits occurring for all. Trade-offs at the transboundary level will largely be about hydropower benefits, on the one hand, and the losses caused by the blockage of fish migration routes and other potential impacts resulting from this infrastructure.

Trade-offs in particular require much analytical work and negotiation between countries, or between sectors, to find the middle ground (or balancing point) where all key players and stakeholders are prepared to agree. All of this requires strong IWRM understanding and capabilities across the basin, and across institutions, and time for consultation and to develop preferred negotiating positions. It will also require close consideration of a range of complementary measures that may be needed to offset or mitigate the impacts of new development proposals.

The BDP Programme has studied the potential transboundary synergies and trade-offs through a cumulative impact assessment of basin-wide development scenarios (MRC, April 2011), with engagement of many stakeholders across the Mekong Basin (see the last Section). The process was technically guided and supervised by the Regional Technical Working Group (RTWG), comprising technical experts drawn from the line agencies, research institutions, national Mekong committees (NMCs), and the MRC Programmes. Other studies have contributed to the scenario assessment, such as the strategic environmental assessment (SEA) of hydropower on the Mekong mainstream (ICEM, October 2010).

7. Scenario Assessment

Each scenario was formulated to represent different combinations of nationally planned sector development, with a focus on public and industrial water supply, irrigation, hydropower, and flood protection. These are the sectors identified by the LMB countries as having the greatest risk of transboundary environment and social impacts. The LMB countries agreed to assess the scenarios against 42 economic, environmental, and social criteria that provide a picture of how well each scenario meets the socioeconomic development and environment protection objectives of each country, as well as the basin's shared goals. In addition, a basin-wide equity criterion is included that measures the degree of equitable development between each country that each scenario produces.

The scenarios selected by LMB country scenarios fall into four main categories: baseline situation (year 2000), definite future situation (2015), foreseeable future situation (2030), and long-term future situation (2060). The scenarios for the foreseeable future and longer-term future were assessed with and without the potential modifying influence of climate change.

Hydrological changes caused by each scenario have been assessed with MRC's suite of simulation models, taking into account the developments and plans in the upper Mekong Basin. Based on the hydrological changes and physical impacts caused by each scenario, a multidisciplinary expert group had conducted an integrated assessment with the set of agreed criteria. The group was assembled from MRC staff and riparian and international scientists and consultants.

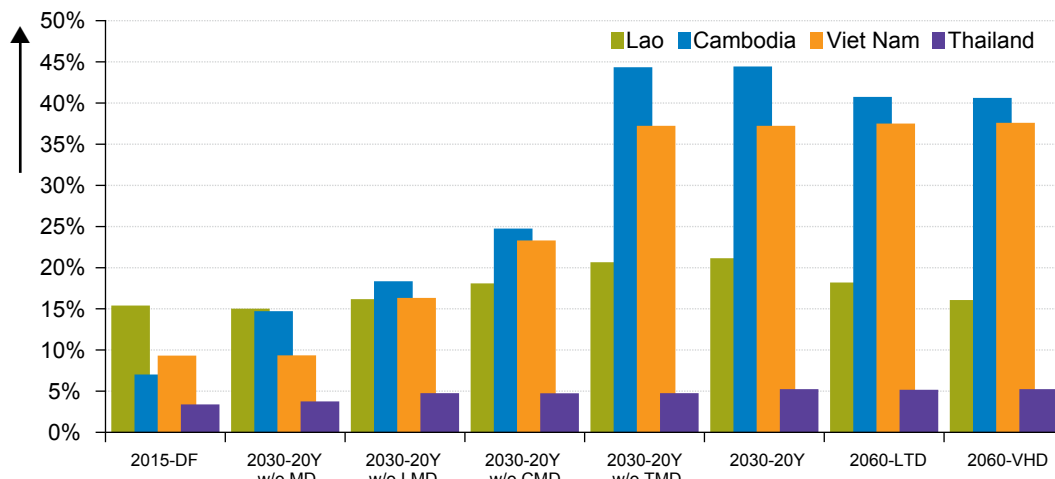
The scenario assessment results are reported in a main report and 13 technical reports (MRC, April 2011). Some assessment results are presented in Table 2 and Figure 3 below. Table 2 shows that both benefits and negative impacts of the considered scenarios are spread unevenly across the four countries, which highlights the need for transboundary cooperation to reach mutually acceptable decisions. Figure 3 shows that the lower of the proposed 11 mainstream dams have the largest impact on LMB's capture fisheries and environmental values. The losses are particularly severe in Cambodia and Viet Nam.

The assessments of climate change point clearly toward more variable conditions within the basin and increasing runoff in the longer term. In the foreseeable future (next 20 years), climate change could further increase the already

Table 2: Comparison of Economic Net Present Value in Each Scenario with the Baseline by Sector and Country
(\$ million)

	Definite Future	20-Year Plan w/o MS Dams	20-Year Plan w/o Lower MS Dams	20-Year Plan w/o Thai MS Dams	20-Year Plan w/o Cambodia MS Dams	20-Year Plan	20-Year Plan + Climate Change	Long Term Dev't Scenario	Long Term Dev't + Climate Change	Long Term Very High Dev't
Hydropower	11,491	17,603	25,002	28,706	30,333	32,823	32,823	37,865	37,865	38,787
Irrigated Agriculture	0	1,659	1,659	1,659	1,659	1,659	1,659	4,268	4,268	16,129
Reservoir Fisheries	91	107	132	202	169	215	215	420	420	473
Aquaculture	1,129	1,261	1,261	1,261	1,261	1,261	1,261	1,892	1,892	2,522
Capture Fisheries Losses	-946	-732	-952	-1,914	-1,218	-1,936	-1,936	-1,818	-1,818	-1,801
Wetland Area Reduction	-228	-176	-178	-225	-178	-225	101	-260	36	-310
Eco-hotspots/Biodiversity	-85	-220	-240	-330	-305	-330	-415	-435	-525	-700
Forests	-153	-183	-228	-349	-254	-372	-372	-731	-731	-822
Recession Rice	-144	-173	-175	-178	-176	-178	278	-226	185	-274
Flood Mitigation	461	360	360	360	360	377	-273	408	-296	432
Saline Area Reduction	20	25	23	21	23	27	-2	22	-2	16
Riverbank Erosion	0	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Navigation	64	64	64	64	64	64	64	64	64	64
Total LMB	11,700	19,596	26,729	29,277	31,739	33,386	33,404	41,469	41,359	54,516
Lao PDR	6,595	11,688	17,636	18,927	22,632	22,588	22,604	26,401	26,501	29,608
Thailand	1,095	2,750	3,913	3,970	4,223	4,410	4,445	5,011	5,097	6,351
Cambodia	693	1,446	1,351	2,237	1,143	2,237	2,628	5,302	5,470	13,134
Viet Nam	3,317	3,711	3,828	4,142	3,741	4,151	3,727	4,755	4,292	5,423
Total LMB	11,700	19,596	26,729	29,277	31,739	33,386	33,404	41,469	41,359	54,516

Figure 3: Capture Fisheries Losses Relative To Baseline (%)



Notes: 2015-DF (Definite Future Scenario), Baseline plus PRC dam cascade and 26 additional hydropower dams in LMB.

2030-20Y (LMB 20-Year Plan Scenario), 2015 DF plus 11 LMB mainstream dams and planned tributary dams (30), irrigation, and water supply.

2030-20Y-w/o MD (LMB 20-Year Plan Scenario without LMB mainstream dams), as above, excluding 11 LMB mainstream dams.

2030-20Y-w/o LMD (LMB 20-Year Plan Scenario without lower mainstream dams), as above, plus 6 LMB mainstream dams in Northern Lao PDR.

2030-20Y-w/o CMD (LMB 20-Year Plan Scenario, excluding the two Cambodian mainstream dams).

2030-20Y-w/o TMD (LMB 20-Year Plan Scenario, excluding the two Thai mainstream dams).

2060-LTD LMB (Long-term Development Scenario), 2030-20Y plus further infrastructure developments in LMB.

2060-VHD LMB (Very High Development Scenario), as 2060-LTD, extended to full potential infrastructure developments.

high year-to-year variability of wet and dry season flows, as well as the frequency and intensity of floods and droughts, reversing the reduction of flooding (and wetlands) caused by current developments in the Decision Support System (DSF). In the longer term, the increased average flood season flows could be offset to some extent by the increased tributary storage.

Scenario data have been extensively reviewed and verified by each country. In all of the above cases, the data appear adequate to support basin-scale assessments. The risks of some incomplete data and knowledge were recognized. However, accelerated developments have demanded early information on transboundary impacts. During the process, the highest priority areas where greater understanding is needed have been identified. These knowledge gaps will be addressed during the implementation of the IWRM-based Basin Development Strategy.

8. The IWRM-based Basin Development Strategy

The Strategy has been owned and driven by the LMB countries through a process of scenario assessment and has been informed by wide stakeholder engagement across the basin. For the first time, the countries have reached—through information sharing and consultation—on a common understanding of each other's plans for water resources development, drawing initial conclusions together on likely transboundary impacts, addressing each other's concerns, developing a shared understanding of the opportunities and risks of water resources development, and agreeing on 12 strategic priorities to guide future decisions on basin development and management (MRC, March 2011).

The Strategy recognizes data and knowledge limitations. It therefore defines a dynamic basin development planning process that will be reviewed and updated every 5 years to ensure that decision making on water and related resources is based on up-to-date knowledge and feedback. A first update of the Strategy is expected in 2015.

8.1 Development Opportunities

The Strategy removes some longstanding barriers to realizing opportunities for sustainable development of the Mekong River. It shows that there is considerable scope for further basin development that will improve water, energy, and food security in the region. This makes the Mekong Basin unusual, if not unique among the world's river basins where water demand often outstrips supply.

The completion of two large storage dams on the Lancang (Mekong) in the PRC and continued dam construction on LMB tributaries for hydropower generation will considerably increase the dry season flows by redistributing water from the wet to the dry season. The increased flows offer an opportunity to source the countries' ambitious irrigation plans—including possible diversions into the Cambodian delta and into northeastern Thailand—without affecting the natural dry season flows, which will be protected through the MRC Procedure on the Maintenance of the Flows on the Mainstream (PMFM).

There is considerable potential for further development of tributary hydropower in the LMB, especially in Cambodia and the Lao PDR, requiring a focus on sustainability both at project and transboundary levels. There is an opportunity to consider some mainstream hydropower, provided the uncertainties and risks associated with mainstream dams are fully addressed, and the opportunity is provided for member countries to consider and address jointly the transboundary impacts of any proposed project (through the MRC Procedure on Notification, Prior Consultation and Agreement [PNPCA]).

There is considerable potential for other water-related developments, such as fisheries, navigation, flood and drought management, tourism, and environment and ecosystem management. The Strategy prioritizes the preparation of basin-wide strategies and the further identification of alternative opportunities beyond the water sector.

However, the Strategy also identifies the significant risks associated with some of these opportunities, including the trapping of sediments and blockage of migratory fish by dams. These risks must be managed and mitigated, both at the national level, and where relevant, through cooperation at the transboundary level.

8.2 Strategic Priorities

The Strategy defines a process to move from development opportunities to implementation and sustainable development, including the following strategic priorities for basin development:

- Opportunities and risks of current developments (to 2015) addressed, including coordination between LMB countries and cooperation with the PRC achieved, to ensure increased dry season river flows; the PMFM implemented to protect the maintenance of the flow on the mainstream; and

- risks of committed projects managed
- Irrigated agriculture for food security and poverty alleviation expanded and intensified; guidelines for fish-friendly development of irrigation schemes and for promoting integrated pest management prepared
- Environmental and social sustainability of hydropower development greatly enhanced, and sub-basins with high ecological value protected
- Essential knowledge acquired to address uncertainty and minimize risks of identified development opportunities, including knowledge on migration and adaptation of fish; trapping and transport of sediments and nutrients; changes in biodiversity, and social and livelihood impacts; climate change trends and extreme events; long-term flood management options for the Mekong delta; and alternative power options, including innovative hydropower schemes that do not affect connectivity in the lower basin
- Options for sharing development benefits and risks in the Mekong Basin identified, based on review of international approaches and case studies
- Climate change adaptation strategy prepared and its implementation initiated; pilot projects relevant to water-related sectors completed and scaling-up initiated
- Basin planning considerations integrated into national planning and regulatory systems, including the implementation of MRC procedures and guidelines, and the maintenance of a register of existing, ongoing, and planned water-related projects.

The Strategy defines strategic priorities for basin management, an essential companion to basin development to ensure sustainability and allow a more holistic and integrated approach to future updates of the development scenarios and this strategy, as follows:

- Basin objectives and management strategies defined for water-related sectors, including fisheries, flood and drought management, wetland management, and navigation
- National basic water resources management processes strengthened, including water resources monitoring, water use licensing, compliance assurance of license conditions and regulations, and data and information management
- Basin-level water resources and related management processes strengthened, including the implementation of MRC procedures, state-of-basin monitoring and reporting, project cycle

monitoring, enhanced stakeholder participation, and developing networks of national water resources management agencies and of RBOs

- Rigorous basin-wide environmental and social objectives and baseline indicators defined to provide a stronger framework for basin and national planning, including the assessment of development scenarios and the implementation of MRC procedures
- Water resources management capacity-building programme implemented, linked to MRC's overall initiatives, and complementary to national capacity-building activities.

The Strategy identifies a long list of essential basin-wide water resources management guidelines and sector guidelines needed for addressing basin-wide issues in sector development and management. Some of the guidelines have been or are being prepared, such as the transboundary environmental impacts assessment framework, preliminary design guidance for mainstream hydropower, and guidelines for integrated flood risk management.

8.3. Implementation of the Strategy

The IWRM-based Basin Development Strategy includes a road map setting out priority actions, timeframes, and outcomes of Strategy implementation. An early action is the preparation in 2011 of a Basin Action Plan that effectively addresses the development opportunities and strategic priorities in the Strategy by the LMB countries (NMCs, line agencies, and RBOs) together with the MRC programmes. The implementation of the Strategy will be supported by the BDP Programme (MRC, July 2011).

The Basin Action Plan comprises a coherent and consistent set of one regional action plan and four national indicative plans, one per LMB country. The regional action plan will include those activities that require joint implementation between two or more countries and which are best undertaken at a regional level. The national indicative plan will take account of existing national policies, regulations, and plans and will identify and describe the activities (both ongoing and supplementary) that the country believes best address the basin-wide development opportunities and strategic priorities in the agreed IWRM-based Basin Development Strategy (MRC, May 2011).

Table 3: Summary List of Main Consultations

Event	No. of meetings	Participants	Objective
MRC Joint Committee meetings	8 at the regional level	20-40	Review and approval of scenario formulation and assessment
National advisors/facilitators	12 at the regional level	5	Advisory, facilitation and mediation services
Regional BDP stakeholder forums	Annually at the regional level	150-300	Discussion of national positions at the regional level
Regional Technical Working Group	9 at the regional level	40-60	Technical validation of assessments
National consultations	4-7 in each country	20-40	Development of national policy and negotiation positions
JC Working Group Meeting	5	15-20	Negotiation of Strategy
Sub-area forums	2 in priority sub-areas	50-100	Data and information improvement
Transboundary meetings	1 in the 3Ss basin	120	Discussion of scenarios and improvement of transboundary cooperation
Meetings with interest groups (M-POWER, private developers, etc.)	6	10-100	Discussion of assessment approaches, methodologies, tools, data, results etc.

Most activities in the Basin Action Plan are likely to be nonstructural projects⁵ and enabling activities.⁶ It is probable that countries will choose to keep the identification and preparation of national infrastructure projects outside the national indicative plan, as they are clearly within national remit, and only enter MRC monitoring and reporting processes when countries are ready to submit proposed projects for the PNPCA process. Whatever the countries decide, it is important that the implementation of the Strategy promotes confidence and trust in the PNPCA process and facilitates the early referral of possible projects, and the use of MRC expertise in the early consideration of new projects.

Each activity identified in the Basin Action Plan will have an 'activity information sheet' sheet completed, which includes fields for objectives, scope, deliverables, monitoring indicators, implementation responsibilities, etc. The implementation of these activities will be aligned, to every extent possible, with MRC programmes and national sector planning and management cycles. Several regional activities have been taken up already by MRC programmes, supported by existing and new donors.

⁵ Examples are investments in improved management of water and related resources, such as monitoring, flood management, navigation, fisheries, and environmental health.

⁶ Examples at the regional level are: studies to reduce knowledge gaps, preparation of best practice guidelines, and strengthening cooperation with the PRC; at the national level: the institutionalization of MRC procedures within national systems, improvements of national plans and regulations, preparation of sector and/or sub-area strategies (fish, navigation, etc.), improvement of stakeholder participation, strategic directions to benefit from the development opportunities and to prevent or mitigate the negative impacts of hydropower development, and capacity building using guidelines and tools prepared at the regional level.

The completed activity information sheets will be used to promote unfunded regional and national activities and to monitor the implementation of the Strategy. The monitoring system will measure implementation progress and the achievement of the outcomes of the Strategy. It is proposed that this will be an electronic system and that consideration is given to web-based entry of progress information and access to progress reports.

It is expected that the implementation of the Strategy will lead to the following benefits for the Mekong Basin and the countries:

- Capture the mutual benefits that can be created by cooperation under the 1995 Mekong Agreement.
- Move the MRC beyond cooperation primarily on knowledge acquisition toward cooperation on water development and management.
- Lead to a strengthened framework for basin planning and management, including the improved implementation of MRC procedures and guidelines.
- Lay the foundation to a strengthened and broader-based approach to the formulation and assessment of scenarios and the updating of the Strategy in 2014/2015.
- Highlight areas where additional funding support is needed.

9. Stakeholders and Participatory Process

The scenario assessment and the IWRM-based Basin Development Strategy is the outcome of a three-year consultation process in which, primarily, each of the four

member States has been fully engaged and steering the planning process through collective decision taking at every stage. A summary of the main consultations held with national agencies, provinces, RBOs, community representatives, NGOs, academia, development partners, dialogue partners and others is provided in Table 3, illustrating the commitment made to ensure relevance and quality of the scenarios and Strategy.

To ensure transparency, all relevant documents have been posted on the MRC web site. The Strategy preparation, including scenario assessment, was overseen by experts from relevant national line agencies, national advisors and the MRC. An independent Panel of Experts provided an expert review of the underlying assessments and drafts of the Strategy.

The wide stakeholder engagement will continue during the implementation of the IWRM-based Basin Development Strategy. This will include national stakeholder forums and regional MRC forums with a mandate to undertake regular stakeholder reviews of the implementation of the Strategy.

10. Conclusion

For the first time since the signing of the 1995 Mekong Agreement, the four lower Mekong Basin countries have negotiated a Basin Development Strategy that provides opportunities for further development of the Basin's water resources and defines strategic priorities to move opportunities toward sustainable development and improve the management of water-related resources in the Mekong Basin. The Strategy recognizes data and knowledge limitations; however, accelerated development pressures demand guidance. The Strategy is a dynamic framework that will be reviewed and updated every 5 years to ensure that decision making on water and related resources is based on updated knowledge of the basin. The next update is expected by 2015.

At the heart of the Strategy is the move beyond regional cooperation primarily on knowledge acquisition towards cooperation on water development and management, and the move beyond national, sectoral planning toward comprehensive basin planning. The implementation of the Strategy has been initiated with the coordinated preparation of action plans at the regional and national levels. The implementation of the identified activities will be aligned, to the extent possible, with MRC programs

and national sector planning and management cycles. The next few years will show how the countries, together with the MRC Programmes, will capture the mutual benefits that can be created under the Strategy.

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MAINSTREAMING OF WETLAND ECOSYSTEM SERVICES IN POLICY PLANNING PROCESS – CASE OF VIET NAM

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Abstract

There is a great diversity of wetlands in Viet Nam that possess a range of resources, biodiversity, functions and important social, economic and cultural values. With an area of more than 10 million hectares, wetlands can be found in almost all ecological regions of the country. These wetlands play a vital role in the lives of the local people and the socio-economic development of the country. However, over the last fifteen years, wetland in Viet Nam has reduced both quantity and quality. The natural area of wetlands has been reduced while artificial wetlands have increased.

Environmental services of wetlands in Viet Nam include groundwater recharge and discharge, freshwater supply, climate regulation, biomass export, flood protection, wave and storm prevention, shoreline erosion control, coastline stabilization, and maintenance of biodiversity. Value of wetland is very significant. Understanding those environmental services would be initial input for mainstreaming the services in policy planning process to sustainable use and conservation of wetland.

The paper will review environmental services of wetland in Viet Nam, analyze the tools and methodologies applied for mainstreaming environmental services in policy planning and propose the approach to mainstream environmental services of wetland in planning progress.

1. Wetlands in Viet Nam

Wetlands in Viet Nam comprise of two groups: inland wetlands and coastal wetlands. Inland wetlands are present in all ecological regions and are very diverse in terms of type, morphology, resources, functions, values and potential for exploitation, usage and protection. Inland wetlands include permanently flooded river deltas, creeks, permanent or

temporary rivers and streams, freshwater lakes, peatland, swamps, saltwater lakes, mountain wetlands, geothermal wetlands, aquaculture ponds, lakes with areas greater than eight million hectares (ha), and marshes. Coastal wetlands are distributed widely along the coastline of Viet Nam, and include estuaries, tidal flats, lagoons, and marine water bodies with a depth not exceeding six meters at low tide.

Mangrove forests and mudflats are concentrated mainly in deltas, estuaries and tidal areas. Lagoons are present mainly along the coastline of central Viet Nam, from Hue to Ninh Thuan. Coral reefs and seagrass beds are distributed in the coastal area of south-central Viet Nam.

The area of wetlands in Viet Nam has decreased dramatically over recent decades. According to Mai Trong Nhuan², tidal wetlands in estuarine areas of the Mekong Delta decreased in area from 1,473,889 ha in

Figure 1: Decline of Mangrove Forests, Viet Nam, 1990-2007



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² As Mai Trong Nhuan, Inventory, Assessment and Planning of significant international and national wetland.

Box 1: Loss of mangroves in Viet Nam³

In 1943, the mangrove area was preliminarily estimated at 408,500 ha (Maurand, 1943), reducing to about 290,000 ha in 1962 (Rollet, 1963), to 286,400 ha after mangroves were sprayed with herbicides (1975) and to 252,400 ha in 1982 (Hong and San 1993). In Northern Viet Nam, from Mong Cai to Do Son, during 1964 – 1997, mangrove area reduced by 17,094 ha. The Red river plain saw mangrove reduction of 4,640 ha from 1975 to 1991, and only after two years (1993) a decrease of 7,430 ha (National Environment Agency, 2003).

The coastal zone of Southern Viet Nam witnessed little change of mangroves (from 250,000 ha to 210,000 ha) during 1950 – 1960; yet, the figure reduced to 92,000 ha of mangroves in 1975 due to the spraying of warring herbicides by the American force (1962 – 1972). During 1973 – 1988, annually, about 6,600 ha of mangroves were lost on average. In Minh Hai province alone (now are Ca Mau and Bac Lieu provinces), from 1983 to 1988, each year saw the loss of 6,820 ha, especially in 1988 – 1989 as much as 10,000 ha were lost (Institute for Fisheries Planning, 2003; Institute for Forest Inventory and Planning, 2003). During 1990 – 1995, 3,200 ha of mangroves were lost annually; in 1990 – 1991 alone, nearly 9,000 ha of mangroves were lost.

Source: Le Nguyen Hong, 2009.

1995 to 1,409,289 ha in 1999. The area of Bach Dang Estuary decreased from 64,169 ha in 1934 to 30,729 ha in 1997. Natural mangrove forests are being converted into aquacultural ponds, tourism facilities and planted forests. Over the past twenty years, 183,724 ha of mangrove forests have been lost while aquacultural areas have increased to 1.1 million ha in 2003. Data reported by the Southern Institute of Water Resources have shown that more than 50% of the total area of the Mekong Delta (approximately two million ha) is currently affected by salinisation. One of the reasons for this phenomenon is the loss of mangrove forests along the coast. Peatlands in U Minh covered about 90,000 ha in 1990, but as of 2005 only about 12,000 ha were left (Southern Sub-FIPI, 2005).

2. Ecosystem Services of Wetlands in Viet Nam

Functions of wetlands in Viet Nam include groundwater recharge and discharge, freshwater supply, climate regulation, biomass export, flood protection, wave and storm prevention, shoreline erosion control, coastline stabilization, and maintenance of biodiversity. Wetlands also provide opportunities for recreation, tourism and a favorable environment for many economic sectors including fisheries, forestry, water transportation, energy production, tourism, and mineral exploitation. Wetlands are vital sources for a major part of Viet Nam's population since they provide many benefits and contribute immeasurable

social, economic, cultural and environmental values to the industrialization and modernization in Viet Nam.⁴

Recharge and discharge of groundwater: During the rainy season, when there is a surplus of surface waters, wetlands act as storage tanks that allow water to gradually infiltrate into the groundwater systems later during the dry season. This is a continuous process that supplies water for groundwater aquifers. In addition, a continuous process of recharge and discharge of groundwater from wetlands and aquifers also contributes to groundwater purification. For instance, wetlands of *Melaleuca* forests in U Minh Thuong play a role in water storage, humidity regulation and moisture maintenance of the peaty soil layer. They can also prevent soil acidification and act as sources of water for domestic uses.

Trapping of sediment and toxic substances: Wetland ecosystems (especially lakes, mangroves, tidal marshes, and coastal bays) can function as sinks trapping sediments, pollutants, toxic substances or general wastes, in order to purify water and reduce the possibility of marine water pollution.

Nutrient retention: Wetland ecosystems can absorb nutrients, mainly nitrogen, phosphorus and micro minerals, which are important for micro-organisms, fisheries and forestry development. This process also reduces eutrophication in the Red River and Mekong River floodplains and some other waterbodies.

³ Le Nguyen Hong, Mangrove Forest In Viet Nam: Management and Proposed Action Plans for Preservation and Development.

⁴ Overview of Wetlands Status in Viet Nam Following 15 Years of Ramsar Convention Implementation.

Microclimate regulation: This function is particularly evident in areas having seagrasses, mangroves, and coral reefs, where wetlands contribute to balancing O₂ and CO₂ concentrations in the atmosphere, regulating microclimate (temperature, humidity, precipitation) and reducing the greenhouse effect.

Flood control: Wetlands (particularly mangroves, natural and man-made lakes) can function as water storage tanks, regulating rainfall and surface runoff, which slows the flow of flood water and reduces floods in surrounding areas of reservoirs such as Hoa Binh, Thac Ba, and Tri An.

Biomass production: Biomass produced in wetlands provides food sources for aquatic organisms, livestock, wildlife and domestic animals. In addition, part of the nutrient source from rotten and decomposed organisms is transported by surface flows and provides food sources to downstream and coastal areas.

Maintenance of biodiversity: Many wetlands, especially mangroves, coral reefs, and seagrasses, are favourable breeding, nursing and growing areas for a variety of wild fauna and flora. Many genetic resources, particularly those of rare and valuable species, are preserved in wetlands.

Wave and storm protection, shoreline stabilisation and coastline erosion control: Thanks to vegetation cover, especially mangrove forests, seagrass beds, and coral reefs, coastal wetlands can protect shorelines from waves, tides, erosion and tsunamis. They also provide a favourable environment for alluvial deposition which contributes to the stabilisation and extension of alluvial flats. Extensive coral reefs have reduced the intensity of waves that otherwise could affect coastlines and the areas surrounding islands during hurricanes and tsunamis. Recently, many natural wetlands (mangroves, coral reefs, seagrass beds) have been considerably degraded due to over-exploitation and land reclamation activities for agricultural and aquacultural development. Thus, shorelines are undergoing continuous change and coastline erosion has increased, especially along the coast of the Red River Delta, central and south-central Viet Nam, and the Mekong Delta.

Other functions of wetlands: Apart from the functions mentioned above, wetlands play a vital role in providing a favourable environment for economic activities in many sectors including agriculture, fisheries, forestry, water transportation, tourism, and mineral exploitation. Notably, 80% of Viet Nam's population is settled within wetlands.

Table 1: Type of Ecosystem Services of Wetlands in Viet Nam

Services	Value
Provision Services	
Food	Total value of mussel exploitation in National Park Xuan Thuy in 2004 has the estimated value of 7 to 10 million USD, contributing to local community income (Nguyen Huu Ninh, Mai Trong Nhuan, <i>et al.</i> , 2003).
Fresh Water	The wetlands in high areas such as Bien Ho, Ayun ha (Gia Lai province), Da Teh (Lam Dong province) has significant role in providing water sources for daily activities of local community and cattle.
Regulation Services	
Flood control	Wetlands (particularly mangroves, natural and man-made lakes) can function as water storage tanks, regulating rainfall and surface runoff, which slows the flow of flood water and reduces floods in surrounding areas of reservoirs such as Hoa Binh, Thac Ba, and Tri An.
Trapping of sediment and toxic substances	Wetland ecosystems (especially lakes, mangroves, tidal marshes, coastal bays and mangrove such as Xuan Thuy national Park, Van Uc mouth lake, Can Gio Mangrove, Tam Giang – Cau Hai – Thi Nai lagoon) can function as sinks trapping sediments, pollutants, toxic substances or general wastes, in order to purify water and reduce the possibility of marine water pollution.
Microclimate regulation	Study results of Le Van Khoi <i>et al.</i> (1999) display that on an area of 20,000 ha of mangrove plantations in Can Gio over the past 25 years, the forest trees have absorbed 10,164,440 tons of CO ₂ and the amount of O ₂ produced has been 6,776,296 tons.
Recharge and discharge of groundwater	Melaleuca forest (U Minh Thuong) plays role of water reservation, moisture control and keep the peatland level in wet condition.
Cultural services	Tourism wetland areas such as Ha Long Bay, Cat Ba Island, Con Dao Island, the beautiful beaches in Phan Thiet and Vung Tau, Phuong Nha-Ke Bang Cave, the historical monument in U Minh Thuong National Park, and ecotourism areas of Xuan Thuy Wetland Nature Reserve and Ba Be National Park have attracted many international and domestic tourists.

Ecosystem services of wetland play important roles for human well-being. The wetlands in the Mekong Delta encompass areas of valuable biodiversity and fertile areas for cultivation. It is these areas in the Mekong Delta that have been since long the rice granary of Viet Nam, which contribute around 80% of the exported rice quantity of the nation.

Mangrove forest plays an important role in disaster control. Estimated value of 3,100 ha of mangrove in Xuan Thuy National Park, Nam Dinh province would be around 2.6 million VND for its protection function for 10.5 km of dyke system in the area. In average, the value of mangrove forest for dyke protection can be calculated as 853,000 VND/ha/year.

3. Policy Framework for Wetland Management in Viet Nam

Over the last fifteen years, the Government of Viet Nam has paid great attention to the formulation and completion of a legislation system to establish a legal foundation for national governance, creating favourable conditions for international integration. A number of these regulations are related to wetland management. Legislation on environmental protection and nature conservation has contributed significantly to wetland protection. Viet Nam has passed more than 500 regulations on environmental protection and nature conservation since 1976. However, of these, only about ten refer directly to wetlands, while the rest are indirectly related through the protection of various components of wetlands such as water resources and wildlife protection.

Table 2: The Cuu Long River Delta Ecosystem Provisioning Services⁵

Item	Unit	1990	1995	2001
1. Food output by paddy	10 ⁶ ton	7.5470	13.986	16.1720
– Paddy	10 ⁶ ton	7.5230	13.885	16.0720
– Corn	10 ⁶ ton	0.0232	0.100	0.0938
2. Buffalo	indvdl.	154,056.0000	124,588.000	63,538.0000
3. Cow	indvdl.	186,017.0000	149,872.000	197,210.0000
4. Pig	10 ⁶ indvdl.	1.1180	2.408	2.9780
5. Poultry	10 ⁶ indvdl.	18.1740	34.052	44.2120
6. Expltd. Timber output	m ³	49,652.0000	315,631.000	459,262.0000
7. Expltd. Fuelwood output	10 ⁶ ster	0.5120	2.163	3.6960
8. Caught sea product output	ton	126,398.0000	421,286.000	648,121.0000
9. Caught aqu. product output	ton	12,860.0000	132,610.000	218,486.0000
10. Brding aqu. product output	ton	20,884.0000	261,797.000	414,386.0000
11. Export turnover	10 ⁶ USD	338.3960	730.485	1,468,946.0000

Table 3: Maintenance and Repair Cost of 20.7 km of Dyke without Protection Mangrove Forest in Giao Thuy (1997 – 2006) (Price in 2006, discount rate r = 10%)⁶

Year	Cost (VND)	Average cost (VND/km)
1997	1,469,403,442	70,985,674
1998	1,540,766,1707	74,433,174
1999	5,846,408,026	282,435,170
2001	1,174,909,885	56,758,932
2002	1,397,300,701	67,502,449
2003	2,376,497,838	114,806,659
2004	1,719,652,000	83,074,976
2005	30,734,000,000	1,484,734,300
2006	615,560,000	29,737,198
Total	46,874,498,598	
Average	5,208,277,622	251,607,615

⁵ Mekong Delta River Wetland Ecosystem Assessment.

⁶ Nguyen Tan Phuong, Forest valuation in Viet Nam.

Viet Nam has formulated and organised the implementation of an action plan relating to the conservation and development of wetlands. Some key documents of relevance to wetland management are the following:

Management strategy to the year 2010 for a protected area (PA) system in Viet Nam, with its main goals to establish and manage effectively PAs located in various ecosystems and to contribute to the protection of natural resources, biodiversity, while preserving the bountiful and unique landscape of Viet Nam. Various activities to develop and manage PAs are provided through this strategy. Conservation activities should be combined closely with development strategies, in order to promote roles and functions of a PAs system. The decisive principle of the strategy is sustainable development. The Strategy forms the basis for developing plans to manage protected areas in special-use forests, wetlands and marine areas. The strategy also identifies a set of strategic actions, including

- PA system planning
- Development of a legal framework for PA system management;
- Strengthening of natural resources management and biodiversity conservation;
- Reforming the organisation of the PA management system;
- Reforming procedures to establish, fund and invest in PAs;
- Training for human resource development, improvement of conservation knowledge and skills;
- Promoting information-education-communication and attracting community participation;
- Involvement in biodiversity conservation;
- Promoting international cooperation.

National Strategy for Environmental Protection Until 2010 and Vision toward 2020 identifies detailed objectives to ensure ecological balance at high level with the following targets:

- Recovering 50% of mining areas and 40% of severely degraded ecosystems;
- Increasing forest cover by 43% of total natural land, recovering 50% of degraded watershed forests and improving forest quality;
- Increasing total area of PNAs by half as much against current area, especially MPAs and wetland preserved areas;
- Recovering the area of mangrove forests by 80% as compared to 1990.

Government Decree No. 109/2003/ND-CP issued on 23 September 2003 addresses the conservation and sustainable development of wetlands. The Government requires establishing wetland reserves under strict protection regulations, including a prohibition of construction works and migration to the wetland sites. Buffer zones for wetland sites must be established, managed and be restricted with regard to exploitation, which would endanger the wetland sites conservation. The Decree identifies principles on conservation and sustainable use of wetlands; identifies detailed tasks on wetland management; and names the main state agencies involved in wetland management.

Circular no. 18/2004/TT-BTNMT dated August 23, 2004 guiding the implementation of the Government's Decree no. 109/2003/ND-CP of September 23, 2003 on conservation and sustainable development of wetlands. The Circular guides the conservation and sustainable development of wetlands with particular eco-systems and high biodiversity, among these those with functions of maintaining water sources or balancing the ecology, or those that are of international or national importance. For the conservation of wetlands, the circular identifies conservation criteria, conservation forms, institutional responsibilities for formulating projects to establish wetland reserves, management of wetland reserves, and the coordination of implementation activities.

The Viet Nam Biodiversity Action Plan (BAP) to the year 2010 and vision to the year 2020. One of the objectives identified under BAP is biodiversity conservation and development in wetlands and marine areas through:

- The increase of the total area of wetlands and marine reserves of national and international importance to over 1.2 million hectares.
- The restoration of 200,000 hectares of mangrove forests;
- The designation of five wetlands to be included in the list of wetlands of international importance (Ramsar sites).

Under major tasks, BAP identifies tasks for biodiversity conservation and development in wetlands and coastal areas, including:

- Building, developing and managing a wetlands and marine reserve system;
- Rehabilitating and developing wetlands and marine ecosystems;
- Sustainable use of wetlands and marine natural resources:

Decree 99 /2010/ND-CP on the Policy for Payment for Forest Environmental Services has identified principles of payment for forest environmental services as following:

- Organizations and individuals benefiting from forest environmental services must pay for forest environmental services to forest owners of forest that create the supplied services.
- Payment for forest environmental services is in money through direct or indirect payment methods.
- The payment for forest environmental services through a Forest Protection and Development Fund is the money that users of forest environmental services entrust the Fund to pay to owners of forests that supply forest environmental services.
- Payment for forest environmental services is factor of the production costs of products that use forest environmental services and does not substitute the resource tax or other payments stipulated by law.
- Transparency, democracy, subjectivity, and equity,

in line with the legal system of Viet Nam and international agreements that Viet Nam ratifies or joins, are ensured.

It can be recognized that even wetland management is mentioned mostly in environmental strategies, but not in development plans. In addition, the system of policies and regulations on wetland management has not been completed or synchronised. Specific provisions in legal documents relating to wetlands and ecosystem management often overlap, and are also often scattered within different pieces of legislation. The most promulgated Decree 99/2010/ND-CP on the Policy for Payment for Forest Environmental Services has provided initial step for taking in consideration the value of ecosystem services through payment system. However, it is can be recognized that ecosystem services have not been considered in many sector development plans. Also, there is still a lack of scientific tools which can help policy makers to consider the value of ecosystem services.

Table 4: Comparison of Valuation Methods

Group	Methods	Summary	Statistical analysis?	Which services valued?
1. Direct market prices	Market prices	Observe market prices	Simple	Provisioning services
2. Market alternative	Replacement costs	Finding a man-made solution as an alternative to the ecosystem service	Simple	Pollination, water purification
	Damage cost avoided	How much spending was avoided because of the ecosystem service provided?	Simple	Damage mitigation, carbon sequestration
	Production function	How much is the value-added by the ecosystem service based on its input to production processes?	Complex	Water purification, freshwater availability, provisioning services
3. Surrogate markets	Hedonic Price Method	Consider housing market and the extra amount paid for higher environmental quality	Very complex	Use values only, recreation and leisure, air quality
	Travel Cost Method	Cost of visiting a site: travel costs (fares, car use etc.) and also value of leisure time expended	Complex	Use values only, recreation and leisure
4. Stated preference	Contingent valuation method	How much is the survey respondent willing-to-pay to have more of a particular ecosystem service?	Complex	All services
	Choice experiments	Given a 'menu' of options with differing levels of ecosystem services and differing costs, which is preferred?	Complex	All services
5. Participatory	Participatory environmental valuation	Asking members of a community to determine the importance of a non-marketed ecosystem service relative to goods or services that are marketed	Simple	All services
6. Benefits transfer	Benefits transfer (mean value, adjusted mean value, benefit function)	'Borrowing' or transferring a value from an existing study to provide a ballpark estimate for current decision	Can be simple, can be complex	Whatever services were valued in the original study

Source: TEEB for local and Regional policymakers.

4. Mainstreaming of Wetland Ecosystem Services in Development Planning – Approach Methodology for Viet Nam

4.1. Tools for mainstreaming ecosystem services in development planning

There are number of tools which can apply to mainstream ecosystem services in to development planning. The following tools would be recommended to apply for Viet Nam:

1. *Poverty and ecosystem service mapping* overlays geo-referenced statistical information on poverty with spatial data on ecosystem services. The resulting maps can highlight important relationships, such as how the location of poverty compares with the distribution of services; which areas provide critically important services to the poor; who has access to natural resources; who benefits; and who bears the cost of changes to ecosystem services. Such overlays do not show causality, but suggest focus for further analysis.

2. *Economic valuation* assigns an economic value to ecosystem services that do not have a value in the market place, such as regulating and certain cultural services. The resulting information can draw attention to the value of ecosystem services that might otherwise be ignored when making decisions that affect ecosystems.

In general, economic valuation is effective in persuading decision makers of the value of ecosystem services by highlighting their economic contributions to societal goals; comparing the costs and benefits of ecosystem service protection versus engineering alternatives; and building markets for ecosystem services, such as global carbon markets or stewardship incentive programs for farmers.

3. *Action Impact Matrix* assesses the two-way interactions between development goals and ecosystems by exploring the effects of development goals on ecosystems as well as the effects of ecosystems on development. It can be used to determine economic, environmental, and social

Table 5: Entry Points for Mainstreaming Ecosystem Services⁷

Entry points	Ministry/Agency/Organization	Examples of decision processes
National and sub-national policies and plans	Development & planning	Poverty reduction strategies, land-use planning, water supply, and sanitation
	Environment	Protected area creation, climate adaptation strategies
	Treasury	National budgets, public expenditure reviews, audits
Economic and fiscal incentives	Physical planning, emergency planning, and response	Integrated ecosystem management of coasts, river basins, forest landscapes, and watersheds
	Finance	Subsidies, tax credits, payments for ecosystem services, import duties, and tariffs
	Budget office	Tax policies to support easements or promote alternative energy technology, pricing regulations for water
Sector policies and plans	Commerce and industry	Corporate codes of conduct/standards, assessment of new technologies
	Science and technology	Applied research, technology transfer, business capacity building
	Agriculture	Extension services, best management practices
	Forestry	Forest sector action programs, mapping initiatives, concession management
	Environment/ Natural resources	State of the environment reports, strategic environmental assessments, environmental impact assessments, information/ tools, legal instruments
Governance	Prime minister's or mayor's office, justice ministries, legislature, local government bodies	Decentralization policies, free press, civil society, accountability of government through elections, access to information and decisions, judicial review, performance indicators

⁷ Ecosystem Services: A Guide for Decision Makers.

priorities that facilitate management and restoration of ecosystem services. The tool is best used as part of a participative process (Munasinghe 2007).

4.2. Entry Points for Mainstreaming Ecosystem Services

Many entry points are at the national or provincial level. Opportunities for mainstreaming ecosystem services can be categorized into four intersecting entry points: national and sub-national policies, economic and fiscal incentives, sector policies, and governance. Table 5 summarizes the key entry point for mainstreaming of ecosystem services with example of decision processes.

4.3 Mainstreaming ecosystem services in development planning for Viet Nam

Given specific characteristic of Wetland in Viet Nam, the following approaches/steps would be recommended for mainstreaming of ecosystem services in development planning for Viet Nam.

Identify ecosystem services of wetland, its current condition and trend: The ecosystem services of variety type of wetland in Viet Nam should be understood and economic valuation of wetland should be conducted as evidence for policy makers to select the best options in their decision. Different method would be applied to assess ecosystem services, including remote sensing, GIS, ecological models, participatory approaches, depending on different types of services.

Develop ecosystem Services Trade-off: It is necessary to develop trade-off matrix to understand the winners and losers of any options while utilization of ecosystem services which can help to select the optimum options and to minimize negative impacts to ecosystem services. Trade-off matrix can be developed to compare the linkages between economic development and ecosystem services or the trade-off among ecosystem services such as provision services and regulating services. Trade-off analysis can strengthen decision making processes in term of selecting the most appropriate options

Choose policies to sustain ecosystem services: There are number of entry for mainstreaming ecosystem services. At national level, Strategic Environmental Assessment would be appropriate tools for mainstreaming of ecosystem services in national socio-economic development strategies, planning and plans; planning for land use,

forest protection and development in inter-provincial or inter-regional areas, etc.⁸ SEA could be used as a tool for taking in consideration the drivers which have negative impacts on ecosystem services in sector planning to reduce its impacts. Focused sector for mainstreaming of ecosystem services would be land use planning, mining, fishery, and forestry. At local level, ecosystem services can be mainstreamed in local development planning such as protected area program, integrated coastal zone management program.

Fiscal reform would be alternative to mainstream of ecosystem services: Other options for sustainable use of ecosystem services would be development of economic and fiscal incentives such as establishing fees for use of resources or services and use taxes or other public funds to pay for the maintenance of regulating and cultural services. Beside payment for forest ecosystem services which has been mentioned in Decree 99 /2010/ND-CP, other environmental services of other wetland type, including inland and coastal wetland would be considered in development planning.

Mainstreaming of natural capital into national accounting system: Incorporating the value of ecosystem services as natural capital in to national accounting system would be other option for conserving the services in Viet Nam. Initial steps would be application of System of Economic-Environmental Accounts (SEEA) to include of natural capital in accounting system.

⁸ These strategies/plans requires SEA before approval according to Law on Environmental Protection 2005.

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THE ROLE OF TREE CROPS IN LOCAL ADAPTATION TO CLIMATE VARIABILITY: LEARNING FROM THE FIELD

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Abstract

In the past decades, Yunnan Province in the southwest of the People's Republic of China has been frequently affected by floods and droughts as climate change impacts are increasingly felt. Based on studies in three villages in Baoshan Municipality, one of the foremost agricultural production areas in Yunnan Province, this paper presents the findings of the study “Too Much and Too Little Water” conducted by the International Centre for Integrated Mountain Development (ICIMOD), International Institute for Environment and Development (IIED) and Stockholm Environment Institute (SEI) together with the World Agroforestry Centre (ICRAF)/Kunming Institute of Botany (KIB), and explores agricultural diversification using trees on farms to support people's capacity to adapt to change, particularly climate-related changes. Results show that optimizing the integration of trees in agricultural landscapes as a tool for increasing adaptive capacity depends on tree crop diversification. In addition, a supportive policy environment is necessary.

1. Introduction

Climate change has had a particularly dramatic impact on ecosystem-based livelihoods, especially farmers engaged subsistence and small farm agriculture. One factor that contributes to household vulnerability is the use of monoculture production systems. Agricultural diversification, particularly when undertaken in relation to environmental or economic risks, has the potential to increase a household's adaptive capacity under climate change (Smit and Skinner, 2002). Diversification may also contribute to general agro-biodiversity and the sustenance of vital ecosystem structures and functions (Mijatovic, Paul Bordonni *et al.*, 2010).

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Agroforestry, the integration of trees into cultivated land, is an approach to agricultural diversification that can provide a range of benefits. It has been proposed as a strategy for climate change mitigation and adaptation as well as for addressing issues of food security and environmental degradation in agricultural systems. Agroforestry is gaining popularity as an adaptation strategy in part because traditional agricultural systems often include elements of agroforestry practices (Rafiq, Amacher *et al.* 2000; Liang, Shen *et al.* 2009). Thus, agroforestry can often be less costly and more efficient to implement than other approaches. However, with increasing market development, monoculture has replaced traditional agricultural diversification practices in some areas. Monoculture systems need to be re-examined for their viability in the context of climate change which will likely lead to changes that reflect growing uncertainty and increasing risks.

In the People's Republic of China (PRC), after severe droughts in 1997 and massive floods in 1998, on-farm tree planting or the “Sloping Land Conversion Program” (also known as the “Grain to Green Program”), was introduced to convert the croplands occurring on steep slopes to forested land in order to reduce water-induced disasters. These actions resulted from the realization that the droughts and floods were at least partially caused by farming on steep slopes and deforestation. This paper presents the findings of one of the case studies conducted in Baoshan Municipality, Yunnan Province, PRC, as part of the consolidated research “Too Much and Too Little Water” from four countries: the PRC, India, Nepal, and Pakistan. The paper focuses on the impact of water stress conditions and communities' coping responses.

2. Research Methodology

The study sites were in Yunnan Province in the PRC. Yunnan covers 394,000 km² and includes the headwaters of three of Asia's largest rivers. It is home to 46 million people, most of whom dwell in mountain regions. The montane geography creates a mosaic of settlement patterns, land use, and livelihood practices. Residents, including 25 distinct ethnic minority groups, have adapted in ways that demonstrate their local ecological knowledge and intimate relationship with the environment and climate.

For the study, three villages in Baoshan Municipality—Xinzhai, Shuiyan and Haitang—were selected for detailed study based on their diversity of elevation, climate, and

agricultural systems (Map 1), additional details are provided in Table 1. Because a severe drought was affecting the study area during the research period, all the villages were experiencing extreme water shortages to different degrees and with different consequences in production and income. The Rapid Rural Appraisal included water source mapping with key informants.

In the first round of the study, we analyzed the response of communities and their vulnerability to climate change. We also documented local practices to cope with climate impacts, including information about community perceptions and observations on the impacts of climate change on tree crops and the role they play in adaptation. We also asked farmers why they plant trees, whether

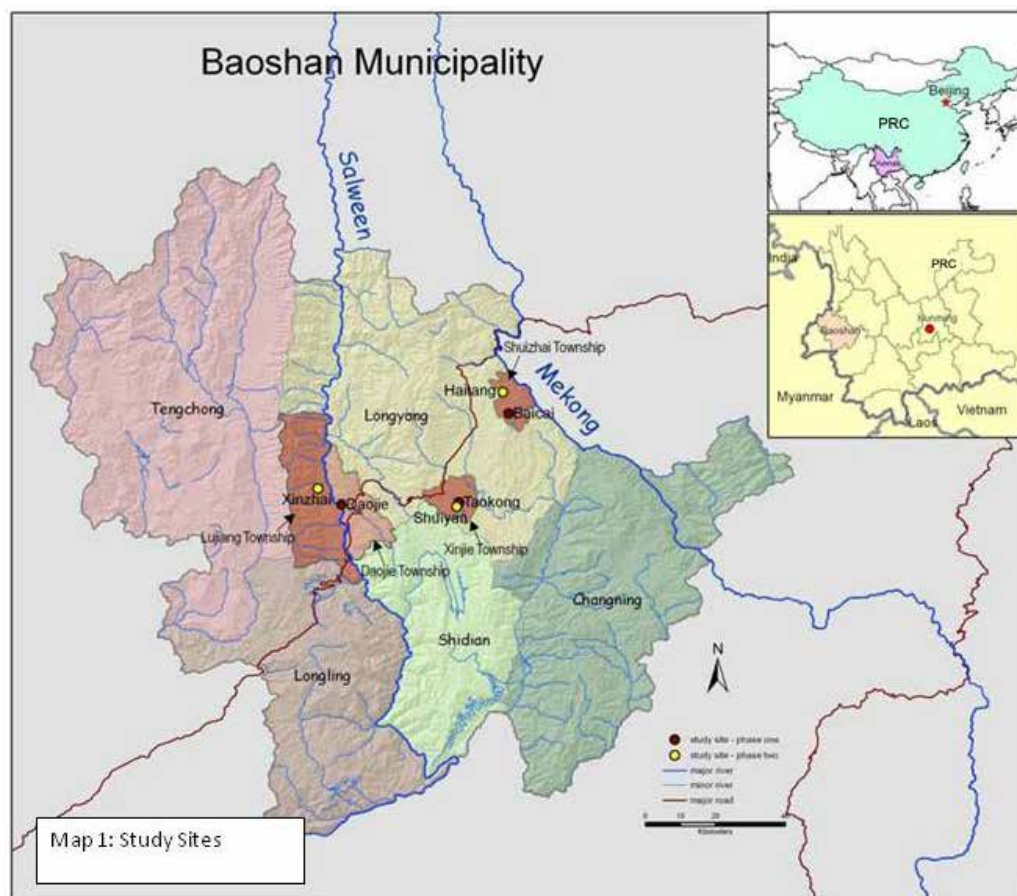


Table 1: Details of Study Sites

Location	Low leivation	Middle leivation	High elvation
Communities	Xinzhai	Shuiyan	Haitang
Elevation (m)	950	1,720	2,473
No. of households	545	560	371
Climate	Hot, low precipitation, high evaporation	Medium to warm temperature and medium evaporation	Low temperatures, high precipitation, and low evaporation
Temperature trend	Increasing	Increasing	Increasing
Major stress as perceived by the community	Water shortage in Spring & droughts	Water shortage in Spring and hail in Summer/ Autumn and droughts	Water shortage in Spring
Major crops on irrigated land	115 ha: coffee, paddy rice	50 ha: tobacco, paddy rice	Not applicable
Major crops on rain-fed land	155 ha: maize, coffee	112 ha: tobacco, maize, walnut, pear	116 ha: maize, barley, potato, beans, pepper, walnut
Population trends	Increasing	Increasing	Decreasing

existing policy and government programs support them, and how tree crops contribute to national adaptation strategies. These qualitative data were supported by quantitative data where relevant.

We discovered that most responses were oriented more toward short-term adaptation rather than long-term planned practices. We also found that policies always play a significant role in peoples' ability to respond to too much and too little water, even though the policies are, at times, unclear and weak in implementation. The capacity of formal and informal institutions also has to be enhanced to cope with and adapt to climate variability.

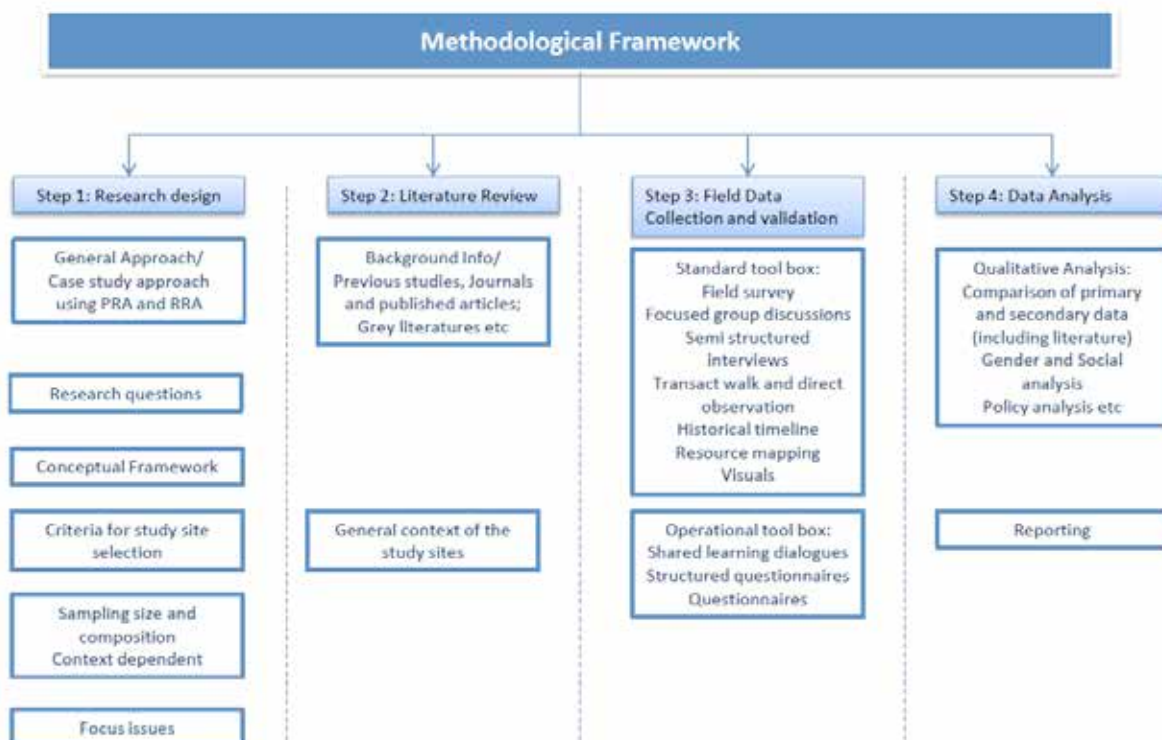
Building upon these findings, in the second round of research in Yunnan, we focused on agroforestry diversification. In this stage, secondary data on the role of trees on farms as an adaptation strategy were collected and analyzed. These data included related published literature, meteorological observations, government policies, event-related press releases and land-use and agricultural production data. Primary data were collected through rapid rural appraisals (RRA), questionnaire surveys involving key informants and group interviews, transect walks, crop calendars, and

field observations (Figure 1). Sites were selected based on the representativeness of the major agro-ecosystems in the area, with consideration of the role of trees in local livelihoods, climate and elevation gradients, and the existence of water stresses and other climate change impacts. Questionnaire surveys of both males and females were carried out in three villages. Finally, quantitative analysis was undertaken using descriptive statistics and ANOVA tests in Microsoft Excel and SPSS.

3. Key Findings and Lessons

The drought experienced in Baoshan in 2009-2010 was the worst reported in 100 years. The impact on tree crops varied depending on the species and age; accordingly, the impact on households varied depending on the species. Different trees not only had different levels of resilience to drought in terms of yield, but functioned differently as long-term assets for households that invest in them. As farmers experience changes that may increase uncertainty and the risk of climate-related shocks, the impacts on production systems invite a re-examination of how they provide resilience against risk events and longer-term change.

Figure 1: Methodological Framework



Following are the key findings and lessons from the research. However, these findings cannot be generalized for all locations and weather conditions.

3.1 Agricultural Production Faces Increased Uncertainty and Risks Due to Climate Change and Variability

The findings of this study validate international and regional discourse that has found that the agricultural sector and livelihoods are most severely affected by climate change and variability (Hendow *et al.*, 2007; Morton, 2007).

In most of the study areas, households depend on agriculture for their subsistence. The sources of irrigation for the agricultural fields are small springs and rivers, monsoon rains, snow melt, and small community irrigation systems. The agricultural sectors in the study areas were already impacted by extreme climatic situations, like flash floods and droughts, that reduced the crop yield and quality, whereas agroforestry systems were found to be more climate-resilient. For example, farmers estimated that walnut trees experienced a yield increase of 20%–30%, which enhanced the coping capacity of farmers and forestry workers.

In addition, farmers in both Haitang and Shuiyan observed that, of the walnut trees planted in 2007–08, only 10%–20% died in the 2009 drought, while of those planted in 2009, about 40%–50% died in the drought in 2010. However, nearly 100% of walnut trees planted five or more years ago survived the drought. Nearly all Sichuan pepper trees, very few of which were newly planted, survived.

3.2 Diversification of Crops, Including Tree Crops, Improved the Resilience of Communities; Monoculture Systems were More Vulnerable to Climatic and Nonclimatic Shocks

Results showed that during droughts, the three villages coped very differently. Although tobacco and grain crops were greatly affected by drought, the Government's extension program targeting tobacco growing areas in Shuiyan was successful in reducing the overall yield loss of tobacco. Also, the diversity of income sources, including non-timber forest products, and resilience of mature stands of walnut trees, meant that household incomes in Haitang were somewhat secure during the drought. However, due to the widespread failure of coffee crops that were the only source of income for the households

in Xinzhai, people were forced to make emergency responses for survival, such as the purchase or rental of water pumps and migration of women and men for off-farm work opportunities.

Monoculture has, in the past, been encouraged because of immediate economic gains, but mountain communities are finding belatedly that reliance on monoculture plantations makes them extremely vulnerable to climate and economic shocks. Therefore, some farmers often look to diversification of crops and livelihoods as an adaptation strategy.

3.3 Adaptive Capacity of Communities is Driven more by Markets and Government Policy than by Awareness of Climate Change

The goal of the governments' Sloping Land Conversion Program was to convert 14.66 million hectares of farmland into forest land to reduce soil erosion. Likewise, Baoshan Municipal Government initiated an expansion of walnut production, with the goal of planting over 30,000 ha of walnut trees in the study area of Longyang District. The Government's policy, however, encouraged farmers to plant tree crops without considering climate resilience. Policies to invest heavily in a single tree crop without diversification fail to account for the impact of climate change and the variability of the single crop, which will have an impact on the income and livelihood of the people.

4. Conclusion and Policy Recommendations

We found that trees on farms play a varied role in farmers' response strategies under changing and increasing climate-related stresses. The benefits of trees depend on a number of factors and conditions often specific to the species. The main climate change-related threats include production systems and the local socioeconomic context. Results showed that integrating or expanding monoculture tree plantations may maintain or increase levels of vulnerability, while the use of multiple tree species often greatly improves resilience in agricultural systems and household livelihoods.

Policies to diversify tree crops and market incentives play strong roles in promoting the adoption of trees on farms. However, the study also showed that current markets and policies do not account for long-term climate changes and the possibility of increasing climate risks that

may affect the productivity and survival of trees. Without greater consideration of the impacts of climate change and climate variability on tree crops, communities will be unable to optimize the use of trees on farms for agricultural diversification or for enhancing their adaptive capacity. We offer the following recommendations to strengthen the impact of national and local policies on adaptation to climate change:

- Revisit the effectiveness of existing and proposed policies and programs to strengthen adaptation strategies and ensure that they do not increase small holders' vulnerability to climate variability and climate risks.
- Allocate government resources to minimize vulnerability and risks and enhance household resilience.
- Document and analyze the knowledge of farmers, local extension workers, and scientists on the response of tree crops to climate change and vulnerability and develop tools to determine their potential to enhance resilience.
- Share information on the implications of climate change on agricultural systems and successful adaptation strategies that employ crop diversification.

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MANAGING CONCESSION FORESTS FOR CARBON BENEFITS IN CAMBODIA

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Abstract

The scheme to reduce emissions from deforestation and forest degradation, including conservation, sustainable management of forests, and enhancement of forest carbon stocks (REDD+) of the United Nations Framework Convention on Climate Change is a carbon-based compensation for projects that resulted in reducing carbon emissions or enhancing carbon sinks or both in tropical forests. However, estimating such emissions and sinks remains challenging, and thus making it impossible to estimate carbon revenues from managing tropical forests. Here, we estimated the reduced emissions and sinks by developing models for setting reference emission level (REL) and project emission level (PEL) for REDD+ projects in concession forests taking emissions under conventional logging (CVL) scenario as that of REL, and emissions under reduced impact logging (RIL) and RIL with liberation treatment (RIL+) scenarios as that of PEL. Cambodia logging was used as a case study. REL under the current 25-year cutting cycle was estimated at 23.1 teragrams of carbon dioxide (TgCO₂)/year. To determine an appropriate cutting cycle, we tested our models with four cutting cycles and found that a 50-year cutting cycle is more appropriate. Taking this 50-year cutting cycle as a REDD+ project, PELs were estimated at 0.4 TgCO₂ and -3.3 TgCO₂/year (“-” means a carbon sink) under RIL and RIL+, respectively. After subtracting REL with PEL and leakages, annual carbon credits from managing 3.4 million hectares of concession forests in Cambodia were estimated at 15.9-18.5 TgCO₂ depending on chosen scenario. At a carbon price of \$5 per megagram of CO₂, total revenues from the sales of carbon credits alone would be \$79.5-92.5 million annually. To ensure continued flow of wood supply from tropical forests while mitigating climate change, we suggest that new climate agreements adopt RIL or RIL+ for sustainable forest management in tropical countries.

1. Introduction

Negotiations for new climate agreements were to be discussed at the 17th Conference of the Parties (COP17) of the United Nations Framework Convention on Climate Change (UNFCCC) in Durban, South Africa in December 2011. Among the expected agreements were the financial incentives for mitigating climate change through reduced emissions from deforestation and forest degradation, improving forest conservation and sustainable forest management, and enhancing carbon sinks or the “REDD+” scheme. REDD+ is an attractive option because it is less expensive (van Kooten *et al.*, 2004; Kindermann *et al.*, 2008; Sasaki and Yoshimoto, 2010) than other options being taken under the Kyoto Protocol. In addition, it contributes directly to improving the livelihood of forest-dependent communities and therefore helps to achieve sustainable development of poor nations, while still contributing to mitigating global climate change (Houghton, 2003; Gullison *et al.*, 2007). The anticipated REDD+ agreements have also attracted increasing research to estimate the carbon emission reductions and the associated costs of implementing the specified management activities, and how such emission reductions can be monitored and verified. Recent data suggest that between 2000 and 2009, land-use change (mostly tropical deforestation) was responsible for the release of 1.1±0.7 petagrams of carbon (Pg C) (about 4 billion tonnes of carbon dioxide [CO₂]) (Friedlingstein *et al.*, 2010). Kindermann *et al.* (2008) suggest that 50% of carbon emissions from tropical deforestation could be halted at carbon prices of \$5.20-38.15 per megagram (Mg) of CO₂ (tonne CO₂) varying by continent.

Sasaki and Yoshimoto (2010) focused on the opportunity costs of managing tropical forests versus clearing these forests to develop industrial plantations, and suggested that managing tropical forests for timber production under the REDD+ mechanism would be preferable because of the huge potential revenues and other benefits from the ecosystem services provided by these forests. Toni (2011) suggests the need for REDD+ decentralization in order to effectively manage the revenues from REDD+ scheme while protecting tropical forests. Although previous studies clarified the fundamental basis for understanding the potential of REDD+, many failed to address the potential reductions in carbon emissions and the timber supply from sustainably managing concession forests. Estimating emission reduction potentials requires an understanding of the reference emission level (REL: emissions in the absence of project activities) and the project emission level

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(PEL: emissions from project implementation) (Ty *et al.*, 2011).

Sustainable forest management (SFM) is an important part of REDD+, because it maintains wood supply from the forests to meet increasing demands for wood while generating employment and revenues for owners of the forest resource or for governments in developing countries. SFM is strongly affected by logging practices (Pearce *et al.*, 2003; Asner *et al.*, 2006; Sasaki and Putz, 2009), and logging practices are generally carried out by logging companies or concessionaires in the tropics. If SFM is finally included in the REDD+ scheme under the new climate change agreements, a sound management system is required for managing concessions because the current logging practices have been responsible for rapid forest degradation and deforestation (Asner *et al.*, 2006; 2010). Furthermore, logging practices strongly influence the end-use wood supply and carbon stocks in concession forests in the tropics (Sist *et al.*, 2003; Kim Phat *et al.*, 2004; Sasaki, 2006), it is therefore necessary to understand which logging systems are both sustainable and economical.

To better inform policy makers as well as negotiators of the REDD+ scheme, there is critical need for developing methods for estimating the REL and PEL. Until recently, there was no agreed-upon method for estimating them (Sist *et al.*, 2003), especially for REDD+ projects leading to reduced forest degradation and/or enhancing carbon sinks in concession forests where commercial logging for hard currency earnings is being practiced. Aiming at proposing an appropriate system for managing tropical forests under the anticipated REDD+ scheme, we analyzed the potential of carbon emission reductions from managing concession forests while maintaining a continuous supply of end-use wood products from concession forests in Cambodia.

2. Study Methods

2.1. Concession forests

Natural forests in the tropics are commonly managed under a forest concession system, in which the government as the forest resource owner issues logging licenses to logging companies, i.e., forest concessionaires, to harvest the timber as per guidelines and laws of the country. In 2006, Cambodia had a total forest cover of 10.7 million ha or about 59% of the country's total land area (Forestry Administration, 2008). Deforestation rate

was estimated at about 0.7% between 1973 and 2003 (Sasaki, 2006) and about 0.8% between 2002 and 2006 (Forestry Administration, 2008). There are three major forest types in Cambodia, namely evergreen, semi-evergreen, and deciduous forests. Other forest types include inundated and mangrove forests and forest plantations, but these represent only a small proportion of the total forest cover. The annual rate of loss of evergreen, semi-evergreen, and deciduous forest was about 0.35%, 1.59%, and 0.73%, respectively, between 2002 and 2006. Of the 10.7 million ha, concession, protection, and conversion forests account for 36.1%, 43.1%, and 20.8%, respectively. The 3.4 million ha of concession forests are under the jurisdiction of the Forestry Administration of the Ministry of Agriculture, Forestry, and Fisheries (MAFF). Prior to a logging ban in early 2002, a 25-year selective cutting cycle was used for managing concession forests in Cambodia. We used this cycle as our business-as-usual cutting cycle.

2.2. Management Scenarios

Almost all logging practices in the tropics are carried out with little or no proper management plan or trained staff (Putz *et al.*, 2008; Sasaki *et al.*, 2011). Such logging is termed here as conventional logging (CVL)—logging practices that require neither formal planning nor trained staff. CVL causes much damage to the residual stands and wastes large amounts of wood, both in the forest and at the sawmill or pulp and paper plant (Holmes *et al.*, 2002). In contrast is reduced-impact logging (RIL) management. A management scenario that includes RIL and a “liberation” treatment is termed RIL+. RIL involves proper training of logging staff; well-defined logging plans; careful planning of main, secondary, and feeder road locations before harvesting and extraction; directional felling; cutting stumps low to the ground; minimizing wood waste caused by felling, skidding, and road transportation; minimizing road and trail widths; minimizing landing size and maximizing landing spacing; minimizing ground disturbance; paying attention to forest aesthetics; and minimizing damage to the residual stand. Holmes *et al.* (2002) and Sasaki and Putz (2009) provide more details about RIL practices. RIL is a promising logging practice for managing tropical forests (Putz *et al.*, 2008) because it involves careful planning to minimize waste and adverse impacts on the residual stand. RIL+ additionally uses a liberation silvicultural treatment, in which unwanted trees that are competing with future crop trees are girdled to kill them. By reducing the competition from unwanted trees, growth rates of the crop trees can be increased by 20%–

60% compared with the growth rate in forests where only RIL is implemented (Peña-Claros *et al.*, 2008; Villegas *et al.*, 2009).

2.3. Carbon Stock Changes

We describe the changes in the above-ground carbon stocks per hectare in tropical forest under the CVL, RIL, and RIL+ approaches using the following modified equations of Kim Phat *et al.* (2004):

$$\frac{dCS_i(t)}{dt} = \text{MAI} - [\text{LM}_i(t) - H_i(t)] \times \text{BEF} \quad (1)$$

$$H_i(t) = \frac{f_M \times f_H}{1 - r} \times \frac{CS_i(t)}{T_c \times \text{BEF}} \quad (2)$$

where:

$CS_i(t)$: aboveground carbon stock (megagrams of carbon per hectare [Mg C ha^{-1}]) under logging system i (where i is CVL, RIL, or RIL+) in year t . It is assumed that forest management starts in 2010, and therefore t_0 is corresponding to 2010, the start of the simulation

MAI: mean annual increment ($\text{MgC ha}^{-1} \text{ year}^{-1}$)

$\text{LM}_i(t)$: carbon in dead trees lost due to logging-induced mortality ($\text{Mg C ha}^{-1} \text{ year}^{-1}$)

$H_i(t)$: harvested carbon ($\text{Mg C ha}^{-1} \text{ year}^{-1}$)

BEF: biomass expansion factor (ratio of total aboveground biomass to stem biomass)

f_M : proportion of mature trees

f_H : legal rate of harvesting permitted by the government

r : rate of illegal logging

T_c : cutting cycle (years). To determine an appropriate logging cycle for managing concession forests in Cambodia, four cutting cycles, namely 25 years (previously adopted cycle), 40 years, 50 years, and 60 years.

2.4. Wood Products Model

Under both logging systems, we calculated the quantities of the following wood components: wood products (WP), wood waste (WAS), logging mortality (LM), end-use wood products (EWP), and end-use wood waste at sawmill or pulp and paper mill (EWAS) using the following equations:

$$\text{WP}_i(t) = (1 - s_i) \times H_i(t) \quad (3)$$

$$\text{WAS}_i(t) = H_i(t) - \text{WP}_i(t) \quad (4)$$

$$\text{LM}_i(t) = \alpha \times H_i(t) \quad (5)$$

$$\text{EWP}_i(t) = (1 - a_i) \times \text{WP}_i(t) \quad (6)$$

$$\text{EWAS}_i(t) = \text{WP}_i(t) - \text{EWP}_i(t) \quad (7)$$

where:

s_i : proportion of unusable wood after deducting losses due to logging, skidding, and damage during transportation

Table 1. Parameters, Assumptions, and Sources of Data

Description	CVL	RIL	RIL+	Sources
CS(0)	134.01	134.01	134.01	Average from Kao and Iida (2003), Kim Phat <i>et al.</i> (2004), Sist and Saridan (1998), Chave <i>et al.</i> (2005), Wellhöfer (2002), and Nascimento and Laurance (2002)
f_M	0.50	0.50	0.50	Kim Phat <i>et al.</i> (2004)
f_H	0.30	0.30	0.30	Kim Phat <i>et al.</i> (2004)
r	0.50	not applicable as explained in equation (11)		Assumed based on Kim Phat <i>et al.</i> (2004)
T_c	25	25	25	Practiced in Cambodia until logging was banned in 2002
MAI (Mean Annual Increment)	0.66	0.66	0.99 ¹⁾	Elsewhere in tropics 0.64 reported in Lewis <i>et al.</i> (2009) and 0.72 reported in Phillips <i>et al.</i> (1998) ¹⁾ : assumed 50% increase in MAI based on Peña-Claros <i>et al.</i> (2008) and Villegas <i>et al.</i> (2009)
BEF	1.74	1.74	1.74	Brown (1997)
α	1.0 ²⁾	0.5 ³⁾	0.5 ³⁾	proportion of $H(t)$ ²⁾ : see Kim Phat <i>et al.</i> (2004) for more explanation ³⁾ : based on Chheng (2011)
s (WAS)	0.30	0.10	0.10	30% waste for CVL, and 10% for RIL. See Kim Phat <i>et al.</i> (2004) for details
Wood waste due to processing				
a (EWAS)	0.50	0.40	0.40	50% waste for CVL, 40% for RIL (see Kim <i>et al.</i> , 2006)

under system i (CVL, RIL, or RIL+)

α : proportion of trees killed by logging, log skidding

a_i : wood processing efficiency (wood recovery) under system i

The units of WP, WAS, LM, EWP and EWAS are $\text{Mg C ha}^{-1} \text{ year}^{-1}$, otherwise stated

2.5. Maintaining the End-use Wood Supply

Sustainable forest management cannot be achieved if maintaining a long-term sustainable wood supply is not part of the management goals. In this analysis, we assumed that the EWP produced under the CVL system is a baseline against which the EWPs from RIL and RIL+ are compared. Therefore, the EWPs from both logging practices must be equal:

$$\text{EWP}_{\text{CVL}}(t) = (1 - a_{\text{CVL}}) \times \text{WP}_{\text{CVL}}(t) \quad (8)$$

$$\text{EWP}_R(t) = (1 - a_R) \times \text{WP}_R(t) \quad (9)$$

where the subscript “R” means that the equation can be used for both RIL and RIL+.

To maintain a long-term wood supply under the REDD+ scenario (using RIL or RIL+) that is comparable to that under the baseline scenario (using CVL), the wood supply under CVL must be maintained:

$$\text{EWP}_R(t) = \text{EWP}_{\text{CVL}}(t) \quad (10)$$

or

$$H_R(t) = \frac{(1 - a_{\text{CVL}})(1 - S_{\text{CVL}})}{(1 - a_R)(1 - S_R)} \times H_{\text{CVL}}(t) \quad (11)$$

This study only includes above-ground carbon stocks. Below-ground carbon and carbon fluxes in various harvested wood products are not accounted for.

2.6. Reference Emission Level, Project Emission Level, and Carbon Crediting

Crediting reduced carbon emissions (carbon credits) requires the understanding of at least three important variables: reference emission level (REL) or baseline emissions or emissions in the absence of project activities, project emission level (PEL) or emissions resulted from implementing the projects, and leakages (L) or the emissions outside the project boundaries. Until recently, there was an agreed formula for determining REL, PEL or L (Angelsen, 2008). As the REDD+ scheme is performance-based compensation for reduced carbon emissions or sinks resulting from project activities,

we developed equations for estimating carbon credits from project implementation in concession forests in the tropics. Carbon credits can be derived by:

$$\text{CC}(t) = \text{REL}(t) - \text{PEL}(t) - \text{L}(t) - \text{EP}(t) \quad (12)$$

$$\text{REL}(t) = [\text{CS}_{\text{CVL}}(t) - \text{CS}_{\text{CVL}}(t-1)] \times 3.67 \quad (13)$$

$$\text{PEL}(t) = [\text{CS}_{\text{RIL}}(t) - \text{CS}_{\text{RIL}}(t-1)] \times 3.67 \quad (14)$$

$$\text{PEL}(t) = [\text{CS}_{\text{RIL}}(t) - \text{CS}_{\text{RIL}+}(t-1)] \times 3.67 \quad (15)$$

where:

CC: Carbon credits

REL(t): Reference emission level at year t ($\text{TgCO}_2 \text{ year}^{-1}$). Emissions under the conventional logging (CVL) scenario is taken as baseline emissions

PEL(t): Project emission level at year t ($\text{TgCO}_2 \text{ year}^{-1}$)

L(t): Leakages or carbon emissions outside project boundary ($\text{TgCO}_2 \text{ year}^{-1}$). L in forestry project is difficult to estimate but Murray *et al.* (2002) found that L varies greatly from one location to another. For simplicity, 30% is assumed for L for our study.

EP(t): Emissions from project's fieldwork activities such as emissions from logging operations and wood transportation. According to UNFCCC (2008), emissions that account for 10% or less of the overall emissions can be excluded from the calculation. Therefore, we excluded EP in our carbon credits calculation because it is unlikely that EP is more than 10% of the overall emissions

$\text{CS}_{\text{CVL}}(t)$, $\text{CS}_{\text{RIL}}(t)$, $\text{CS}_{\text{RIL}+}(t)$: Carbon stocks in the year t under CVL, RIL, and RIL+ scenarios, respectively (TgC)
3.67=44/12: is the ratio of the molecular weight of CO_2 (44) to the molecular weight of carbon (12)

If $\text{PEL}=0$, the project neither generates carbon sinks nor source. If $\text{PEL}(t) < 0$, the project generates sinks from the applications of RIL or RIL+ because their application can reduce harvested wood, thereby reducing damage to residual stands, while still maintaining the wood supply equivalent to that under the business-as-usual scenario; e.g., under conventional logging. If $\text{PEL}(t) > 0$, the project generates sources. But, as long as $\text{PEL}(t) < \text{REL}(t)$, “additionality” or “carbon credits” can still be achieved.

2.7. Wood Products and Overall Carbon Stocks

Total wood products and carbon stocks for each scenario from managing 3.4 million ha of concession forests in Cambodia are the products of respective variables and area of concession forests.

3. Results and Discussion

3.1. End-use Wood Products and Wood Wastes

The study assumes that the demand of end-use wood products is equivalent to that produced under the conventional logging scenario (Equation 10), regardless of the source of end-use wood products, due to the lack of information on actual timber demand and supply in Cambodia. The supply is maintained under the RIL and RIL+ scenarios. Under the cutting cycle of 25 years for all three management scenarios, managing 3.4 million ha of concession forests in Cambodia produces, on average, 3.1 million cubic meters (m^3) per year of end-use wood products, but at a declining rate of 1.8% annually over the entire 25-year period (Figure 1). In terms of wood wastes (on-site and at the sawmill), CVL creates 5.8 million m^3 /year over the same period, while only 2.6 million m^3 /year of wastes are created under the RIL (including RIL and RIL+) or less than half that created by CVL. Wood wastes under CVL result from unprofessional logging, log skidding, trimming and transporting, and wastes at the sawmill.

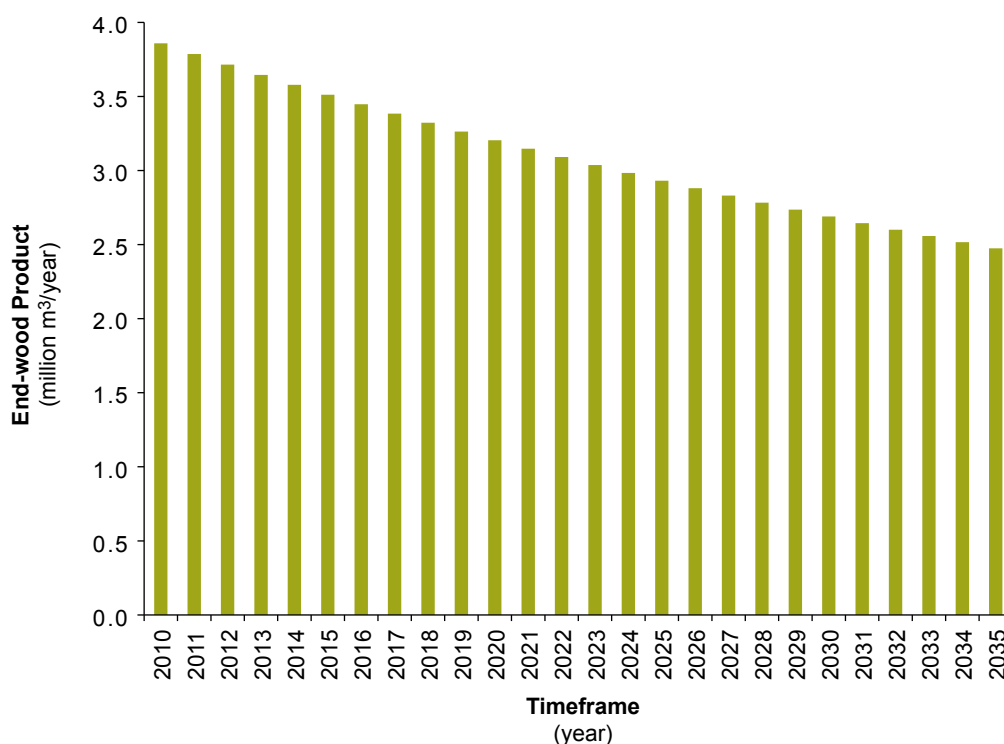
Illegal logging strongly influences the quantities of end-use wood products and carbon stocks in the forests. If half

of the wood from illegal logging is eliminated ($r = 0.5/2$), wood supply is maintained at 2.3 million m^3 /year but rate of decline is about 1.0%. If illegal logging is completely eliminated ($r = 0$), wood supply is maintained at 1.8 million m^3 /year while the rate of decline is only about 0.7%. Our estimates are well within wood production estimates of the World Bank *et al.* (1996) and DAI (1998) who reported annual wood production (including illegal production) to be 1.5–4.3 million m^3 from 1995 to 1997.

3.2. Carbon Stock Changes

Our models suggest that under CVL, total carbon stocks in 3.4 million ha of concession forests decrease from 455.6 teragrams of carbon (Tg C) at the start of the management ($t = 0$) to 292.2 Tg C at the 25th year (the end of the cutting cycle, $t = 25$), representing an annual degradation (emissions) of 6.5 Tg C or 23.9 Tg CO_2 (1 Tg CO_2 = 1 million tonnes CO_2) or 1.4% annually. Under the RIL and RIL+, carbon stocks also decrease from 455.6 Tg C and 455.6 Tg C at $t=0$, respectively, to 403.4 and 428.2 Tg C at $t = 25$, representing an annual degradation of 14.7 Tg CO_2 (0.9%) and 11.4 Tg CO_2 (0.5%) over a 25-year cutting cycle (Figure 2).

Figure 1: Volume of Annual End-Use Wood Products under Three Management Scenarios over a 25-Year Period



Illegal logging also strongly affects carbon stocks in the forests. If half of the rate of illegal logging used in our study is halted, annual carbon loss (degradation) is 15.3 Tg CO₂, 8.0 Tg CO₂, and 4.4 Tg CO₂ under CVL, RIL, and RIL+ scenarios, respectively. If illegal logging is completely eliminated, these scenarios result in annual carbon loss (degradation) of 10.2, 4.3, and 0.6 Tg CO₂, respectively over the 25-year cutting cycle (Figure 3).

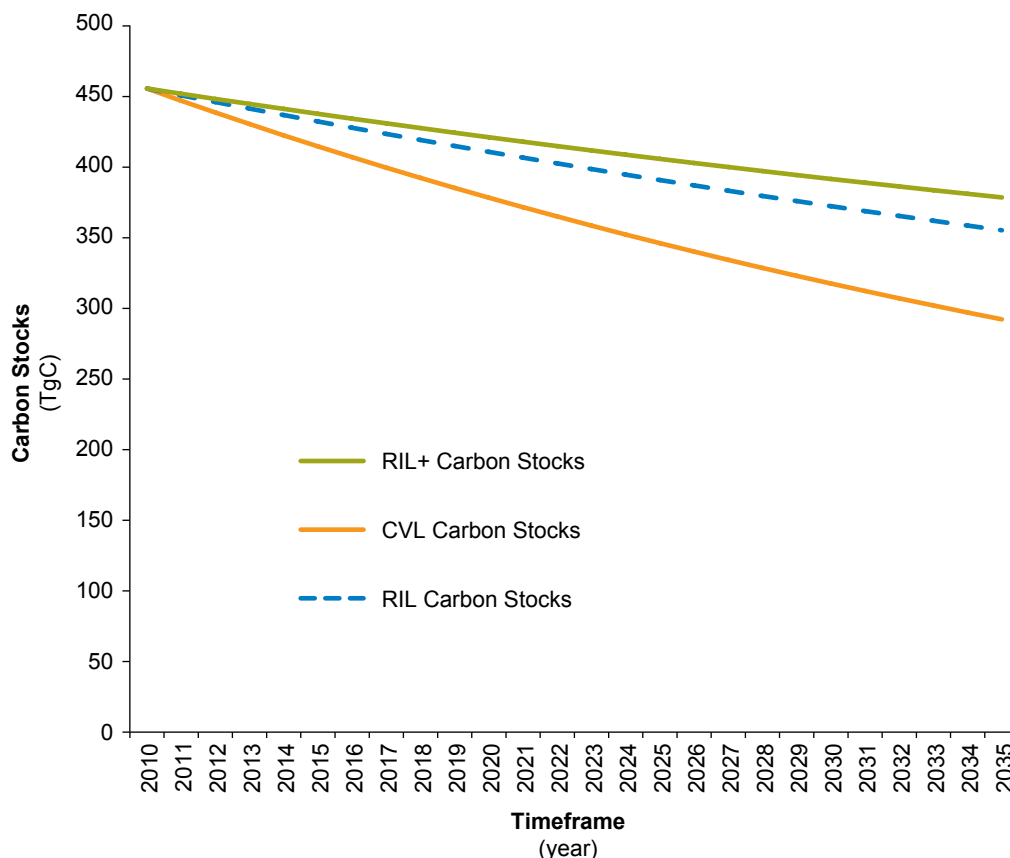
Previous studies on avoiding emissions from forest degradation through managing concession forests are very limited and difficult to compare with our study. Asner *et al.* (2009, 2010) found that at least 20% of tropical forests were under various forms of selective logging; forest degradation in the Amazon doubled during the 2000s. Conventional logging caused rapid deforestation in the Amazon, where 16% of selectively logged areas were deforested within a year of logging, with a subsequent annual deforestation rate of 5.4% for 4 years after timber harvests (Asner *et al.*, 2006).

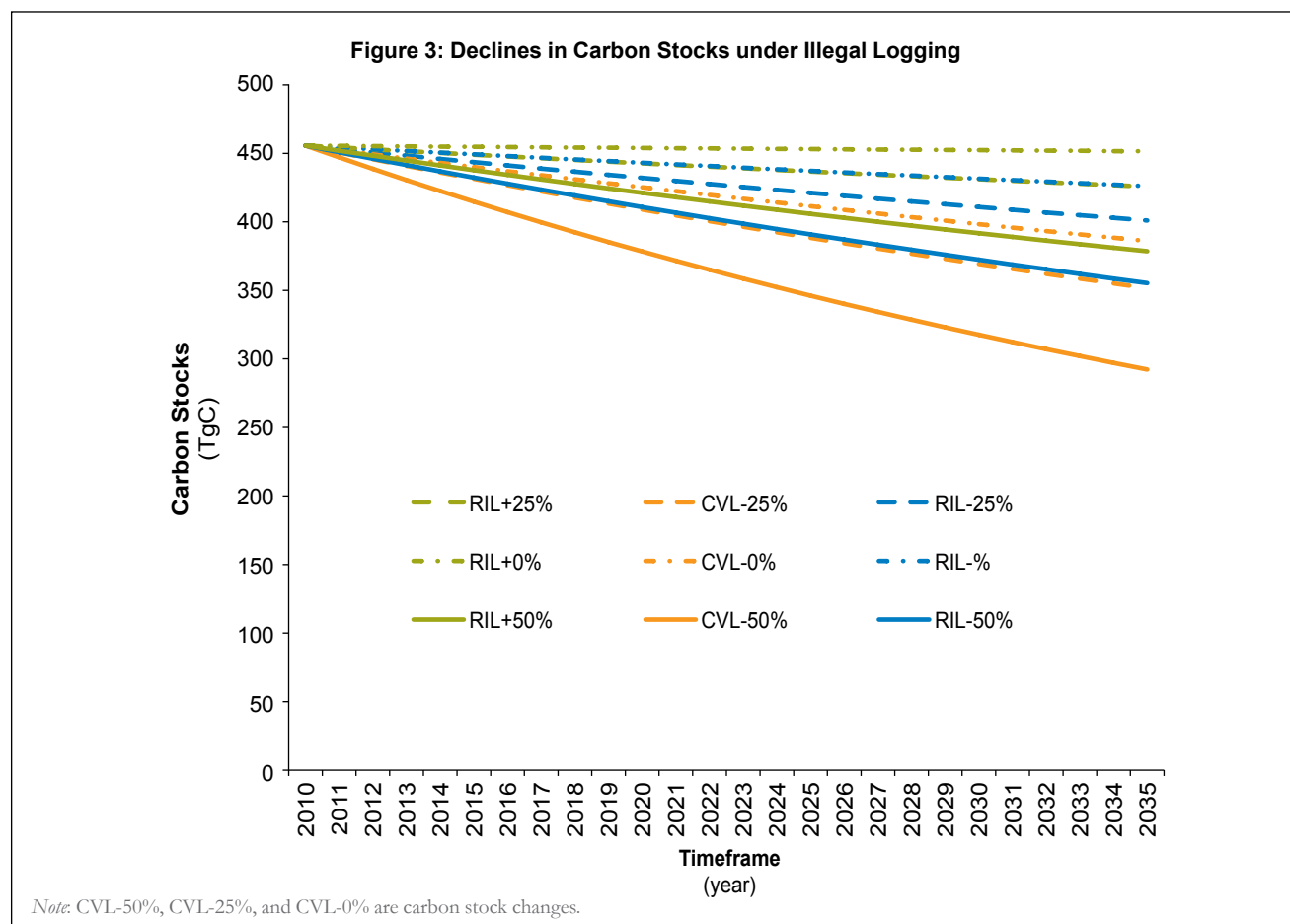
3.3. Appropriate Management System

In order to determine the appropriate management system to maintain a sustainable supply of end-use wood products from managing concession forests in Cambodia, three more cutting cycles were tested under the three management scenarios with three rates of illegal logging, namely 50%, 25%, and zero. The results (Figure 4) indicate that the annual volume of end-use wood product from 3.4 million ha of concession forests would be about 1.08 million m³, increasing 0.06% annually under a 60-year cutting cycle when illegal logging is reduced to 25% (Table 2). If illegal logging is completely eliminated, a 40-year cutting cycle would ensure the sustainable supply of end-use wood product of 1.21 million m³ under RIL or RIL+ practices.

Given the nature of illegal logging and governance problems in developing countries, it is unlikely that illegal logging can be completely eliminated. Taking into account the need for investment return, a cutting cycle of between 40 and 60 years would be appropriate. Cutting cycles

Figure 2: Decline in Carbon Stocks under the Three Management Scenarios over a 25-Year Cutting Cycle



**Table 2. Average Annual End-Use Wood Product Volume under 4 Cutting Cycles and 3 Rates of Illegal Logging**

Cutting Cycle (year)	Illegal logging rate: 50%		Illegal logging rate: 25%		Illegal logging rate: 0%	
	(million m ³)	(%)	(million m ³)	(%)	(million m ³)	(%)
25	3.41	-0.88	2.41	-0.48	1.86	-0.26
40	2.28	-0.43	1.58	-0.15	1.21	0.00
50	1.86	-0.26	1.28	-0.03	0.98	0.10
60	1.58	-0.15	1.08	0.06	0.82	0.16

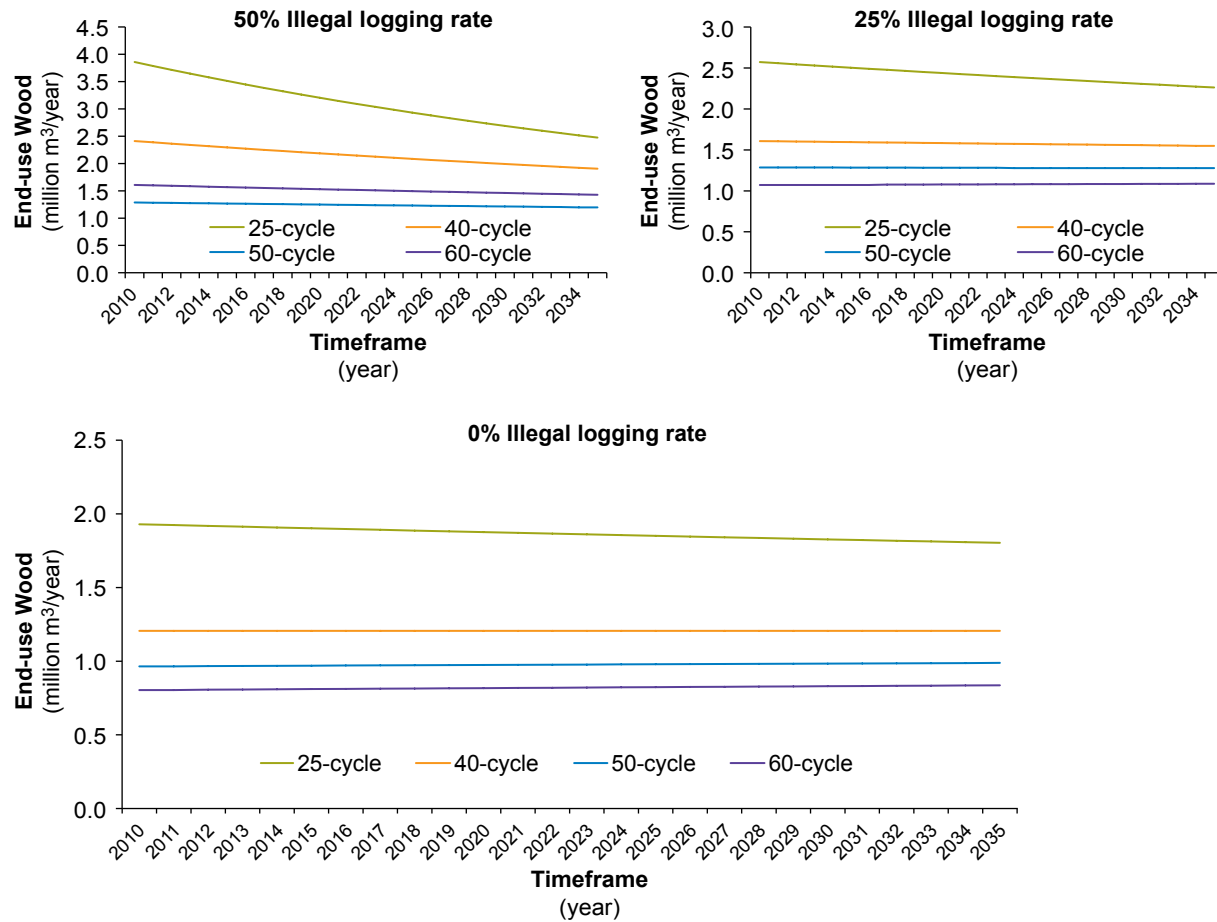
Note: Values in this table are the average for 25-year modeling timeframe.

that are shorter than 40 years cannot ensure a long-term sustainable supply of end-use product. The results also indicate that short cutting cycles coupled with illegal logging would produce high production of end-use wood but on a sharply declining basis as shown in Figure 4. Countries with unstable political situations are likely to adopt the short cutting cycles for immediate financial gains at the expense of forest resources and carbon stocks. Such practices have been the cause of rapid forest degradation and deforestation in the tropics during recent decades (Casson and Obidzinski, 2002).

Taking into account past experience with illegal logging and governance and the inability to completely reduce

illegal logging, a 50-year cutting cycle with 25% rate of illegal logging is more realistic, and therefore appropriate for managing forests under the REDD+ scheme.

Liberation treatment should be used with precaution since only two experiments have been done so far (Peña-Claros *et al.* [2008]; Villegas *et al.* [2009]). This practice should be carefully undertaken by well-trained professionals who have knowledge about tree species and their interactions with other organisms in the forests. Otherwise, only highly commercial tree species will be left to grow at the expense of other species and tree-dependent biodiversity.

Figure 4: Supply of End-Use Wood Products under Four Cutting Cycles with and without Illegal Logging

3.4. Reference Emission Level, Project Emission Level, and Carbon Credits

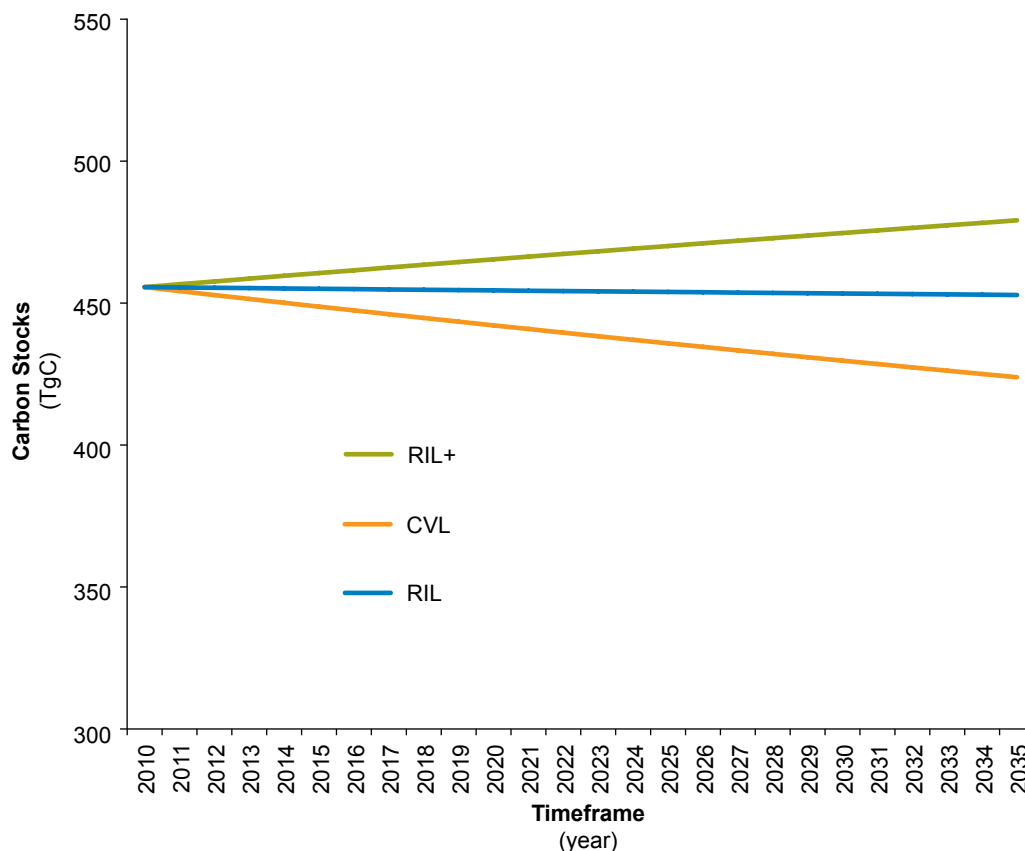
By taking a 50-year cutting cycle as the basis of a REDD+ scheme, REL, PEL and carbon credits can be determined. Assumed that the first carbon crediting period is 25 years (half of the cutting cycle) and the project is able to reduce the current rate of illegal logging to 25%, carbon stocks under CVL, RIL, and RIL+ scenarios are 455.6 Tg C at the beginning of the management ($t = 0$) and 423.9, 452.9, and 479.2 Tg C, and 499.5 Tg C at the 25th year (end of first crediting period), respectively, declining 1.3 Tg C (0.3%), 0.1 Tg C (0%), and -0.9 Tg C (-0.2%) (Figure 5). (By conventional, minus '-' indicates a carbon sink).

With the above assumptions (25-year carbon crediting period, 50-year cutting cycle, 25% rate of illegal logging), two types of REL can be argued, namely REL under the CVL with a 25-year cutting cycle and REL under CVL with a 50-year cutting cycle. REL under the latter is unlikely because it is a proposed practice for the RIL

or RIL+ system that would be adopted for future REDD+ projects in concession forests (Sasaki, 2010). Therefore, we chose REL under CVL with a 25-year cutting cycle for comparison in our study. REL and PEL were estimated at zero at beginning of the project ($t = 0$). At the second year, REL increased to 31.5 Tg CO₂, then decreased to 17.7 Tg CO₂ by year 25 of the project implementation. This decrease is caused by the decrease of available timber for harvesting. On average over the first crediting period, REL was estimated at 23.1 Tg CO₂/year.

PEL increased to 0.4 Tg CO₂ and -3.7 Tg CO₂ at the second year, respectively under RIL and RIL+ scenarios. PEL remained constant at 0.4 Tg CO₂ under RIL but slowly declined to -3.2 Tg CO₂ under RIL+ at the 25th year of project implementation (Figure 6). Average PELs were 0.4 Tg CO₂/year and -3.3 Tg CO₂/year under RIL and RIL+, respectively. After subtracting 30% from [REL(t) - PEL(t)], annual carbon credits under the RIL or RIL+ were estimated at about 15.9 Tg CO₂ or 18.5 Tg CO₂ under RIL and RIL+ scenarios, respectively. If carbon is priced at \$5

Figure 5: Carbon Stocks under a 50-Year Cutting Cycle with 25% Rate of Illegal Logging in Concession Forests in Cambodia in the First Crediting Period



(average carbon price at the voluntary carbon market was \$7.88 per Mg CO₂, ranging from \$0.67 to \$50 [Hamilton *et al.*, 2009]), total annual carbon-based revenues from managing 3.4 million ha of concession forests would be \$79.5 million under RIL to \$92.5 million under RIL+. In addition to these carbon-based revenues, revenues from timber royalties and other benefits from long-term management of concession forests can also be obtained. The carbon-based revenues alone are more than 4 times higher than the timber revenues from logging in Cambodia reported in 1995 (Chheng, 2011).

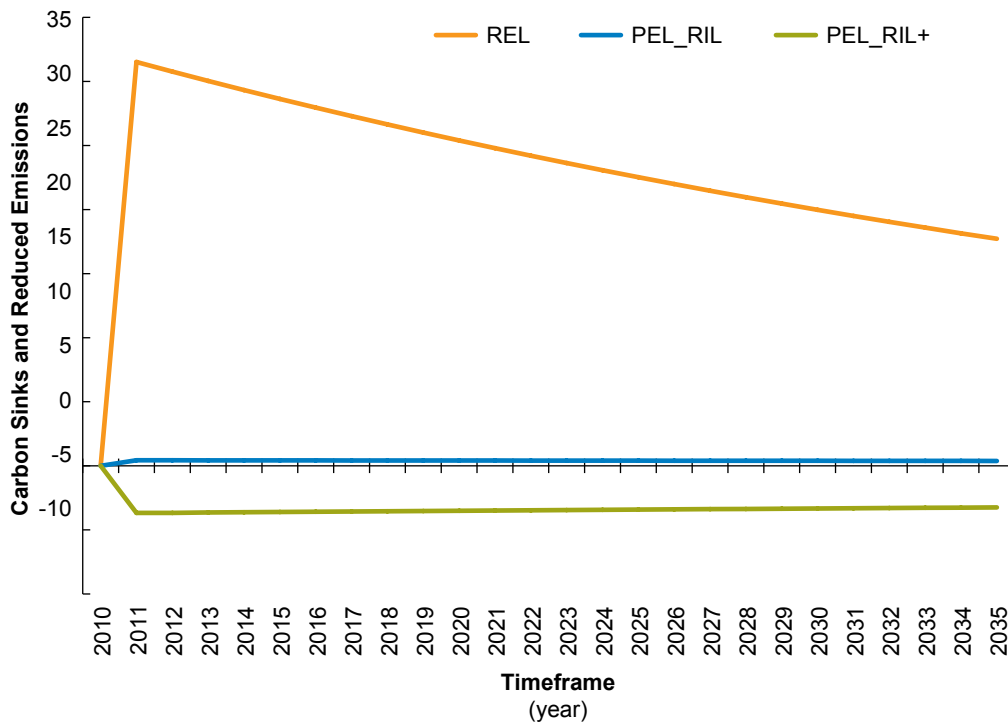
Logging costs had been generally thought to be expensive under the RIL or RIL+ options; however, based on various studies in the tropics, Sasaki *et al.* (2011) argued that costs are not expensive as previously thought. However, cost-effective analysis is beyond the scope of this paper.

4. Conclusions

We developed methods to estimate REL, PEL, and carbon credits for REDD+ projects in tropical forests under three management scenarios: management under conventional logging, reduced impact logging (RIL) and RIL with liberation treatment (RIL+). Carbon credits generated from the REDD+ projects are huge and would be attractive to project developers if there are continued financial incentives and/or carbon markets for such credits. The inclusion of the REDD+ scheme in the new reduction mechanisms for post-Kyoto project implementation will ensure such incentives and carbon market.

Our results suggest that the 25-year cutting cycle practiced in Cambodia is too short to sustain the flow of end-use wood production. A 50-year cutting cycle under reduced-impact logging (RIL) or RIL with liberation treatment (RIL+) could maintain a permanent supply of end-use wood products but at a lower rate than that under conventional logging with a shorter-term cutting cycle. Achieving sustainable

Figure 6: Reference Emission Level and Enhanced Carbon Sinks



Note: PEL_RIL and PEL_RIL+ are project emission levels under the RIL and RIL+ scenarios.

forest management under the REDD+ mechanism will require the adoption of sound logging practices that will reduce damage to residual forest stands and the soils that sustain these stands, and that will reduce disturbances to upstream resources (e.g., forests that protect catchment ecosystem services) while maintaining a continuous flow of end-use wood products. Without such carbon-based incentives, RIL+ will not be adopted and emissions from logging cannot be avoided, putting efforts to mitigate climate change and achieve sustainable development in developing countries at risk.

Financing currently made available from fast-start climate finance sources should also be used for capacity building on RIL or RIL+ for effective implementation when the REDD+ scheme becomes an international binding agreement—under which RIL or RIL+ will be required for managing tropical forests. For RIL+, precautionary measures should be taken to prevent the killing of commercially less important but biologically important tree species.

Acknowledgments

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FORESTS, PAST, PRESENT AND FUTURE IN THE GMS

Alastair Fraser¹

Abstract

Inappropriate policies in relation to land, market, employment, environment, and governance issues have been major contributory factors to continued destruction and degradation of forests throughout the subregion, according to a 2001 report. The report also showed that the value of forests was generally very much underestimated because of lack of appreciation of the economic and environmental costs of destroying forests, leading to market distortions that have contributed to forest degradation and destruction. Little if anything has changed over the past decade. The same issues still predominate, although the rise of Reducing Emissions from Deforestation and Forest Degradation (REDD+) has focused attention on the issues and may yet achieve some action.

The forestry sector provides a number of investment opportunities that can greatly contribute to poverty reduction. Realizing these opportunities is not dependent on an existing forest resource, since the demand for forest products and services is strong, even in countries with little or no natural forest, and can be largely met by establishing plantations.

Sustainable forest management will require a stable resource base and countries need to have land-use plans that determines as far as possible, the balance between the alternative uses, that brings the greatest overall benefit. Under-valuation of forest resources promotes wasteful use, illegal logging, and corruption and results in reduced government revenue.

Low political priority for forestry has generally meant that national forestry agencies are under-funded, under-staffed, and are being split and downgraded in all the countries of the subregion. Additionally, in most countries, communities that live in or near forests and that are dependent on forests for their livelihoods and a stable environment, have very little political influence.

The demand for wood products will rise steadily as economic growth proceeds in the region, and sector is undoubtedly important for environmental protection with the increasing number of hydropower dams and greater risk of climatic extremes, but strategic plans for the sector need to set out clearly how these demands will be met and how much investment is needed. The days of muddling along must end.

1. Introduction

The forests of the Greater Mekong Subregion (GMS) are simultaneously among the richest forests in the world for biodiversity and among the most threatened with destruction. Newby (2009) reported that 1,068 new species had been discovered in the subregion during the previous decade. During the same period, according to the FAO Forest Resource Assessment for 2010, an estimated almost 6 million hectares (ha) of forest were lost in the GMS countries, excluding the People's Republic of China (PRC).

This richness in biodiversity is considered to be a result of the climate changes that took place during the last ice age, when sea levels were lower and tropical forest species were able to migrate and survive in the land that is now covered by sea between Thailand, Malaysia, and Indonesia, while more temperate forest species invaded the cooler mountainous areas. As the climate warmed, the tropical forest with all its associated biodiversity recolonized most of what is now the GMS. The recent more rapid phase in climate change attributed to human activities is also reported to be affecting the ecology of the subregion and Newby reported that changes in the frequency of storms and periods of drought combined with rising temperatures and melting of glaciers in the Himalayas, are all affecting the ecology of the subregion as well as agricultural productivity.

At the opening of the 20th century, forests covered about three quarters of the land surface of Thailand (McKinnon, 1997) and it is reasonable to assume that they covered a similar proportion of the lower Mekong Basin, in Cambodia, the Lao People's Democratic Republic (Lao PDR), and parts of the central highlands of Viet Nam. The vast majority of the population lived in the Mekong, Chao Phaya, and Red River deltas and coastal plains and practiced irrigated agriculture, while a minority of "hill tribes" lived in small scattered communities in the hill areas and practiced mainly shifting cultivation.

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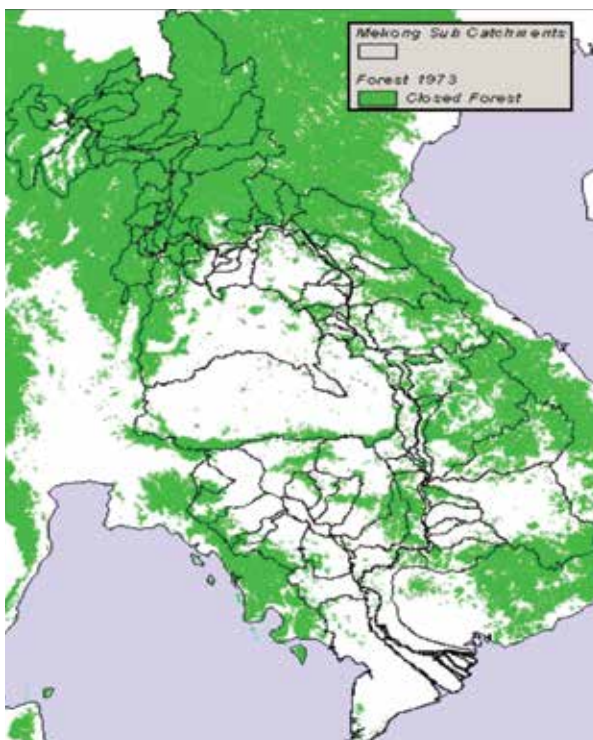
The climax forest type over most of the Mekong basin is semi-deciduous or deciduous monsoon forest as a result of the seasonal characteristic of the rainfall and the pronounced dry season. In the southern part of the basin to the south of about 10°, which is considered to be more or less the boundary between the evergreen and monsoon forest types, the climax forest is evergreen rainforest. To the north of this boundary a mosaic of evergreen and deciduous forest may be found where local climate, drainage, and soil conditions result in moister conditions and favor the development of evergreen species. The species composition of these two major forest types is different, and further local differences may occur at higher latitudes, higher altitudes and in riparian, wetland and coastal forests.

The first comprehensive survey of forest cover for the lower Mekong Basin in 1973 suggested that forest cover had been reduced to about 55% over the basin as a whole, with an estimated forested area of about 34.5 million ha within the basin area of 62.5 million ha.

Figures 1 and 2 show the distribution of forest cover in the lower Mekong Basin in 1973 and 1997, respectively. Over the 24 years from 1973 to 1997, almost 16 million ha of forest were lost, averaging 660,000 ha annually or about 2% of the forest area and reducing forest cover to around 30% by 1997.

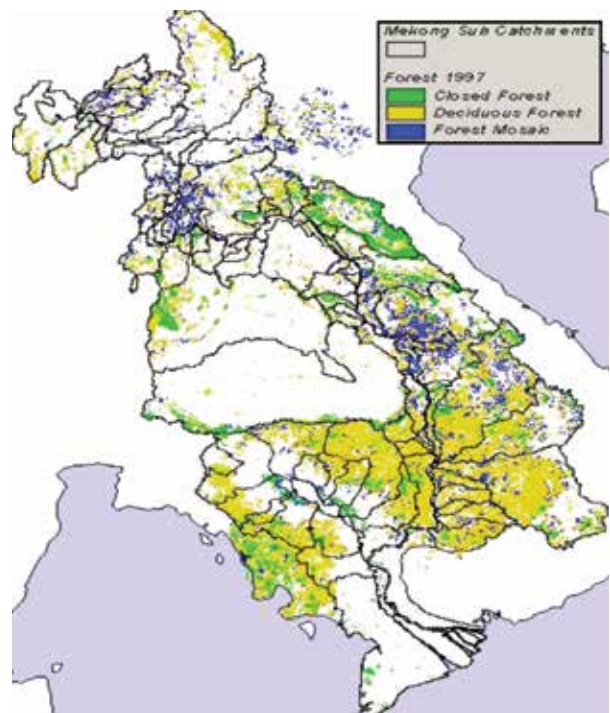
Examination of the distribution of forest cover by Fraser and Jewell (2003) according to slope classes in 1973 and the subsequent deforestation revealed that deforestation was relatively higher on the steeper slopes than on the flatter land. Of the 16 million ha of forest that were lost during 1973–1997 almost 25% appears to have been on slopes steeper than 21%, although this slope class only accounts for about 11% of the total area of the basin. Table 1 gives a summary of the apparent loss of forest cover during the intervals between the surveys on each of the slope classes. Table 2 gives the apparent annual loss of forest cover by slope class during the periods between the surveys, expressed as a percentage of the forest area at the beginning of the period.

Figure 1: Closed Forest (1973) from Landsat Multispectral Scanner Data



Source: Data from Tropical Rain Forest Information Center, Michigan State University.

Figure 2: 1997; Closed, (green) and Open Forest (brown) and Forest Mosaic



Source: Mekong River Commission.

Table 1: Change in Forest Area 1973–1997 by Slope Class in the Lower Mekong Basin

Slope class	Forest Area ('000 ha)				
	1973	1985	1993	1997	Loss 73-97
Steep	6,459.9	11,085.1	3,560.5	2,679.5	3,780.4
Intermediate	24,051.3	17,047.9	14,901.2	12,520.9	11,530.4
Gentle	4,030.4	3,600.0	3,990.8	3,494.9	535.4
Total	34,541.6	31,733.0	22,452.6	18,695.4	15,846.2

Source: Fraser and Jewell (2003).

Table 2: Average Annual Rate of Change of Forest Cover 1973–1997 by Slope Class in the Lower Mekong Basin

Slope class	Rate of Change in Forest area (%)				
	1973–1985	1985–1993	1993–1997	1973–1993	1973–1997
Steep	0.28	6.83	5.32	2.81	2.73
Intermediate	0.44	5.44	5.29	2.32	2.41
Gentle	0.92	1.45	3.66	1.07	1.37
Total	0.68	3.66	4.18	1.75	1.91

Source: Fraser and Jewell (2003).

Table 3: Total Annual Deforestation ('000 ha) in five GMS Countries, 1981–1990

Countries	Deforestation (annual)	Evergreen	Moist Deciduous	Dry Deciduous	Hill and Montane	Logged
Cambodia	131.4	18.3	39.0	73.2	1.0	3
Lao PDR	129.4	39.6	42.7	20.6	26.5	9
Myanmar	400.6	161.6	169.7	4.2	46.3	198
Thailand	515.3	150.8	195.8	122.3	17.9	37
Viet Nam	137.0	47.7	55.7	15.7		58
Total	1,313.7	418.0	502.9	236.0	91.7	305

Source: FAO Forest Resource Assessment for 2010.

This relatively high loss of forest cover on moderate and steeply sloping land has implications not just for the forest resources but also for water and soil conservation and the likely impact of the reduced forest cover on the potable water, irrigation, and hydropower utilities.

Table 3 uses FAO data covering the whole of five countries in the GMS, with a total area of about 190 million ha and a forest area of about 77 million ha or about 40.5% in 2000. The total area of these countries is almost three times larger than the lower Mekong Basin referred to above. Table 3 shows that during 1993 to 1997, about 1.3 million ha of forest were lost annually throughout the 5 countries, representing an annual loss of about 1.4%. The rate of loss of forest cover appears, therefore, to have been substantially higher in that part of GMS that lies within the lower Mekong Basin than in the GMS as a whole.

As a consequence of this rapid decline in forest resources, most countries in the subregion have imposed logging bans and the measured contribution of the sector to national gross domestic product (GDP) has declined steadily. These indicators, however, do not take account of the impact on national GDP of the reduction in the value of the ecosystem services provided by forests or the economic

costs to communities living in forested areas that have lost access to nontimber forest products, on which many communities rely heavily.

2. Declining Performance of the Forest Sector

A forest policy paper for ADB in 2001 indicated that the main constraints that contributed to the under-performance of the sector prior to that time were:

- uncertainties relating to land tenure and “ownership” of the resource;
- misguided or inefficient pricing policies relating to forest products and competing sectors, especially agriculture;
- lack of assessment of the economic value of forests and the costs of environmental degradation; and
- low political priority to forestry and national institutional weakness in implementation of policy and projects.

Based on this assessment, appropriate interventions in the forestry sector were identified that would simultaneously address the sector’s needs for development and poverty reduction:

- Land issues, covering the appropriate valuation of land under different uses, the assessment of economic rent and the most appropriate ways for governments to capture the rent.
- Market issues, covering both pricing policies that avoid distortions, and mechanisms for creating a market for forest goods and services that will stimulate greater private sector involvement in the sector.
- Employment issues, covering both the creation of additional off-farm employment opportunities, in particular for women, and the appropriate valuation of labor inputs.
- Environmental issues, covering both the proper valuation of the costs of environmental degradation, and the benefits of environmental services provided by forests.
- Governance issues, covering institutional capacity to undertake economic evaluation of forestry activities, identify the appropriate instruments to use in support of policy, and reduce intersectoral conflicts, particularly those arising from market failures; and eliminating corruption.

Mir and Chandrasekharan (2006) examined the economic cost of the destruction of the forest resources of the GMS and also took account of the impact of the steady degradation of the remaining forest that does not show up in crude measures of forest area changes. Their conclusion was that between \$27–54 billion of capital value in the forest was being destroyed annually. This only took account of the apparent loss in growing stock with a timber or fuel market value that could not be accounted for by official records of timber harvested and took no account of the value of soil lost due to erosion in forest that had been cleared on steep slopes, or any contribution to flooding and river siltation that may also be attributed to reduction in forest cover. Mir and Fraser (2003) in their study of illegal logging in the subregion pointed out that the officially recorded annual harvest of industrial logs in 2000 for the countries of the Asia-Pacific region was 283 million cubic meters (m^3) while the volume of wood required to produce the recorded volumes of all products was 440 million m^3 . Imports from outside the region accounted for about 55 million m^3 of the difference, but there was still a discrepancy of around 100 million m^3 that was unrecorded and probably illegal.

While these figures are for the wider Asia-Pacific region there have been numerous studies of illegal logging and trade of logs within the GMS. Meyfroidt and Lambin (2009) examined the apparent log supply deficit in Viet Nam. They

concluded that in 2006, the deficit in logs in Viet Nam was around 10 million m^3 , most of which was being met by illegal log imports from neighboring countries. Had these logs been harvested from Vietnamese forests they would have suffered substantial deforestation and reversed the trend in increasing forest cover shown by Vietnamese statistics as a result of expansion of plantations. Instead the deforestation was displaced to neighboring countries. Since no royalty or fee is paid on illegal logs, this represents a substantial financial loss to the governments of the countries from which the logs are taken as well as a longer-term impact on the growth of the forest due to the reduced growing stock (capital).

3. The Current Status of the Forestry Sector in the GMS

A regional study undertaken by ADB in 2006 on Poverty Reduction in Upland Communities in the Mekong Region through Improved Community and Industrial Forestry showed that the forestry sector provides investment opportunities that can greatly contribute to poverty reduction through the creation of employment and increase off-farm income-earning possibilities, improved rural infrastructure, provision of renewable energy in convenient forms, sequestration of carbon, provision of a resource for small and medium-size enterprises, protection of the environment and the landscape, health care support through the supply of natural drugs, and the promotion of the well-being of women and minorities in rural areas through sound planning of the above activities.

Realizing these opportunities is not dependent on an existing forest resource, since the demand for forest products and services is strong, even in countries with little or no natural forest, and can be largely met by establishing plantations. The analysis also showed that risks associated with investments in forestry include normal commercial risks, such as fire and disease that can be assessed and minimized and serious governance and political risks that are much more difficult to handle. These risks will need to be minimized in the future if investment in the sector is to be attractive and to be economically efficient, with possible beneficial impact on poverty reduction.

Sustainable forest management will require a stable resource base and countries need to have land-use plans that determine as far as possible, the balance between the alternative uses that brings the greatest overall benefit. Forests should only be converted to another use where

it can be demonstrated that the total net benefits from the alternative will exceed the loss of benefits from the forest that is converted. Under-valuation of forest resources promotes wasteful use, illegal logging, and corruption, and results in reduced government revenue. Illegal logging is a symptom of a lack of appreciation of the resource, and if it is allowed to persist it will undermine the benefits of any further investment in the sector.

Successful investment in forestry requires good management, and national forestry agencies are not organized for management. The role of government should be to ensure a sound regulatory framework, with the use of appropriate fiscal and other financial incentives and to enforce compliance. The latter requires more monitoring effort. Low political priority for forestry has generally meant that national forestry agencies are under-funded, understaffed, and have very low status within government. These shortcomings show up as a general lack of any clear prioritized and realistic strategic objectives related to the available investment funds for the sector and lack of any appreciation of its economic value.

The future for the sector does not look bright as forestry departments are being split and downgraded in all the countries of the subregion, so that responsibility for forest management is split between agencies according to the primary function of the forest. In fact, all forests have multiple functions, although within a forest management unit, different functions (conservation, protection, production) may be given priority in specific areas. In all countries, the responsibility for the resource is separated from the responsibility for the subsequent processing of the wood and coordination is generally very poor, with the result that the industry agency may be pushing to expand wood processing while the resource is being depleted. This leads, among other things, to a temptation to the industry to engage in illegal logging

In most countries, communities that live in or near forests and that are dependent on forests for their livelihoods and a stable environment, have very little political influence. The priority attributed to forestry is, therefore, generally low except where influential people have a direct stake in forestry activities. This low priority is, however, not always justified in economic terms on the basis of the full contribution that the whole forestry sector is making to the national economy.

The demand for wood products will rise steadily as economic growth proceeds in the subregion, and sector

is undoubtedly important for environmental protection with the increasing number of hydropower dams and greater risk of climatic extremes, but strategic plans for the sector need to set out clearly how these demands will be met and how much investment is needed. The days of muddling along must end.

4. What Hope for the Future for GMS Forests?

The growing international attention to climate change may bring a respite to the steady decline in the fortunes of forestry sectors around the subregion. With most of the valuable timber already logged in areas designated for production, attention has turned to the conservation and protection functions of forests, and this has been helped by the realization that forests are both a source of carbon dioxide (CO₂) emissions contributing to global warming and also a sink for it, if trees are able to grow. The steady deforestation and forest degradation in the past throughout much of the subregion has resulted in high levels of CO₂ emissions, which are generally declining due to lower carbon stocks in the remaining forests when cleared. Despite this, and the relatively low current market value for CO₂, protecting what forest that is left and restoring forest cover wherever multiple benefits can be obtained, to include soil, water, biodiversity, and carbon, are becoming economically attractive. Many donors are now supporting forest protection and conservation and the international negotiations on REDD+ have opened the door to the possibility of substantial funding for such activities.

Since a high proportion of the poverty in the subregion is in the more remote and often upland areas where forests still survive, these opportunities need to be used to involve these rural communities and ensure that they receive a substantial share of the benefits in order to overcome their poverty. At the same time, there needs to be a realization among political leaders that the days of vested interests making money out of illegal logging must finish. Access to REDD+ funds will be severely hampered if changes in carbon stocks cannot be accounted for. This applies not only to forests within countries, but also cross-border leakage, which will jeopardize efforts by the countries that are being exploited. There is evidence to show that if log harvesting is carried out well, with proper attention to pre-planning of access, directional felling, and careful extraction, emissions of CO₂ resulting from the collateral damage to remaining trees can be greatly reduced. Illegal logging, which pays no attention to these matters, results in far higher emissions and has the added negative impact

that young regenerating trees are damaged and often killed and the future health and growth of the forest is compromised.

There is much emphasis in forest policies and strategies around the subregion on achieving a specified percentage of forest cover. However, plans for restoring forest cover depend mainly on plantations. Restoring natural forest areas by natural regeneration or enrichment planting with a wide range of indigenous tree species will contribute to the conservation and even enhancement of biodiversity, but plantations of exotic species such as *Eucalyptus* and *Acacia* should be treated along with rubber as commercial tree crops.

It would be better if forest strategies focused more on protecting and managing a more limited area of forest where multiple benefits are derived. These should include peri-urban, coastal, and riverine forests that protect the environment and provide good opportunities for recreation and tourism as well as upland forests that provide biodiversity, soil, and water conservation benefits. Industrial timber plantations provide a longer-term and more sustainable means of supplying timber needs and strategies need to base the areas to be planted on estimates of future demand to be supplied from national sources and imports (from legal and sustainable sources) as appropriate. The natural forests in the subregion contain mainly hardwoods and many of the species are highly prized for decorative purposes. Strategies should aim to conserve stocks of these valuable species and use them to maximum value and build resources of plantation species for utility purposes, such as construction and joinery, where the decorative properties are not required.

Modern furniture makes increasing use of medium-density fibreboard, which can be enhanced by facing with a veneer of the valuable species, and forest and wood industry development strategies need to be synchronized so that demand and supply are as closely balanced as possible. This will help to reduce the pressure to log illegally. Forest strategies need to be far more specific and realistic and should prioritize what needs to be done according to the resources, both human and financial, that are available. This will ensure that the strategies can actually be implemented rather than being a shopping list of things it would be nice to do.

Fraser (2001) pointed out that for forestry strategies to work there needs to be an understanding of what the strategy is trying to achieve, general agreement on the

approach and measures to be adopted, and full support for it by all, with a vision of how forests will contribute to the well-being of the population in the future. There also needs to be clear specification of the various legal and financial instruments that will be used to implement the strategy as well as the human resources. The human resources need capacity building, which takes time and costs money; what is achievable will depend on the time frame for building the necessary capacity.

These implementation measures are generally lacking from forest strategies. There seems to be a trend to fragment responsibility for forestry matters in the subregion, with the wood industry being under Industry, forest conservation under Natural Resources and Environment and general forestry under Agriculture. This makes it extremely difficult, or even impossible to develop and implement a coherent strategy that would enable the sector to make its proper contribution to the economy. Foresters need to assert themselves more and find political champions who will press the case for reforms, and especially to face up to the threat from illegal logging.

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USING SPATIAL MODELS TO IMPROVE THE OUTCOMES OF LAND-USE PLANNING: THE CASE OF QUANG NAM PROVINCE, VIET NAM

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Abstract

Land-use planning has to carefully balance increasing pressures from development with the coping capacity of underlying natural resources and systems. A decline in the abundance, quality, and resilience of natural resources does not only affect the environment itself, but also sectors that heavily depend on intact ecosystem services, such as hydropower and ecotourism.

To better account for these conflicts as early as possible in sector planning and facilitate the identification of sustainable alternatives, the Quang Nam Province Department of Natural Resources and Environment commissioned a Strategic Environmental Assessment of their Provincial Land Use Plan 2011-2020. Support on scenario development and evaluation of corresponding impacts was provided by the Greater Mekong Subregion Environment Operations Center and the Netherlands Environmental Assessment Agency. Two scenario-based geographic models played a critical role in improving depth and detail of this assessment: The CLUE-s land demand allocation model previewed the risks of land conversion in hydropower catchments, and the GLOBIO3 biodiversity pressure model identified potential future biodiversity loss in important ecotourism sites.

1. Introduction

The Economic Corridor Concept is the main instrument of the Asian Development Bank (ADB) to close the gap between urban and rural disparities in the Greater Mekong Subregion (GMS). Transboundary roads between major economic centers are aligned through remote and impoverished areas to establish connectivity to markets. This is followed by corridor and sector plans laying out options for local investments. Together, road development

and attached investment plans create an economic corridor that provides new livelihood opportunities for previously marginalized population. Currently, there are 3 main corridors: The North-South Economic Corridor (NSEC) linking Bangkok, Kunming, Hanoi, and Nanning; the East-West Economic Corridor (EWEC) linking Da Nang to Yangon, crossing the Lao People's Democratic Republic (Lao PDR) and Thailand; and the Southern Economic Corridor (SEC) linking Bangkok, Phnom Penh, and Ho Chi Minh City.

All three corridors pass through remote areas: the NSEC through the Golden Quadrangle, the EWEC through the central Annamite mountains, and the SEC through the Cardamom Mountains and Northern / Easter Plains Dry Forest. Catalyzing development in such socially and environmentally sensitive areas comes with impacts that might—if not managed carefully—outweigh the benefits for the local people. Recognizing that GMS governments need support to ensure sound investment planning along the corridors, ADB spearheaded the integration of geographic information systems (GIS) into strategic environmental assessments (SEAs) of sector strategies and plans.

Developing baseline maps is an important first step to leverage the potential of a GIS for sector and land-use planning and related SEAs. Planners and decision makers can use such thematic maps to (i) better understand the environmental, social, and economic condition of a landscape, and (ii) identify where different landscape components form synergies or conflict each other.

The potential of GIS, however, goes far beyond the production of basic thematic maps. GIS can further be used to develop predictive models that combine geographic layers with expert knowledge on safeguards, past trends, and future scenarios. Such models can generate maps that preview the geographic outcomes of different development pathways, quantify related impacts, and help identify sustainable alternatives. This GIS functionality blends well with the analytical requirements underlying most strategic sector plans.³

The usefulness of GIS models for environmental assessments and performance monitoring was demonstrated in several publications and pilot projects. Since 2004, the GLOBIO3 biodiversity pressure model has been extensively used in global environmental reporting (e.g., United Nations Environment Programme

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³ In particular, demand projections and (alternative) scenario development components.

[UNEP] Global Environmental Outlook [GEO3], United Nations Convention on Biological Diversity [CBD] Global Biodiversity Outlook [GBO2,3]). The GLOBIO3 framework has also been implemented as part of subregional Monitoring and Evaluation (M&E) frameworks, among them the ADB-UNEP Subregional Environmental Performance Assessment Report. In the GMS, the Netherlands Environmental Assessment Agency (PBL) also supported the development of national biodiversity pressure maps in Viet Nam through a collaboration and training program with the Ministry of Planning and Investment.

Most of these applications, however, focus on the post-evaluative part of the planning process (i.e. monitoring and evaluation). While that has successfully raised broader awareness of the impacts of past development, it has had limited influence on ex-ante decision making, namely sector strategies and plans. In the GMS, the Environment Operations Center (ADB Regional Technical Assistance [RETA] 6289) has applied the CLUE-s land demand and GLOBIO3 biodiversity pressure models to improve scenario development and impact assessment of the SEAs of the NSEC Strategy and Action Plan. Apart from that, GIS models remain underutilized in GMS ex-ante planning processes, losing out on important opportunities to improve decision making and avoid or mitigate costly impacts.

2. At the Gate of the EWEC: Viet Nam's Quang Nam Province

Viet Nam's Quang Nam Province is in unique geographic position: Together with TT Hue Province, it encloses the city of Da Nang, Central Viet Nam's largest business hub and the country's third largest economic center. Da Nang has also established itself as a node for international and regional trade through its sea port and the gate to the EWEC.

Quang Nam contributes to and benefits from Da Nang's industrial development, mainly through supplying important

natural resources and services: agriculture and aquaculture outputs from the coastal plains in the east; and timber, minerals, and hydropower from the Annamite Mountains to the west. Particularly the latter, however, is environmentally sensitive and has a limited carrying capacity with regard to land conversion and resource extraction. This has already resulted in several conflicts. Increased soil erosion from upstream deforestation and mining activities threatens the performance of hydropower plants (maintenance, operational period) and their ability to contribute to energy security targets (Figure 1). Water contamination from mining operations in the upper watersheds has impacts on downstream fisheries, irrigation, and safety of potable water. A loss of attractiveness of eco- and ethno-tourism sites—like national parks and indigenous villages—is limiting the growth potential of the tourism sector (Table 1).

Besides the risks to individual sector performance, the people most vulnerable to the impacts are marginalized ethnic minorities living in the Annamite Mountains. Immigration into the area increases pressure on their ancestral land, compromises their traditional forest-

Figure 1: Land Conversion on Slopes, Sediment Load in Rivers, Ta Bhing commune, Quang Nam Province, Viet Nam



Table 1: Growth Trends in Quang Nam Province

Indicator	2000	2010	Increase
Population	1,395,297	1,425,395	2%
Agriculture - industrial plantation (rubber, coffee, tea) (ha)	3,528	8,312	136%
Agriculture - orchards (ha)	4,698	8,782	87%
Tourism - tourists (number of arrivals)	1,362,000	2,400,000	76%
Tourism - revenue (billion VND)	900	2,162	140%
Hydropower - number of dams	0	10	-
Hydropower - installed capacity (MW)	0	714	-
Hydropower - remaining potential (MW)	1,328	614	-

ha = hectare, MW = megawatt, VND = Vietnamese dong

based livelihoods, and exposes them to new health and disaster risks (e.g., communicable diseases, floods, and landslides), essentially moving them from one form of marginalization (lack of connectivity to markets) to another (displacement from their land and forest resources). Achieving poverty targets (national goals and Millennium Development Goals [MDGs]) might not be realistic if there is not enough consideration on how to properly assess and respond to impacts on their livelihoods with appropriate compensation and mitigation measures.

3. Applying Predictive Models in Quang Nam's land-use planning

To help the Department of Natural Resources and Environment (DONRE) of Quang Nam Province to better account for the increasing land and resource demand and its implications on sector, environment, and social performance, the Environment Operations Center supported a SEA of the Quang Nam Land Use Plan 2011–2020. Development of a land-use plan (LUP) started in February 2010 and concluded in December 2010 with the submission of the draft LUP to the Provincial People's Committee (PPC) for approval. The SEA ran parallel (ex-ante) to the land-use planning process (baseline assessment, scenario development, economic valuation, plan) and complemented each step with specific inputs:

1. **Baseline assessment:** preparation of thematic maps highlighting environmentally sensitive areas (steep slopes, protected areas) and investments (hydropower, ecotourism sites).

2. **Scenario development:** review of the “business as usual” scenario used by the LUP team, development of an alternative scenario.

3. **Economic valuation:** quantification of the potential risks of two scenarios to the performance of two main growth sectors—hydropower (catchment integrity) and ecotourism (site attractiveness).

4. **Plan:** recommendation on revisions of demand allocations and inclusion of safeguards and mitigation measures.

Two geographic models were piloted in steps 2 and 3 to identify potential conflicts between sector land demands and requirements (agriculture vs. hydropower and ecotourism) and facilitate a discussion on finding mutually beneficial alternatives. The models—a land demand allocation model for hydropower catchment integrity and a biodiversity pressure model for ecotourism site attractiveness—are introduced in the following sections.

3.1 CLUE-s Land Demand Allocation Model

3.1.1. Approach

The CLUE-s model – short for Conversion of Land-Use Change and its Effects – is a land demand allocation model developed by the Wageningen Agricultural University. The SEA team used CLUE-s to translate Quang Nam Province land demand scenarios into future deforestation maps in hydropower catchments. The CLUE-s modeling framework achieves this through the following inputs:

1. **Land demand scenarios:** Formulation of projected land demand in hectares, established from past land conversion trends (business as usual) and sector development targets (business as usual, sustainable alternatives).

2. **Conversion sequences:** Definition of how land-use types convert between each other, guided by economic values/prioritization.

3. **Land-use map:** A representation of the present distribution of land cover and land uses.

4. **Conversion restrictions:** Identification of areas that are restricted for future land conversion, such as protected areas or land concessions.

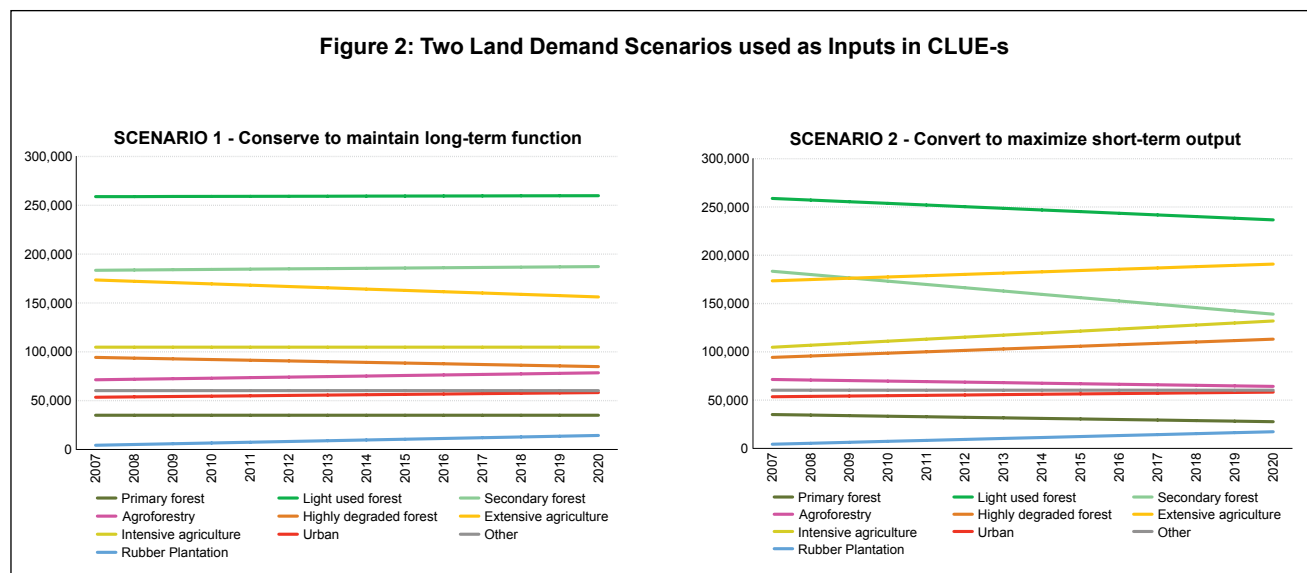
5. **Aggregated land suitability:** A set of underlying geographic layers (e.g., slope, soil type, distance to road, distance to settlement) with strong influence on the distribution of individual land uses.

The modelling framework includes both nonspatial and spatial components. The nonspatial components (1, 2) are developed through consultation with decision makers and allow them to engage in and influence the outcomes of the modeling process. Based on this knowledge and spatial inputs (3, 4, 5), the land demand allocation procedure calculates future land-use maps for each scenario.

3.1.2 Scenario development

The nonspatial components of the model were developed in consultation with the LUP and SEA stakeholders in February and May 2010, with follow up literature review in November 2010. These inputs broadly defined past development trends and present sector demands, establishing the base for formulating 2 land demand scenarios (Figure 2).

Land Demand Scenario 1 – Conserve to maintain long-term function: This scenario puts emphasis on the conservation of environmental assets to secure performance and enhance potential of the tourism and energy (hydropower) sectors that rely on healthy ecosystems. Additional demand from the agriculture sector is met through productivity



enhancement measures rather than land expansion. Sustainable financing tools and mechanisms engage local communities, provide them with new sustainable livelihood opportunities, and provide other sector developments with incentives for “greening” their investment portfolios.

Land Demand Scenario 2 – Convert to maximize short-term output: This scenario focuses on timber harvesting and expanding commercial plantations to satisfy the increasing demand from the manufacturing sector (furniture, rubber, pulp and paper). This is combined with maximizing agricultural outputs through land conversion rather than productivity enhancement. Spatial restrictions—despite existing—are not enforced efficiently.

3.1.3 Spatial data inputs

In order to develop model results that closely align to the provincial land-use planning procedure, official government datasets and expert knowledge were used wherever possible. In case of the baseline land-use map, however, different government datasets showed different strength and weaknesses: MARD-FIPI forest data are accurate on forest cover but broad in terms of land uses, and MONRE data show appropriate detail for agricultural land uses but remain broad in forest areas. Therefore, to leverage the best of both and improve on the accuracy of the model outputs, the baseline land-use layer (2007) was collated from 3 sources: MARD/FIPI Forest Cover Classification of 2008 (for forest classes), MONRE Land Use Classification of 2005 (for land-use classes), and classification of AWIFS satellite imagery of 2007 (to fill gaps between the MARD/FIPI and MONRE datasets).

Following the development of the baseline land-use map, additional spatial components of the model were prepared. A layer of spatial policies and restrictions was generated from information on protected areas (special use forest, MONRE) and biodiversity conservation corridors (ADB CEP-BCI⁴). The land suitability component of the model was configured with eight “explanatory” layers: elevation, slope, aspect, cost-distance to coast, cost-distance to road, cost-distance to rivers, population density, and cost-distance to settlement.

3.2. GLOBIO 3 Biodiversity Pressure Model

The second predictive model, the GLOBIO3 biodiversity pressure model, was developed by a consortium consisting of the UNEP World Conservation Monitoring Centre, UNEP/GRID Arendal, and The Netherlands Environmental Assessment Agency (PBL). In the context of the SEA of the Quang Nam LUP 2011–2020, it was used to broadly assess the threat of biodiversity loss to the value of ecotourism assets (protected areas).

3.2.1 Approach

The GLOBIO3 model uses one of the indicators listed by the CBD (CBD, 2006): the mean species abundance (MSA), expressing the relative abundance of original species at present compared to their potential abundance in undisturbed ecosystems. This measure provides a good indication for the overall “naturalness” of an ecosystem and the “intactness” of embedded ecosystem services.

⁴ <http://www.gms-coc.org>

Unlike other biodiversity models, GLOBIO3 does not measure biodiversity directly, but translates the magnitude of past, present, and future human-made pressure into loss of biodiversity (Alkemade *et al.*, 2009). These losses are subsequently discounted from potential (undisturbed) biodiversity levels, resulting in a map of “remaining” biodiversity. Pressure factors considered in the model are land-use change, infrastructure and population, fragmentation, climate change, and atmospheric pollution—each expressing a unique cause-effect relationship with biodiversity. These individual cause-effect relationships are translated into biodiversity loss using conversion coefficients derived from the literature through meta-analysis for comparable ecosystems. For subnational application, the quality of these global figures can be improved using local datasets and expert knowledge.

There are several advantages to this approach. First, GLOBIO3 does not require time-consuming, large-scale biodiversity surveys but “reverse calculates” the CBD MSA indicator from more readily available information on biodiversity pressures. By describing the state of biodiversity through the degree of pressure it is exposed to, the model also blends in better with the impact assessment focus of SEAs and Environmental Impact Assessments. Furthermore, GLOBIO3 integration into a GIS combines information on ecosystem quality (MSA indicator) with data on ecosystem quantity (extent), providing more comprehensive baseline figures for valuation exercises, environmental targets, and safeguards development.

3.2.2 Scenario development

The implementation of the GLOBIO3 model in the SEA of the Quang Nam LUP 2011–2020 was divided into two steps: calculation of MSA as of today (2007), and estimation of change in MSA (biodiversity loss) between 2007 and 2020 as result of development.

Compared to CLUE-s, which uses a scenario to project thematic information (land use) into the same thematic information in the future, GLOBIO3 only translates thematic information (e.g., land use) into another measure (biodiversity pressure from land use). As such, GLOBIO3 does not have a scenario development component itself but builds on the outputs of scenario-based models (e.g., CLUE-s land-use maps of 2020). Pressure from future infrastructure and population was accommodated by increasing the road buffer width and assuming a population growth rate of 1% per year.

3.2.3 Spatial data inputs

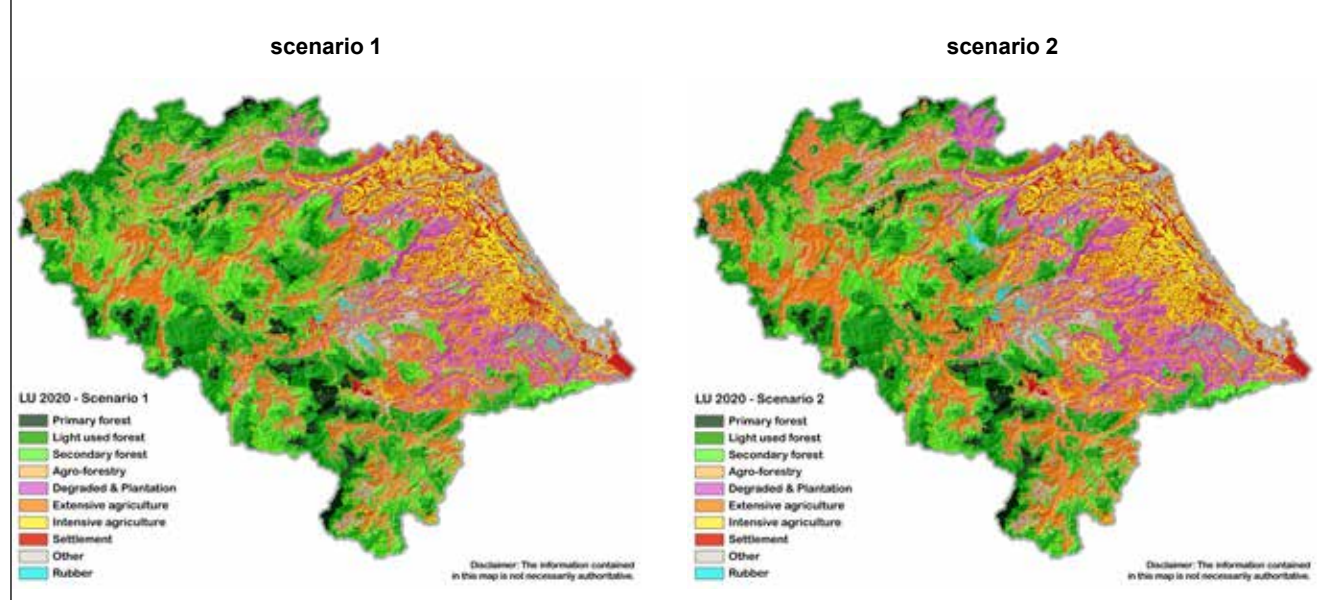
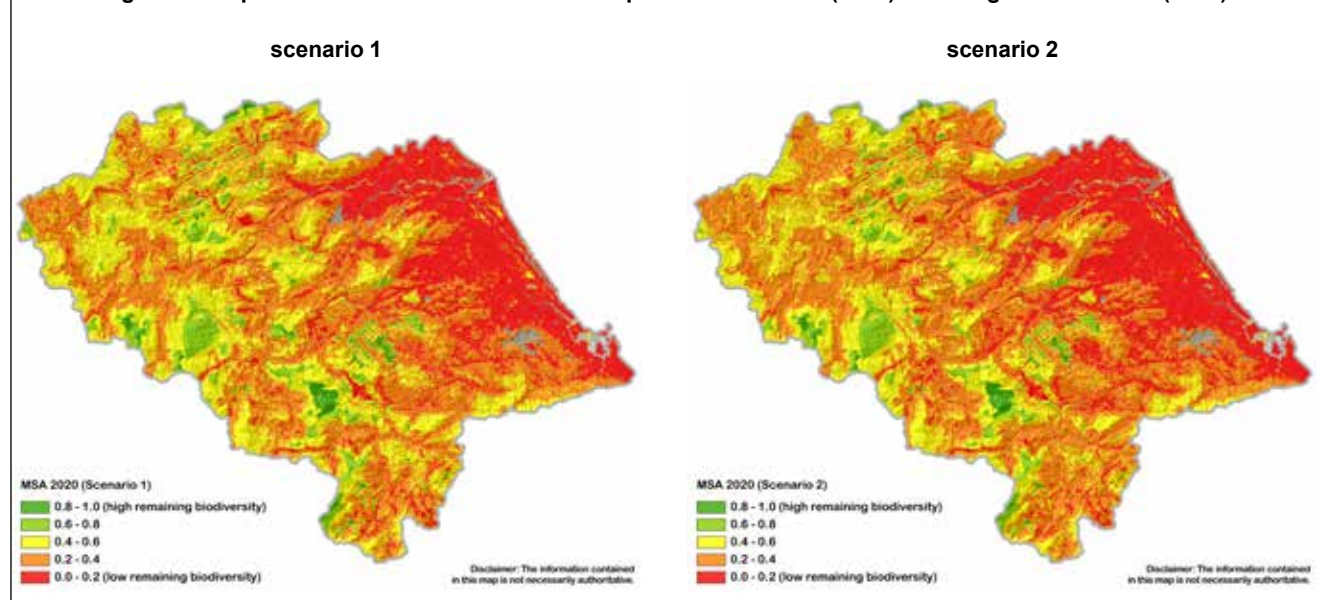
The World Wide Fund for Nature (WWF) map of terrestrial ecoregions⁵ was used as a reference to identify the mean species abundance without human interference. For the calculation of biodiversity loss by 2020, future land-use maps (CLUE-s outputs) were used as input for the land conversion and fragmentation components. Two more layers already used in the CLUE-s model are the provincial road layer (DONRE, 1:50.000) and the gridded population density (LandScan 2009); for GLOBIO3, they were used to calculate pressure from infrastructure and population development. Climate change and nitrogen deposition pressures components were not included because data of sufficient resolution were not available, supported by the fact that these pressures are unlikely to be significant over the plan period.

4. Results

The CLUE-s model produced two land-use maps: one of land use in 2020 following scenario 1 (Conserve to maintain long-term function) and one of land use in 2020 following scenario 2 (Convert to maximize short-term output) (Figure 3). A third map was produced combining both CLUE-s outputs for 2020 with the baseline map of 2007, showing (i) which areas change in both scenarios, (ii) which areas change in either scenario, and (iii) which areas do not change, regardless of scenario. These areas were highlighted in a land conversion map (Figure 5).

Corresponding to the land demand scenarios, the GLOBIO3 model produced two MSA (= biodiversity loss) maps: one for 2020 following scenario 1 (conserve to retain function) and the other of land use in 2020 following scenario 2 (convert to maximize output) (Figure 4). As a reference, an MSA map of 2007 (biodiversity loss as of 2007) was produced (Figure 6). Similar to the CLUE-s implementation, the difference between MSA in 2007 and 2020 was calculated for both scenarios and visualized in two corresponding maps (Figure 7).

⁵ <http://www.worldwildlife.org/science/ecoregions/item1267.html>

Figure 3: Output of the CLUE-s Model: Future Land-Use Maps of Quang Nam Province (2020)**Figure 4: Outputs of the GLOBIO3 Model: Mean Species Abundance (MSA) of Quang Nam Province (2020)**

5. Analysis

5.1. CLUE-s: Deforestation in Hydropower Catchments

The CLUE-s outputs show similar land-use conversion patterns in the coastal lowlands for both land demand scenarios (Figure 5). Toward the Annamite Mountains, the differences between the scenarios become apparent: At the fringe between the coastal lowlands and the upland

areas, conversion rates of scenario 1 reduce significantly, while scenario 2 maintains high conversion rates, even with a tendency to larger patch sizes compared to the lowlands. Land-use conversion trajectories generally align to mountain valleys, reaching even remote areas near the Laotian border.

Overlaying the catchments of major hydropower dams in Quang Nam on the land conversion map (Figure 5) puts the risk of deforestation into direct context with the

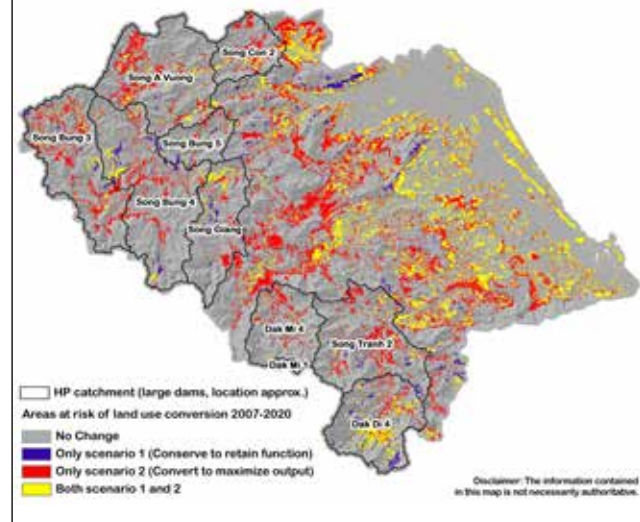
needs of hydropower investments for intact watersheds. Depending on the scenario and hydropower catchment, 4%–18% of the land is at risk of being converted (Table 2). The average conversion rate under scenario 1 is 5%, significantly lower than for scenario 2 (12%). Also, while in scenario 1 only one catchment (Dak Mi 4) faces the risk of more than 10% deforestation until 2020, scenario 2 has 7 hydropower catchments facing the same risk. The land demand allocation model also reveals that some dams are expected to be less affected by different development scenarios than others: while Song Bung 5, Dak Mi 1 and Dak Mi 4 show almost equal levels of risk of forestation in both scenarios, other dams show that a careful choice of development scenarios can result in significantly reduced risk of land conversion in hydropower catchments (e.g., Song Con 2: scenario 1: 5%, scenario 2: 18%; Song A Vuong: scenario 1: 4%, scenario 2: 15%).

Using these results as inputs into subsequent models, such as the Universal Soil Loss Equation can provide even more detailed figures for cost-benefit analyses and provide further important arguments for forest protection and development of ecosystem service payment trials in selected hydropower catchments.

5.2. GLOBIO3: Biodiversity Loss in Protected Areas

Starting with assessing the present levels of (remaining) biodiversity, Figure 6 suggests that in 2007 there were few pockets left where ecosystems were completely void of human influences and biodiversity was at or near pristine levels. Coastal lowlands have been almost entirely transformed into agricultural monocultures or settlements, and even small patches of forest might be plantations rather than natural forest. Corresponding to this, MSA values are generally low (<0.2 or 20%). Toward the

Figure 5: Land Conversion Map overlaying the Spatial Impacts of Scenario 1 and 2 overlaid on major Hydropower catchments.



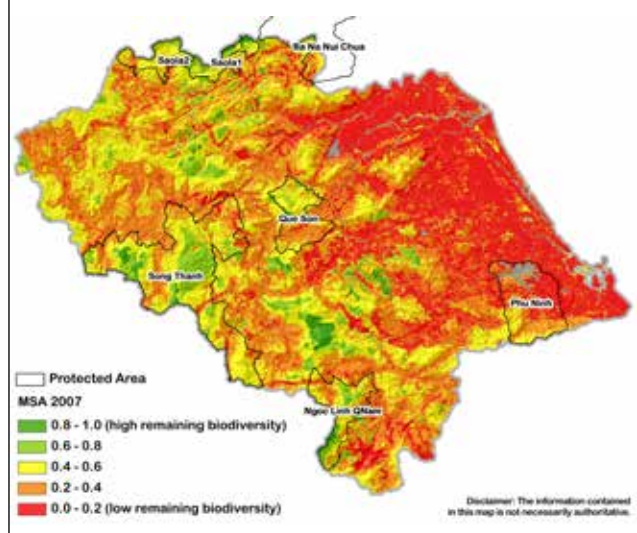
mountainous areas, MSA levels generally remain higher, even though large valleys still do not show much more remaining biodiversity than coastal lowlands (20%–40%). Only very few areas—some mountain ridges—still show near-pristine biodiversity levels of 80%–100%. Overall, even in the mountains, most areas have biodiversity levels well below 60% of the pristine situation. That includes many areas labeled as “forest,” suggesting that simply measuring the extent of forest is not a good proxy to make reliable judgments on ecosystem intactness and richness in biodiversity.

Calculating the difference between MSA maps of 2007 and 2020 provides the base for identifying which areas are expected to suffer from further biodiversity losses, and which areas are potentially relieved from pressures

Table 2: Risk of Land Conversion (Deforestation and Degradation) in major Hydropower Catchments of Quang Nam Province by 2020.

Dam	Total Area (ha)	Conversion Scenario 1 (ha)	Change (%)	Conversion Scenario 2 (ha)	Change (%)
Dak Di 4	45,919	6,285	14%	7,224	16%
Dak Mi 1	2,223	40	2%	28	1%
Dak Mi 4	34,217	677	2%	2,999	9%
Song Tranh 2	60,056	2,161	4%	7,697	13%
Song A Vuong	68,496	2,543	4%	10,059	15%
Song Bung 3	63,049	2,483	4%	9,281	15%
Song Bung 4	82,592	4,237	5%	8,103	10%
Song Bung 5	19,836	988	5%	1,229	6%
Song Con 2	24,099	1,197	5%	4,280	18%
Song Giang	41,462	2,411	6%	4,074	10%
Total	441,949	23,022	5%	54,974	12%

Figure 6: Mean Species Abundance of Quang Nam Province in 2007, overlaid on Protected Areas.



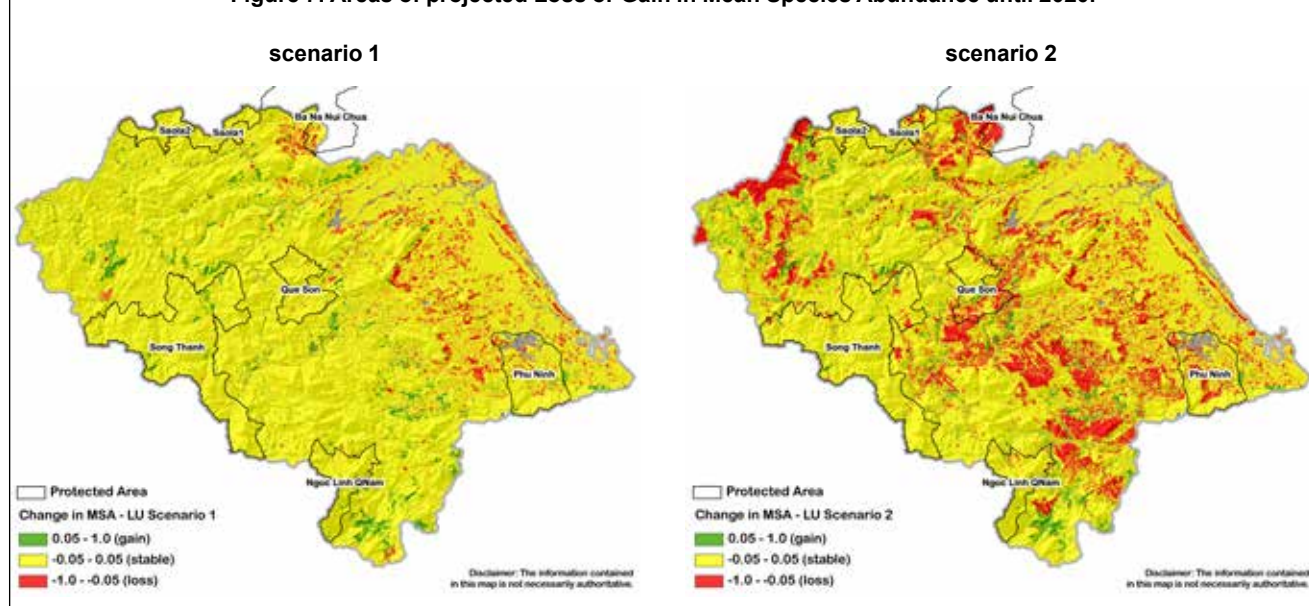
and even show signs of biodiversity recovery. Overlaying protected areas (PA)—the key assets for ecotourism—onto these maps reveals the different levels of impact of different development scenarios (Figure 7, Table 3). First, most PAs in Quang Nam have already incurred a significant decline in biodiversity: even though pockets of near pristine MSA exist in most of Quang Nam's PAs (>90% in Ngoc Linh, Que Son, Song Thanh, and Sao La 1), the majority of the park areas were subject to significant levels of human intervention, resulting in area-weighted MSA values of 58% for Sao La 1 and as low as 29% for Phu Ninh.

The additional impact of development differs by scenario: scenario 1 (conservation-oriented) keeps additional biodiversity loss well below 1% for all protected areas except Ba Na Nui Chua. In scenario 2 (convert to maximize output), biodiversity loss rates increase by factor of 3–5, with Que Son, Sao La 1, and Ba Na Nui Chua subject to potential biodiversity losses of 4.3%, 4.9%, and 11.7%, respectively, until 2020. Even if these biodiversity losses

Table 3: Risk of Biodiversity Loss in key Protected Areas of Quang Nam Province by 2020

Protected Area	Area (ha)	MSA 2007		MSA 2020 - Scenario 1				MSA 2020 - Scenario 2			
		Max	Mean	Max	Change	Mean	Change	Max	Change	Mean	Change
Ba Na Nui Chua (QN)	3,220	76%	36%	76%	-0.2%	33%	-3.7%	53%	-23.4%	25%	-11.7%
Ngoc Linh (QN)	19,114	95%	50%	95%	0.7%	49%	-0.3%	95%	0.0%	49%	-1.1%
Phu Ninh	27,965	87%	29%	87%	0.0%	29%	-0.5%	87%	0.0%	27%	-2.2%
Que Son	18,596	92%	42%	92%	-0.2%	42%	-0.5%	90%	-2.5%	38%	-4.3%
Sao La 1	8,005	96%	58%	96%	0.0%	57%	-0.9%	96%	-0.7%	53%	-4.9%
Sao La 2	9,881	65%	48%	64%	-0.2%	48%	-0.7%	64%	-0.7%	46%	-2.3%
Song Thanh	85,459	96%	49%	96%	0.0%	48%	-0.3%	96%	0.0%	48%	-0.9%

Figure 7: Areas of projected Loss or Gain in Mean Species Abundance until 2020.



still seem low over a period of 13 years (2007–2020), they have to be seen in context of the already low biodiversity levels in 2007. These seemingly low rates of biodiversity loss can cause 3 out of 7 of Quang Nam's PAs to drop below 25% of their remaining biodiversity by 2050, potentially depriving Quang Nam's tourism industry of its essential assets.

6. Outcome and Conclusion

The purpose of this pilot study was to raise awareness with national and regional planners on the relevance of GIS-based models in ex-ante planning. Selected models were introduced and their application demonstrated along a specific planning example, the Quang Nam Land Use Plan 2011–2020.

The exercise yielded several tangible outcomes. All relevant provincial stakeholders, the Department of Agriculture and Rural Development (DARD) and Department of Planning and Investment (DPI) as well as DONRE, were involved in scenario development. CLUE-s outputs highlighted the potential impacts of unrestricted agricultural land expansion on the integrity of hydropower catchments. Similarly, GLOBIO3 facilitated discussion on the conflicts between land expansion and the attractiveness of ecotourism assets. Outputs of both models proved to be powerful cross-sector communication tools, increasing the recognition of sector conflicts and understanding of the role of ecosystem intactness in sector performance (hydropower, tourism). As a result of this discussion, the LUP team revised the land allocation figures twice to better reflect these dependencies and harmonize sector requirements. Besides raising awareness with high-level planners and decision makers, the pilot project also built conceptual and technical capacity on CLUE-s and GLOBIO3 among DONRE, DARD, and DPI technical staff, creating the foundation for the successful application of these models in future provincial planning.

Despite these successes, several broader challenges remain. First, with no legal requirement for SEAs of provincial plans, commitment of provincial authorities to support SEA exercises with comprehensive scenario and impact assessment components remains limited. The LUP land allocation procedure is not transparent and appears to be demand driven (sector and national targets) rather than being based on a realistic assessment of the supply side, i.e., land suitability and coping capacity. Significant limitations with regard to GIS data availability and

accuracy, particularly land cover and land-use data, make it difficult to turn this process around and develop reliable spatial information on sector-specific land suitability and budgeting of related supply. The result is that much of the land allocation used in land-use plans is actually coming out of commune-level statistical surveys rather than actual land-use maps, leading to significant inconsistencies between the plan and the associated land-use map. Viet Nam's rapid economic growth, sector diversification, and resource demands require significant investments in a national and provincial spatial data infrastructure that can cope with the resulting increased planning complexity.

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LAND, WATER, FORESTS, BIODIVERSITY, AND CLIMATE CHANGE IN MYANMAR

Htwe Nyo Nyo¹

Abstract

Myanmar, a tropical coastal country, has a climate generally favorable for various agricultural practices, growth of forests, and development of fishing industries, all of which support the livelihood of majority of the population.

Climate change is likely to affect the agricultural economy. The projected increasing temperature and decreasing rainfall in central Myanmar may lead to the expansion of the country's dry zone, in which annual rainfall is less than 1,000 mm. In other areas, increasing heavy rain in the upper watersheds can increase the occurrence of flash floods, resulting in drowning of people and livestock and destroying infrastructure. Late monsoon onset will delay agricultural cycles, such as soil preparation for rice cultivation. This delay will disturb crop growth in the subsequent months, while abnormal weather may damage the crops. In the harvesting period, adverse climatic conditions can damage the ripening crop. Also, if climate-sensitive sectors, such as agriculture, livestock, and fisheries are largely disrupted by climate extremes, food security of rural communities could be impaired. Under such situations, they would have no alternative but to turn to the forests for intensified exploitation of wood and non-timber products for their survival and livelihood, and could finally destroy the forests.

Measures have been taken by the Government to develop agriculture. However, to reduce vulnerability to climate change, policies, legislation, and other supporting tools need to be developed by government agencies in a coordinated manner. This will help identify and implement adaptation strategies toward a peaceful modern country. For this purpose, institutional strengthening, technology innovation and transfer, provision of advanced tools and equipment, enabling condition with adequate funds, and collaboration with relevant national, regional, and international institutions and agencies are indispensable.

1. Introduction

Myanmar is situated between latitudes 9° 53" and 28° 25" north and longitudes 92°10' and 101°10' east. Myanmar shares a border of 2,192 km with the People's Republic of China on the northeast, 224 km with the Lao People's Democratic Republic on the east, and 2,096 km with Thailand on the southeast. It also shares a 1,331 km border with India on the northwest and 256 km with Bangladesh on the west. Its 2,832 km coastline faces the Bay of Bengal in the west and the Andaman Sea in the south and southwest.

Myanmar has a land area of 676,577 km². The maximum width from east to west is 936 km and length from north to south, 2,051 km (including a 1,200 km long peninsula in the southeast) (Figure 1). Seven States and seven Divisions constitute the Union of Myanmar. The population in 2010 was estimated at 59.8 million, of whom some 67% are rural.

The climate is influenced by the tropical southwest and northeast monsoons. Myanmar has three distinct seasons: rainy, winter, and summer. During the rainy season, the weather is humid, wet, and warm, typical of the tropics. During the winter and the summer seasons, rain-showers occur occasionally.

The economy of Myanmar is currently in transition to a market-oriented structure. Efforts are being made to modernize and liberalize the economy on the basis of free enterprise and market mechanisms, with the provision of safety nets for vulnerable groups during the transition. Positive economic growth, as measured by gross domestic product (GDP), has been recorded in certain sectors of the economy. However, neither the rate of social decline and inequality nor the deterioration of natural resources usually associated with economic growth, has been satisfactorily studied or reported. With continued economic growth, challenges that face the country include macroeconomic instability, volatility of foreign exchange earnings, unstable exchange rates, low level of savings, large deficit, distortions in the price and incentive system, indiscriminate land use, and ecosystem instability. In 2010, the per capita GDP of Myanmar was only \$702 (at current prices), according to International Monetary Fund estimates. However, because of its wealth in natural resources, Myanmar has great potential for economic development.

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Figure 1: Map of Myanmar



2. Land, Water, Forest, and Biodiversity

2.1 Land Resources

The total area of 676,577 km² is divided into several land types as shown in Table 1. Forest covers about 49% of the total; the net sown area about 18% (including fallow land), and the cultivable waste land about 8%. The land area is divided into mountainous and plateau, plains, and river valleys. The mountain ranges and the plateau occupy the majority of the total area. The trend of expanding agriculture into forest lands can be seen clearly in the Ayeyarwady Delta, where agricultural fields and fish ponds are increasing among the forest in the northern part and mangroves in the coastal area.

Table 1: Area by Type of Land, 2009–2010

Type of land	Area (million ha)	% of total
Reserved forest	16.90	24.98
Other wood land	16.25	24.02
Current fallows	0.24	0.35
Net area sown	11.98	17.71
Cultivable waste other than fallows	5.61	8.29
Others	16.68	24.65
Total	67.66	100.00

Source: Ministry of Agriculture and Irrigation, 2011.

Forest areas are also divided according to types of vegetation, such as closed-broad-leaved, mangroves, bamboos, and conifers. Grasslands are few, intermingling with other vegetation. Alpine regions are found in the northwest, north, and northeast; coniferous forests occur along the eastern borders the northwest, north, and northeast; and coniferous forests are found along the eastern borders. Dry forest ecosystems generally dominate the arid and semi-arid regions, which make up about 20% of the land, especially in the central part of Myanmar where temperature is very high, rainfall is low,

and the soils are generally deteriorating due to drought and desertification.

Shifting cultivation is practiced by about 2.6 million people living in hilly regions. It covers an area of about 142,000 hectares. Shifting cultivation is one of the main causes of deforestation, which in turn has led to soil erosion and land degradation. In the coastal and the delta region, waterlogging, flooding, and seawater encroachment are the principal causes of land degradation. Flooding and annual tidal water encroachment have caused soil salinization in these areas.

The topography of Myanmar can roughly be divided into three regions, the eastern hills, the central valley, and the western hills. There is extraordinary topographical diversity, with elevation ranging from sea level to nearly 6,000 m in the high mountain peaks in the north. The major mountain ranges are the Eastern Himalayan Range in the north; the Chin Hills in the west, extending northwards to southern India; the western plateau, between the Ayeyarwady River and the Bay of Bengal; the Bago Yoma located between the Ayeyarwady and the Thanlwin rivers; the eastern plateau located in the northeast of the country bordering with the PRC, the Lao PDR, and Thailand; and the Taninthayi mountain range located in the southern peninsula bordering Thailand.

2.2 Water Resources

Myanmar has eight river basins as shown in Table 2. The Mekong River flows along the border with the Lao PDR. According to 2003 data, the annual average potential amount of surface water is 828 km³ and groundwater 495 km³ (Table 2).

Water withdrawals in Myanmar have been increasing, particularly in the agricultural sector. Table 3 shows total

Table 2: Annual Average Water Resources Potential, by River Basin

Name of Principal River Basin	Catchment Area ('000 km ²)	Average Annual Surface Water (km ³)	Estimated Groundwater Potential (km ³)
Chindwin River	115.30	227.920	57.578
Upper Ayeyarwady River (up to its confluence with Chindwin River)	193.30	141.293	92.599
Lower Ayeyarwady River (from confluence with Chindwin to its mouth)	95.60	85.800	153.249
Sittoung River	48.10	81.148	28.402
Rivers in Rakhine State	58.30	139.245	41.774
Rivers in Tanintharyi Division	40.60	130.927	39.278
Thanlwin River (from Myanmar boundary to its mouth)	158.00	257.918	74.779
Mekong River (within Myanmar territory)	28.60	17.634	7.054

Source: Ministry of Agriculture and Irrigation, 2011.

Table 3: Water Use (km³) in Different Sectors

Sector	Surface water	Groundwater	Total	Percent
Irrigation	40.69	0.81	41.5	91
Domestic	1.15	2.55	3.7	8
Industrial	0.32	0.08	0.4	1
Total	42.16	3.44	45.6	100

Source: Ministry of Agriculture and Irrigation. 2003. *Water Resources Management in Myanmar, 2003*.

water use in different sectors for the year 2004-2005 (Win, 2006). The agricultural sector is by far the largest water user. Previously, the government irrigation investment strategy was strongly oriented toward increasing the water supply by developing storage capacity, particularly by construction of dams, weirs, and sluice gates.

Wetlands, including big lakes and marshlands, also constitute a mechanism to regulate storage and flow of water in the country. Inle Lake, with its scenic beauty and traditional cultural attraction is shrinking due to soil erosion from the surrounding area because of forest depletion and degradation and unsustainable agricultural practices. Indawgyi Lake in Kachin State is also shrinking. Similar situations have occurred in many other places in Myanmar. Some tributaries of large rivers are contaminated with chemicals due to mining activities in their watersheds.

Groundwater is a major component of the available water resources. Groundwater, pumped manually and mechanically, provides additional water to villages that rely on ponds for harvesting rainwater during the rainy season.

Myanmar is rich in diverse inland aquatic ecosystems that contain an abundant fauna of freshwater fish and both resident and migratory birds, and aquatic plants. Inland waters and their biodiversity are a vital resource for the people in the country for agriculture, food, and transport as well as cultural and spiritual integrity.

Irrigation for agriculture has been developed, particularly in the dry zones, by pumping water directly from rivers and by drilling tube wells. Also, since 1990 to the end of 2010, the Irrigation Department has constructed 233 dams and reservoirs for irrigation and flood protection; about 1.68 million hectares of cropland are now irrigated, 17% of total sown area in 2009-2010.

2.3 Forest Resources

Forests are the most important of Myanmar's natural resources, not only for the livelihood of the people but also for the national economy as well. About half the total land area is covered by forests. There is a wide diversity of forest ecosystems. Forest types range from high alpine forests to coastal tidal forests (Table 4). Forest flora can be divided into 48 ecological subdivisions based on climatic, edaphic, and other factors. Among the principal categories, the mixed deciduous teak and hardwood forests and dipterocarp forests are the most important commercially. The mangrove forests in the coastal areas and Ayeyarwady Delta are vital for the ecological stability of these areas.

These diverse forests provide a wide range of goods and environmental services. Forty-five commercial timber species are extracted, with teak, ironwood, and rosewood being the most valuable and best known. The forests provide fuelwood to rural households and local cottage industries. Although the forestry sector accounted for only 0.54% of total GDP in 2006-2007, it generated about 10% of total export earnings, second only to the agriculture and petroleum sectors (CSO, 2008). Thus, the state of forest resources is of major significance for livelihoods and the economic stability of the nation. The areas under different forest types are presented in Table 4.

Non-timber resources include bamboo, rattan, bark, cosmetic *thanakha*, thatch, *indwe*, bat guano, pine, resin, bush meat, and parts of animals (hides, horns, bones,

Table 4: Major Forest Types

No.	Forest Types	Area (ha)	% of total forest area
1.	Tidal Forest	1,376,900	4
2.	Beach and Dune Forest		
3.	Swamp Forest		
4.	Tropical Evergreen Forest	5,507,800	16
5.	Mixed Deciduous Forest	13,425,300	39
6.	Dry Forest	3,442,400	10
7.	Deciduous Indaing (Dipterocarps)	1,721,200	5
8.	Hill and Temperate Evergreen Forest	8,950,100	26
	Total Forest Area	34,423,700	100

Source: Forest Department, Ministry of Forestry.

snout, hooves, fur, and tongues). Forest resources also include some 800 species of herbs, shrubs, and climbers, among which more than 300 are said to be potent and used as medicine. Many of these medicinal forest plants have been domesticated and are grown in nurseries and home gardens. Rural people still rely on these medicinal plants in times of illness and diseases.

Mangroves provide such products as charcoal, firewood, and housing materials; they also provide ecosystem services, such as feeding and spawning grounds for aquatic species, nesting places for wildlife, and protection against strong winds and seawater intrusion.

It is interesting to note the social attitudes toward forest conservation. In the dry zone of central Myanmar, agriculture is now at its upper limit and further horizontal expansion is almost impossible. The agricultural lands under private ownership are now being managed intensively and scientifically. Good practices have been spreading to other private lands under cultivation. Tree planting in private lands as well as in religious compounds is now a common practice in the dry zone. To reduce deforestation and forest degradation, cutting of trees for firewood has been prohibited in this zone by local authorities. Local people have solved the firewood shortage on their own. The groves of wild jujube (*Zizyphus jujube*) plants, which are now privately owned, are considered a gold mine.

The rate of deforestation increased and then declined over time, from a 2% annual loss between 1975 and 1989, 7% during 1989 to 1998, and 3.2% during 1998 to 2006, to 1.8% during 2006 to 2010 (FAO, 2010).

2.4 Biodiversity

Protection of soils, water, biodiversity, and the natural environment is identified as an important imperative in the 1995 Myanmar Forest Policy. Fauna and flora in Myanmar recorded to date are shown in Table 5. Flora include 273 plant families and 2,371 genera, of which 2,300 are trees, 97 bamboos, 26 rattan (cane), and 841 orchids. However, the market for wildlife and their parts is increasing in neighboring countries and the wildlife trade in Myanmar to meet the demand is growing, and has become a direct threat to wildlife. Unintentionally introduced invasive alien species further threaten the survival of native flora and fauna.

A protected areas system is well established, including parks and sanctuaries. Myanmar is committed to sustainable development of forests and biological

Table 5: Wildlife Fauna and Flora in Myanmar

No.	Description	Number of species
1.	Birds	1,056
2.	Mammals	251
3.	Reptiles	153
4.	Butterflies	1,200
5.	Plant species	7,000

Source: NCEA (1997, 2009c).

resources through accession to a number of international conventions and agreements. The forestry sector is said to maintain a balance between environment, development, and social needs.

So far, 23 sanctuaries and 5 parks, constituting about 2.3% (15,270 km²) of the total land area of the country, have been established. It is stipulated in the Myanmar Forest Policy that the coverage of the protected area system will be increased to 5% in the short term and 10% in the long term.

The Myeik Archipelago on the west coast, a beautiful island group comprising more than 800 islands with exposed peaks and several submerged ridges, has rarely been visited by humans, despite being in the geographical center of Asia. The archipelago offers a rare chance to see a natural environment almost untouched. Most of the archipelago's high islands retain forest cover dominated by tropical wet, evergreen forests in the interior and mangrove forests along the coast. The Myeik Archipelago is one of the few areas left on earth where there still exists a continuous transition from rain forest to coastal mangrove swamps.

The economy of Myanmar is largely based on the agriculture sector, which makes up 36% of the gross domestic product (GDP) and 35% of total export earnings, employing 63% of the total labor force. With about 20 million ha of total arable land, a projected population of 60 million in 2010, and 2% population growth rate, the agriculture sector will continue to play a very significant role in the future. Therefore, its first and foremost objective is to develop and promote economic sectors based on agriculture. For the development of the agriculture sector itself, increasing productivity and improving product quality are two principal objectives.

Soils and climatic conditions in many parts of Myanmar favor cultivation of rice, the principal agricultural crop. Rice is the staple food of the entire population and per capita rice consumption Myanmar is one of the highest in the world. Myanmar is a rice-surplus country. It is planned to increase the rice cultivation area to 8.09 million ha.

Rice production in the country has already increased significantly due to the introduction of summer rice in 1.22 million ha as well as the use of high-yielding, or modern, crop varieties (MVs), hybrid seeds of vegetables, and associated technologies.

Since Myanmar is the home of many tropical crop species, their genetic diversity is immense. However, with the introduction of MVs, the continued existence of these genetic resources is at risk. Destruction of the habitat of wild species and related genera by rapid urbanization can also be expected in the very near future. Socioeconomic issues and unsustainable agricultural practices are additional threats to agricultural biodiversity. In order to prevent the permanent losses of genetic diversity for many tropical crop species, plant genetic resources management, conservation, and utilization research activities are critical issues for Myanmar agriculture.

The fishery sector plays an important role in providing food and income, contributing to the social and economic status of Myanmar. Thus, it is essential to conserve the country's 0.5 million hectares of coastal wetlands that provide the essential spawning grounds, nursery areas, and feeding grounds for marine and brackishwater fauna.

3. Climate Change in Myanmar

3.1 Climate

Myanmar's climate is greatly influenced by the tropical monsoon circulating system. The Rakhine Mountains, bordering Bangladesh and India, obstruct the southwest monsoon from central Myanmar, which is consequently semi-arid, characterized by summer temperatures above 40°C and low annual rainfall of about 500 mm.

During the winter and summer seasons, the northeast monsoon winds bring pronounced cold weather with occasional rain falls to the northern parts of Myanmar and hilly regions, while other parts are moderately cold. Rainfall is influenced also by the locality. The coastal regions receive about 5,000 mm of annual rainfall. In the far north there are snow-capped mountains.

3.2 Climate Change

Climate change impacts are likely in the tropical coastal regions due to global warming as projected in reports by the Intergovernmental Panel on Climate Change. The

increasing frequency of cyclones and accompanying strong winds, storm surge, floods or inundation, intense rains, extreme temperatures, droughts, and sea-level rise are evidence of climate change-related impacts to which Myanmar has to pay serious attention.

3.3 Natural disasters

Myanmar lies in a climatic zone that is frequently subjected to cyclones and river flooding. The former occur periodically, but unpredictably and cause extensive damage to property, soils, and crops, and take a heavy toll on human and animal lives. Flooding, sometimes caused by cyclones, but more often by excessive precipitation in the mountainous watersheds, is a regular feature of Myanmar's extensive floodplains. Each year, 2 million ha of land are severely flooded and another 3.25 million ha are moderately inundated. These floods reduce agricultural production, cause erosion and sediment loading, and spread infectious disease. Finally, much of upper Myanmar lies in a tectonically active zone.

During the last four decades, Myanmar had five major cyclones: Sittwe in 1968, Patheingyi in 1975, Gwa in 1982, Maungdaw in 1994, Cyclone in 2006 and Nargis in 2008. Nargis, which struck Ayeyarwady Delta and the eastern part of Yangon in Yangon Division with a wind speed of over 260 km per hour, and the associated floods, caused the deaths of over 100,000 people, as well as massive physical destruction of mangroves, agricultural fields, houses, and utility infrastructure. Furthermore, flooding, especially of saltwater into agricultural lands and freshwater bodies, caused further extensive economic, social, and environmental damage.

In central Myanmar, streams that are often dry are subject to flash floods caused by heavy rain in the upper watersheds, resulting in drowning of people and livestock and destroying infrastructure.

However, projected increasing temperature and decreasing rainfall in central Myanmar under climate change may lead to the expansion of the country's dry zone, in which annual rainfall is less than 1,000 mm.

3.4 Vulnerability of Different Sectors to Climate Change

Agriculture. Severe climate change effects could affect the country's production of rice and other crops on which the population depends. Climate change might also affect

local varieties, already endangered due to replacement with MVs, urbanization, deforestation, and growing population pressure.

Forestry. Myanmar's forest areas have been destroyed by cyclones, strong winds, floods, extreme temperatures, and droughts in addition to human pressure. The dominant forest type is the deciduous forest that sheds leaves during the dry season when the climate is extremely hot and catches fire easily. Forest fires are becoming more severe, killing wildlife. Climate change is likely to cause increased dryness—as well as wetness—and thereby affect the survival of flora and fauna.

Biodiversity. Myanmar is often cited as the last frontier of global biodiversity in Asia. By their nature, forests are highly vulnerable to climate extremes such as warming and drought. Many species of fauna and flora are highly endangered. Strenuous efforts to maintain the network of protected areas are needed to prevent biodiversity loss.

Mangrove Ecosystems. In some coastal areas of Asia, a 30 cm rise in sea level can result in 45 meters of landward erosion (Tun, 2009). Sea-level rise tends to aggravate the currently eroding coastal areas; thus, mangrove forests and swamp areas along the Myanmar coast are facing degradation. Loss of mangrove ecosystems means loss of the valuable products and ecosystem services mentioned earlier.

Coral Reefs. The vast and diverse coral reefs of Myeik Archipelago are of immense ecological and economic importance for the country. Sea-level rise is likely to significantly affect the social and economic situation of coastal areas like the Myeik Archipelago. If the corals die due to high temperature-induced bleaching, the production of lucrative fish and the farming of fish, pearl oysters, deep sea lobster, and seaweed will all be affected. Some species of marine fish may disappear or move to colder regions, as will some native species of whales and dolphins.

Coastal Erosion. Many sandy beaches along the coastal areas of Myanmar already face problems of coastal erosion due to structural development, changes in living patterns, and recreational activities, including ecotourism. Such activities are affecting marine turtle nesting beaches, such as Maungmakan beach in Taninthayi Division. Such degraded areas are highly vulnerable to climate change hazards.

Some of the islands located on the Rakhine coast that are important areas for marine fisheries production are

also affected by waves during the monsoon season. In Thandwe District, two out of three villages have already been displaced by coastal erosion. In the monsoon season, some residents move to other villages and some seek shelter at the monastery in their village. This situation will be worsened as sea level rises under climate change.

3.5 Needs and Concerns Arising from Adverse Effects of Climate Change

The loss and damages due to Cyclone Nargis in the Ayeyarwady Delta reflect, to a certain extent, the vulnerability of Myanmar to climate extremes. As a developing country, people's livelihoods mainly depend on favorable climate conditions and availability of natural resources, such as land, water, and forest resources.

In the agricultural sector, late monsoon onset will delay agricultural cycles, such as soil preparation for paddy cultivation. This delay will disturb crop growth in the subsequent months. During the growing season, abnormal weather will damage the crops. In the harvesting period, adverse climate can damage the ripening crop.

Disruption in agricultural activities will affect the socioeconomic development of the country through increasing prices of basic commodities and transport. For example, during the relief and recovery period after Cyclone Nargis, the prices of basic food items rose significantly, because of the fear that there would be decreased food supply from the Ayeyarwady Delta. In fact, rice production from the delta contributes only about 10% of the country's total rice consumption. Nevertheless, this fear remained for several months, keeping prices high.

Freshwater resources in the coastal areas are mainly the impounded waters in ponds and reservoirs and groundwater. In the event of cyclones, freshwater storage facilities are damaged by strong winds and seawater inundation. Also there is disruption of municipal water supplies and groundwater supply owing to problems in electricity supply. Water shortages cause a number of problems, especially in urban areas where hygiene levels become low and can result in outbreak of diseases.

In the event of climate extremes, forests are vulnerable not only to climate change but also are at high risk of being over-exploited. If climate-sensitive sectors, such as agriculture, livestock, and fisheries are largely disrupted by climate extremes, food security of rural communities could be impaired. Under such situations, they would

have no alternative but to turn to the forests for intensified exploitation of wood and non-timber products for their survival and livelihood, and could finally destroy the forests.

4. Conclusion

Myanmar, a tropical coastal country, with north-south running mountain ranges and river systems, is endowed with substantial water resources mainly due to the southwest monsoon. It is rich in biodiversity due to the extensive forest cover. Myanmar has fertile river valleys, an extensive deltaic plain, and a long coast line with diverse marine resources.

Measures are being taken by the Government to ensure the country's food security, which is one of the principal requisites for national development. There have been improvements in the irrigation system, such as construction of new reservoirs and dams, installation of more river pumping stations, and increased groundwater harvesting. Systematic use of fertilizers and introduction of some advanced agricultural technologies are also being undertaken. Summer rice production and wetland cultivation in addition to rained cultivation are promoted. However, adaptation plans for this sector should be further enhanced for increased earning of foreign exchange and national economic development.

The climate is generally favorable for various agricultural practices, growth of forests, and development of fishing industries, all of which support the livelihood of majority of the population. Extreme events and climate variability disrupt the livelihoods of rural populace, particularly farmers, and affect national development. Cyclones from the Bay of Bengal usually cross the Rakhine coast at least about once in every two years. Floods and droughts in certain areas occur annually. The landfall of Cyclone Nargis in 2008 over the Ayeyarwady Delta demonstrated that Myanmar is vulnerable to cyclones originated in the Bay of Bengal, although presently rare.

To reduce vulnerability to climate change, policies, legislation, and other supporting tools need to be developed by government agencies in a coordinated manner. This will help identify and implement adaptation strategies toward a peaceful modern country. For this purpose, institutional strengthening, technology innovation and transfer, provision of advanced tools and equipment, enabling condition with adequate funds, and collaboration with

relevant national, regional, and international institutions and agencies are indispensable.

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Session 2.3: Energy

MEKONG ENERGY METABOLISM: CONNECTING ENERGY DEMAND INTO THE NEXUS OF FOOD-WATER- ENERGY SECURITY

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Abstract

The Greater Mekong Subregion (GMS) is composed of countries and economies described as dynamic, politically, socially and economically diverse, and ambitious in terms of national aspirations, expansion and growth. Until 40 years ago the Mekong River remained a relatively unmodified river system connecting the primary livelihood pursuits of agriculture, fishing and forestry of a predominately rural population. The current portfolio of policy instruments, strategies, and metrics developed in the GMS is generally associated with the expertise and evidence arising from the relatively stable and weak levels of connectivity associated with an unmodified Mekong. Human migration, natural resource flows, and private and State financial investments are amongst a cluster of factors likely to influence the critical dynamics generating increased levels of connectivity between Mekong countries.

High levels of connectivity increase complexity, biasing the reliability of predicted outcomes and increasing the potential for unforeseen consequences of national decisions. Strong connectivity implies that interacting factors transmit the effects of substantial changes from one part of a region or sector to another.

The paper takes high levels of connectivity into account, describing the nexus between energy, water, and food by reviewing one energy development pathway based on large-scale hydropower. By “pathway” we refer to patterns of choices made by public and private actors which lead to intended as well as unintended consequences. By way of literature based insights and review, we describe the consequences of the hydropower pathway on the GMS energy system and the likely interactions and implications of hydropower generation

for food security, water security and livelihoods in a strongly connected Greater Mekong Subregion.

1. Introduction

In this paper we describe energy considerations and policy deliberations when linked to food, livelihood and water security in the “wider Mekong region,” which covers all the Greater Mekong Subregion (GMS) as defined by the Asian Development Bank (ADB, 2004), except Guangxi Zhuang Autonomous Region of the People's Republic of China (PRC). The wider Mekong region covers more than 2.3 million km² and its population exceeds 278 million (ADB and UNEP, 2004).

The dynamics of connectivity and interdependence between the energy, food and water sectors are changing rapidly. The paper takes high levels of connectivity into account and provides a partial cross-sectoral assessment of development-directed investments in the GMS initiated to satisfy aspirations of national economic growth. We contend that increasing energy demand and national objectives of energy security are central to and catalyze economic growth imperatives. Contingent on a strongly connected region, a singular, linear appraisal of energy security that fails to account for the consequences on food and water security is likely to lead to substantial social cost. The achievement of national energy security objectives may mean either substantially compromised regional energy security or reduced food and water security at both national and regional scales.

The current portfolio of instruments, responses, strategies, and metrics developed in the wider Mekong region is generally associated with the expertise, experience, and evidence arising from the relatively stable and weak levels of connectivity associate with a relatively unmodified Mekong. Periodic amendments have arisen, but have not been subject to notions or threats of redundancy and high probabilities of policy failure due to changed connectivity levels. A tension arises when institutional arrangements and analysis underpinning policy decisions are geared to assumptions of weak connectivity and analysis confined to a single economic sector (De Landa 2006, Molle *et al.* 2009).

Regardless of the level of connectivity, we assume that measures of well-being focused on poverty levels and livelihoods remain the major metrics to appraise policy and governance performance, together with gross domestic product (GDP) and gross national product (GNP).

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We illustrate the nexus between energy, water, and food by reviewing one energy development pathway based on large-scale hydropower and a contrasting pathway based on the production of bio-energy. By “pathway” we refer to patterns of choices made by public and private actors, emphasizing governance contexts, which lead to intended as well as unintended consequences. We explore the consequences of the hydropower pathway on the Mekong region’s energy system and detail the interactions and implications of hydropower generation for food security, water security and livelihoods in a strongly connected Greater Mekong sub-region.

The remaining six sections of the paper describe existing and foreseeable interactions and connections of hydropower construction, generation and operation in the Mekong mainstream with water security, livelihoods, food security and land-use change.

Section 2 provides background information and theoretical rationale.

Section 3 describes the historical and contemporary factors influencing the dynamics and levels of GMS sectoral and regional connectivity. Central to the background synthesis are the three enabling conditions influencing the degree of regional connectivity: (a) the endowment, scarcity, and accessibility of resources within the connected region; (b) the financial capacity to activate these resources as production factors; and (c) the institutional conditions enabling resource transfers to occur.

Section 4 details the region’s energy demand as a catalyst for increased food and water connectivity, focusing on the development of mainstream hydropower construction and operation.

Section 5 describes the interactions of hydropower electricity generation with livelihoods (focusing on occupation and income), migration and food security (emphasizing nutrition) in the Greater Mekong sub-region.

Section 6 reviews the current literature concerned with the potential consequences of hydropower dam construction and operation inclusive proposed irrigation diversions. The discussion focuses on changes to in-stream sediment and nutrient loads; mainstream wet and dry season hydrological characteristics; and the volume, timing and duration of flood pulses (emphasizing the aquatic environs of the Tonle Sap lake).

Section 7 describes likely changes in land use patterns and activities. The paper concludes by synthesizing the previous discussion and points to further research foci.

2. Background

Dynamic, diverse, ambitious, and driven are words central to describing the contemporary Mekong region. The region is dynamic: it has a youthful, growing population, an expanding workforce, and consequently significant movement out of smallholder agriculture. It is economically and politically diverse: there are the three ‘least-developed’ economies: Cambodia, Lao People’s Democratic Republic (Lao PDR), and Myanmar; two large economies, Thailand and Viet Nam; and Yunnan Province of the PRC. It is ambitious: not just in terms of the aspirations of younger people and their parents, but of its leaders and policy makers to expand trade, mining, manufacturing, transport, tourism, and industry. The Mekong region is projected to grow rapidly. For Thailand and Viet Nam, the two largest economies of the region, APEC (2009) projects GDP as growing 4.5% and 6.2% per annum, respectively, during 2005–2030. The 2012 growth projection for Cambodia is 6.7%, for the Lao PDR 6.9%, Thailand 4%, Viet Nam 7.2%, and PRC 8.1% (Business Monitor International, 2011).

The region is driven and stimulated by a number of exogenous influences. These pertain to the Mekong region’s position as a purveyor of labor, food, tourist destination, textiles, and other manufactured goods connected to the global economy, but also include such factors as the reality of climate change and the social responses to adapt to those changes.

Until 40 years ago the Mekong River remained a relatively unmodified river system of low impoundment, connecting the primary livelihood pursuits of agriculture, fishing and forestry of a predominately rural population. The Mekong has thus acted as an historical conduit of relatively stable cultural, economic, agricultural and spiritual connection across the Mekong region countries, despite periods of political and economic turbulence (Molle *et al.*, 2010).

Human migration, natural resource flows, and financial investments are amongst a cluster of factors that influence the critical dynamics generating increased levels of connectivity between Mekong countries (Dore, 2003; Harima *et al.*, 2003; Theeravit, 2003; Contreras, 2007).

The three enabling conditions central to the degree of regional connectivity are (a) the endowment, scarcity, and accessibility of resources within the connected region; (b) the financial capacity to activate these resources as production factors; and (c) the institutional conditions enabling resource transfers to occur.

A set of bio-physical and hydrological conditions over the past 40 years has also promoted high levels of economic and political connectivity between Mekong riparian countries (Theeravit, 2003; Molle *et al.*, 2009). The steep elevation gradients of the head waters and upper catchments of the main tributaries have provided opportunities for impoundments and hydropower generation, tentatively coexisting with biodiversity hotspots, small scale localized irrigation, and swidden agriculture. The rapid gradient transition to the extensive plains and deltas has allowed water diversions for agrarian landscapes, including extensive irrigation, fisheries, and river-based transport. Resource endowments, however, are geographically dispersed and characterized by variable extraction costs and relative scarcity at national scales.

Theeravit (2003) claims the financial strength of Chinese, Thai, and Vietnamese private and state companies has accelerated their potential to invest internationally. A political environment conducive to increased direct foreign and private investment is likely to cohere the bio-physical and institutional conditions in neighboring countries to facilitate the supply of demanded resources leading to increased wider Mekong region connectivity.

International financial organizations and aid donors that have historically supported Mekong countries are increasingly being substituted by direct foreign investment, private financiers, and government elites in order to source, and alternatively conserve, natural resources or manufacturing capacity in neighboring countries (Middleton *et al.*, 2009; Molle *et al.*, 2009). Alternate resource financing arrangements can either bypass existing regulatory processes and enforcement statutes, remain undetected as primary agents of connectivity, or challenge the efficacy of institutions geared to historically low levels of connectivity.

High levels of connectivity increase complexity, biasing the reliability of predicted outcomes and performance and increasing the potential for unforeseen consequences of national decisions (Cechich *et al.*, 2003; Sawyer, 2005; De Landa, 2006). The effects of large-scale investments in weakly connected regions are generally constrained to locales proximate to the initial target area within a

particular country. In contrast, strong connectivity implies that interacting factors transmit the effects of substantial changes from one part of a region to another.

The constellation of biophysical and socioeconomic factors and dynamics has implications for the political economy of the Mekong (Dore, 2003). Inter-country discussions to activate economic potential and satisfy aspirations of national economic growth can stimulate the development of supra-national institutional arrangements and governance processes that reinforce regional connectivity.

Examples for such reinforcing processes are bilateral agreements to reduce the capital outlays and operational costs of infrastructure necessary for transporting resources. Changes in land-access rights and foreign investment regulations are likely institutional amendments. As a corollary, changes in migration legislation might be required to satisfy labor requirements, further buttressing the connectivity beyond national boundaries. Similar implications arise for the relationships between labor, electricity, water, minerals, and agricultural resources. As these links intensify, regional connectivity increases and over time a highly connected region can emerge, such as the Mekong region.

3. Impending Decisions with Regional Implications

As part of the Exploring Mekong Futures project,⁵ two expert panel workshops identified and analyzed six large-scale impending investments with potentially regional implications by altering the degree of sectoral and agency connectivity. The six potential investments represent the final result of extensive consultation and collaboration with regional policy makers, government agencies and decision influencers. The objective of the expert panel process was to articulate the first, second and third order system interactions and influences of the potential Mekong investments with respect to; livelihoods, energy, water resources, food security, mining and large scale land use changes.

The connectivity aspects discussed in this paper focus on one of the identified investments: the development of mainstream hydropower dams as a primary component of national and regional energy generation. The construction of mainstream hydro power dams influences, and in turn, is influenced by the other identified investment proposals. To complete the context of the expert panel process, the six

⁵ <http://www.csiro.au/resources/Mekong-Futures-brochure.html>

impending development decisions, which are interacting and interdependent factors of connectivity in the wider Mekong region, are briefly described below.

1. *Large-scale water diversion, in particular transfers within and between the Lao PDR and Thailand.*

Water diversion is already a reality within the wider Mekong region and the Mekong Basin. Several combinations of inter- and intra-basin diversions have been considered (MRC, 2005a, b). The workshop assumed diversions from the Lao PDR Nam Ngum tributary for irrigation in northeastern Thailand, by building a diversion dyke and tunnel under the Mekong (Molle and Floch, 2008).

2. *Investments in response to sea level rise.*

Global sea levels are likely to increase in accord with Intergovernmental Panel on Climate Change (IPCC) assumptions on increasing global temperature (Rahmstorf, 2007). Average projections of global sea-level rise are around 20 cm by 2030 (Rahmstorf, 2007), subject to wide geographic variability dependent on surface temperatures. The Vietnamese Institute for Meteorology, Hydrology and Environment assumes 65–100 cm by 2100 (IMHEN, 2010, p. 30). Similarly, IPCC predicts a sea level rise for the Mekong region of up to 100 cm by 2100 (IPCC, 2007, Chapter 5.2), the reference level considered by the Mekong River Commission (MRC, 2009). Salinity intrusion is already a significant problem in the Mekong Delta (MRC, 2003). We assume that a sea level rise of 20 cm will further accelerate salinity intrusion and the severity of storm surge.

3. *Land-use changes in response to accelerated increases in rubber demand.* We assume that by 2050 an additional area of 1.6 million ha will be converted to rubber plantations (Ziegler *et al.*, 2009; Fox *et al.*, 2010). Further we assume that half of the rubber plantations will be managed by small holder farmers and half by large concession holders.

4. *Construction of transport infrastructure, in particular the Kunming-Cambodia railway.* Regional railway lines in all countries are planned for development (or rehabilitated) to further regional integration and connectivity in the Mekong Region. The status of Mekong region transport proposals is highly fluid, with substantial changes or possible abandonment likely. Current proposals include

- Cambodia: rehabilitation of the railway funded by the Asian Development Bank (ADB) and the Australian Agency for International

Development (AusAID);

- PRC: financing the feasibility study for a rail link between Phnom Penh and the border with Viet Nam;
- PRC: building a new line to the Viet Nam and Myanmar borders;
- Thailand: considering improvements to the Thai rail system and development of a high-speed train line and new links to the Lao PDR and onward to Viet Nam;
- Viet Nam: considering lines to the Lao PDR and Cambodia;
- A connecting rail link through the Lao PDR to form part of the Association of Southeast Asian Nations (ASEAN)-PRC railway has been proposed but is currently in abeyance. If constructed the link will run from Yunnan Province through the Lao PDR to Thailand, Malaysia, and Singapore.

5. *Mining operations, in particular bauxite mining in the southern Lao PDR, Northeast Cambodia, and Viet Nam highlands.* Deposits of bauxite have been prospected and explored for the last four years in the Bolaven Plateau in the southern Lao PDR (Champasak Province next to the Cambodian border). A commercially viable alumina refinery is feasible, although requiring upwards of 0.5 million tons of alumina output or between 1.0 and 1.5 million tons of raw bauxite per year, dependent on the grade of the bauxite, for a period of not less than 20 years. Such a venture requires a considerable volume of electricity, possibly in the region of 150 megawatts (MW), and large quantities of water (Sekong River and Sekong dams). Processing of the alumina in an aluminum smelting operation into saleable aluminum is not currently an option as it requires 100% reliable electricity in the order of 600–800 MW, dependent on the technology applied and the scale of the operation. It would only be possible if more hydropower development becomes available. The proposed railway linking Kunming and the Lao PDR makes bauxite mining more viable.

6. *Mekong River mainstream dams.* For the purpose of this discussion, we assume that 12 hydropower dams will be built on the Mekong mainstream during 2011–2025 (ICEM, 2010). The estimated total peaking capacity is 12,980 MW, with 64,229 gigawatt hours (GWh) mean annual energy generated (ICEM, 2010, Table 3.1) (Table 1).

Table 1: Assumptions for Mainstream Mekong River Dam Construction

MAINSTREAM DAM	LOCATION	DEVELOPER	MANAGEMENT STATUS			DESIGN SPECIFICATIONS										DIMENSIONS		
			EARLIEST POTENTIAL COMMISSION DATE	DESIGN STATUS	ENVIRONMENTAL ASSESSMENT STATUS	Rated Head (m)	Plant Design Discharge (m³/s)	Installed Capacity (MW)	Peaking Capability (MW)	Mean Annual Energy (Gwh)	Firm Annual Energy (Gwh)	Full Supply Level (mamsl)	Low Supply Level (Mamsl)	Live Storage (mcm)	RESERVOIR AREA (km²)	Length of dam (m)	Height (m)	
Pak Beng	Lao PDR	Datang International Power Generation (China)	2016	MoU, feasibility	IEE submitted	31	7,250	1,230	1,230	5,517	4,073	340	334	442	87	943	76	
Luang Prabang	Lao PDR	PetroViet Nam Power Corporation (Viet Nam)	2016	MoU, feasibility	Feasibility study,	40	3,812	1,410	1,412	5,437	4,205	310	308	734	90	1,106	68	
Xayaburi	Lao PDR	SEAN & Ch. Karnchang Public Co Ltd (Thailand)	2016	MoU, feasibility	Feasibility & full ESIA submitted	24	6,018	1,260	1,260	6,035	5,139	275	270	225	49	810	32	
Pak Lay	Lao PDR	CEIEC and Sino-Hydro (China)	2016	MoU, feasibility	IEE submitted	26	4,500	1,320	1,320	6,460	4,252	240	237	384	108	630	35	
Sanakham	Lao PDR	Datang International Power Generation (China)	2016	MoU, feasibility	Not yet	25	5,918	700	1,200	5,015	3,978	220	215	106	81	1,144	38	
Pakchom	Lao PDR Thailand	N/a	2017	MasterPlan	Not yet	22	5,720	1,079	1,079	5,318	5,052	192	190	12	74	1,200	55	
Ban Koum	Lao PDR Thailand	Italian Thai Asia Corp. Holdings (Thailand)	2017	MoU, feasibility	Not yet	19	11,700	1,872	1,872	8,434	8,012	115	115	0	133	780	53	
Lat Sua	Lao PDR	Charoen Energy and Water Asia Co Ltd (Thailand)	2018	MoU, pre-feasibility	Pre-feasibility study submitted	10.6	10,000	686	686	2,668	1,524	97.5	95.5	0	13	1,300	27	
Don Sahong	Lao PDR	Mega First (Malaysia)	2016	PDA, detailed planning	Full EIA submitted,	17	2,400	240	240	2,375	1,989	75	72	115	290 (ha)	1820-720-2730	10.6-8.2-8.3	
Thakho diversion	Lao PDR	CNR & EDL (France/Lao)	2016	MoU, pre-feasibility	IEE submitted	16	380	50	50	360		71.7	68.7	n/a	n/a	Channel 1,800m	n/a	
Stung Treng	Cambodia	Song Da Construction Co. (Viet Nam)	N/a	MoU, pre-feasibility	Not yet	15	18,493	980	591	4,870	2,937	55	50	70	211	10,884	22	
Sambor	Cambodia	China Southern Power Grid (China)	2020	MoU, pre-feasibility	Pre-feasibility submitted	33	17,668	2,600	2,030	11,740	9,150	40	39	465	620	18,002	56	

Source: ICEM (2010, Annex 1 p. 150)

4. Energy Demand as a Catalyst of Food and Water Connectivity

GDP is projected to grow rapidly in the Mekong region as a function of rapid industrialization and an impetus to export production. The rate of change of electricity demand is correlated with GDP increases, although the magnitude of change is disputed by governments and agents of civil society (Molle *et al.*, 2010). Primary annual energy demand for Thailand and Viet Nam is projected to grow at 3.0% and 3.8% respectively for the period 2005-2030 (Asia Pacific Energy Research Center, 2009). The region is part of ASEAN. An International Energy Agency's reference scenario projected ASEAN's primary energy demand as growing 2.5% per annum between 2007 and 2030, significantly higher than the average rate in the rest of the world (IEA, 2009).

In the reference scenario, ASEAN demand for electricity grows even more rapidly, 4.2%, during the same period (IEA, 2009). The World Bank (2006) estimates electricity demand in Viet Nam is growing at 16% per annum, and will increase by a factor of 4 to 40,700 MW by 2015. Thailand's electricity demand is estimated to double to 58,000 MW by 2021 (EGAT, 2010). Table 2 indicates that energy consumption per capita is more modest in the Lao PDR, Cambodia, and Myanmar. Electricity consumption per capita in Thailand is almost an order of magnitude greater than that of Cambodia, as is energy use per capita.

4.1 Governance Regimes

Hodgson (2006) argues that institutions represent systems of established and prevalent social rules that

structure social interactions. Governance systems are the operational expressions of institutions and their dynamics, determining how change is enacted. Governance is therefore central to the selection of which energy/electricity generation pathways are pursued. This section outlines a number of key institutional and governance features of the Mekong energy supply regime.

Technical Preferences. Planners perceive that large-scale supply is the most cost-effective way to meet rapidly growing demand (Foran *et al.*, 2008). For instance, the computer optimization models used by Electricity Generating Authority of Thailand include the following options to meet rising demand (EGAT, 2007):

- 700 MW coal-fired thermal power plant;
- 700 MW gas-fired combined cycle power plant;
- 230 MW gas turbine power plant; and
- 1,000 MW nuclear power plant

Until recent diversification decisions, the Thai power utility compared imported hydropower solely on a cost basis against the cost of domestic combined cycle natural gas turbine.

Smaller-scale options, such as <100 MW biomass combined heat and power (CHP) plants are introduced into Thailand's final Power Development Plan ex post cost-optimization analysis. In other words, they are not evaluated concurrently and impartially against large-scale generation options. Likewise, energy efficiency is not treated as a "resource", meaning that energy efficiency options are not considered in candidate power plants in the planning model, despite being allocated arbitrary quotas.

Table 2 Greater Mekong Subregion, selected indicators, 2004

	Cambodia	Guangxi	Yunan	Lao PDR	Myanmar	Thailand	Viet Nam
Land Area (1000 km ²)	181.0	236.7	396.8	230.8	657.6	510.9	325.5
Population (million) (2004)	13.8	48.9	44.2	5.8	54.3	64.2	82.1
GDP (current \$ in billion)	4.9	40.2	35.9	2.2	13.6	150.1	41.2
GDP per capita (current \$)	361	869	813	420	250	2,519	551
GDP per capita (ppp current \$)	2,338	4,340	4,061	1,935	2,009	8,179	2,704
Foreign Direct Investment (US\$ million)	131	300	142	17	556	1,064	1,610
Electricity Use per capita (KWh)	45	703	838 ^a	160	123	1,752 ^a	433 ^a
Energy use per capita (Kgoe)	180.0	663.0	778.0	355.0	217.0	1,405.7 ^a	544.3 ^a
Fuelwood share in total primary energy	88%	23%	9% ^b	67%	70%	16%	49%

a 2003 data

b 2000 data

Source: IRM-AG (2008).

Financial Incentive Structure. Another powerful driver of supply-side solutions stems from the fact that the region's energy organizations operate according to a traditional rate-of-return or "cost-plus" utility model. Under this structure, profitability hinges directly on gross revenues. There is limited incentive to invest in energy savings, and maximum incentive to invest in generation plants owned by the utility.

Meaningful Participation. Decision-making by government elites is common in the region, with limited or negligible public input into a range of important and sensitive issues, ranging from locating power station sites to major privatization initiatives (Greacen and Greacen, 2004; Foran, 2006; Nakhooda *et al.*, 2007).⁶ Thai governments have had significant and recurrent problems with gaining public acceptance of new power stations and gas pipelines. Coal is particularly controversial in Thailand, but even small-scale biomass plants have proven difficult. These difficulties are driven by the lack of impartial local consultation processes, occasional corruption of local government, and the perception by civil society organizations that environmental impact assessment processes have little bearing on decision making.

In this context, a review of Mekong hydropower governance found four key sets of development and governance issues (Foran *et al.* 2010b), which together define the "Mekong hydropower regime:" (i) resilience of the Mekong's aquatic ecosystems, in particular its fisheries, which are uncertain but expected to decline as more dams are built throughout the region; (ii) structure of the electricity industry, in particular an electricity supply chain dominated by monopolistic state utilities, in which willingness to pay, consumer choice, and awareness of sustainability issues are limited; (iii) hydropower host country regulation, which has limited accountability to citizens and is constrained in terms of technical and legal enforcement capacity; and (iv) "bottom-up" river basin development, where a range of project sponsors or proponents (multilateral and private financiers and developers), confront relatively weak state regulatory practices. Among various project sponsors, we can detect higher- and lower-risk project design and investment decisions with respect to environmental and social impact mitigation.

⁶ In the United States, participation in the affairs of energy organizations occurred as a response to crisis in public utility financing, in the wake of the first and second oil crises.

4.2 Options

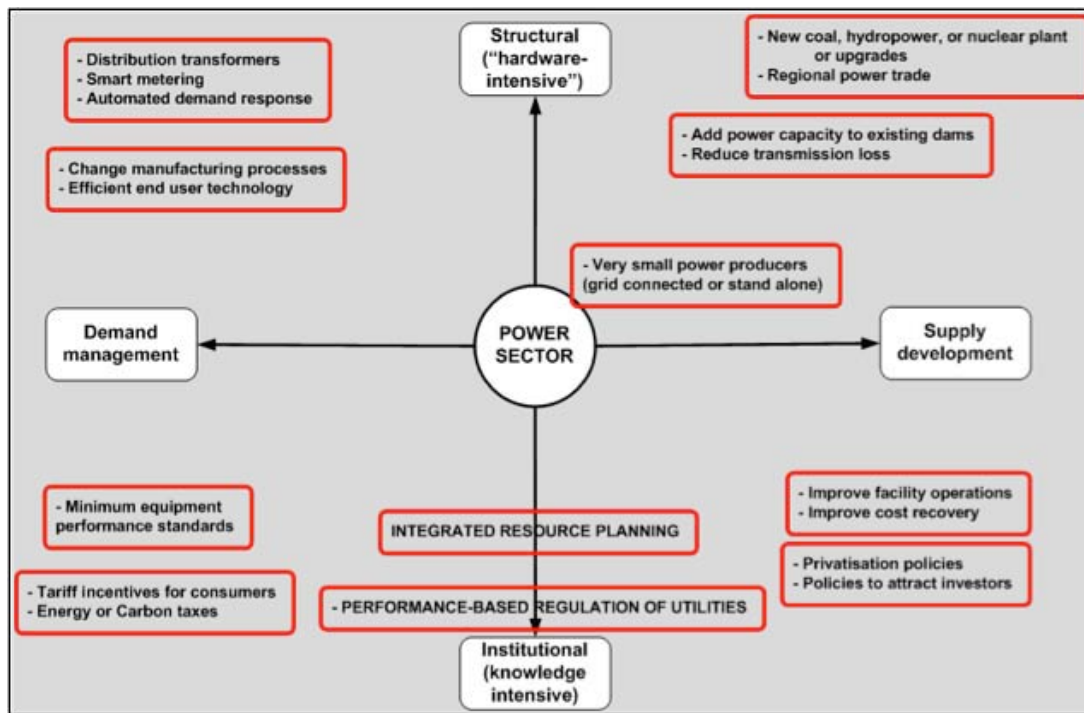
Decision makers are increasingly aware that a range of options exists (Figure 1). Such increasing awareness has many influences, including the explosion of interest in renewable independent power producers (IPPs), the international awards won by Lao-based entrepreneurs for solar home systems, the success of demand-side management programs, local resistance to the siting of large power stations in Thailand, international debates over Mekong mainstream hydropower, and anxiety about the safety and cost of nuclear power post-Fukushima. Furthermore, decision makers, even those with minimal exposure to global climate change policy discourses, would be aware of international efforts to limit the emission of greenhouse gases to 450 ppm in an attempt to avoid dangerous climate change. In this context they are likely to be aware of calls for, as the International Energy Agency (IEA) puts it, a "transformation" of energy systems (IEA, 2009).

Although options exist, combining them into coherent portfolios that expand and evolve over time is no small task. The energy system includes both stationary uses (e.g., process heat, space cooling, industrial motors) and transport uses. Both uses have been dominated by fossil fuels (although noncommercial biomass is actually a leading source of total primary energy supply) and centralized grids.

The complexity of energy options has increased in recent years, due to falling costs of new technologies, rising oil prices, hybrid architectures, the desire to limit negative impacts on ecosystems, and the recognition of renewable energy as an alternate and viable source of employment.

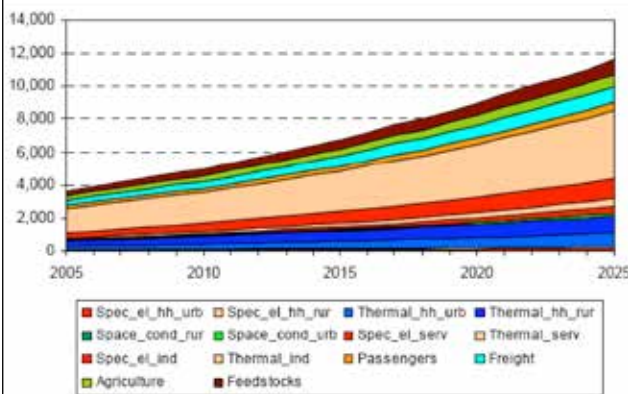
To deal with such complexity, planners have thus far established separate plans or strategies for electric power and transport energy. (No unified energy master plan exists capable of actually allocating energy sources to all of the above end-uses in Figure 2). Multiple options, whole-of-energy-system analysis, if done transparently, would assist in identifying additional pathways. Such analysis is constrained by timing imperatives, resources, and data requirements. It is further constrained by planners' belief systems (i.e., the technical preferences discussed above, as well as restricted planning mandates. For instance, energy planners do not dictate future national industrial policy, even though the latter will influence energy demand).

Figure 1: Examples of Options for Energy Services Development



Source: after Practical Action Consulting (2006).

Figure 2: Mekong Useful Energy Demand, 2005–2025
(joule $\times 10^{15}$)



Source: IRM-AG (2008, p. 96). Notes: el = electricity; hh = household; urb = urban; rur = rural; space_cond = space conditioning; serv = service sector; ind = industry.

Thus, the most holistic or transitional energy planning tends to be the specialty of academic and international organizations, such as the IEA, while strategic planning by energy operators tends to be more incremental in nature. Figures 3A and 3B show two different perspectives on how the ASEAN or GMS energy systems might evolve.

Figure 3A is from IRM-AG (2008). Commissioned by ADB, this analysis shows Mekong final energy demand by generation source. The trajectories include an estimate of environmental and social damage costs (Nilsson, 2008) and include \$/ton estimates for emissions of carbon dioxide (CO_2), methane, nitrous oxide, nitrogen oxides, and sulfur dioxides, as well as \$/MWh estimates of damages from hydropower (IRM-AG, 2008, pp. 50–51). The environmental and social costs were introduced incrementally, adding 10% of the full estimated cost per year over a 10 year period beginning 2005. According to IRM-AG, the average price of energy after internalizing the damage costs was approximately 15% greater than not internalizing. This scenario also assumed a -0.20% price elasticity of demand. Accounting for these costs results in a reduced total demand of <5%). The inclusion leads, in particular, to the reduced use of coal, oil, and synthetic liquid hydrocarbons in the least-cost fuel mix, and increased use of bio-fuels, coke,⁷ LPG, and natural gas (IRM-AG, 2008, Table 140).

The direct effect of including environmental and social costs on the entire energy portfolio is to add \$13 billion

⁷ A by-product of heating coal, which can be further used for industrial (and household) heating.

Figure 3A: Mekong Primary Energy Demand, 2005-2025
(joule $\times 10^{15}$), ADB “Low Carbon” Scenario

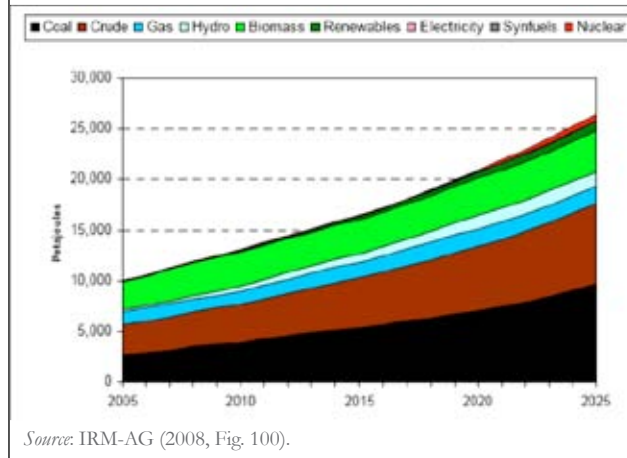
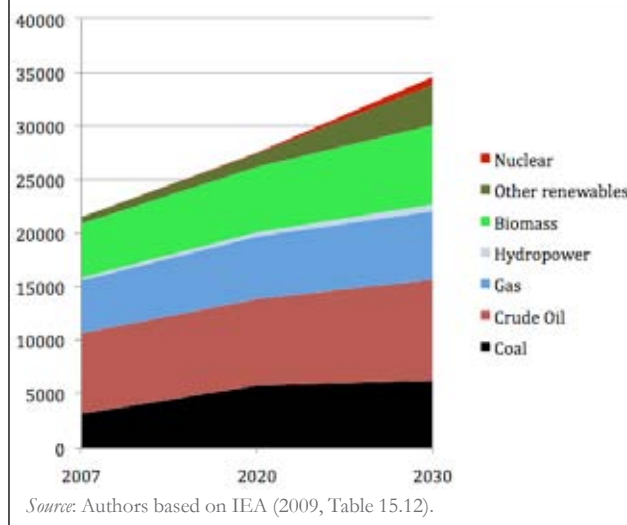


Figure 3B: ASEAN Primary Energy Demand, 2007-2030
(joule $\times 10^{15}$), IEA 450 Scenario



dollars to the discounted total portfolio cost of \$1,072 billion (IRM-AG, 2008, p. 227).

By contrast, the IEA's so-called 450 Scenario (Figure 3B), produced after the 2008 financial crisis, assumes that countries worldwide implement a number of country-specific policy measures, such as implementing building and appliance efficiency standards (IEA, 2009, Chapter 5). It further assumes all countries implement fuel efficiency (and carbon emission) standards for new light-duty passenger vehicles, with different average targets established for each world region. The PRC is considered part of the “other major economies” (OME) region; the other Mekong countries are classified as “other countries.” A similar agreement is assumed to be implemented for the cement, and iron and steel industries.

For power generation, the “other countries” are assumed to make similar, independent decisions to invest more heavily in renewables, nuclear, and hydropower, selling their emissions reductions to regions of the world that are assumed to adopt formal binding reductions targets (i.e., the Organisation for Economic Co-operation and Development [OECD] and, after 2021, the OME).

Although world events since 2009 have diverged from the modeling assumptions, the 450 Scenario illustrates one broad strategy to stabilize atmospheric CO_2 to a level believed to provide a 50% chance of limiting global average temperatures to 2°C . Comparing Figures 3A and 3B we see that the 450 Scenario (3B) projects greater expansion of biomass energy, while slowing the rate of increase for coal, oil, and gas energy. The main difference between the IRM-AG and the IEA modeled cases is that the latter is linked to an assumed global 450 parts per million (ppm)- CO_2 constraint whereas the IRM-AG work is not.

Figure 4 (from IRM-AG, 2008) illustrates the estimated proportions of power generation sources, for the case where environmental and social costs have been included. According to IRM-AG, the effect of internalizing those costs results in significantly less use of coal and biomass, significantly greater use of hydropower, natural gas, and solar energy, and only significantly less use of nuclear power.

4.3 Energy Development Pathways

Notwithstanding the lack of comprehensive energy decision making, relatively rapid growth in the region

Figure 4: Estimated Wider Mekong Region Power Generation Mix, 2005-2025 (MWyear)

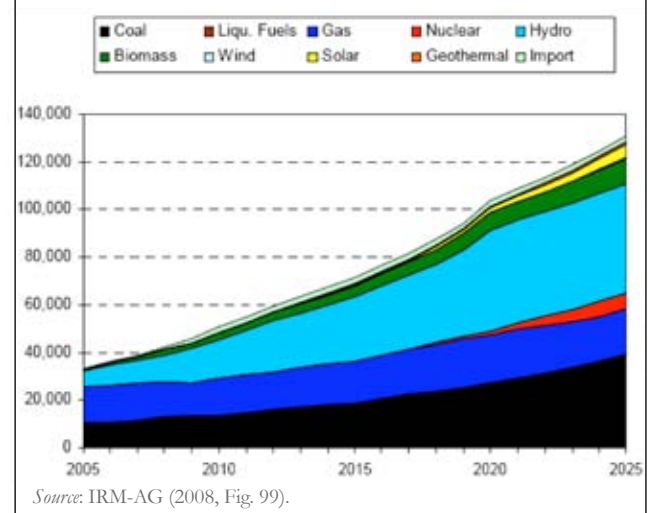


Table 3: Examples of Energy Path-Setting Activity

Country/Region	Activity (Targets, Plan, Market)	Policy Frameworks, Instruments, and Complications
People's Republic of China	<i>Electric power.</i> Target: 362–500 GW renewable power capacity by 2020 (representing 23% to 32% of 1600 GW expected total capacity in 2020), of which: hydropower 300 GW; wind 150 GW; biomass 30 GW; solar photovoltaics 20 GW (Martinot, 2010)	Renewable Energy Law 2005 (revised in 2009) Increased feed-in tariffs for wind and biomass Renewable power purchase obligations for utilities <i>Needs enabling investment in energy storage systems</i> (Martinot, 2010)
Regional	<i>Integration.</i> Visions: Trans-ASEAN Gas Pipeline Infrastructure Project (series of gas pipelines connecting 10 countries); ASEAN/GMS power grid (ADB, 2009; IEA, 2009; Sovacool, 2009) <i>Domestic biogas for cooking.</i> Market: Estimated 360,000 households linked since 1989; additional 1 million planned by 2015 (SNV, 2011) <i>Multi-scale rural electrification.</i> Vision: public private partnership business model to deliver services to rural households, funded by independent trust fund (Henschel, 2008)	<i>Needs harmonization of national rules and standards</i> <i>Estimated energy investment required GMS is \$15.6 billion (ranging from 0.6% to 8.5% of members' long-term GDP) (ADB, 2009)</i> <i>Transnational gas and power grid will require much more explicit consideration of opportunity costs, and of economic and social risks</i> (Sovacool, 2009)
The Lao PDR	<i>Large hydropower.</i> Market: 23 hydropower projects either in advanced planning or under construction. Another 45 preliminary agreements signed with developers. Hydropower revenues projected increase to 4% of GDP by 2024 (Foran <i>et al.</i> 2010b; World Bank, 2010) <i>Pico-hydropower.</i> Estimated 60,000 units exist but overlooked by mainstream energy planners (Smits and Bush, 2010)	Commercial project development framework supplemented by environmental impact assessment mechanisms <i>Needs process to screen high-risk projects at early stage greater transparency in awarding concessions and greater implementation capacity</i> (World Bank, 2010)
Thailand	<i>Total primary energy.</i> 14.1% renewable share of total final energy demand by 2022 (of which 7.6% thermal energy; 4.1% biofuels; 2.4% electric power) (Sutabutr, 2009) <i>Transport.</i> 4.5 million liters per day of B100 biodiesel, and 9 million liters of ethanol by 2022 (IEA, 2009, Table 15.9) Potential to set a 33% ethanol blending mandate by 2018 (Damen, 2010) <i>Electric power.</i> Reduce natural gas share in fuel mix: GWh from coal (26.6%), imported power (11.3%), and nuclear (11%) (EGAT, 2010b)	Feed-in tariffs Multi-stakeholder consultation around 15-year renewable energy and biofuels target-setting (Sutabutr, 2009)
Viet Nam	<i>Total primary energy.</i> 5% renewable share of total commercial primary energy by 2020: giving priority to small hydropower and biomass renewable power (Ölz and Beerepoot, 2010, p. 50) <i>Electric power.</i> 100+% increase in total hydropower capacity to 20,178 MW by 2025 (Soussan and Nilsson, 2009) <i>Transport.</i> 5% of gasoline and oil demand met by biofuels (Ölz and Beerepoot, 2010, p. 50)	Use of strategic environmental assessment in power development planning

Source: Authors, based on above references plus interviews.

means that we can identify key energy development pathways that are likely to have ramifications not just for energy but also for food, water, and livelihood systems (Table 3). This section reviews hydropower generation in the Mekong. The development and operation of large-scale hydropower resources benefits power producers in Cambodia, the Lao PDR, Myanmar, and Viet Nam, and electricity consumers in Thailand and Viet Nam.

A second energy pathway involves expanding the production and consumption of bio-energy, for heating energy, electric power, and transport (in increasing order of value). Detailed pathway analysis for bio-energy with implications for food and water security is currently being undertaken as part of the Exploring Mekong Futures project (Smajgl *et al.*, 2011; Foran, forthcoming).

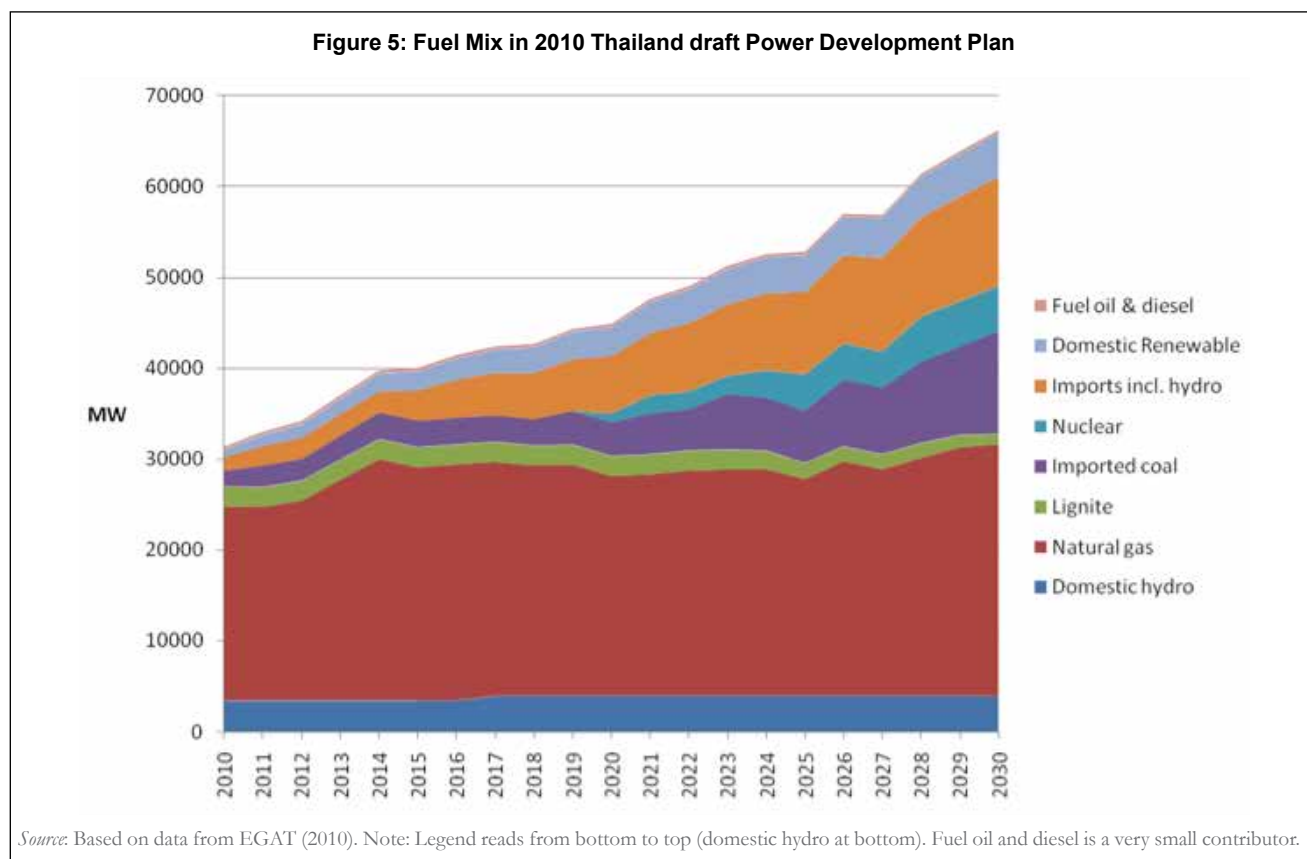
The pathways are quite different in terms of their social dimensions. Large hydropower development, for instance, has higher barriers to entry than bio-energy production. For instance, it requires the negotiation of exclusive rights to develop water resources in a specific river basin, which yields economic rent (above average profit) to the developer. By contrast, most Mekong bio-energy, whether crop based or residue based, is presently sourced from smallholder farmers. Thus, a much greater

number of producers (and decision makers) is involved in the supply chain than is the case for hydropower. If sugar cane, cassava, and oil palm plantations were to expand in Cambodia, the Lao PDR, and Myanmar, in a manner characterized by land alienation, it could result in loss of food and energy security. Dispossession has been documented by (Baird, 2009) for rubber in the southern Lao PDR; however, rubber is a higher return crop than all of the above (Damen, 2010).

4.4 Hydropower Pathway and the Consequences on Energy Configurations

Figures 3 and 4 illustrate that large-scale hydropower can be found in the power development pathways of all countries in the region. This section focuses mainly on technical and political impacts of hydropower expansion on the energy system.

Hydropower enables substitution of natural-gas powered end-uses. For energy security of supply reasons, Thailand has a policy of diversifying its power generation fuel mix away from natural gas (Figure 5). The Thai power system turns mainly to imported coal, imported power (orange shape), and nuclear (Figure 5).



According to EGAT's 2010 power development plan, Thailand plans 11,459 MW of imports (EGAT, 2010a). Most of these projects are not yet specified by name or fuel, but based on precedent and preliminary development agreements in the Lao PDR, most are likely to be hydropower (Foran *et al.*, 2010a).

Conservation of natural gas would allow it to be strategically directed toward more high-value, and higher efficiency combined heat and power systems, marginally raising the energy efficiency of commercial buildings. Alternatively, if the same grade of gas used for power generation can be used as transport fuel, this would displace petroleum fuels, reducing transport sector CO₂ emissions.

Controversial nature of hydropower and large thermal power plants in Thai society. Large hydropower development, including schemes located outside the country, is politically controversial. Such controversy is open in Thailand but has also emerged among civil society and some state agencies in Viet Nam. Construction of new schemes is likely to spur transnational advocacy aimed at halting projects, and possibly even local resistance movements, especially for projects along the Thai-Lao or Thai-Myanmar border. Projects might face delays resulting in losses for developers and heightened reputation and political risk for financial sponsors. This combination of resistance and controversy could act as a force for improving the transparency and accountability of decision making around the Thai power system in particular, as well as strengthening calls for small-scale renewable alternatives.

Higher-order impacts of developing hydropower. Releases of peaking power could allow better integration of intermittent renewable energy (e.g., wind and solar). During construction, we can also expect a marginal increase in demand for transport energy required to build the schemes and industrial energy (e.g., demand for concrete, steel and other materials), with multiplier effects on the regional economy. If such demand increases lead to fuel price increases, this would have macro-economic impacts including increased incidence of income poverty.

Higher-order impacts of avoiding hydropower and natural gas. If decisions are made to avoid or postpone large hydropower projects at the same time as conserving natural gas for higher-value uses, this implies more demand and opportunity for energy efficiency measures, small domestic renewable energy, and large thermal plants. With new nuclear plants expected to be vigorously contested in

Thailand, the second least-cost alternative for base-load power, from the financial perspective of mainstream planners, is imported bituminous coal. Smaller-scale commercial biomass is regarded as a higher per unit cost option. Coal plants could be sited inside Cambodia near the Thai border.

In summary, hydropower development is likely to contribute to a path-dependent trajectory, where expanding cross-border electricity sales provide electricity to customers who are willing to pay. The conviction that the GMS will benefit in aggregate economic terms from expanded energy trade has already stimulated a series of technical analyses by such agencies as ADB and ASEAN.

The effect of hydropower on this trajectory is mainly to substitute for the use of fossil fuel in the power generation supply mix. However, because Mekong mainstream hydropower development is especially controversial, a decision to proceed with all 12 mainstream projects—as well as domestic coal and nuclear projects—could trigger escalating political opposition demanding a re-evaluation of the dominant energy (socio-technical) regime. In Thailand and Viet Nam, this could lead to increased policy support for renewable energy and energy efficiency, potentially lengthening the already-long hydropower development life cycle, reducing financial returns to sponsors.

5. Connections of Mainstream Dams to Livelihoods and Food Security

Section 5 describes the interactions of hydropower electricity generation with livelihoods (focusing on occupation and income), migration and food security (emphasizing nutrition) in the Greater Mekong sub-region.

Osborne (2010) suggests that the livelihoods of 29.6 million people in Cambodia, the Lao PDR, and Thailand, as well as 14 million people in Viet Nam could be negatively affected if all planned Mekong mainstream dams are constructed. Results of the SIMVA (MRC, 2010a) survey supports the magnitude of estimated impacts, in which 93.3% of households stated that they consumed fish in the preceding week. Twenty five million people live in the 15 km corridor surrounding the Mekong River. Although dependency on fish increases with proximity to the river, the loss of fish affects households well beyond the 15 km corridor (Bouapao and Hall, 2010). About 80% of the fish sold in the local markets of Champasak in the Lao PDR

Table 4: Impacts of Mekong Mainstream Dams

Indicator	Occupation	Income	Food	Migration
Cambodia	No change	Decrease	Decrease	Increased migration into Thailand and Viet Nam
Yunnan, PRC	No direct trans-boundary impacts	No direct trans-boundary impacts	No direct trans-boundary impacts	No direct trans-boundary impacts
Lao PDR	No change	Decrease	Decrease	Increased migration into Thailand and Viet Nam
Myanmar	No change	N.A.	N.A.	N.A.
Thailand	No change	Negligible	Negligible	Negligible
Viet Nam	No change	Decrease	Decrease	Increased migration from Cambodia and the Lao PDR

are from the Khong District of the Mekong (Baird *et al.*, 2001). Twenty five percent of the total fish catch of Tonle Sap in Cambodia is consumed by local fishing households, indicating that most of the catch is for consumers located in centers beyond the lake boundaries, such as Phnom Penh (Hall and Bouapao, 2010).

According to the national consultation workshop on the proposed Xayaburi hydropower dam on the Mekong mainstream, held in Can Tho on 14 January:

The Workshop participants expressed their great concerns and worries about the possible impacts of the project on the productivity of the Mekong Delta and the livelihood of millions of people living in the Delta. Potentially [f]acing double impacts, from climate change and sea water level rise, and from the fast development in the Mekong upstream part, especially on the mainstream, the Delta would be adversely threatened by severe impacts resulting in the intrusion of saline sea water far into the inland, immense damage to the fisheries, declination of agro-productivity vital to millions and unpredictable degradation of the invaluable bio-diversity, cited most of the comments at the Workshop (Viet Nam National Mekong Committee, undated).

5.1 Foreseeable Future Scenario

Based on the estimates of biophysical impacts detailed in the Basin Development Plan Programme, Phase 2 (Podger *et al.* 2004; ICEM 2010; MRC 2010, a,b,c), of all 12 proposed dams proceeding, the livelihood impacts are summarized in Table 4 and subsequently discussed.

5.2 Occupation

Based on the estimated loss of fish reported in the Basin Development Plan Programme, Phase 2 (MRC 2010a), if

all dams are built, the overall loss to fish catch in the river and its floodplain is estimated to be 58% of the baseline yield of 593 thousand tons per year. By countries, the decline is 84%, 63%, 41%, and 40% for the Lao PDR, Cambodia, Thailand, and Viet Nam, respectively. This alone does not indicate that fishing households would give up fishing. The SIMVA results (MRC, 2010a) show that 37% of fishing households would give up fishing if the daily catch was less than 1kg. Estimates of fish catch based on the SIMVA data indicate that the decline in all countries does not reduce the catch below 1kg per day. This implies that the number of fishing households in Cambodia, the Lao PDR, Thailand, and Viet Nam would remain stable.

However, by 2030 the proportion of fishing households would decline due to the combination of population growth and further decline in fish. Observations made in the context of tributary dams such as Pak Mun indicate a decline in fish catch of 50%–100%, resulting in a drop of fishing households in areas upstream of the dam ranging from 66.7% to 95.6% (Amornsakchai *et al.*, 2000).

5.3 Food security

The estimated loss of fish due to expected dam construction and operation will result in less food availability. The average calorie intake in the Tonle Sap area in 2009 was 2,121 calories per capita per day, of which fish contribute 335 calories or 16%. A 63% reduction of the fish catch would reduce daily per capita calories to 1,910 (Table 5). This is less than the regional recommended minimum of 2,100 calories.⁸ Moreover, fish contain essential micronutrients not found in rice (or other staple food crops), as well as fatty acids that are essential for the development of the brain and body. Other sites will

⁸ FAO standard, as supplied by the National Statistics Office of Lao PDR.

Table 5: Calorie Intake by Study Sites

Study Sites	Fish Intake, 2009 (calories)	Total Calorie Intake, 2009	Decline in Fish due to 12 Dams (%)	Impact (calories)
Tonle Sap Lake, Cambodia	335	2,121	63	1,910
Siphandone, Lao PDR	300	3,171	84	2,919
Chiang Saen and Udonthani, Thailand	281	2,471	41	2,356
Mekong Delta, Viet Nam	301	1,864	40	1,744
Total	303	2,407	58	2,231

Source: Hall and Bouapao (2010).

Table 6: Income Per Capita per Day

Study Sites	Per Capita Income per Day (\$)	Fish Contribution (\$)	Decline in Fish Due to 12 Dams (%)	Impact (\$)
Tonle Sap Lake, Cambodia	1.02	0.36	63.0	0.80
Siphandone, Lao PDR	1.43	0.08	84.0	1.36
Chiang Saen and Udonthani, Thailand	3.48	0.01	41.0	3.47
Mekong Delta, Viet Nam	1.57	0.05	40.0	1.55

Source: Hall and Bouapao (2010).

also be affected, including the Mekong Delta, where the total daily calorie intake in 2009 was only 1,864 calories per capita.

The total catch from hydropower reservoir fisheries is expected to increase by 10,000–30,000 tonnes or \$40 million (MRC, 2010a,b). These gains are offset by estimated reductions in the Mekong capture fishery, currently estimated at 2.1 million tonnes or 22% of world freshwater fisheries. The 2030 scenario without Mekong mainstream dams will reduce the Mekong fishery by 210,000–560,000 tonnes/year (10%–27% reduction) and the development of the 12 mainstream dams will cause additional losses of 340,000 tonnes/year (\$476 million) or another 17% of the total catch. Aggregate reservoir fisheries could compensate for approximately 10% of the lost capture fisheries production predicted without mainstream dams. The effects of upstream changes on the Mekong marine fishery are not certain (currently estimated at 0.5 million tonnes/year or replacement value of about US\$ 40 million): the multiplier effects on other subsectors, such as boat and fishing tackle manufacture, salt and ice production, and fish processing, estimated at \$2–4 billion (MRC, 2010a), also remain uncertain.

5.4 Income

A 63% loss in capture fisheries would have considerable impact on the income of people in the Tonle Sap area. The SIMVA results (MRC, 2010a) show that the average per capita income in the Tonle Sap area was just slightly above \$1 per day, less than the current World Bank poverty line of \$1.25/day, while US\$2 per day is recommended as a

more realistic number for development planning.⁹ Income from fish and other aquatic organisms contributes 35% to household income. A 63% loss of fish results in an average household income of less than \$1 in Tonle Sap (Table 6). In the Thai sites, however, the share of income from fish in the total income is small and there is likely to be very small impact on income.

The projected losses of agricultural lands, riverbank gardens, and biodiversity will further deteriorate food availability and reduce income. With the estimated losses in these resources, it is likely that there will be increased reliance on aquatic organisms, which have been traditionally used during the dry seasons and drought years, when less fish are available (Balzer *et al.*, 2005)

However, in the Mekong Delta, the potential increase in dry season flow may reduce salinity, hence increase rice yield. This could lead to an increase in income from rice production.

5.5 Migration

Losses in access to fish, riverbank gardens, and inundated agricultural areas will be important push factors for migration from rural to urban areas and from Cambodia and the Lao PDR to Thailand. Observations from such cases as the Pak Mun dam (Amornsakchai *et al.*, 2000) show that members of households affected by the loss of agricultural

⁹ World Bank (2004), Millennium Development Goals, <http://web.worldbank.org/WBSITE/EXTERNAL/EXTABOUTUS/0,,contentMDK:20104132~menuPK:250991~pagePK:43912~piPK:44037~theSitePK:29708,00.html>. Accessed on 25 August 2010.

lands, riverbank gardens, and fisheries are likely to migrate to either urban areas or to forest reserve areas (or other common properties), because compensation may not be enough to buy alternate land. These groups will become more acutely vulnerable because of the partial sale of their livelihoods assets due to the shift from farm-based occupation and decline in grazing lands. It is also likely that by 2030, people in Cambodia and the Lao PDR will migrate to Viet Nam for wage employment.

6. Connections of mainstream dams to water security

Section 6 reviews the current literature concerned with the potential consequences of hydropower dam construction and operation inclusive proposed irrigation diversions. The discussion focuses on changes to in-stream sediment and nutrient loads; mainstream wet and dry season hydrological characteristics; and the volume, timing and duration of flood pulses (emphasizing the aquatic environs of the Tonle Sap lake).

The MRC (BDP, 2003) and Pech and Sunada (2008) estimate that by 2025, irrigated agriculture water use will account for about 22% (104,503 [million cubic meters MCM] of the average annual discharge of the Mekong River and about 25% to 30% by 2050 depending on irrigation scale and intensity. Despite estimates of total irrigation demand in the MRB being substantially less than average annual river flow, the estimates neglect uneven distribution of flow in time and space inclusive of flow fluctuation between wet and dry seasons, and from wet year to dry year (BDP, 2003; Pech and Sunada, 2008). In addition, sufficient flows are required to maintain the function of aquatic ecosystems and aesthetic/recreational purposes (Ravenga and Mock, 2000).

Davis (2003) estimated that by 2025 the share of domestic and industrial uses will constitute about 14% and 21%, respectively, of total water withdrawals in Southeast Asia. MRC (2010) estimates domestic and industrial water consumption in the Mekong Basin at 2,773.58 MCM, which is less than 1% of the average annual Mekong flow. The 2050 domestic and industrial water demand is projected to increase to about 11.5%–15.5% of the total average annual Mekong flow (BDP, 2003; Pech and Sunada, 2008). Despite modest demand by current domestic and industrial water uses, aggregate water demand when combined with agriculture will constitute 32%–50% of the total annual flow by 2050 (ibid). This will further increase the competition

for water resources during the low flow conditions of drier and driest years.

By 2030, the dams in the Mekong tributaries will have a substantial impact on mainstream river flows and alter the hydrological regime of the entire MRB (MRC, 2010). Active water storage will potentially increase by 700% from 9.9 to 69 km³ and about 23.7 km³ or 36% will be within Yunnan Province, mainly from its two largest hydropower dams that have an active storage of about 22.2 km³ (MRC, 2010b). With the construction of the 11 lower basin mainstream projects, 55% of the total length of mainstream stretch between Chiang Saen (Thailand) and Kratie (Cambodia) will be converted to reservoirs and transform the river into a series of managed impoundments with slow water movement, interspersed with rapid and broad flow fluctuations in response to dam operations (ICEM, 2010).¹⁰ The reduced flood season flows would reduce the extent and duration of the inundation of floodplains and contribute to bank erosion on the critical stretches and infilling of deep pools (MRC, 2009).

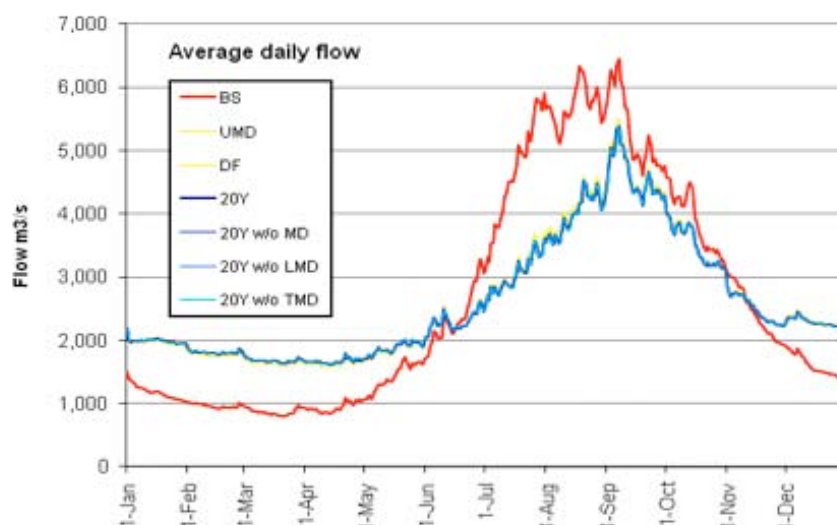
The operation of the mainstream dams can cause significant downstream fluctuations during any one day if they are operated as peaking projects. In this case, water level fluctuations locally may amount to typically 2–4 m or more in extreme cases (MRC, 2010C)¹¹. This may have severe implications for local navigation and riverbank gardening.

The increase in dry season flow is estimated to be able to meet a planned increase in irrigation abstractions over current levels depending on location along the mainstream. The construction of dams in the PRC is expected to cause a dramatic increase in mean minimum annual dry season flows at all stations, except for Kratie. Dry season flow increases by 70% at upstream stations, and 10% at the Mekong Delta. The flow increase is lowest in the Mekong Delta where the dry season irrigation demand is highest. About 54% of the riverbank gardens along the mainstream stretches from Chiang Saen to Kratie will be flooded due to higher low flows and reservoir inundation (Ward, P., personal communication).

¹⁰ Ward P, 2010. Power Point Presentation at Regional Consultation Workshop of June 2010: About 66% of the total 1,760 km river distance, Sambor dam (Kratie) site to the upper end of Pak Beng reservoir, will be affected.

¹¹ Ward P. 2010. Personal communication: The time elapse for a rapid fluctuation from opening the turbines—planned and unplanned circumstances, and breakdowns of plant and electrical transmission systems at the proposed Luang Prabang dam site, will be about 1.0–1.5 hours to the city of LuanPrabang, very little warning time for bank-side residents to prepare for inundation.

Figure 5: Changes in hydrology at Chiang Saen



Source: MRC (2010b).

The increase in dry season flow means more water for irrigation, water supply, and other uses, but expansion and consolidation of agriculture and irrigation will also lead to increased use of chemical fertilizer to offset loss of nutrients and sediments. The production costs of water fees, production inputs, and labor will be potentially much higher.

The change in water surface area will cause a substantial seasonal redistribution of flow from the wet season to the dry season and reduce sediment transport in the Mekong mainstream, especially in the area above Vientiane (MRC, 2010c). The reduction in the maximum water level and an increase in low flow will be observed in the next decades, associated with water storage in large capacity reservoirs. As a result, the overall flow will be smoother, especially in the transition to the flood season (ICEM, 2010).

The onset of the transition from dry to flood season will be significantly reduced by 7-8 weeks earlier in Chiang Saen,¹² 2-4 weeks earlier upstream of Pakse and 1 week at Kratie. This change will see a reduction in the important freshwater 'spates' which drive many ecosystem functions such as fish spawning, larvae drifting, and fish migration.

There has been substantial debate about the roles of reservoirs in regulating flood peak flow ("downstream flood benefit"). Mainstream dams would provide some level of flood protection immediately downstream of the site only

(MRC, 2010b, 2010c, 2010d). The peak daily flows will be reduced by -18% (1,100 cubic meters per second [m^3/s]) at Chiang Saen, 15% (-2,381 m^3/s) at Vientiane, 7% (-3,456 m^3/s) at Kratie, and only 4% (-855 m^3/s) in the Mekong Delta in Viet Nam (Tan Chau). The flood reduction functions of the dams may cause a false sense of security in the face of historical floods (100-500 year recurrence floods) and dam failure due to earthquakes. Records from around the world indicate that flood protection (which does not bring in revenue) tends to be neglected in multipurpose projects (Regional Panel of Experts 2010).

There will be an overall 7% reduction in flooded area (309,000 ha) in an average rainfall year. The reduction areas are expected to be smaller in wet years and larger in dry years. The greatest area of reduction occurs in Cambodia (142,000 ha), the Lao PDR, and Thailand (17% and 19% reduction, respectively) (MRC 2009, 2010d).

The 2030 dam development scenarios will result in significant changes in the ecology of Tonle Sap. Lake inundation is predicted to be reduced by 5%-10% (500-600 km^2); the reverse flow in the Tonle Sap river will start at least a week sooner, and the average number of days of reverse flow 8 days shorter. The area of dry season inundation is estimated to increase by 5%-8% turning a seasonal terrestrial ecosystem into a permanent aquatic ecosystem. These changes will affect ecosystem and farming productivity, fish migration, and sediment flushing capacity. The decrease in reverse flow volume to Tonle Sap will result in a reduction of flooded area, flood depth and duration, and a reduction in sediment inflow into

¹² MRC (2010b): At Chiang Saen, peak daily flows will be reduced by 18% (1,100 m^3/s), and dry season flow volume will be increased by about 61% (12,093 MCM); peak daily flows at Kratie will be reduced by 7% and dry season volume will be increased by 23%.

Table 7: Summary of Impacts on Water Sector from 12 Mainstream Hydropower Dams

	Water indicators	Estimated changes
Hydrological changes	Water level	Development sector alters the hydrological regime of the entire MRB; active storage increases from 9.9 to 69.8 km ³
	Flow level in dry season at specific locations	Dry season flow increases by 70% at upstream stations and 10% at the Mekong Delta
	Flood timing	Reduction in the onset of dry to flood transition; 7-8 weeks earlier at Ch Saen, 2-4 weeks earlier at Pakse, 1 week at Kratie
	Flood duration	Will affect upper reaches of the lower basin above Pakse and Vientiane
	Flood level and area	Flow decrease by 18% at upstream stations and 2% at the delta; corresponding reduction in flood area
	Reverse flow/water level in Tonle Sap	Reduction in duration and volume of the reverse flow
	Inundated area, duration, and timing	Dry season inundation area increased significantly
	Storage	700% increase in the active storage volume
	Change in water quality (turbidity and relevant quality parameters)	7%-80% Reduced sediment transport. Loss of nutrients in floodplains and coastal estuary.
	Change in salinity intrusion – extent, duration, and concentration	5%-10% increase in flow, but subject to increased water diversion and sea level rise; salinity intrusion may increase.
Other water elements; geo-morphological changes	Barrier effects and dis-connectivity	37%-82% of waterways obstructed
	Sediment and nutrient from upper basin	Reduction in stream velocity and energy moving over stream bed and turbulent flow dissipation. 75%–81% reduction in sediment load
	Reservoir conditions	Changes in siltation and deltaic formation
	Downstream and critical deep pools and habitat	Downstream erosion and long-term impact on 48%–70% of deep pools. Loss of natural fertilizer and food chains
	Mekong Delta	Erosion instability of shore lines; cessation of land mass advances of 60–80 meters annually; annual erosion of 45 meters annually
	Coastal zones	Loss of nutrient and possible reduction in marine fisheries; effects uncertain.

Source: FAO (2004, footnote 12), report on the formulation of a national water vision to action in the union of Myanmar, Bangkok: Regional office for Asia and the Pacific. <http://www.fao.org/docrep/008/ac546e/ac546e04.htm>

the lake, as well as blockage of fish migration paths by mainstream dams (ICEM, 2010).

With mainstream hydropower power projects operating, there will be reduced water energy to suspend and transport particles, resulting in enhanced sedimentation, with the formation of deltaic type deposits at the head of each of the reservoirs, and middle and lower parts of each reservoir associated with reduced velocities/gradients (ICEM, 2010; MRC, 2010d). Only the load of suspended particles has been measured at several stations on the Mekong mainstream since the 1960s.

The dam development will also potentially reduce fine sediment transport by 70%–80%. (75%–81% reduction in sediment load from upper Mekong Basin (from 90 million to 20 million tons/year at Chiang Sean, and from 165 million to 88 million tons/year at Kratie) (Ward, 2010). The reduction will result in a significant loss of nutrients in floodplains and coastal offshore zones, affecting farming and fisheries within and beyond the Mekong basin as well as long-term changes to river beds and bank erosion.

Reduced sediment loads pose a threat to the stability of delta shaping processes, which are potentially exacerbated by sea level rise.¹³

Navigability will be substantially improved with lower requirements for channel improvement to provide cheaper and more affordable means of transport. However, with proposed improvements in road and rail-links, river navigation is not seen as the highest priority. The 2030 dam development scenario will offset navigation benefits by introducing additional navigational barriers and dis-connectivity, because 37%–81% of the watershed is estimated to be obstructed.

¹³ Loss of sand-sized sediments to the Mekong Delta and marine environment result in loss of nutrients (phosphates) to agriculture = 3,400 tons/year worth \$24 million in replacement value/year, and reduction in nutrient loads to over 18,000 km² of Cambodia's floodplain and 5,000–10,000 km² of Mekong Delta floodplain and the Mekong marine sediment plume.

7. Connections of mainstream dams to land-use change

The MRC SEA report (ICEM, 2010) identifies increased irrigation area, and loss of forest, farmlands, and aquatic resources as the major land use consequences of mainstream dams.

The Pak Chom, Ban Koum, and Lat sua hydropower dams, located in Loei, Ubon Ratchathani provinces, and the southern Lao PDR, respectively, are planned river impoundments associated with irrigation schemes. The total irrigation area is anticipated to increase by 17,876 hectares primarily for either rice production or cash crops. Irrigation projects associated with the hydropower developments are projected to improve land productivity and rice production, resulting in an estimated increase of 77,701 tons of rice/year or a value of approximately \$15.54 million/year (ICEM, 2010).

The loss of land is a direct consequence of hydropower projects. The MRC SEA report (ICEM 2010) shows that the construction of reservoirs, access roads, and transmission lines will result in the loss of approximately 30,886 ha of forest land (mostly degraded forest) and 15,786 ha of agricultural land, inclusive of 829 ha of irrigated land. The report estimates that 11,966 ha of riverbank gardens will be submerged by the reservoirs and wetland loss may amount to about 7% of the wetlands or 73,500 ha within a 50 km corridor of the mainstream Mekong.

Assuming current agricultural productivity levels, an equivalent area of land of similar agricultural potential will be required to maintain the living standard of affected communities that continue to practice farming livelihoods strategies. If the productivity of riverbank gardens is assumed to equate to 50% of farmland, 71,769 ha of replacement farmland will be necessary to maintain current levels of agricultural production.

The potential of hydropower generation in Myanmar is estimated at 39,624 MW compared with 30,000 MW (MRC, 2010a) in the lower Mekong Basin. Based on the previous assumptions, the potential for land use change due to the development of reservoirs would approximately double if the full potential of hydropower generation in Myanmar were to be developed.

8. Conclusion

The past 40 years have provided conditions that promote increasing connectivity of the political economy and economic sectors of Mekong riparian countries. Despite periods of political and economic turbulence, the Mekong River has acted as a conduit of relatively stable cultural, economic, agricultural, and spiritual connection across the countries. The three enabling conditions central to the degree of regional connectivity are (a) the endowment, scarcity, and accessibility of resources within the connected region; (b) the financial capacity to activate these resources as production factors; and (c) the institutional conditions enabling resource transfers to occur.

The financial strength of Chinese, Thai, and Vietnamese private and state companies, a reduced reliance on traditional donors, human migration, natural resource flows, and direct foreign financial investments are amongst the factors cited that influence the critical dynamics generating increased levels of connectivity between Mekong countries. High levels of connectivity increase complexity, biasing the reliability of predicted development outcomes and increasing the potential for unforeseen consequences of national decisions. Strong connectivity implies that interacting factors transmit the effects of substantial development decisions at multiple spatial and temporal scales and across multiple sectors. This paper focuses on the connectivity or nexus of water, food, and energy security because these are jointly articulated as crucial policy objectives of Mekong region countries.

The construction of proposed Mekong River mainstream dams, primarily for hydropower electricity generation has diverse consequences on food and water security, livelihoods, and land-use change across the Mekong region countries. Occupations are predicted to remain relatively unchanged in all the countries. Income, food security (using nutrition as a surrogate metric), and migration levels are estimated to remain relatively stable in Yunnan Province and Thailand. Income and food security are predicted to decrease in Cambodia, the Lao PDR, and Viet Nam. Migration from the Lao PDR and Cambodia into Thailand and Viet Nam is estimated to increase.

Mainstream dams are predicted to have substantial and prolonged consequences on Mekong water resources and security. Predicted hydrological changes include altered flow regimes caused by the construction and operation of mainstream dams, as follows:

- Active storage increases from 9.9–69.8 km³, altering the hydrological regime of the MRB.
- Dry season flow increases by 70% at upstream stations and 10% at the Mekong Delta.
- Reduction in the onset of the dry to flood season transition.
- Reduced flood area correlated to a flow decrease by 18% at upstream stations and 2% at the delta.
- Reduction in duration and volume of the Tonle Sap reverse flow.
- Dry season flood inundation area increased significantly.
- 70–80% reduced sediment transport; loss of nutrients in floodplains and estuarine sedimentation.
- Subject to increased water diversion and sea level rise, salinity intrusion estimated to increase.
- 37%–82% water ways obstructed, limiting navigation.
- Reduction in stream velocity and energy moving over stream bed and turbulent flow dissipation.
- Downstream erosion and long term impact on 48%–70% of deep pool habitats and a loss of natural fertilizer and food chains.
- Changes in siltation and deltaic formation in reservoirs.
- Increased erosion instability of delta shore lines.

The additional irrigation area associated with dam construction is anticipated to increase by 17,876 hectares, primarily for either rice production or cash crops, resulting in an estimated increase of 77,701 tons of rice/year or a value of approximately \$15.54 million/year. Land loss also occurs as a direct result of dam construction. Assuming current agricultural productivity levels, 71,769 ha of replacement farmland will be necessary to maintain current levels of agricultural production and maintain the living standards of affected communities that continue to practice farming livelihood strategies.

We have attempted to account for high levels of connectivity and describe a partial cross-sectoral assessment of development-directed investments in the wider Mekong region. We have argued that increasing energy demand and national objectives of energy security are central to, and catalyze, economic growth imperatives. We have also provided a review of evidence that supports a position of a strongly connected Mekong region.

Contingent on a strongly connected region, reliance on a singular, linear appraisal of energy security policies that fail to account for the consequences on food and water

security is likely to overestimate the probability of satisfying policy objectives and underestimate the subsequent social cost. The singular achievement of national energy security objectives may mean either substantially compromised regional energy security or introduce unforeseen impediments to meeting articulated food and water security objectives at both national and regional scales.

Analysis of alternate energy pathways to reveal the magnitude of connectivity with the food-water security nexus is the subject of ongoing research.

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WATER RESOURCES MANAGEMENT IN THE GREATER MEKONG SUBREGION: LINKAGES TO HYDROPOWER PLANNING FOR A SUSTAINABLE FUTURE

Jeremy Bird¹

Abstract

Challenges for water resources development in the Greater Mekong Subregion (GMS) are increasing as populations rise and rapid economic growth stimulates aspirations for better standards of living and higher levels of consumption. The linkage between growth and degradation of the natural resource base of the region has to be addressed if future demand is to be met. Fortunately the levels of water stress in the GMS are not as acute as in many other parts of the world, yet competition for water does exist and increases in productivity will be required. Cumulative impacts on water availability, water quality and aquatic ecosystems are apparent and the prospect for further deterioration is high given the rapid scale of development. A major driver of change to water resources and the environment of the region is hydropower. Significant hydropower development potential exists and can be exploited sustainably provided changes are made to the way projects are planned and implemented.

The paper argues that achieving optimal outcomes and avoiding unintended consequences requires lessons from within the region and beyond to be incorporated into regulatory and planning systems. There is space for a reinvention of 'master' or 'strategic' planning to achieve sustainability goals and a balance of development and protection. A combination of tools and methods exist to move beyond the current stepwise development model, including use of development scenarios, strategic environmental assessments, sustainability assessments and procedures to facilitate regional dialogue. The framework emerging from the Bonn2011 Conference on Water, Energy and Food Security Nexus identifies six opportunity areas to stimulate a more inter-connected approach. That framework is used to highlight what can be done to promote the sustainable development

of hydropower and protection of vital ecosystems and livelihoods. Experience gained in the region and elsewhere demonstrates additional benefits can be achieved from a more inclusive and inter-linked approach.

1. Water resources – status and trends

Global assessments of water resources point to a situation of increasing scarcity and a widening gap between demand and supply. Estimates vary, but the trend is characterized by the report of the Water Resources Group (WRG, 2009) which projects a 40% shortfall in supply by 2050 even after measures to improve efficiency and manage demand have been implemented. Such stark assessments call for more sustainable approaches to water resources planning and management; ones that provide the foundation for economic and social development that is needed, while at the same time avoiding unnecessary conflicts arising over resource use and maintaining the integrity of services provided by aquatic ecosystems. It is an approach consistent with the concept of a Green Economy that aims to decouple resource exploitation and economic growth and move towards a situation where growth '*neither degrades the environment nor imposes costs on others*', (UNEP, 2011).

Analyses by WRG and others provide a generic indication of stress, but more detailed national and sub-national assessments are needed to provide the basis on which responses can be formulated. Within the Greater Mekong Subregion (GMS), this is certainly true with wide variations in the distribution of water resources, in geography and climate as well as in the development status and aspirations of individual countries. For example, the basinwide analysis prepared by the Mekong River Commission (MRC) suggests that water is available for proposed future irrigation development without compromising other needs, (Lennaerts *et al*, 2012).

Differences exist also in the nature of the issues and challenges being faced and in the inter-connectivity and linkages between decisions in one sector and the consequences and constraints for another. This was recently demonstrated in the 2011 Bonn Conference on the Water, Energy and Food Security Nexus.² It argued that these inter-linkages need to be more openly considered and addressed at early stages of policy development and

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² See <http://www.water-energy-food.org/>

project planning, for instance, to avoid price subsidies in one area such as biofuels, having adverse effects on food security, (Rosegrant *et al*, 2012).

This paper starts with a brief summary of the water resources status and trends of river basins within the GMS area, moves on to examine some of the inter-linkages, particularly between energy and water sectors, and then identifies a number of approaches and tools from the region and elsewhere that embrace coordination and start to break down the 'silos' of sectoral thinking.

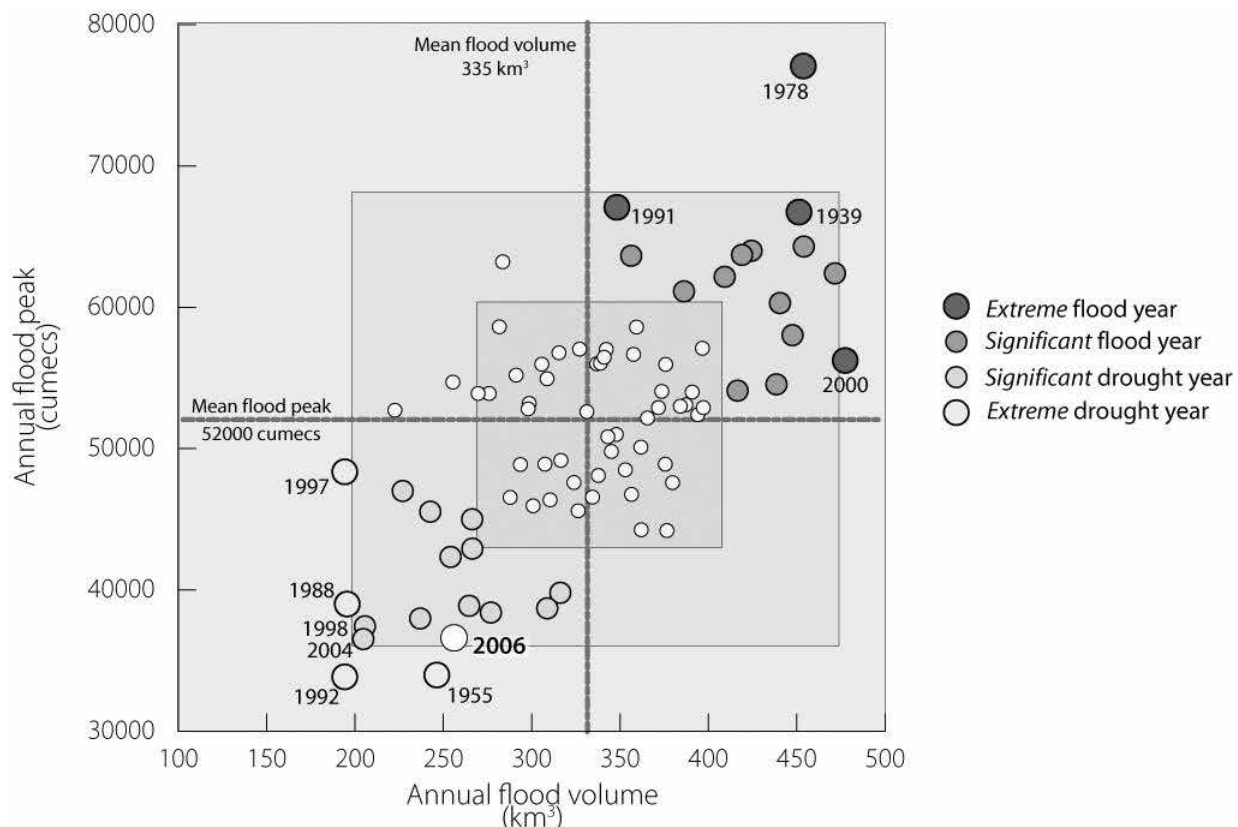
1.1 Overview of GMS Basins

Of the six river basins making up the GMS, two lie wholly within national borders, the Chao Phraya in Thailand and the Pearl River in People's Republic of China, while the other four are transboundary, the Salween, Irrawaddy, Lancang-Mekong and Red Rivers. Basic characteristics of the six basins can be found in the GMS Atlas of the Environment (ADB, 2012) and the MRC's State of the Basin Report, (MRC, 2010).

The Irrawaddy, Lancang-Mekong and Pearl rivers combined represent 85% of the annual river discharge of these six major rivers although the annual average figures mask a significant variability from wet to dry seasons and from year to year. The average wet season flow of the Mekong at its mouth is 52,000 m³/s, 3.5 times larger than the average dry season flow of 14,500 m³/s. Figure 1 shows the considerable variability in wet seasons from year to year with a minimum of about 33,000 m³/s in 1992 to a high of 77,000 m³/s in 1978 (Adamson *et al*, 2010). This existing natural variability is important when considering climate change adaptation.

Flooding is a frequent occurrence in the river systems of the GMS, both regional flooding in the mainstream rivers (MRC, 2008) and flash floods in the steep tributary rivers. The most recent experience was in the Chao Phraya basin in October/November 2011 in which areas of Ayuthayya and outer Bangkok were inundated for weeks with the loss of more than 500 lives and major impacts on industries, agriculture and tourism. Similar extreme events were experienced in Bangkok in 1942, 1983 and 1995. The value

Figure 1: Variability of Mekong Flood Discharge and Flood Volume (Adamson *et al*, 2010)



of infrastructure and assets at risk is now considerably higher. The region is also subject to recurring drought, most recent of which was experienced in the upper part of the Mekong in early 2010 giving rise to regional tensions between upper and lower riparians, (MRC 2010b).³

Agricultural land is extensive in each basin and an important factor in the local economy and social fabric of what is still a predominately rural area. In the Lower Mekong, 75% of the population is rural. Agriculture is mainly rainfed, with irrigated land covering on average only 7% or about 15 million ha of the total basin area. This land is located mainly in the productive floodplains. The Chao Phraya basin is the most developed for agriculture with 12.5% of the basin area irrigated. Water withdrawals for agriculture dominate the total abstractions, for example in the range of 68 to 98% of all withdrawals for GMS countries compared to 1 to 26% for industrial uses and 1 to 8% for domestic uses (Johnston, 2012, Table 1). Total withdrawals remain relatively low at about 14% of total renewable water resources, but the rising trend is expected to continue in response to rising demand and agricultural intensification.

At the river basin scale, concerns on water availability in this tropical climate are less severe than in semi-arid regions, but they do exist at sub-basin levels. This was demonstrated in the experience of the Ping river, a tributary of the Chao Phraya, where conflicts between water uses led to mobilization of community action groups and subsequently formation of a river basin committee to resolve upstream – downstream management issues.⁴

Water quality similarly varies across the region from the largely good quality tributary upland streams to areas of high population density and industrial development where untreated wastewater is discharged directly into the river systems. Quality also deteriorates in areas of intensive agriculture and aquaculture where high rates of fertilizer and pesticide applications cause non-point pollution. Public information on water quality is becoming more available in a form that can be understood by non-experts as illustrated by publication of annual report cards for water quality and ecosystem health for the Mekong, (MRC, 2010c, 2010d). They provide a valuable tool to highlight year to year trends to decision-makers and stimulate further investigation and actions where quality is deteriorating.

Hydropower development has a major potential in the region both for meeting domestic demand and for generating export earnings. At the same time, the cumulative development of hydropower projects is a major driver of change for water resources. Although not a consumptive user of water, hydroelectricity generation can significantly alter river flow regimes on a seasonal and daily basis due to reservoir storage and peaking power releases, can reduce sediment flows downstream causing morphological changes in river profiles and can block migration routes for fish moving between upstream breeding grounds and downstream habitats. Measures to mitigate some of these impacts have been introduced on the Nam Theun 2 and Theun Hinboun projects. They include re-regulation reservoirs to smooth out daily peaks in flow, multi-level offtakes and aeration weirs to restore water quality, watershed management programs and support for livelihood development initiatives for affected people.

The GMS region is home to an incredible natural biodiversity both on land and in the rivers. WWF describes it as one of the most diverse on the planet where “*Since 1997, over 1500 new species have been described by science in the jungles, rivers and even urban areas of the Greater Mekong.*”⁵ The Mekong River is home to at least 850 species of fish, a significant proportion of which are long distant migratory species. Capture fisheries have an annual value of approximately \$2.6 billion, (MRC, 2010 p98), and fisheries provide a significant part of the livelihoods of more than one third of the population and a significant protein for many more, (MRC, 2010e). The river is also home to iconic species including the Giant Catfish, Julien’s Golden Carp and the Irrawaddy Dolphin.⁶ Although the size of fish caught has been getting smaller and effort needed to catch them has increased, the overall biomass of the annual catch of more than 2 million tonnes is considered relatively stable.

Further information on environmental, social and economic conditions and emerging challenges is available in the GMS Environmental Atlas (ADB, 2012) and MRC’s State of the Basin Report (MRC, 2010). Such state of the basin reporting provides an important step in making management information more accessible and could be a model for other basins in the GMS.

³ See also BBC report on the 2010 drought at <http://news.bbc.co.uk/1/hi/8603112.stm> and WHO report on 2008 flood at http://www.wpro.who.int/sites/cha/disasters/2008/lao_floods/LAO_floods_18082008.htm

⁴ See ADB Water Champions at <http://www.adb.org/water/champions/jompakdee.asp>

⁵ http://wwf.panda.org/what_we_do/where_we_work/greatermekong/

⁶ See WWF River of Giants http://wwf.panda.org/what_we_do/where_we_work/greatermekong/publications/?194324/River-of-Giants

1.2 Development opportunities and challenges

The discussion on meeting future food demands of an increasing population with changing dietary preferences is presented in GMS2020 by the International Food Policy Research Institute (Rosegrant *et al*, 2012) and the International Water Management Institute (Johnston *et al*, 2012). Policy and pricing reforms and an increase in productivity from rainfed and irrigated land are part of the recommendations. Countries of the region project an increase in irrigated land and demand for more irrigation water.

As part of a recent sector review, countries of the Lower Mekong Basin identified their projections of irrigation land to 2030. The irrigable area is expected to rise approximately 50% from approximately 4 million ha under the Definite Future Scenario to almost 6 million ha in the 20 Year future scenario, (MRC, 2010f, Table 2).⁷ Most of the increase was projected in Cambodia, Lao PDR and Thailand, with irrigable areas in Viet Nam already being extensively developed. Although such estimates tend to be optimistic in timescale, there will be a progressive increase in demand for irrigation water from the current 12% of mean annual runoff to 20%. Any change in the dry season, when irrigation is needed most, could have a significant effect on the flow regime in the Mekong Delta and salinity intrusion which in turn influences crop production and availability of water for municipal purposes. In the case of the Mekong however, it is not a zero-sum game. The development of reservoirs on the Lancang in Yunnan is adding about 20 billion cubic meters of storage and, when released for hydropower generation in the dry season, will increase flows to downstream areas offsetting increased demand (Lennaerts *et al*, 2012).

According to the GMS Environmental Atlas, *'growth in energy consumption in the GMS has remained constant over the last decade, averaging at 5% per year between 1999 and 2009. Highest growth in energy consumption was in Guangxi (11%) and Yunnan (9%); energy consumption in the Lao PDR, Myanmar, and Viet Nam grew at an average of 5%, while in Thailand and Cambodia, increase in energy consumption was slightly slower at 4% and 2%, respectively'*, (ADB, 2012, Chapter 13). Still, about 74 million or 24% of the region's population lacks access to electricity and this remains a major development goal. Current

development of hydropower in the GMS is 21GW out of an estimated potential of 248GW representing a significant future source of electricity. Biomass is widely used by over 50% of the rural population and has implications for sustainable management of forest resources.

Demand for electricity is projected to reach 237GW in 2025 from 77GW in 2010 (ADB, 2012, Chapter 13). The predominant generating technology in the region will remain conventional thermal followed by hydropower. Coal-fired generation requires water for cooling purposes. For example, the Hongsa lignite project currently being developed in northern Lao PDR is constructing a large dam to supply water to the project.⁸

The GMS Study on Power Interconnection envisages that by 2025, there will be an electricity interconnection between the GMS countries involving export capacity to Thailand and Viet Nam of 10GW from northern Lao PDR, 3.5 GW from southern Lao PDR and 2.5 GW from Cambodia. Exports from Myanmar to People's Republic of China and Thailand would be 28GW, (ADB, 2010. Fig 1.4.1). This suggests a significant increase in cross border trade relying on hydropower development in the next decade. The results are also subject to decisions on mainstream projects on the Mekong for which a cumulative impact assessment is suggested by the Study. The Strategic Environment Assessment of proposed mainstream projects commissioned by MRC provides insight into the complexities and current uncertainties surrounding these developments and recommended deferment and development of other options until the gaps in understanding have been addressed, (MRC, 2010f).

Forest cover in the GMS has reduced by 8 million ha (FAO, 2011) and forest clearance remains relatively constant at 0.4 to 0.5 per cent per annum representing a loss of 8 million hectares between 1990 and 2010. The FAO Outlook report suggests that *'throughout the region forests are becoming increasingly degraded' and 'unless action is taken to address key drivers of change in forests and forestry, many countries will fall short of forest cover targets and values associated with forests will be lost.'* Associated losses include biodiversity and ecosystems services and there will be changes in hydrology as established forests are replaced by agriculture or rapidly growing plantations.

⁷ Irrigable area is defined as the area developed for irrigation. Actual irrigation area in the dry season is currently estimated as 1.2 million hectares and this is also expected to expand by 50% (Lennaerts *et al*, 2012). Larger areas are provided supplemental irrigation in the wet season.

⁸ <http://www.teamgroup.co.th/en/credentials/projects/environmental-management/171-emp-rap-and-raw-water-system-design-for-hongsa-coal-fired-power-plant-lao-pdr.html>. The law on water and water resources further stipulates that any changes to water flow also need approval from the National Assembly. http://www.na.gov.la/docs/eng/sess5_leg6/250708/apprval_of_lignite_power.htm

Concessions to large scale multi-national mining companies and smaller scale operators with less capacity for environmental management have increased dramatically. A study of two provinces in Lao PDR conducted in 2009 revealed that 290,000ha of mining concessions had been outsourced in Vientiane Province and estimated there were between 2 to 3 million ha of all types of concessions across the country as a whole (GTZ, 2009). Incidences of water pollution affecting drinking water supplies for communities, livestock and fisheries from poorly regulated operations have been reported, (MRC, 2010, p203). Proposals for large mining operations such as bauxite in the Bolaven Plateau in Lao PDR require significant energy and water supplies placing additional demands on water resources locally and regionally.

The consequences of climate change on temperature and hydrology will be superimposed on what are already highly variable systems (Figure 1). Rainfed farming will be particularly affected and may lead to calls for greater storage of water in small and large scale systems and more supplemental use of groundwater. For irrigated systems the situation is dependent on the source of water. Modeling undertaken as part of the MRC's Basin Development Strategy suggests that the overall climate related changes for Mekong river flows will be offset by those due to dam construction. For example, increased dry season flows due to dams in Yunnan will offset seasonal any reductions in rainfall. However, persistent drought conditions for more than one season as well as the frequency and intensity of tropical storms need to be factored into planning and adaptation processes.

In coastal and delta areas, the main climate threat comes from sea level rise and storm conditions that would significantly exacerbate the flooding risk to coastal communities and major cities. In the Mekong Delta, increases of 0.5 to 1.0m in sea levels have been projected by 2100 potentially affecting millions of people and the most productive agricultural land in Viet Nam.

2. Inter-linkages

2.1 Water, Energy and Food Security Nexus

The inter-connected nature of water resources has long been recognized yet cross-sectoral cooperation remains a challenge. The Bonn2011 Conference on Water, Energy and Food Security Nexus highlighted that the current pathways of development are not only failing to meet

targets for access to water and energy services and food security, but also the lack of coordination is resulting in sub-optimum allocation of resources – both financial and natural (SEI, 2011).⁹ Bonn2011 concluded that:

A nexus perspective increases the understanding of the interdependencies across water, energy, food and other policies such as climate and biodiversity. The nexus perspective thus helps to move beyond silos and ivory towers that preclude interdisciplinary solutions.... In this way, unintended consequences can be avoided.

Six opportunity areas emerged from the Bonn2011 Conference and will contribute to the overall aims of achieving access to water, sanitation, energy, and food; raising resource productivity; and sustaining ecosystems and biodiversity (see Box).

The Nexus is premised on the understanding that the discourse on development planning within a country, region or basin needs to cut across sectors and engage effectively with all key ministries so that the inter-linkages and connectivity are effectively reflected early in sector planning. It does not argue for major institutional reform so that implementation remains firmly within the mandate of sectoral agencies within an effectively regulated environment.

Later in the paper, the Nexus framework is used to discuss emerging and new initiatives to encourage a more coordinated approach to hydropower development.

2.2 Connectivity in hydropower planning

As utilization of natural resources expands and reaches limits of sustainability, and competition between water uses increases, it is inevitable that more coherence in policy development, planning and management will be required. Private sector finance is essential to meet the development demands of the region and it has achieved results unattainable by the public sector alone. However, in practice, a shift in financing of major projects from public to private sector and limited capacity of regulatory frameworks have combined to strengthen the sectoral perspective. The drive towards Integrated Water Resources Management (IWRM) introduced 20 years ago, and confirmed by countries at the World Summit on Sustainable Develop-

⁹ http://www.water-energy-food.org/en/bonn_2011_process.html

Bonn2011: Water, Energy and Food Security Nexus – Key messages

Increase policy coherence - by ensuring that synergies and trade-offs among water, energy and food are identified both in design and implementation of policies, plans and investments. And by incentivizing co-operation and coordination for mutually beneficial approaches, multiple benefits and fewer unintended or adverse consequences.

Accelerate access - by progressively realizing – in a more coordinated way – the human rights obligations related to water, sanitation, energy and food to reap the resulting health, productivity and development benefits. And by prioritizing access for the poor and the marginalized in sector strategies, planning and investments.

Create more with less - by increasing resource productivity, establishing mechanisms to identify the optimal allocation of scarce resources for productive purposes, and sustainably intensifying the use of land and water to achieve equitable social, economic and environmentally sound development.

End waste and minimize losses - by reducing waste and losses along supply chains to capture significant economic and environmental gains within and across sectors and reduce demands on water, land and energy. And by changing mindsets and incentivizing technological development to turn waste into a resource and manage it for multiple uses.

Value natural infrastructure - by investing to secure, improve and restore the considerable multi-functional value of biodiversity and ecosystems to provide food and energy, conserve water, sustain livelihoods and contribute to a green economy while strengthening the basic role that nature plays in supporting life, well-being and cultures.

Mobilize consumer influence - by acknowledging and actively utilizing the catalyzing role that individuals have in choosing consumption patterns on water, energy and other resource footprints and improving efficiency of resource use both through their direct actions and in influencing the way business is done.

ment in 2002, aimed to cut across sectoral silos.¹⁰ But the buy-in to these processes by key energy and industry ministries has been limited.

Without an effective regulatory environment and incorporation of water resources, environmental and social considerations early in the process, not only will adverse impacts be frequent, but also the opportunities of attaining multiple benefits will be foregone. On its own, environmental impact assessment of major projects is unlikely to demonstrate a major influence as it is carried out late in the project cycle when the room for considering options including timing or funding are constrained.

There have been some notable exceptions to this characterization, where developers have committed to international good practice and safeguards have been

adopted through the involvement of international finance institutions, either as co-financiers or in providing risk guarantees.¹¹ Pressure from advocacy groups has similarly contributed to improved outcomes.

In Lao PDR, a far reaching policy on social and environmental aspects of hydropower development was approved in 2005,¹² but implementation capacity takes time to develop. In the interim period, the risk is that projects proceed with problems emerging on resettlement, downstream flow, water quality, fisheries and ecosystem health. Steps are being taken to raise the status of the policy and strengthen capacity, but the pace of development and pressure for rapid project implementation remain high.

¹⁰ In the Johannesburg Plan of Action, countries committed to preparing IWRM plans by 2005.

¹¹ As for the Nam Theun 2 and Theun Hinboun Expansion Projects.

¹² National Policy on Environmental and Social Sustainability of the Hydropower Sector in Lao PDR of 2006.

Conversely, concerns have been voiced that new, more inclusive approaches take too long to implement and are too costly for wider replication. The question in the long term should perhaps be turned around into whether a country could afford not to follow more sustainable practice? Adopting new processes that treat affected people as beneficiaries of a project represents a major shift from the more conventional compensation perspective. Positive experience has been gained that can be used to accelerate implementation and reduce costs on subsequent projects.

3. Risks – from the perspective of the user

Understanding the boundaries within which development occurs is fundamental and argues in favor of a more strategic approach in which some of the potentially divisive questions on water management can be addressed as part of a joint process among riparian countries or provinces, such as:

- how much water can safely be abstracted?
- can multiple benefits be achieved?
- how to best share benefits of development?
- what quality of water is acceptable for specific purposes?
- to what extent can changes to the natural variability of flow be accepted?
- how can peoples' livelihoods be secured and a balance achieved with conservation of ecosystems and biodiversity?
- how can shortfalls in water supply in times of drought be managed?

Regional cooperation frameworks provide an opportunity to move beyond the rather basic question on allocation to consider the broader issue of sharing benefits beyond just the water itself. This can increase the negotiation space¹³ as was done in the case of the 1961 Columbia Treaty between the United States and Canada for the development of hydropower and provision of flood management benefits.¹⁴

The relative emphasis on each of these questions depends on the type of development, for example whether it

is consumptive irrigation or non-consumptive use for hydropower or thermal cooling. Given its importance for the region, this paper focuses mainly on hydropower. An understanding of the potential consequences of hydropower development on different users in the conceptual planning stage helps to identify solutions before the timeframe and financial negotiations of project processing begin to constrain options. Increasingly this is of importance to private banks in terms of reducing risk to their investments including reputational risk.

For hydropower, the hydrological issues revolve around a range of issues: downstream flows (whether water is diverted from one river to another or to a location downstream of the dam thereby reducing flows in the intervening reach or river); redistribution of flows from wet to dry season and changes in river hydrograph; attenuation of flood peaks; rapid fluctuations of flow and the daily peaks as projects are 'ramped' up and down in response to peak electricity demand on the grid; and morphological issues related to interruption of sediment flows.

A range of benefits and impacts may occur:

- A farmer may benefit from additional water in the dry season for irrigation but be adversely affected by rapid fluctuations in downstream river levels and lose opportunities for recession agriculture on traditional riverbank gardens.
- Fishers experience difficulties in setting fish traps on rivers that are fluctuating hour to hour rather than on a more gradual seasonal cycle or lose fish stocks due to deteriorating water quality and low oxygen content.
- Communities living in flood prone areas may benefit from reduced flood peaks, whereas important flood pulse triggers for migrating fish may be removed from natural cycle of river flow.
- Species of fish change and capture fisheries reduce as dams provide a barrier to migrations, whereas reservoirs provide an opportunity for reservoir fisheries to develop – the benefits however accrue to different people.
- The trapping of sediment in reservoirs provides "clean" water downstream but disrupts the natural energy of the river system causing bank and bed erosion, reduced delta formation and is a net loss of nutrients to downstream ecosystems.
- Villagers living in reservoir affected areas can lose livelihoods or alternatively benefit from new opportunities and services.
- Navigation may be easier due to higher water levels,

¹³ See also Sadoff, C. and Grey, D. (2008). Why share? The benefits (and costs) of transboundary water management. Chapter 2 in, Sadoff, C., Greiber, T., Smith, M. and G. Bergkamp (eds.) SHARE - Managing Water Across Boundaries. IUCN, Gland, Switzerland. 2008.

¹⁴ http://www.bpa.gov/corporate/pubs/Columbia_River_Treaty_Review_-_Feb_2009.pdf

or hindered by rapid level fluctuations on a daily or hourly basis.

- Tourism can be affected positively by creating new eco-attractions or negatively by reducing sites of important diversity.
- Endangered species are more at risk by the opening up of access to remote areas or are benefitted from added protection provided through funding from project revenues.

In the situations above, it is easy to see that risks will be viewed differently depending on the stakeholders' perspectives. This can be further demonstrated in the case of mainstream dam projects constructed on the Lancang River in Yunnan upstream of Lao PDR and Thailand. The first, Manwan hydropower dam, was completed in 1993. The storage is relatively small and the hydropower use non-consumptive, so the project had little impact on the river's hydrography although some sediment was retained in the river. Subsequently, as up to 20 billion cubic meters of storage and hydropower generation capacity are added in the Lancang, further sediment and nutrient flows will be lost whereas low flows in the dry season in the Mekong will increase providing benefits downstream.

Communities along the river in northern Lao PDR and Thailand view the seasonal changes and daily fluctuations in river level as a result of upstream control. Naturally, they then associate these dams as the cause of all future extreme events, whether or not they have natural origins as was the case of the flood in 2008 and drought of 2010.¹⁵ Once public opinion has been formed it is difficult for technical analysis alone to change perceptions. Although there has always been a plan to build a re-regulating reservoir upstream of the border (now to be located at Galanba), this structure will not be completed for several years. The deterioration of relations between these communities and their upstream neighbor has already occurred and will be difficult to turn around.

The issues and challenges around hydropower development are not 'black' or 'white' as typified by either anti-dam advocacy groups or pro-dam promoters. There is a lot of 'grey' in the middle and a balance is needed. The complexity of the issues requires a more inclusive and coordinated approach, bringing in different expertise and capacity. It is one that looks upon hydropower as an integrated development opportunity rather than as a single sector objective. A major concern is that the

current institutional setup of relatively weak regulation and planning does not lead to this outcome. As in the case of deteriorating water quality or diminishing fisheries, the cost of retrofitting solutions to fix unanticipated impacts can be significant and greater than making adequate provisions in the planning stages.¹⁶

Returning to a traditional master planning process may not be suited to the prevailing private sector development model. Other methods and tools are needed that define the boundaries within which development takes place, examine the inter-linkages between sectors, consider cumulative impacts on the environment and set the direction for social inclusion. These are discussed in Section 4.

4. Adopting new approaches for strategic planning

A fundamental question for planners is how to avoid the gradual progression towards unsustainable cumulative consequences of individual project decisions. Such decisions may appear fully justifiable on economic and financial grounds in the short term, but only if externalities are ignored which has often been the case in practice. A related question is whether water resources systems and other natural resources have to reach crisis points, or 'tipping points' before sustainable management practices are implemented. In other words, how is it possible to develop a more strategic framework and operationalize considerations of the Green Economy? To what extent for example, will private sector developers and investors be prepared to join as partners in more integrated regional development programs?

A recent report by the World Bank on the hydropower and mining sector in Lao PDR points to some of the issues facing hydropower development in the region (World Bank, 2010):

The project-by-project approach so far employed will not be appropriate....In particular, the cumulative effects of mining and hydropower need to be addressed through a strategic framework at the national or river-basin level.

Various new approaches have been adopted elsewhere. In Europe, the Water Framework Directive introduced in 2000 requires member states to gradually move towards 'good' river status. Any development proposals need to

¹⁵ See footnote 3.

¹⁶ See costs of remediation of fisheries in the Columbia River, <http://www.nwcouncil.org/library/1999/99-3.htm#5>

be tested against this requirement during the regulatory processes. The recently approved Danube Water Resources Management Plan sets out a program for gradual improvement in river status.¹⁷

In Norway, a balanced approach for hydropower development has been operating for 30-40 years and has enabled investments in new schemes as well as increasing efficiency and output of existing systems while protecting sensitive areas. Two plans were adopted by Parliament and work in parallel:¹⁸

- a protection plan first adopted in 1973 that defines certain tributary systems to be free of future development; and
- a master plan approved in 1986 identifying potential sites across the country that are available for project promoters to develop.

Regulation of the industry in Norway comes under the Water and Energy Regulatory Authority (NVE), combining the two sectoral functions into one agency. Coordination across projects within a regulated river basin is provided through hydropower users associations.¹⁹ The Norwegian experience of parallel protection and master plans appears particularly relevant to parts of the GMS, including Lao PDR. Developing a similar framework protection plan for key aquatic systems, either whole tributaries or critical reaches, would complement long existing terrestrial protected areas. Importantly it could help frame the environmental debate which is currently repeated on each individual project, (rarely with satisfactory results), and facilitate projects in non-protected areas to be pursued with greater confidence and reduced conflict. Biodiversity and conservation objectives would be accommodated to the extent possible in the prior discussion on protected areas.

The Lower Mekong Basin already has procedures in place under the 1995 Mekong Agreement through which large projects are considered. The Procedures for Maintenance of Mainstream Flows (PMFM) sets thresholds for minimum flows at key points in the river system and for the timing of flow reversal into and out of Tonle Sap Lake that is so important for fisheries and biodiversity.²⁰ Similarly, the Procedures for Water Quality (PWQ) derived from negotiations among

the four member countries define agreed water quality parameters that should not be violated.²¹

The process for notifying countries of prospective projects and requesting feedback is achieved through the Procedures for Notification, Prior Consultation and Agreement (PNPCA).²² Although a significant step forward in regional cooperation and consultation on major projects, the PNPCA also comes rather later in the project cycle and therefore needs to be supplemented by a strategic and cumulative assessment. For proposed mainstream projects, the MRC commissioned a Strategic Environmental Assessment (SEA) (ICEM, 2011) and the IWRM-based Basin Development Strategy have undertaken extensive modeling and flow assessments under different scenarios to identify what has been termed a 'Development Opportunity Space' within which individual projects can then be considered.²³ In terms of tributary development, the Strategy states:

*There is considerable potential for further development of tributary hydropower in the LMB, especially in Lao PDR and Cambodia, as well as for improvement in operation of existing hydropower projects. Utilising this opportunity requires a focus on sustainability both at project and transboundary levels...*²⁴

The Strategy, approved by MRC Council (of Ministers) in January 2011, then sets out the opportunities and safeguards that should govern future sustainable hydropower development on the tributaries, including:

- Identifying sub-basins with high ecological value to be protected and those where hydropower can be developed with limited social and environmental impacts;
- Evaluating hydropower projects from a multi-purpose perspective to increase overall economic benefits and decrease adverse effects on other water uses;
- Mitigating negative impacts of hydropower, such as through: re-regulation reservoirs downstream of peaking projects; multi-level water intakes or aeration facilities to manage water quality/temperature; fish passage; and minimizing sediment entrapment;

¹⁷ http://www.icpdr.org/icpdr-pages/river_basin_management.htm

¹⁸ See licensing history in Norway at <http://www.nve.no/en/Licensing/History/>

¹⁹ http://www.sustainablehydropower.org/site/siteresource_pages/schemes_pdfs/glomma.pdf

²⁰ <http://www.mrcmekong.org/assets/Publications/policies/Procedures-Maintenance-Flows.pdf>

²¹ <http://www.mrcmekong.org/assets/Publications/policies/Procedures-for-Water-Quality-council-approved260111.pdf>

²² <http://www.mrcmekong.org/assets/Publications/policies/Procedures-Notification-Prior-Consultation-Agreement.pdf>

²³ <http://www.mrcmekong.org/assets/Publications/strategies-workprog/BDP-Strategic-Plan-2011.pdf>

²⁴ IWRM-based Basin Development Strategy, Section 4.1.

- Developing management plans for environmental hotspots impacted by changed flow regimes; and
- Evaluating benefit-sharing options, such as watershed development and management benefitting hydropower generation and funded from hydropower revenues.

Adopting a modified form of the Norwegian experience of parallel master and protection plans could result in a more coordinated development path for hydropower in line with the Strategy and provide a space for dialogue on introducing multiple benefits into what are currently typically conceived as single purpose projects. Without it, there would be uncoordinated project development and higher levels of impact on vital ecosystems and biodiversity than would otherwise be necessary.

GMS is a dynamic and innovative area. Where political commitment exists, innovations can be taken up in a relatively short timeframe. For example, the requirement in Viet Nam under the National Water Resources Strategy for projects to consider environmental flows is a major step forward for downstream communities that was not previously a regulated consideration, (GoV, 2006).²⁵

4.1 Recommendations

There are a number of innovations and new tools relevant to the GMS that can be used to address interconnectedness surrounding water decisions. The Bonn2011 framework of six opportunity areas (Section 2) is used here to present some of these with emphasis given to those related to energy and hydropower.

Increase policy coherence

- Use Strategic Environmental Assessments to identify the key development issues and challenges (including economic and social) at an early stage of planning and programme development. Examples include the SEA of the Hydropower Master Plan in Viet Nam (SEI, 2009)²⁶ and the SEA of proposed mainstream dams on the Mekong (ICEM, 2010). The outcomes of these assessments and the subsequent dialogue they stimulate can identify opportunities for multiple benefits beyond electricity generation, lead to more effective environmental

management and feed into other long term planning studies such as for regional power interconnection.

- Consider adaptation of the master plan and protection plan model for strategic planning pioneered in Norway.
- Apply sustainability assessment tools to rapidly identify the key issues for new developments. These include:
 - the project-oriented Sustainability Assessment Protocol²⁷ of the International Hydropower Association (IHA) that was developed and tested through a global multi-stakeholder dialogue process over several years; and
 - the Rapid Basinwide Sustainability Assessment Tool (RSAT)²⁸ which was designed through collaboration of ADB, MRC and WWF to supplement the IHA Protocol by providing a cumulative perspective within sub-basins. The RSAT has been tested in a number of sub-basins in the Mekong.
- Ensure that a process for cross-sectoral policy dialogue exists, e.g. on pricing policy and incentives for biofuels as raised by IFPRI and the resulting consequences for food production and food prices, (Rosegrant *et al*, 2012).

Accelerate access

- Move beyond conventional development orientations to include affected communities as part of a broader integrated approach including emphasis on benefit sharing from project revenues, providing basic water and electricity services and support to livelihood opportunities.²⁹
- Explore the multiple options that hydropower development presents, including the benefits of using storage to supplement dry season irrigation flows and improve resilience to increased hydrological variability in the long term due to climate change. Currently these opportunities tend not to be factored into project concepts due to the single sector focus.

²⁷ http://www.hydropower.org/sustainable_hydropower/HSAF.html

²⁸ <http://www.mrcmekong.org/assets/Publications/Reports/RSAT-Revision-3-for-printingOCT-3-2010-Corrected-FINAL.PDF>

²⁹ An extensive review and knowledge base of benefit sharing mechanisms has been prepared by MRC under its Initiative on Sustainable Hydropower and is scheduled for web publication in due course. <http://www.mrcmekong.org/about-the-mrc/programmes/initiative-on-sustainable-hydropower/>. See also Haas, L.J.M., D.V. Tung. 2007. Benefit Sharing Mechanisms for People Adversely Affected by Power Generation Projects in Viet Nam. Final Report of ADB TA4689-VIE. Manila.

²⁵ Vietnam National Water Resources Strategy 2006, GoV MoNRE, - section 2.2a http://www.vnwatersectorreview.com/files/NWRS_FINAL_VERSION.pdf

²⁶ http://www.sei-international.org/mediamanager/documents/Publications/Policy-institutions/sea_hydropower_vietnam_full%20report.pdf

- Integrate sustainable community management of reservoir fisheries into project planning and conduct further research on options for migratory fish passage in the context of highly diverse tropical river systems.

Create more with less

- Explore the potential for upgrading existing hydropower projects with new more efficient generating equipment and technology and adding capacity where possible.³⁰
- Use basin modeling techniques to optimize production from the group of hydropower projects within a sub-basin and explore opportunities to identify win-win solutions that can be integrated into existing and future concession agreements, (see also objectives of ecosystem protection below).
- Consider how irrigation system rehabilitation and expansion can be linked to hydropower development including low head energy generation and other productivity improvements encouraged such as more efficient agricultural practices and intensification programs.³¹

End waste and minimize losses

- Actively pursue policies for demand management and application of low energy technology and appliances for consumers.³²
- Reduce the considerable losses experienced in post-harvest processing, transport and marketing.³³
- Intensify assessment of opportunities for second generation biofuels and use of waste products for energy generation and wastewater for irrigation, particularly in peri-urban areas in cooperation with municipal authorities.

³⁰ See for example the initiative of multiple agencies in the US Government for increasing the potential at existing hydropower facilities http://www.usbr.gov/power/data/1834/Sec1834_EPA.pdf

³¹ Examples include improved productivity of water at the Zhang He Irrigation Project in People's Republic of China, and effective rationing of power supplies for groundwater pumping in Gujarat under the Jyotigram Sheme, see <http://www.lk.iwmi.org/china/china.htm#zan> and <http://www.iwmi.cgiar.org/Publications/Other/PDF/NRLP%20Proceeding-2%20Paper%2015.pdf>

³² See focus on efficiency and demand management in People's Republic of China. Jiang Kejun (undated) Management of Energy Resources in China. Energy Research Institute http://siteresources.worldbank.org/DEC/Resources/84797-1251813753820/6415739-1251814084145/Kejun_Energy_China.pdf

³³ See the focus on 'more crop per drop' and reducing 'field to fork' losses in the concluding statement of the 2011 Stock.

Value natural infrastructure

- Recognize the value of the environment in regulating and providing essential services to hydropower production and its physical sustainability by adopting the model of Payment for Ecosystems Services.³⁴ Similarly explore the opportunities for a coordinated approach with projects under REDD+.³⁵
- Avoid daily disruption of river flows and resulting community opposition due to peaking operation by incorporating re-regulating reservoirs and related mitigation measures as a matter of development policy and design standards (Locher, undated).
- Use re-operation software to explore the multiple benefits that can accrue from greater inter-linkage between economic, environmental and social considerations.³⁶
- Build capacity and financing arrangements for existing and new aquatic protection areas such as the Tonle Sap Biosphere Reserve and other key wetland areas.
- Support a research agenda that addresses gaps in knowledge identified in the SEA on mainstream dams and review reports prepared during the PNPCA of the Xayaburi project (MRC, 2011).
- Identify options for reversing the trend in water quality degradation in rivers learning from successful programs elsewhere.³⁷

Mobilize consumer influence

- Recognize that it is more efficient to "avoid" problems rather than to "remediate" them. Learn lessons from sub-basins where conflicts have already emerged including appropriate institutional structures that can facilitate better understanding and dialogue on solutions.
- Work with civil society at an early stage in project planning to address areas of concern rather than wait until conflicts intensify.

³⁴ See Smith, M., de Groot, D., Perrot-Maite, D. and Bergkamp, G. (2006). Pay – Establishing payments for watershed services. IUCN. Gland. Reprint 2008. <http://data.iucn.org/dbtw-wpd/edocs/2006-054.pdf> . Also watershed management program under the Nam Theun 2 project http://www.namtheun2.com/index.php?option=com_content&view=article&id=62&Itemid=72

³⁵ UN Reduced Emissions from Deforestation and Forest Degradation

³⁶ See Global Dam Reoperation Initiative coordinated by the Natural Heritage Institute. <http://www.global-dam-re-operation.org/resources/documents-presentations.html>

³⁷ See for example <http://www.adb.org/water/actions/prc/changing-community-mindsets.asp>

- Be transparent on availability of data and river basin status in terms of quantity and quality. Promote openness and transparency of information as a vehicle to bring about changes in public attitude and changes in behavior.

5. Concluding remarks

Underlying the call for a more inter-linked approach to water resources and energy planning is the premise that current single-sector dominated viewpoint and relatively unregulated development of the private sector is leading to avoidable social and environmental impacts and is not providing the multiple development benefits that are possible. The gradual increase in impacts of a cumulative nature could eventually lead to exceeding 'tipping points' for critical ecosystems and undermine the livelihoods they support. A number of progressive solutions have been demonstrated to deliver better outcomes, but require a more integrated and 'joined up' approach.

Greater coordination and inter-linkage are inherent to the principles of integrated water resources management (IWRM). Unfortunately these principles have tended to stay within the domains of the water, agriculture and environment professionals and not had much traction with energy sector professionals. They appear to have had little effect on early planning of hydropower projects in the Mekong region to date. IWRM therefore needs a new stimulus and pragmatism to move from policy formulation to implementation. The Nexus perspective highlighted through the Bonn2011 process attempts to do that by opening up discussion on specific inter-linkages at an early stage of planning, while retaining implementation responsibility within existing sectoral agencies.

The separate planning processes for water resources and the energy sector need to be aligned at an earlier stage rather than wait for provisions of current regulatory frameworks that tend to be applied late in the planning and project cycles at a time when the flexibility for introducing changes and examining other options is minimal.

Responding to diverging stakeholder perspectives requires more open and accessible information, inclusive debate, and commitment to sustainable outcomes that consider externalities. Rather than dealing with the recurring issues of hydropower development on a case by case project basis, many of the generic problems can be dealt with up-front and avoided or mitigated. Strategic

planning exercises, SEAs and basin-wide sustainability assessments are available tools to improve the knowledge base, stimulate regional dialogue and provide the basis upon which options can be considered and decisions taken. Similarly, the combined 'master plan' and 'protection plan' model adopted by Norway for its hydropower development is one that is worth adapting in the context of GMS countries where a significant proportion of hydropower potential is yet to be developed. At project-level, tools exist to share benefits more equitably and provide financing for sustaining ecosystems services.

Although controversial by nature, expanding tributary hydropower development in the GMS provides considerable benefits and stimulus for economic growth and provision of basic services. Evidence exists that current planning approaches can be considerably enhanced to improve social and environmental outcomes and done so in a timeframe and budget that is not restrictive. The policy framework is generally in place, now the focus needs to shift to how it is implemented to achieve sustainable outcomes.

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THE ROLE OF CLEAN COAL TECHNOLOGIES IN THE GREATER MEKONG SUBREGION COUNTRIES

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Abstract

Worldwide, the combination of abundant coal reserves at relatively low prices and a need to reduce greenhouse gas (GHG) emissions reinforce the critical importance of clean coal technologies (CCTs) and appropriate climate change policies to promote such technologies. In order to meet a rapidly growing need for economic development and power generation, coal will play an increasingly major role in the Greater Mekong Subregion (GMS) countries in coming years. All the GMS countries are building or have in place coal power stations, which once built will be operating for another 40–50 years.

Rising populations, food prices, and competing needs for water in the GMS for power and food will increase the pressure on policymakers to identify strategies to develop a sustainable development pathway for the GMS. Energy production is top priority, but declining freshwater supplies could impede future new energy development. Water needs within the GMS by coal, oil, and gas producers could take precedence over other economic sectors.

This paper describes the coal reserves and existing and planned coal-fired power generation in the GMS and examines the use of coal, clean coal technologies, and competition with water and food in the subregion. To achieve a low carbon pathway, the energy development decisions made now will play a key role in the GMS. The trend toward implementing policies that reduce greenhouse gas emissions inevitably brings regulatory, environmental and technical pressure on the electricity industries, where coal-based power production remains an essential source. It is widely accepted that coal will continue to play a major role in securing power supply for many emerging economies in the foreseeable future. This paper uses the IEA definition for clean coal technologies which encompasses “technologies designed to enhance the efficiency and the environmental acceptability of coal extraction, preparation and use”, which includes CO₂ capture and storage.

Globally older coal-fired power plants operate at an average of 32–35% efficiency due to the current international coal fleet consisting mostly of subcritical pulverised coal units and even lower efficiencies where unwashed and/or low grade coals are used. The state-of-the-art PCC power plant based on supercritical or ultra-supercritical technology, can achieve generating efficiency of 42–45% for hard coal or lignite. Continued improvements in power station component materials are being developed allowing for higher steam temperatures and pressures, pushing materials and generation efficiencies to ever greater limits. It is expected that advanced nickel-based alloys for boilers, high pressure turbines and piping will be available in decades to come, such that efficiencies may reach values of today’s modern gas-fired CCGT at around 55%.

For the period to 2012, the Kyoto Protocol under the United Nations Framework Convention on Climate Change (UNFCCC) is the main international climate policy instrument. There are several proposals for post-2012 climate policy frameworks covering a broad spectrum from Kyoto-type agreements with mandatory targets to technology cooperation with voluntary commitments, such as national appropriate mitigation actions (NAMAs) that could have a role for CCT in the GMS region.

In order to achieve higher efficiencies for CCT in the GMS over the next decade, several elements are needed: incentive schemes for CCTs, international cooperation on research and development and technology transfer, additional incentives for the GMS region, and minimum performance standards for existing and/or new coal plants.

It is not necessary that all these elements are included if other policies cover some elements. It is important to set any incentives over a time horizon that takes into account the long turnover time of capital. The GMS requires ongoing cooperation in information, data, research and development, and technology transfer to obtain the best use of its resources. Additional incentives could be available through the new technology mechanism and Green Climate Fund under development by the UNFCCC members. Implementation of minimum standards for all new and, if possible, existing coal-fired power plants will enable improvements in use of water, air quality, and security of supply up to 2020.

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1. Introduction

Coal can play a key role in contributing to energy security, recognizing that a combination of providing energy security as well as climate change mitigation measures to limit greenhouse gas (GHG) emissions requires a balanced policy. In the Greater Mekong Subregion (GMS), there are several countries where the economy is growing rapidly and that have abundant coal supplies with low prices, such as the People's Republic of China (PRC) and Viet Nam.

Governments and companies within the Greater Mekong Subregion (GMS) will need to make key decisions over the next few years on investment in energy supply, which is likely to include a combination of energy sources (fossil, renewable, and nuclear). Consequently, it is important that when this investment takes place that the issues of energy security, water scarcity, increasing environmental sensitivity, and climate change mitigation are considered by decision makers. In recent years, there have been several major changes to energy supply with increasing gas, oil, and coal prices.

The Mekong area has long been regarded as the foundation of Southeast Asia's economic growth and prosperity, necessitating cooperation between the countries. In 1995, the "Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin" signed by the governments of Cambodia, the Lao People's Democratic Republic (Lao PDR), Thailand, and Viet Nam formed the Mekong River Commission (MRC). The MRC facilitated joint management of shared water resources and collaboration on development issues, such as hydropower development. In 1996, the PRC and Myanmar (Burma) became Dialogue Partners of the MRC. In the PRC, the Guangxi Zhuang Autonomous Region and Yunnan Province are the areas pertaining to the Mekong.

The five countries and two provinces of the Greater Mekong Subregion (GMS) have a combined land area of 2.6 million km² and a total population in 2009 of around 320 million people, mostly living in rural areas; 45 million people still live in poverty. Approximately 74 million or around 20% of the population do not have access to electricity (ADB, 2009a). All share in some manner the Mekong River, which flows for 4,200 km through the GMS into the South China Sea. The basin of the river is 795,000 km², through which some 475,000 million m³ of water flows annually (UNEP, 2007).

The countries within the Mekong region have different types of energy resources. The Lao PDR, Myanmar, and Yunnan Province have large hydropower resources. It is expected that hydropower will meet their energy needs for the foreseeable future. The total hydropower potential of the Mekong River Basin is estimated to be 53,000 megawatts (MW). In the four lower Mekong countries of Cambodia, the Lao PDR, Thailand, and Viet Nam, an estimated 30,000 MW of hydropower are technically available (ICEM, 2010).

A 2009 Asian Development Bank (ADB) report on "Building a Sustainable Energy Future: The Greater Mekong Subregion" failed to recognize clean coal technologies (CCTs) as an option in the low carbon scenario due to carbon and other damage costs. There was also an argument that CCTs have higher capital costs and require international financial support. This is partially correct but the example of the PRC and Viet Nam investing in supercritical coal-fired power stations indicates this is not always the case. This report describes CCTs, discusses the use of coal in the four lower GMS countries, and proposes inclusion of CCTs in national appropriate mitigation actions (NAMAs) as a form of mitigation of emissions.

To ensure the use of coal in contributing to energy security and mitigation of carbon dioxide (CO₂) emissions and air pollution requires the deployment of CCTs, because they can increase the efficiency² of power stations. A 1% increase in thermal efficiency can reduce CO₂ emissions between 2% and 3% depending on the coal and technology.

Supercritical coal combustion (SPCC) and integrated gasification combined cycle (IGCC) with CO₂ capture and storage are key CCTs. In addition, the increasing use of low-rank coals with high ash will make the implementation of circulating fluidized bed combustion (CFBC) more attractive. However, CFBC currently makes up only 2% of the world's coal fleet and so has a limited role. Fluidized bed combustion (FBC) operates at a lower temperature than conventional pulverized boilers and this reduces the amount of nitrogen oxides (NO_x) formed. Sulfur oxides (SO_x) can also be controlled by using limestone added to the coal. The limestone is injected into the combustion chamber with the coal and this can result in up to 90% of the sulfur being absorbed and removed as a solid compound with the ashes. The use of FBC is ideal for poor

² Efficiencies are given in Lower Heating Value (LHV). As opposed to Higher Heating Value (HHV), LHV does not include the condensation heat of the water produced in the combustion process.

quality fuels with high moisture content and low heating value, such as biomass, municipal wastes, and paper and pulp industry wastes and sludge.

The term supercritical refers to power plants that have operating pressures above the normal boiling point. The water changes from liquid to vapor without nucleate boiling. The supercritical point of the water occurs at pressures in excess of 22.1 megapascals (MPa). This allows supercritical units to achieve thermal efficiencies of above 45%, compared with typical subcritical plants of 30%–38%. The key features of supercritical power generation units are once-through boilers designed to operate with pressures of 22.1 MPa to 30 MPa, compared to a high of 19 MPa with subcritical boilers. There are many new power plants being proposed and built worldwide to perform at “supercritical” and “ultra-supercritical” conditions of temperature and pressure. The result could be an increase in electricity generation efficiency to 40%–50% and higher.

Energy capital stock has a long life; coal-fired power plants last up to 40 years and beyond. Decisions on the development of CCTs will thus have far-reaching impacts. There are long-term economic and environmental benefits to countries using CCTs, such as supercritical power plants, including

- higher thermal efficiency;
- reduction of SO_x, NO_x, and particulate matter emission due to improved efficiency and combustion resulting in better air quality;
- costs are comparable with subcritical technology if flue gas desulphurization and selective catalytic reduction are used;
- reduced fuel costs that can represent up to two thirds of the total operating costs of a plant;
- reduction of CO₂ emissions as less fuel is required per unit of electricity generated;
- plant efficiencies are less affected by part load operation and the availability can average up to 85%;
- plant at a future date could be integrated or retrofitted with new CCS technology (Nalbandian, 2008).

2. Greater Mekong Subregion Coal Resources and Use

The GMS faces several important development challenges. A large part of the population relies on traditional sources of energy, such as biomass. There is also a difference

between rural and urban areas in terms of energy access and services. Cambodia and Thailand are becoming more dependent on importing energy. To meet this energy demand there is an increasing growth of fossil fuel use. Yunnan Province has coal resources that could potentially generate 125 gigawatt hour (GWh), of electricity over a 30-year period (ADB, 2008).

There are also other countries that have sizeable coal reserves, including the Lao PDR, Thailand, and Viet Nam. Next to the PRC, northern Thailand has the largest coal-fired power station at the Mae Moh lignite mine site. This is followed by Viet Nam with large quantities of anthracite and brown coal reserves. In the Lao PDR, there are large lignite reserves totaling about 810 million tons.

The Mekong River provides livelihoods for over 60 million people, many of whom still live in poverty and are reliant on the river for fish and other resources. The river is used for energy production, transportation, and water for cooking, irrigation, cleaning, and sanitation. A key issue in the Mekong area is energy and hydropower development. Coal is also a key resource, with several countries along the Mekong River proposing, developing, or already building coal-fired power stations. Along with hydropower, the further use of coal will increase the demands on the Mekong River. This paper focuses on development of coal-fired power in the four lower Mekong countries. Up to 17 new coal-fired power stations are being built, including a 1,200 MW power station in Viet Nam—the first of possibly many—due for completion on the Mekong River in 2014 (ICEM, 2010). Viet Nam and Thailand will make up 96% of energy demand by 2025 (Table 2).

From 2010 to 2025, the overall growth in electricity demand is estimated to grow from 45 GW to 130 GW. The majority of this demand will be met by nuclear, gas, coal, and hydropower (ICEM, 2010).

2.1 Viet Nam

Key Coal facts

Total coal production (2009, estimated)	:	43 million tons (Mt)
Total coal demand (2008, estimated)	:	20–25 Mt
Exports (2008, estimated)	:	20 Mt
Imports (2006)	:	0.3 Mt

Table 1: Electricity Demand Forecast in Lower GMS Countries (ICEM, 2010)

		2010	2015	2020	2025
Cambodia	Peak Demand (MW)	467	1,008	1,610	2,401
	Annual Growth		16.6%	9.8%	8.3%
	Estimated Load Factor	65%	66%	68%	67%
	Energy Demand (GWh)	2,659	5,828	9,449	14,302
Lao People's Democratic Republic	Peak Demand (MW)	618	1,911	2,665	2,696
	Annual Growth		25.3%	6.9%	0.2%
	Estimated Load Factor	65%	66%	67%	68%
	Energy Demand (GWh)	3,519	11,049	15,641	16,060
Thailand	Peak Demand (MW)	23,936	31,734	42,024	53,824
	Annual Growth		5.8%	5.8%	5.1%
	Estimated Load Factor	72%	72%	72%	72%
	Energy Demand (GWh)	150,969	200,153	265,054	339,479
Viet Nam	Peak Demand (MW)	19,544	32,210	48,662	71,445
	Annual Growth		10.5%	8.6%	8.0%
	Estimated Load Factor	72%	72%	72%	72%
	Energy Demand (GWh)	123,268	203,155	306,921	450,618
All Countries	Peak Demand (MW)	44,565	66,863	94,961	130,366
	Annual Growth		8.5%	7.3%	6.5%
	Estimated Load Factor	72%	72%	72%	72%
	Energy Demand (GWh)	280,415	420,184	597,066	820,458

Recoverable reserves : 2,000–3,000 Mt
(2006, estimated)
Port capacities : 34 Mt
(2008, estimated)

Much of the following is drawn from an IEA Clean Coal Centre report on Viet Nam (Baruya, 2010). Coal in Viet Nam is seen as an important aspect of energy policy, with a substantial domestic mining industry that currently exports half its output; however, this is set to decline. The coal export business is encouraged now in order to earn foreign currency revenues to help finance development in the economy. The coal industry is highly strategic, being geared toward exports or the domestic market whenever it is necessary to do so. The state-run Viet Nam Electricity (EVN) intends to build a great deal more coal-fired power. New coal-fired power projects are being urged by the Government in order to bring a reliable supply of electricity to the main demand centers in the north and south.

While the state coal and mining company Vinacomin will endeavor to expand exploration, surveys, and production, there is a possibility that coal that was once destined for the export market will be retained within the country for use by Viet Nam's power stations. Every coal rank is found in Viet Nam, from large amounts of anthracite already mined, to bituminous and subbituminous coals, lignite coals, and peat. Current proven reserves, totaling 6 gigatons (Gt), are anthracite (67%), subbituminous (26%), peat (5%), and brown coal (2%) (Thanh Son, 2006; Baruya, 2010)).

According to Viet Nam's Second National Communication, energy-related emissions are projected to increase from 113 Mt by 2010, to 251 Mt by 2020 and to 471 Mt by 2030. The energy sector's share of total emissions has risen 35% since 2000 and could rise by 90% in 2030 (MONRE, 2010).

The Sixth Master Plan for Power Sector Development, for 2006–2015 (with a perspective to 2025), envisages power generation capacity to increase from 13,138 MW in 2007 to 85,200 MW in 2025. Viet Nam's total generating capacity is around 13 gigawatts (GW) with annual electricity production in excess of 60 terawatt hour (TWh). Hydropower accounts for 42% of this total, natural gas for 42% and coal for 14% (ASEM, 2009). In the past, the country relied heavily on hydropower; in the future, a combination of nuclear power and coal-fired plants is expected to account for a growing proportion of total electricity production.

Water reservoir capacity is limited in Viet Nam, and current facilities can supply power for up to a week under normal use. Dry seasons lead to limited hydropower availability in succeeding months and create major shortages in the availability of electricity (Baruya, 2010). Hydropower increases are unlikely because most sites are already being exploited, and gas and oil reserves are limited.

There are plans to build 13 nuclear reactors by 2030, with a combined capacity of 15 GW. Coal-based capacity was boosted recently by the announcement in December 2010 that Doosan Heavy Industries is to build two new power

plants, each of 1,200 MW. Electricity demand is forecast to increase at a yearly rate of 9%–10% during 2011–2025. The structure of the power sector is forecast to change as more coal is used, generating 49% of the country's electricity in 2015, 55% in 2020, and stabilizing at 68% by 2025. The resultant domestic coal demand is expected to be (Van Can, 2007):

- 2010: 29–32 Mt/year;
- 2015: 47–50 Mt/ year;
- 2020: 69–72 Mt/ year;
- 2025: 112–115 Mt/ year.

Coal is set to become the most significant source of energy. Coal-based power generation capacity is expected to expand 20-fold to reach 35,600 MW in 2025 or 42 % of total capacity (compared to 13 % in 2007). Imports of coal will become increasingly important. To meet domestic demand for coal, Viet Nam is planning to reduce exports of coal from around 29 million tons in 2006 (mainly to the PRC and Japan) to 12 million tons in 2010 and stop exports from 2015, thus turning one of Asia's main coal exporters of anthracite into a net importer of steam bituminous coal. Demand for coal in the power sector for 2008 was estimated to be 6.5 Mt, with a possible 2.5 Mt rise in 2009. Under the Viet Nam Coal Industry Development Strategy, coal production could reach 48–50 Mt in 2010, 60–65 Mt in 2015, and 70–75 Mt in 2020, and 80 Mt in 2025 (Baruya, 2010).

In 2005, the Transport Development and Strategic Institute carried out a study on inland waterways in northern Viet Nam, part of which encompassed the coal-producing region of Quang Ninh, but concentrated mainly on the demand and economic centers around Ha Noi. According to this study, some 20 Mt of coal was transported by river barge (World Bank, 2008). This makes river transportation a significant provider of infrastructure for the coal mines and power stations, possibly contributing to the movement of a quarter of the country's coal and also a quarter of the

tonnage carried by the waterways (legally) in 2005. Coal-fired stations and cement works may be sited close to such waterways, partly for coal transport, but power stations are often adjacent to rivers for cooling water.

One of the most important outcomes of the study is the projected growth in volumes of coal, and coal-related goods that will make use of inland waterways, recognizing a massive need for investment in improving equipment and services throughout all the main courses, tributaries, and canals in and around the Red River, Duong River, and Da Bach River regions. By 2020, coal movements could rise to a considerable 50 Mt/year, resulting primarily from the demand for coal from power stations within Viet Nam, as well as the potential for exports. Barge capacities are little more than 2,500 deadweight tons, and so shipments are small. With the first coal-fired power station being built on the Mekong River, there will be an increase in the growth of related services on the river.

Table 1 lists the 9 coal-fired power plants, in chronological order, that were in operation in 2008. Uong Bi 7 is separated from the other units as it was built 30 years after the remainder of the site. Uong Bi 5-7 410 megawatt hour electrical (MWe), Pha Lai 1 & 2 1,040 MWe, and Ninh Binh 220 MWe are owned by EVN subsidiaries. This leaves three smaller power stations of 12–126 MWe, totaling 370 MWe that are operated by independent power producers (IPPs). IPPs provide around 18% of the total coal-fired capacity. Na Duong (100 MWe) and Cao Ngan (100 MWe) are still owned by the state via Vinacomin and so are independent of EVN, but not privately owned.

Coal-fired power development in Viet Nam was slow before 2000. It took almost 20 years to build 800 MWe of coal-fired capacity. Some 1.2 GWe were built between 2001 and 2006 with the construction of Pha Lai 2 and Uong Bi under EVN, and a number of plants owned by Vinacomin, Formosa, and Ha Bac Nitrogen Fertilizer.

Table 2: Coal-fired Power Plants in Viet Nam

Plant name	Owner or operator	Mwe	Fuel	Date of commissioning
Uong Bi 5 & 6	Uong Bi Thermal Power Co	110	Anthracite	1965 & 1974
Ninh Binh	Ninh Binh Power Co	220	Anthracite	1974-1976
Pha Lai-1	Pha Lai Thermal Power JSC	440	Anthracite	1983-1987
Bai Bang Mill	Bai Bang Paper Co	28	Anthracite	1982
Pha Lai-2	Pha Lai Thermal Power	600	Anthracite	2001
Na Duong	Vinacomin	100	Lignite	2004
Nhon Trach Formosa	Hung Nghiep Formosa	126	Anthracite	2004
Cao Ngan	Vinacomin	100	Anthracite	2006
Uong Bi 7	Uong Bi Thermal Power Co	300	Anthracite	2006
Ha Bac Plant	Ha Bac Nitrogen Fertilizer	12	Anthracite	

Source: Baruya (2010).

Coal is likely to take over from hydropower as the main energy supply. The latest development on the Mekong Delta is the construction of a \$1.4 billion coal-fired power plant. The 1,200-megawatt plant will be built in the Long Phu District, and supply electricity to 16 million people in the delta. It is scheduled to be completed in 2014. The Government is planning to build 90 coal-fired plants by 2025, investing \$83 billion.

There appears to be little research carried out on the implications of increasing the use of coal versus hydropower on the Mekong River.

2.2 Lao PDR

The total land area of the Lao PDR is 236,800 km²; the country is land locked, surrounded by Cambodia, the PRC, Myanmar, Thailand, and Viet Nam. The Lao PDR has a population of around 6.4 million living in 16 provinces (CIA, 2011a). The main energy source is almost entirely hydropower. The Mekong River flows through 1,835 km of the Lao PDR and it has been estimated that over half the hydropower potential in the lower Mekong Basin is within the Lao PDR. The country has no developed infrastructure or railway network and currently a low energy consumption pattern, with wood making up the major share of total primary energy consumption (Watcharejyothin and Shrestha, 2009).

There is an estimated 810 Mt of proven lignite reserves at Hongsa in the northwest. Around 530 Mt is economically recoverable. There is also an estimated 100 Mt of proven anthracite reserves. Based on the reserves of coal it has been estimated that a 2,000 MW coal-fired power station for lignite could be built and a 500 MW one for anthracite (ADB, 2009b). The Hongsa thermal plant will likely be the only lignite fired power station built unless more reserves of lignite are discovered.

The annual growth of Lao PDR primary energy up to 2030 will be around 21% from coal due to development of the Hongsa thermal plant with an installed capacity of 1,800 MW (ASEAN, 2009). However, the sole purpose of the coal power plant on its completion in 2015 is to export electricity to Thailand. There are several developments underway to use the Lao PDR's energy resources in Thailand.

Hydropower is the main indigenous energy resource, with a technical potential estimated at 18,000 MW. A major government goal is to provide substantial exports after the countries generation needs are met. The Nam Theun

2 hydropower project is intended to enable the Lao PDR to export 995 MW to Thailand and use the remaining 75 MW for domestic use. There is also the thermal Hongsa Project, a joint investment with Banpu, Rathaburi Electricity Generating Holdings, and Holding State Enterprise, for a 1,878 MW lignite-fired thermal plant. The Lao PDR Government also intends to build up to 30 new dams by 2020. In northeastern Thailand, there are currently 5 transmission lines already supplying power from the Lao PDR, with a further 2 lines under construction and 4 more planned.

2.3 Cambodia

Cambodia, with a total land area of 181,035 km², is bordered by Thailand, Viet Nam, and the Lao PDR. Cambodia has a population of around 14.8 million (CIA, 2011b). Cambodia has no national power grid; provincial towns and cities have their own power generation plants using mainly diesel. Only 20% of the population has access to mains electricity. There are government plans to triple Cambodia's energy output from around 800 MW in 2009 to up to 3,000 MW by 2020. This would supply electricity to 70% of the population. The Cambodian Government's power development plan to 2020 includes the construction of 9 hydro dams and 9 coal plants. Once operational, the combined plants will provide an estimated 3,000 MW of energy. The 193 MW Kamchay hydropower dam on the Mekong River is due to be completed in 2013.

In recent years there have been discoveries of coal reserves of around 150 Mt or enough coal to supply a 400 MW coal-fired power for more than 30 years. A Malaysian company is building a 100 MW coal-fired power station due for completion in 2012 and discussions are underway about construction of a further 700 MW using imported coal. This is likely to be needed as the hydropower capacity is only full during the rainy season; in the rest of the year capacity is reduced to one third.

2.4 Thailand

The total land area of Thailand is 513,115 km²; the country is bordered by Cambodia, the Lao PDR, Malaysia, and Myanmar. Thailand has a population of around 65.5 million living in 76 provinces (CIA, 2009). Increasingly, coal could play a major role in the future energy mix of Thailand. The energy sector over the last decade has undergone a period of restructuring and privatization.

Key coal facts

Total coal production (2008 estimate)	:	18–19	Mt
Total coal demand (2008 estimate)	:	32–36	Mt
Imports (2008 estimate)	:	17–18	Mt
Proven reserves (2008 estimate)	:	2,000	Mt

In 2007, the installed generating capacity of Thailand was around 29 GW. The generation capacity of the Electricity Generating Authority of Thailand (EGAT) power plants was 16 GW, or 55 % of the country's total generation capacity. Private power sector facilities as well as sources in nearby countries provided the remainder. This was made up of 10 GW from domestic IPPs, 2 GW from small power producers under firm energy purchase contracts, and 640 MW imported from the Lao PDR and Malaysia (EGAT, 2009).

A major challenge facing energy planners in Thailand is the issue of energy security with its heavy reliance on natural gas for power generation and increasing environmental concerns from the public and environmental nongovernment organizations. In recent years, the Government has begun to explore a strategy of energy security diversification and increasing consultation with the public over energy projects.

In 2007, the Ministry of Energy and EGAT produced the latest power development plan (PDP) to provide a framework for long-term power development (2007–2021). The PDP outlines an objective to increase coal-fired power stations during 2011–2021 from 7,000 to 11,900 MW. The PDP includes nuclear power plants with a total generating capacity of 4,000 MW by 2021 (Kessels, 2010). The rationale behind increasing the use of coal and nuclear power stations is to reduce reliance on natural gas, which currently generates nearly 70% of Thailand's power.

The largest coal power plant in Thailand is the Mae Moh lignite thermal power plant made up of ten 300 megawatt (MW) units and able to produce more than 2,500 MW. In

the 1990s, there were serious problems with SO₂ pollution which led to environmental protests and more stringent air quality standards being introduced. As a result, all the operating units are now equipped with ionizing wet scrubbers for the collection of fly ash. Lime (calcium oxide) desulfurization was also added to remove sulfur oxides from the flue gases. Six of the units supply fly ash to the cement industry with the remainder of fly ash disposed of at a disused mine.

The BLCP power plant, commissioned in 2007, consists of two coal-fired conventional units. The rated output per plant is 717 MW with the total power generation capacity of the two plants up to 1,434 MW. The coal used is from low-sulfur bituminous coals imported from Australia and Indonesia; diesel oil is used as the start-up fuel. The plant is located in the Map Ta Phut Industrial Estate in Rayong Province in southeastern Thailand. The power station is on reclaimed land 3 km from the eastern coastline of Map Ta Phut Port and is surrounded by sea, considering the entry of large coal ships. The project is under a 25-year power purchase agreement between EGAT and BLCP (Kessels, 2010). The demand for coal in Thailand is projected to increase (Table 3).

There are also several other thermal plants, including some circulating fluidized bed (CFB) plants operating since 1998 with an installed capacity of 2x150 MWe and fed with bituminous coal and anthracite. They are compact boilers and include a reheat steam by-pass system. The National Power Supply (NPS) Company operates a power plant in Tha Toom village of Prachinburi Province. It began commercial operation in February 1999. The power plant has two identical units of 150 MWe. The boilers are designed to use coal and biomass with rice husks purchased from local suppliers and eucalyptus bark from a nearby pulp and paper mill. The NPS Power Plant sells 60% of its power output to EGAT. The process steam and the remainder of the power are sold to local customers at an Industrial Park and a pulp and paper mill (Barisic *et al.*, 2008).

Table 3: Thailand Coal Demand and Future Outlook ('000 ton)

Year	2006	2007	2011	2016	2021
Supply: Domestic	18,867	19,746	17,525	16,183	15,722
Import	11,472	15,229	20,643	33,209	39,654
Total Supply	30,339	34,975	38,168	49,392	55, 376
Domestic	19,304	22,821	22,775	28,751	27,805
Demand	7,724	8,508	10,142	13,615	18,233
Power Cement	3,310	3,646	5,251	7,026	9,338
Others					
Total Demand	30,339	34,975	38,168	49,392	55, 376

Source: Suksumek (2007).

3. GMS National Appropriate Mitigation Actions

Figure 1 below makes a distinction (in dashed boxes) between three important groups of countries in the climate negotiations: 1) countries that have not ratified Kyoto; 2) industrialized countries that have ratified Kyoto; 3) developing countries that have ratified Kyoto. In addition to preventing dangerous climate change, these groups have some common and different interests and goals, expressed in the ovals. Although the issues in the ovals are not exhaustive, they represent the major issues at this time. Energy security and air quality appear to be common interests for all countries, whereas GHG targets are currently mostly desired by Kyoto industrialized countries.

Post 2012 climate policy will be driven by several economic, environmental, social and political factors. The horizontal arrow should not be regarded as a timeline, more as the general direction of the process towards a post-2012 climate policy framework.

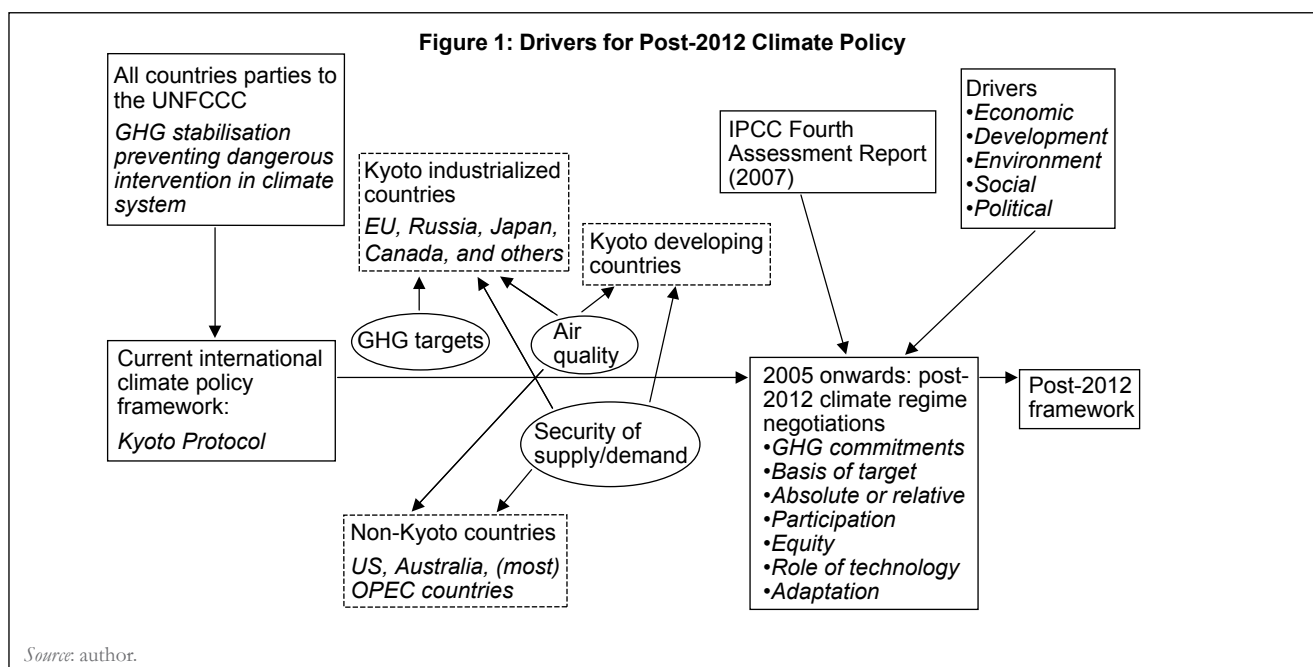
A recent development to mitigate GHG emissions in developing countries is national appropriate mitigation actions (NAMAs). The 2007 Bali Action Plan called for NAMAs by developing country parties in the context of sustainable development, supported and enabled by technology, financing, and capacity building, in a measurable and verifiable manner. There is as yet no

recognized NAMA, but several countries including Brazil, the PRC, India, and South Africa are working on or are considering a NAMA.

Three types of NAMA have been under discussion:

- unilateral or autonomous actions that developing countries implement without support from developed countries;
- conditional actions that developing countries agree to undertake with support from developed countries; and
- actions that could be partially or fully credited for sale in the global carbon market.

An example of a unilateral action is one that a country intends to follow for reasons other than just climate change mitigation, which could have other benefits, such as energy security or reducing poverty. However, actions may cross over into mitigation, such as by increasing energy efficiency. A NAMA with conditional actions is one where a developing country agrees to undertake mitigation action with financial or technology support from developed countries. The mitigation actions could involve those with higher costs or needing specific assistance, such as carbon capture and storage projects. The last category of NAMA is one that generates credits to be sold on the global carbon market. The developing country would need to set a crediting baseline for their actions and credit only the actions implemented in addition to this baseline level of activity.



The design of the NAMA could include supercritical pulverized coal combustion (SPCC) and integrated gasification combined cycle (IGCC) technologies capable of:

- *Power plant efficiency improvements.* Globally, efficiency improvements provide scope for achieving CO₂ emission reductions of 10% through the gradual replacement of existing plants and the increasing use of state-of-the-art technology.
- *Carbon dioxide capture and storage.* CCS technology may prevent up to 90% of coal-based CO₂ emissions from electricity generation, if applied to all coal power plants worldwide.

However, there should be scope in the NAMA to include other CCTs if they can improve efficiency or provide an option for CCS, such as ultra-SPCC or use of biomass.

An option to consider to improve the likelihood of accelerated implementation of CCTs in the GMS could be to include CCTs either in individual countries or if feasible a regional NAMA. A first step is to determine each country's power and industrial sector coal-based CO₂ emissions as a baseline. This would make it possible to calculate emission savings in the future.

The implementation and development of CCTs in the lower GMS within a NAMA will require consideration of several factors. First is the lengthy timescale for deployment of advanced CCTs, up to 4–7 years and considerably longer for CCS, which is not occurring anywhere in the GMS. Second is the range of barriers that CCTs must successfully overcome in the lower GMS to enter into widespread commercial use. Third is the role of the lower GMS countries in creating an enabling policy framework to encourage the construction of CCTs by private companies and research by universities. There are many technical and market issues that CCTs must overcome to enter into widespread commercial use, including performance, cost, consumer acceptance, safety, training, enabling infrastructure, incentive structures for firms (e.g., licensing fees, royalties), regulatory compliance, and environmental impacts (IPCC, 2004).

The IEA and ADB could play a role in providing objective data and assist in the formulation of the rules and monitoring and verification requirements needed for the NAMA. The IEA Clean Coal Centre database could be used for accurate and impartial measurement of average and higher coal plant efficiency by individual countries and regions. Countries participating in this type of NAMA

would have to provide information on current coal use and technologies being used. Consequently, new plants built with higher efficiencies or CCS technology would receive incentives based on the NAMA. This would also create an economic incentive for application of new CCTs within the GMS.

4. Conclusions

Coal will continue to play a key role in providing energy in the long term in the GMS. Policymakers, specialists, and scientists point out that the expansion of coal usage faces a number of sizeable environmental barriers. Simultaneously, it is recognized that the technical potential exists for large-scale emission reduction from coal-fired power plants through the use of CCTs, in particular improved power plant efficiencies and CCS technology. Lacking, however, is a framework or agreement providing the incentives necessary for CCT deployment in the subregion.

The decisions on the use of coal and clean coal technologies in the GMS will have an impact on how the future energy mix will develop. An integrated strategy that takes into consideration the competition with water and food could result in a low carbon pathway. To achieve this will require decisions and policies that recognize the value and use of clean coal technologies in current and future energy developments in the GMS, particularly in Viet Nam and Thailand.

The use of the proposed new NAMA structure as discussed in this paper could stimulate the commercial deployment of clean coal technologies. To date, the Kyoto Protocol has failed to encourage the large-scale use of CCTs. Designing a NAMA oriented toward CCT implementation in the lower GMS could be a way forward to increase the uptake of CCT. As a starting point, countries within the lower GMS could develop a plan with historic, current, and projected emissions from the coal sector, based on IPCC inventory guidelines. This plan should in the first instance apply to all the existing, and future additional, large coal-based GHG emission point sources. Due to the projected growth in coal-based power plants in Viet Nam and in other lower GMS countries it is important to encourage the uptake and deployment of all types of CCT as early as possible.

The core of the NAMA would be an increase in efficiency of coal-based power production over time in all participating countries and support for carbon capture and storage

where suitable. The baseline to measure emission reductions could vary from country to country depending on such factors as best unit in operation in 2010, noting that coal quality, availability of cooling water at specific temperatures, and other factors will all affect efficiencies as well as steam conditions.

Solely relying on the Clean Development Mechanism to encourage CCTs results in a piecemeal approach to the problem of climate change and leads to few projects involving the use of CCTs. Developing a new framework for the stimulation of CCTs through the use of NAMAs could be a step forward for the GMS on the path to energy security and mitigation of climate change.

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BIOFUELS IN THE GREATER MEKONG SUBREGION: ENERGY SUFFICIENCY, FOOD SECURITY, AND ENVIRONMENTAL MANAGEMENT

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Abstract

Global production and trade of biofuels have expanded rapidly in the last decade, spurred on by the adoption of policies and incentives to support their increased use in the European Union and the United States. In the Greater Mekong Subregion (GMS), growing demand for biofuels could help support the agriculture sector and provide an alternative source of energy. However, experience from the subregion and elsewhere has shown that, if deployed unsustainably, biofuel development can be associated with numerous risks, particularly in terms of food security, impacts on soil and water quality, and biodiversity, which in turn have negative ramifications for human development. This paper draws extensively on existing literature and integrates various themes to provide an overview of four main issues related to biofuels deployment in the GMS: the need for alternative energy sources, risks to food security, considerations for environmental management, and opportunities for rural development. The paper finds that with increasing fuel demand projected for the GMS, biofuels could make a significant contribution to offsetting oil demand and to increased agricultural and rural incomes, though the overall benefits to the region's population depends largely on how risks to food security are managed and on the production system that is adopted. Using examples from within the GMS, the paper illustrates that expansion involving surplus land, smallholder-based production, and an emphasis on non-food crops and second-generation biofuels could pave the way for sustainable utilization of biofuels in the GMS.

1. Introduction

Biofuels have been the focus of intense interest, discussion, and debate in recent years. Spurred on by the adoption of policies and incentives to support their increased use in the European Union (EU) and the United States (US), both global production and trade of biofuels have expanded rapidly in the last decade (IEA 2010a). In response, several Asian governments announced ambitious plans to promote biofuels production for both domestic consumption and export (Zhou and Thomson 2009) and, as a result, the total production of biofuels in Asia increased from just over 5 billion liters in 2002 to almost 11 billion liters in 2010 (OECD-FAO 2011).

For decision makers in the Greater Mekong Subregion (GMS)⁵, growing global demand, particularly for first-generation biofuels,⁶ could provide a new market for existing agricultural products, and help support the agriculture sector, which sustains the majority of the region's population. It has been argued that due to the availability of farm land, abundant labor, and favorable weather conditions in the subregion, biofuel expansion could help farmers diversify their activities and earn additional income (Malik et al. 2009). Conversely, experience from the subregion and elsewhere has shown that, if deployed unsustainably, biofuels development can be associated with numerous risks, particularly in terms of food security, impacts on soil and water quality, and biodiversity, which in turn have negative ramifications for human development (USAID 2009).

Much work has been done on the regional impacts of biofuel deployment in Southeast Asia (Elder et al. 2008; USAID 2009; Zhou and Thomson 2009). Much of the work considering the GMS, however, has either focused on an individual aspect of biofuel deployment, such as impacts on trade (Yang et al. 2009) and employment (Malik et al. 2009), or has presented results of case studies from individual countries (ERIA 2009; Shepley et al. 2009). This paper draws extensively on existing literature and integrates various themes to provide an overview of three main issues related to biofuels deployment within the overall

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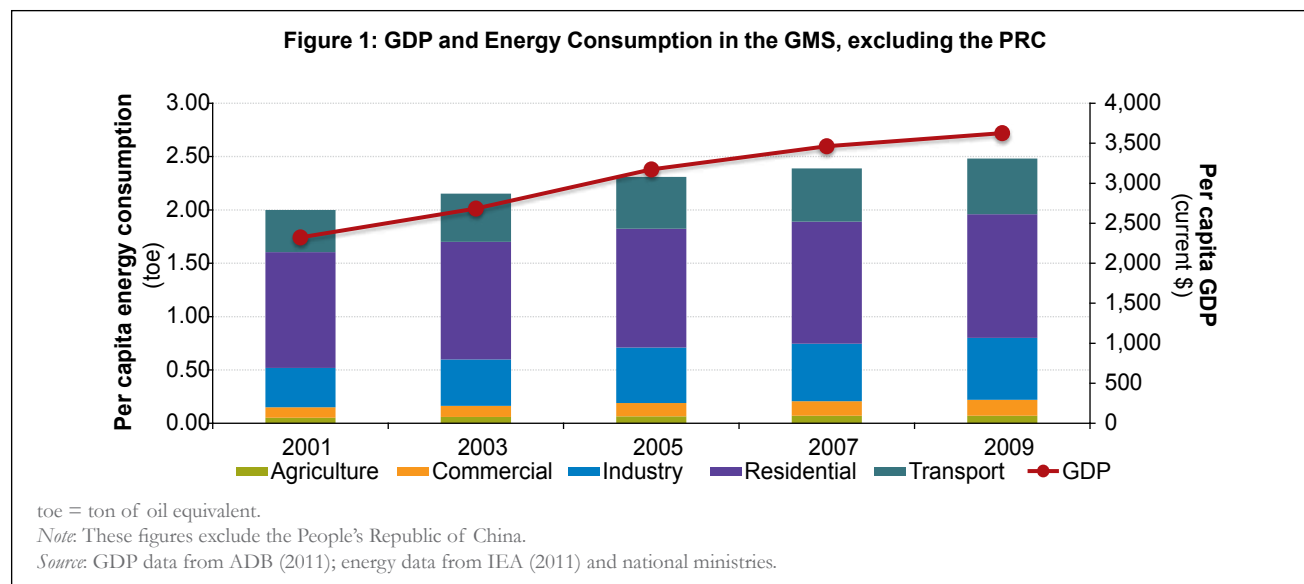
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⁵ The Greater Mekong Subregion (GMS) is a natural economic area bound together by the Mekong River, covering 2.6 million square kilometers and a combined population of around 326 million. The GMS countries are Cambodia, the People's Republic of China (PRC, specifically Yunnan Province and Guangxi Zhuang Autonomous Region), Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, and Viet Nam.

⁶ First-generation biofuels are primarily derived from food crops, such as grain (corn, wheat, etc.), sugarcane for bio-ethanol, and oil seeds (such as palm oil) for biodiesel production.



context of energy demand and environmental trends in the GMS. The initial sections of the paper describe the energy utilization context and biofuels industry in the subregion, and analyze the extent to which biofuels development in the GMS could offset fossil fuel demand under different scenarios. Subsequent sections of the paper discuss three major issues related to biofuels development in the GMS—food security, environmental management, and rural development. Finally, recommendations are made on how policies need to be designed and implemented to ensure that the production and utilization of biofuels in the GMS may be sustainable.

2. Energy Demand, Supply, and Security in the GMS—the Need for Alternatives

GMS countries have seen a rapid growth in their gross domestic product over the last 2 decades. Concomitantly, energy demand has risen as well (Figure 1). Across the region, while electricity demands are met through coal and hydropower, the transport and industry sectors are primarily dependent on diesel and gasoline, and therefore account for the largest share of energy demand from fossil fuels. These sectors are constantly growing—for example, transport energy demand in the GMS (excluding the People's Republic of China [PRC]) increased 50% between 2000 and 2009, from 20 million to 30 million tons oil equivalent (IEA 2011). Throughout GMS countries, the consumption of energy outstrips production, which indicates a heavy dependence on fossil fuel and other energy imports. Larger energy consumers such as Thailand imported over 60% of its domestic energy needs between 2002 and 2006 (Chirapanda et al. 2009), while

Cambodia and the Lao People's Democratic Republic (Lao PDR) imported all their commercial fossil fuels in 2006.

Under a business-as-usual (BAU) scenario over the next decade, energy consumption in the subregion is expected to increase between 7% and 16% per annum, at rates much higher than that of increases in economic growth (ADB 2006). Within the transport sector, gasoline and diesel consumption over the next decade is also expected to increase as illustrated by current trends in vehicle sales and registration. In Myanmar, for example, the number of vehicles registered is increasing at 19% per year, and in Cambodia, the energy demand from transport is expected to grow between four- and fivefold by 2030 (Kyaw et al. 2009; Luyna et al. 2009).

The consumption of petroleum and dependence on imports impact national budgets, trade balances, and household incomes. Most countries have to subsidize fuel costs in order to protect their populations and industries from fluctuating fuel prices. Even so, changes in fuel subsidies and increasing fuel prices do affect consumers and can cause significant civil unrest.⁷ Diversifying sources of energy, and in particular identifying new indigenous sources for the transport and industry sectors, is important if GMS countries want to increase their energy security.

The use of fossil fuels in the subregion is also associated with environmental and health impacts. Over 21% of energy-related greenhouse gas (GHG) emissions in the GMS (excluding the PRC) in 2007 were from the transport

⁷ Recent examples of fuel price hikes and associated civil riots include riots in Indonesia in 2005 in response to government reduction in fuel subsidies, and protests in Myanmar in 2007 in response to a fuel price increase.

sector, which highlights the significant role that transport plays in driving climate change (WRI 2010). These emissions are a direct result of the current modal split in GMS countries that favors road transport systems, and the dependence of road transport on fossil fuels. Other air pollutants associated with fossil fuels, particularly from the road sector, include emissions of particulates, and nitrogen and sulfur oxides, which have significant health impacts, particularly in urban and peri-urban areas. Figure 2 shows particulate emission levels in urban areas in the GMS compared to World Health Organization (WHO) guidelines and illustrates that air pollution in GMS countries is still a concern with serious ramifications for human health.

In summary, there is a significant need for introducing alternative fuels to the GMS, particularly for the transport sector, including bio-ethanol and biodiesel, to offset projected demand using energy produced from local resources, with fewer environmental impacts.⁸

3. Current Development and Potential Production of Biofuels in the GMS

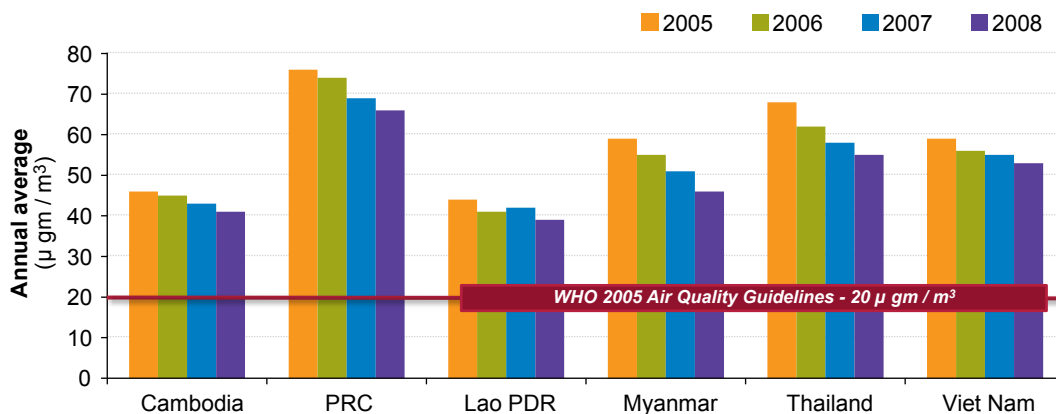
3.1. Current Status

Following the market demand for biofuels, the GMS countries have responded or are responding with strong national biofuel programs to support energy security,

renewable energy, and a new attractive growing market for the agriculture sector (Malik et al. 2009; Yang et al. 2009). National biofuel programs, production capacity, and industry development vary greatly across the GMS countries, with the PRC, Thailand, and Viet Nam taking the lead with established policies, targets, and incentives. Table 1 presents a summary of biofuels policies in the GMS. Policy mechanisms include regulatory instruments like blending targets and mandates to create demand coupled with incentives for the private sector to get involved in biofuel development and, finally, provision of subsidies to reduce the cost of production so that biofuels are favorable when compared with fossil fuels. In all countries, the biofuels industry is still dependent on government incentives due to higher production costs when compared with fossil fuels.

The PRC is the third largest producer of bio-ethanol in the world, producing just over 1.78 million (metric) tons of liquid biofuels in 2008 using mostly maize and wheat (IEA 2011). Biodiesel production is much lower, 0.2 million tons per year based mainly on waste vegetable oil. One of PRC's five main bio-ethanol producing plants is located in Guangxi Zhuang Autonomous Region and had a production of 0.2 million tons in 2007 using only cassava (Malik et al. 2009; Huang, Qiu, et al. 2009). The government targets for the whole country are to produce 5 million tons per year of bio-ethanol by 2012 and 12 million tons per year by 2020. The PRC is also the only GMS country with experience on second-generation biofuels (IEA 2010b).⁹

Figure 2: Particulate Emissions in Urban Areas in the GMS Compared with WHO Guidelines



μgm^3 = microgram per cubic meter

Note: The data are averaged over all areas within a country with populations of over 100,000 inhabitants.

Source: World Bank Environment and Data Statistics (accessed 23.09.11).

⁸ In terms of impact on air pollution, biofuels have been shown to lead to lower volatile organic chemicals (VOCs), sulfur, and carbon monoxide (CO) emissions, but also to potentially increased nitrogen oxide (NOx) emissions and ozone, and in some cases particulates (USAID 2009). Overall, if land clearing and the burning of vegetation are avoided, biofuels would have a smaller impact on air pollution than fossil fuels.

⁹ Second-generation biofuel: biofuels produced from cellulose, hemicellulose, or lignin (IEA 2010b).

Table 1: Summary of Biofuel Policies and Targets in the GMS

Country	Policies / Incentives	Policy Targets (million liter per year)
Cambodia	No policies	N.A.
PRC ^a	E10	Bio-ethanol: 12 by 2020 ^b
	Subsidies for producers	Biodiesel: 6 by 2020 ^b
Lao PDR	E10 by 2015	Insufficient information
	E20 by 2020	
Myanmar	E5 and E15	Insufficient information
	B5 to B20	
Thailand	E10 and E20	Bio-ethanol: 3,285 by 2022 ^c
	B5	Biodiesel: 1,643 by 2022 ^d
	Tax incentives	
Viet Nam	1% of total fuel demand in the transportation sector in 2015 and 5% by 2025	Bio-ethanol: 684 by 2020
	E5	Biodiesel: 128 by 2020

N.A. = not available

Notes:

1. Bio-ethanol and biodiesel density assumed to be 789 tons/million liter and 845 tons/million liter (USAID 2009), respectively.

2. B5 and B20 refer to percentage of biodiesel in diesel fuel.

3. E5 and E10 refer to percentage of bio-ethanol in gasoline.

a These policies cover the whole of PRC.

b million tonnes per year

c Suryadi 2010.

d Department of Alternative Energy Development and Efficiency (DEDE) 2009.

Source: Authors.

The target for biodiesel is to use *Jatropha* and reach 6 million tons per year in 2020 (Malik et al. 2009). Yunnan province is the national *Jatropha* demonstration province for the PRC. The provincial government has proposed 14 biodiesel refining plants with a production capacity of 3.2 million tons of biodiesel per year. Table 2 provides an indication of production and yield of different feedstock in the three major biofuel-producing countries in the GMS,

and shows that sugarcane is a good potential source for bio-ethanol in Yunnan and Guangxi.

Thailand is one of the top eight global biofuel producers and has sufficient feedstock for both biofuel and other uses as illustrated by the country reporting a net surplus of bio-ethanol feedstock production in recent years (Chirapanda et al. 2009). The government has established a biofuels

Table 2: Feedstock Production and Yield in the PRC, Thailand, and Viet Nam

	Yunnan and Guangxi PRC		Thailand		Viet Nam	
	Land used (‘000 ha)	Yield (t/ha)	Land used (‘000 ha)	Yield (t/ha)	Land used (‘000 ha)	Yield (t/ha)
Bio-ethanol						
Cassava	320	19.8	1,148	21.0	492	16.5
Maize	1,698	3.8	1,021	4.0	1,079	3.9
Rice	3,801	7.2	10,541	2.9	7,343	5.0
Sorghum	5	2.2	36	1.8	–	–
Sugar beet	–	–	–	–	–	–
Sugarcane	1,126	69.7	996	60.8	276	58.3
Sweet potato	23	20.0	–	–	170	8.1
Wheat	1,102	6.0	–	–	–	–
Biodiesel						
Castor	–	–	13	0.8	7	0.8
Coconuts	–	–	253	6.5	120	8.7
<i>Jatropha</i>	40	0.0	–	–	30	0.0
Oil palm	–	–	420	16.8	–	–
Rapeseed	226	1.5	–	–	–	–
Soybean	–	–	131	1.7	183	1.4

ha = hectare, t = metric ton

Source: FAO 2011.

program whereby bio-ethanol has been introduced for the transport sector in the form of E10¹⁰ gasoline. In 2010, bio-ethanol consumption was approximately 329 kiloton oil equivalent (ktoe) (approximately 648 million liters) and average production of bio-ethanol was estimated at 1.16 million liters per day. Moreover, the government has mandated the use of B5¹¹ since 2011 and B10 should become available by 2014. The main source for biodiesel has been oil palm while *Jatropha* is being used for small-scale applications. In 2010, biodiesel consumption was approximately 475 ktoe (589 million liters) (Chirapanda et al. 2009; Malik et al. 2009; USAID 2009; Yang et al. 2009; DEDE 2011a, 2011b).

In 2007, the Government of Viet Nam put forward their target for biofuels: 1% of total fuel demand in the transport sector in 2015 and 5% by 2025.¹² The volume of biofuels needed to meet 5% of total petroleum demand by 2020 is estimated to be around 1.6 million tons (540 million tons of bio-ethanol and 1.09 million tons of biodiesel) (Nguyen et al. 2009; Yang et al. 2009). Bio-ethanol is to be sourced from sugarcane, sweet sorghum, and molasses, and biodiesel from catfish oil and *Jatropha*. Bio-ethanol production capacity from sugar factories is estimated at 53 million liters per year and from cassava 320 million liters per year (Nguyen et al. 2009).

In Cambodia and the Lao PDR, food security is a critical issue for decision makers and the current focus has been on pilot biofuel projects using *Jatropha* to raise awareness on process and technology. In Cambodia, policies are particularly directed at rural electrification and there are no particular policies and targets regarding biofuels (Luyna et al. 2009). In the Lao PDR, the government is planning to promote biofuels and has stated that it expects E10 to be commercially available by 2015 and E20 by 2020. In terms of biodiesel, the Lao PDR has already been producing biodiesel from *Jatropha*, coconut, oil palm (low potential), and castor oil plants, although these are currently at a pilot stage (Sanatem et al. 2009).

The Government of Myanmar has tested some programs for biofuel development in parts of the country and plans to replace gasoline with E5 for use at the community level and E15 (using anhydrous bio-ethanol) nationwide

(Khaing 2010). Diesel is to be replaced by B5 to B20 at both community and national levels (Suryadi 2010). Biofuel production and commercialization only started in 2008 and, consequently, production is relatively low compared to other GMS countries. In 2009, the production capacity of anhydrous bio-ethanol was estimated at least 659,000 liters per year. Sugarcane is the main source of bio-ethanol followed by maize, cassava, and sweet sorghum. Biodiesel production is still at the demonstration level and the main source is *Jatropha* (Kyaw et al. 2009; Yang et al. 2009; Khaing 2010). The government initially introduced a 3-year plan for *Jatropha* for 2006–2008, which raised a lot of interest initially due to the increase in diesel prices at the time. However, plantations were seen to conflict with demand for land for food production in poor areas and proved to be unsuccessful in matching national biofuel demand (Cushion et al. 2010; Suryadi 2010).

3.2. Potential for Expanded Biofuels Production in the GMS

An initial analysis of potential production of biofuels in GMS countries is given in Table 3. The analysis estimates the amount of biofuels that could be produced in each country if a) 10% of available land in the countries were converted to biofuel feedstock production,¹³ b) all the crop production that is currently lost on-site postharvest (referred to as “wasted grain or crop”) were converted into bio-ethanol using current technologies,¹⁴ and c) crop residues were recovered and converted to bio-ethanol using emerging technologies.¹⁵

¹³ This analysis assumes a production of a certain mix of crops and land intensity per crop on available land in each country. These figures are based on national data and current crop production trends. Land intensity (liter/ha) is taken from USAID (2009) and available land (for crop production) from Malik et al. (2009). The following assumptions have been used. Split of crop types: Cambodia (cassava – 20%, *Jatropha* – 20%, oil palm – 20%, sugarcane – 20%, maize – 20%); PRC (cassava – 25%, *Jatropha* – 25%, sugarcane – 25%, sweet sorghum – 25%); Lao PDR (cassava – 25%, coconut – 25%, *Jatropha* – 25%, sugarcane – 25%); Myanmar (cassava – 8.5%, *Jatropha* – 33%, sugarcane – 25%, maize – 8.5%, sweet sorghum – 25%); Thailand (cassava – 33%, oil palm – 33%, sugarcane – 33%); and Viet Nam (cassava – 33%, *Jatropha* – 33%, sugarcane – 33%).

¹⁴ This analysis is based on USAID (2009) and assumes that between 1% and 7% of various crops are wasted due to inefficiencies in collection, processing, and transportation. The estimates of total ethanol volumes that could be produced in each country from wasted crop were developed using data on harvested area, crop production, and yields for various food crops and cereals obtained from FAO’s database and from national ministries in each country.

¹⁵ This analysis is based on crop residue estimates for different crop types and locations from Lal (2005) and Gadde, Menke, and Wassmann (2007). Crop residues are defined as the non-edible plant parts that are left in the field after harvest and can include both above-ground and below-ground biomass.

¹⁰ E10: terminology used to indicate the percentage of ethanol in gasoline. In this case, 10% ethanol mixed with 90% gasoline.

¹¹ B5: diesel blended with 5% of biodiesel.

¹² Target stated under Decision 177/QĐ-TTĐ on “Strategy for Developing Biofuel for the Period 2005–2015 and Vision to 2025.”

Table 3: Summary of Potential Biofuel Production in the GMS

Country	Possible Production of Biofuels from Conversion of 10% Available Land (million liter)		Possible Production of Biofuels from Wasted Crop (million liter)		Lignocellulosic (million liter)	
	Biodiesel	Bio-ethanol	Biodiesel	Bio-ethanol	Biodiesel	Bio-ethanol
Cambodia	182	257		138		845
PRC, Yunnan and Guangxi	219	1,298		873		20,472
Lao PDR	87	145		70		504
Myanmar	238	962		626		4,901
Thailand	130	176		773		14,609
Viet Nam	26	142		857		7,803

Source: Authors.

The analysis in the first case serves to show that due to apparent land availability in the GMS, countries like Myanmar, and Yunnan Province and Guangxi Zhuang Autonomous Region in the PRC have the potential to produce large volumes of biofuels (over 900 million and 1.2 billion liters, respectively), without impinging on current cropland. However, this is based on the assumption that land availability figures used accurately reflect the situation in the countries, which is not always the case as competition for land resources in the GMS is often a serious concern. The second case shows that feedstock of first-generation biofuels in the form of wasted grain/crop, if recovered, could also be converted into considerable amounts of bio-ethanol—ranging from 70 million liters in the Lao PDR to 873 million liters in Yunnan and Guangxi in the PRC annually—depending on the agricultural activity in each country. In the third scenario, potential bio-ethanol production from crop residues is shown to be an order of magnitude higher than the other two scenarios, ranging from 500 million liters in the Lao PDR to 20 billion liters in the PRC. However, these numbers are purely hypothetical as the technologies to produce these biofuels are still under development and are not commercially viable as yet.

Additionally, a proportion of biomass residues is currently used to revitalize the soil or as a local fuel source, and an abundance of residues (as is assumed here) may not be available.

The aim of the analysis is to understand the extent of the difference biofuels could make to the overall energy mix of the GMS countries, particularly to diesel and gasoline demand from the transport sector, based on current land and crop production trends. Table 4 compares the potential production of biofuels from the first two cases, i.e. conversion of 10% of available land and wasted grains in the GMS, to current and projected gasoline and diesel demand in 2020. It shows biofuels could offset some of the transport energy demand, though there is considerable variation across GMS countries. In Thailand and Viet Nam, when compared to current demand, bio-ethanol could offset demand up to 13% and 20%, respectively, though these numbers are somewhat more conservative when compared to demand in 2020 (3% and 10%, respectively). Biodiesel using feedstock grown on currently available land is seen to have much less potential in these two countries, partially due to the significant demand for diesel

Table 4: Potential Biofuel Production in the GMS Compared with Demand

Country	Transport Demand (million liter)				Share of Transport Demand Met through Biofuels (%)			
	Gasoline		Diesel		Bio-ethanol ^a		Biodiesel ^b	
	2009	2020	2009	2020	2009	2020	2009	2020
Cambodia	903	1,729	2,235	4,396	44	23	8	4
PRC, Yunnan and Guangxi	2,978	5,404	4,970	8,518	73	40	4	3
Lao PDR	208	540	323	839	104	40	27	10
Myanmar	590	1,656	702	856	269	96	34	28
Thailand	7,417	27,692	1,8480	64,049	13	3	1	0
Viet Nam	5,095	10,132	8,533	14,667	20	10	0	0

Note: For all GMS countries except Cambodia, linear regression analysis was used to forecast the future demand of gasoline and diesel consumption based on the current consumption trends. For Cambodia, International Energy Agency (IEA) projections (IEA 2010a) for Association of Southeast Asian Nations (ASEAN) countries were used.

a This includes bio-ethanol produced from converting 10% of available land and from wasted grain/crops.

b This includes biodiesel produced from converting 10% of available land.

Source: Authors.

in the future. In the rest of the GMS, biofuels seems to have more potential to offset fossil fuels—bio-ethanol could make up over 40% of gasoline demand in 2010 (Cambodia) and between 20% and 40% of demand in 2020 (in Cambodia, Lao PDR, and Yunnan and Guangxi). Based on this analysis, biofuel potential could overshoot transport demand in Myanmar, though this is largely due to the availability of land in the country and comparatively low demand for transport fuels.

The assessment given here is based purely on crop production and land availability data for the GMS countries and considers production of feedstock in isolation. It does not take into account the social ramifications of feedstock production, or the economic feasibility of any of the scenarios. In reality, the feasibility of biofuel production is very much dependent on both these aspects. As a result, the figures shown are an overestimate and provide an upper boundary for production potential. Overall, the analysis serves to show that biofuels (based on current land and crop trends in the GMS) have the potential to offset fossil fuel demand, particularly in countries such as Cambodia and the Lao PDR, and provide an opportunity for GMS countries to diversify the sources of their fuels. Other similar analyses for Asian countries have demonstrated that biofuels will not be able to offset all the demand for transport fuels (Elder et al. 2009; USAID 2009), and the estimates developed in this paper echo those as well. In order to meet future demand, the expanded use of biofuels will need to be complemented with energy efficiency improvements, such as improvements in vehicle fuel efficiency and use of electric and/or hybrid vehicles.

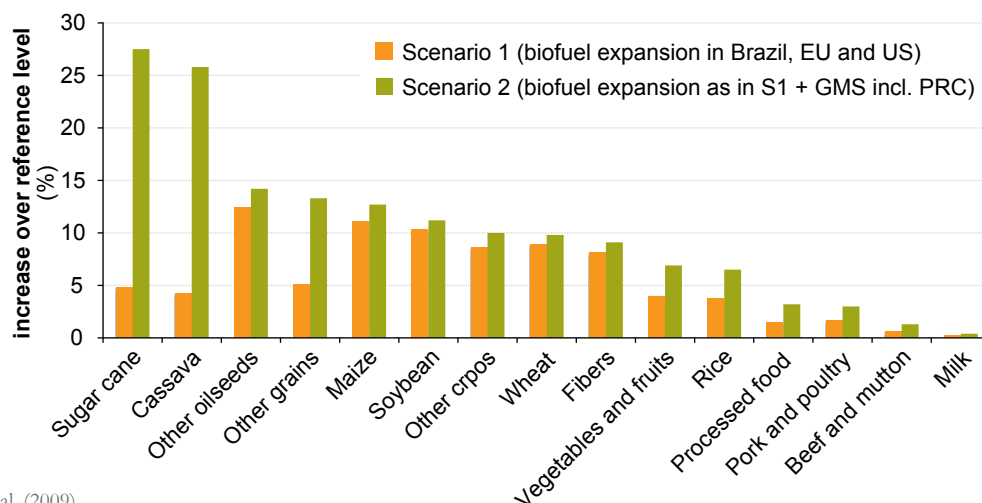
4. Overview of Sustainability Issues Related to Biofuel Deployment

The main drivers for increasing biofuels in the GMS and other Asian economies are the desire to increase energy security, address environmental issues and climate change, and provide income opportunities for the rural population and agriculture sector (Zhou and Thomson 2009). Alternatively, biofuels have also been known to entail significant social and environmental risks by increasing food insecurity, negatively impacting biodiversity, and requiring significant subsidies (USAID 2009). A review of the main issues related to the sustainability of biofuels is presented in the following section.

4.1. Biofuels and Risks to Food Security

Soaring food prices in early 2011 brought into sharp focus the need for countries to increase the security and sustainability of their food supply (FAO 2011). Rising food prices, particularly for commodities like sugarcane and corn, have been attributed to biofuel expansion. However, in the GMS there is still some debate on the extent to which biofuels could impact food prices. Huang, Yang, et al. (2009) used a general equilibrium model to assess the impact of increasing global bio-ethanol and biodiesel production on agricultural production, trade, and prices in the GMS and found that although biofuel expansion would significantly increase the prices of agricultural products (Figure 3), this could be beneficial to countries that were increasing their feedstock production. For example, due to increasing prices of biofuel feedstock, the study argues that countries that increase production and exports to the rest of the world would raise the national self-sufficiency of these commodities—a benefit for the agriculture sector. In reality, this is only one side of the equation, because a dramatic increase in biofuel production would have an impact on the structure of agricultural production and trade, potentially at the expense of other crops. Additionally, apart from direct impacts on food prices, increasing biofuel exports could also have an indirect impact by increasing the prices of feedstock for other food commodities. For example, the PRC is currently increasing its bio-ethanol production from cassava and as a result is sourcing this feedstock from neighboring countries like Cambodia, the Lao PDR, and Thailand (Rosenthal 2011). Though not a main component of food commodities in the GMS, cassava has been used for animal feeds, and increasing demand for biofuels in the PRC could lead to an increase in the price of meat or dairy products in other GMS countries.

Additionally, even with current policy responses to this issue in place, an expansion of biofuels would have impacts in terms of competition for resources. As described in Section 3, in response to food security concerns, some GMS countries (e.g., Cambodia and the Lao PDR) are promoting those biofuels that do not directly conflict with food crops, i.e., biofuels based on energy crops like *Jatropha*. The advantages of such crops are that they could be grown on marginal land or wasteland, and, in the case of *Jatropha*, may not require as much water as other feedstock. However, in reality, the yields from *Jatropha* on marginal land have been far less than forecasts predicted 5 years ago, and in order to produce enough biofuel to displace a significant proportion of fossil fuel demand, energy crops will likely need to be cultivated on cropland and would pose

Figure 3: Increase in Prices of Agricultural Commodities in 2020 against a Reference Level

Source: Huang et al. (2009).

a risk as they compete with other agricultural products for land, water, and agrichemicals. Although land availability is not a serious concern in the GMS at the moment, the subregion's population is expected to increase to 340 million by 2050¹⁶ and Johnston et al. (2010) estimate that demand for food, and therefore land, could increase 25% by 2050.

Increasing yields of biofuel feedstock to increase production is another approach to ensure additional volume of feedstock for biofuel use without requiring expansion of cultivation areas. Yields between GMS countries vary, and as shown in Table 5, Cambodia, Lao PDR, and Myanmar could potentially improve their production yields by learning and adopting more advanced farming practices and use of

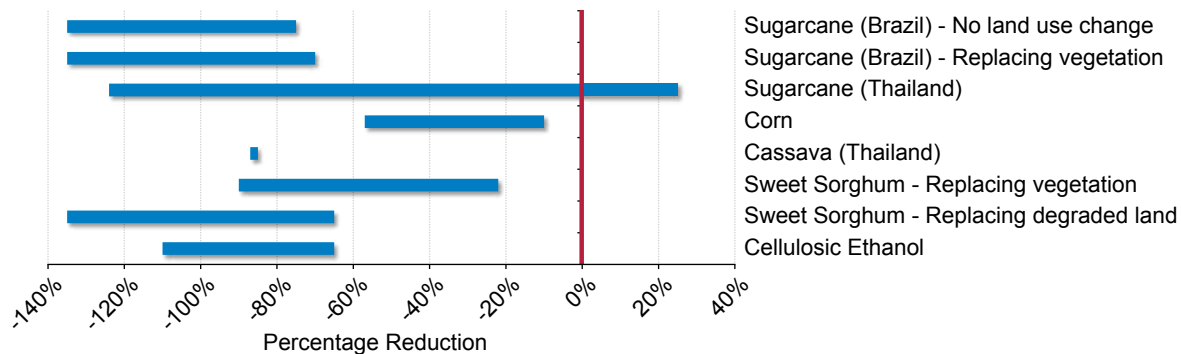
Table 5: Total Production of Selected Energy Feedstock Crops, by Yield and Area Harvested in the GMS, 2005–2009

	Production (ton)	Area harvested ('000 ha)	Yield (ton/hectare)
Sugarcane			
Cambodia	245,253	10.21	24.02
PRC, Yunnan and Guangxi	78,487,123	1,125.60	69.73
Lao PDR	322,640	9.15	35.28
Myanmar	8,492,329	157.90	53.78
Thailand	60,595,791	996.10	60.83
Viet Nam	16,083,007	275.80	58.31
Cassava			
Cambodia	2,370,320	114.25	20.75
PRC, Yunnan and Guangxi	6,320,000	320.00	19.75
Lao PDR	171,180	12.01	14.26
Myanmar	275,880	20.87	13.22
Thailand	24,142,055	1,148.20	21.03
Viet Nam	8,112,616	492.10	16.48
Palm Oil			
Cambodia	—	—	—
PRC, Yunnan and Guangxi	—	—	—
Lao PDR	—	—	—
Myanmar	—	—	—
Thailand	7,078,293	420.40	16.84
Viet Nam	—	—	—

Source: FAO statistics 2011, data presented are averages of values for 2005–2009.

¹⁶ This figure excludes Guangxi Zhuang Autonomous Region.

Figure 4: Range of Greenhouse Gas Reduction from Biofuels When Compared with Fossil Fuels – Bio-ethanol Systems



better plant varieties from Thailand, PRC, and Viet Nam. However, it must be noted that increasing the intensity of agricultural production comes with its own impacts, including those on biodiversity (Section 4.2).

It is also important to note that irrespective of biofuels programs, food security is an issue that is increasingly coming to the forefront in the GMS due to a number of external factors. Increasing incidence of extreme weather events and the looming threat of climate change are expected to affect agricultural productivity and the supply of food. Underdeveloped domestic storage and processing systems, deficient distribution, and infrastructure constraints mean that food deficits still occur in countries like Cambodia, the Lao PDR, and Viet Nam, even when the country as a whole records a food surplus (GMS Phnom Penh Plan 2008). In Myanmar, over 60% of townships were classified as being vulnerable with respect to food security in 2003 (Kyaw et al. 2009). Food wastage is another key issue to be considered. Gustavsson et al. (2011) estimates that 125 kilograms of food per person are lost every year in Southeast Asian countries, most of which occurs at upstream stages in the food supply chain (i.e., post-harvest, processing, distribution and storage, etc.).

In summary, biofuels expansion in the GMS will likely impact crop and food prices, both directly and indirectly, and the current biofuels policy framework in countries needs to be strengthened and improved based on regional experiences to take account of this. Additionally, other risks to food security need to also be assessed, and integrated policies that take into account storage and distribution, waste, and climate change and natural disasters need to be defined to reduce the vulnerability of poorer communities.

4.2. Biofuels and Reduction in Greenhouse Gases

With the increasing awareness of the risks and impacts of climate change, one main advantage of applying biofuels over fossil fuels is that they can (theoretically) significantly reduce GHG emissions. Life-cycle analyses (LCA)¹⁷ conducted for multiple biofuel feedstock and fuels show a considerable variation in results when compared with fossil fuels, with some studies showing significant positive results and others showing negative results (Elder et al. 2008). One fact that is clear across the literature is that GHG balances produced from LCA studies vary significantly by country and region. USAID (2009) compared GHG balances from bio-ethanol and biodiesel production systems in Asia against a baseline fossil fuel production system, taking into account a range of production conditions for biofuels.¹⁸ Figure 4 presents the percentage reduction in GHG emissions for bio-ethanol systems based on their study.

As demonstrated by USAID (2009), the benefits from greenhouse gas reductions are significant for most different feedstock for bio-ethanol systems, though the production conditions used clearly impact the magnitude of emission reductions. Particularly, plantation on existing crop land or degraded land produces the greatest savings

¹⁷ Life-cycle analysis is a holistic inventory of the environmental impacts of a given product along its production chain (extraction and processing of raw materials, transport, end use, and disposal) including all resource inputs and discharges to the environment.

¹⁸ Best-case production conditions assumed low fertilizer and pesticide inputs, plantation on degraded lands, optimal process efficiency, utilization of co-products, and the treatment of wastes. Worst-case production conditions assumed high fertilizer and pesticide inputs, replacement of native vegetation (primarily forests and grasslands), poor process efficiency, poor co-product utilization, and no treatment of wastes (USAID 2009).

in emissions. Also, although savings can be achieved from all feedstock, some are more favorable than others. For example, in Asia, sugarcane and cassava produce higher savings than corn for bio-ethanol systems (Elder et al. 2008). For biodiesel systems, the analysis shows that where palm is planted on areas of peat, shrub, or existing forest, there are no GHG reductions, and in fact the GHG balances for all feedstock become unfavorable against fossil fuel systems under such conditions (USAID 2009).¹⁹

Another factor to be considered in relation to GHG emission savings is carbon debt and payback periods. These are affected by the previous use of the land for biofuel development. USAID (2009) shows the carbon payback period when planting on cropland to be around 1 year, whereas when planting on secondary tropical forest, the carbon payback period could range from 10 to 1,000 years, depending on the forest type and location. The analysis demonstrates that there is no justification in terms of GHG savings for planting biofuels on forestland.

4.3. Biofuel Impact on Biodiversity

Within the GMS, biodiversity is a key concern that must be taken into account when developing biofuels policies. The subregion is a biodiversity hotspot and home to a number of globally significant populations of threatened species and new species. Between 1997 and 2008, 1,231 new species were discovered across the GMS, with 308 new species identified in 2008–2009 alone (WWF, 2011). Concurrently, forest loss in the subregion has been a serious threat to biodiversity with over 8 million hectares of forest being lost in the last 2 decades (FAO 2010). The primary drivers of forest and biodiversity loss in the subregion are demand for natural resources, particularly expansion of agricultural land. The concern is that biofuel development could exacerbate these trends as has been the case in neighboring countries. In Indonesia and Malaysia, for example, it has been estimated that slightly more than half the oil palm expansion has occurred at the expense of forest area (USAID 2009). Additionally, development of large-scale monoculture plantations for biofuels may have an additional impact in that they could reduce biodiversity within the existing agriculture systems in the GMS.

4.4. Biofuels and Poverty Reduction: Small- vs. Large-Scale Deployment

One main driver for the expansion of biofuels in the GMS is the opportunity to provide access to global markets for agricultural products and increase livelihood opportunities for rural farmers. This opportunity, however, is affected by a number of factors, not least of which is the scale at which biofuels are deployed.

Economies of scale within biofuel production systems may mean that these systems are more suited to large-scale operations. Bio-ethanol production from modern processing plants, for example, has been seen to require a steady input of a large amount of feedstock in order to produce fuels at competitive prices (USAID 2009). However, a biofuel industry dominated by large-scale producers in the GMS may not positively impact rural development and poverty reduction. Larger-scale operations are likely to focus on achieving low costs of production, not on generating rural employment, and may increase income disparity and vulnerability of rural farmers. This is particularly relevant in the GMS, where the agricultural industry has been at the heart of conflicts between large-scale private developers and rural farmers. Economic land concessions in Cambodia, for example, where private companies have been given access to land for agricultural and other development, have faced issues due to a lack of transparency and uncertainties related to consultation with rural users of the land (UN-OHCHR 2007). Attributed to “poor enforcement” of existing legislation, these issues have affected the engagement of development partners in Cambodia. The granting of these concessions highlights the risks to rural development and local livelihoods from developing large-scale agricultural systems.

Many reports on biofuels in GMS countries stress the importance of investing in “pro-poor” or smallholder-based biofuel systems in order to achieve maximum benefits for rural development (Nivitchanyong et al. 2008; Malik et al. 2009; Shepley et al. 2009). By integrating smallholders in the supply chain of biofuels, additional income for farmers could make a significant difference to their socioeconomic situation. For example, Markandya and Setboonsarng (2008) compared *Jatropha* development projects involving both concessionaires and smallholders in Cambodia and the Lao PDR and found that the latter had the potential to lift four times as many farmers out of poverty as the former. A series of case studies of biofuel development at the community scale in the lower Mekong countries also revealed that

¹⁹ Removal of forest and disturbance of peatlands result in reduced carbon sequestration and a net flux of CO₂ from soil reservoirs to the atmosphere. In these situations, the GHG savings attributed to reducing fossil fuel use are negated by these additional emission sources.

smallholders benefited significantly from community-based biofuel initiatives, particularly in cases where biofuel systems were locally oriented and a proportion of fuel generated was locally used (Shepley et al. 2009).

Even with the potential benefits for smallholder-based biofuels, some significant challenges remain. Small-scale biofuels initiatives require significant support and established market systems in order to succeed. A study of small-scale *Jatropha* development in Yunnan showed that as there are currently no alternative uses for the plant, farmers engaged in these activities are vulnerable to uncertainties in the currently immature *Jatropha* market, and that remote villages face reduced revenues from planting *Jatropha* due to high transportation costs (Sano, Romero, and Elder 2011). In Myanmar, *Jatropha* expansion by the government has focused on smallholders. However, due to the lack of refineries and processing infrastructure and limited technical support and awareness raising of farmers, benefits from the program have been restricted (ECDF, 2008; Cushion et al. 2010).

Current established agri-business models in the GMS which may hinder the development of efficient and profitable smallholder biofuel production pose another challenge. The concession model, as in Cambodia and the Lao PDR, utilizes farmers only as daily wage labor and may not achieve rural development outcomes in the long run (Malik et al. 2009). However, a case study of biofuels initiatives in Tay Ninh province in Viet Nam revealed that biofuel processing enterprises that relied solely on the supply of feedstock from unorganized smallholder farms experienced constraints with raw materials, optimal capacity utilization of their machinery, and difficulty in meeting their profit margins (Shepley et al. 2009).

One community-based business model that has had initial positive results for both rural development and efficiency in the agriculture sector is the cooperative or association model. In Thailand, for example, the government has supported the organization of villagers into community enterprises to enable them to buy and manage their own small-scale biofuel extraction facilities. This has allowed farmers to collect and extract fuel from their crop and sell the finished product blended with diesel as biodiesel (Chirapanda et al. 2009). In this way, smaller communities retain the returns from value-added processing. However, the development of such projects was resource-intensive as skilled management staff were seen to be necessary to run the cooperatives and the plant, and a regular supply of feedstock was required to achieve a base level of efficiency.

The final issue that tends to arise out of small-scale biofuel development is the availability of land. In order to counteract issues of food security, some GMS governments are promoting the use of marginal land, i.e., plantations of *Jatropha* along roads and as hedges between farm properties. In practice, these policies have had mixed results. In Yunnan, the government's prohibition of land clearing and the use of farmland were seen to be followed by villages reviewed in one study (Sano, Romero, and Elder 2011), while in the Lao PDR, in a contract farming system involving smallholders in the production of *Jatropha*, farmers encroached on forest areas to develop plantations rather than adhere to marginal lands. This was attributed to poor enforcement of the principle by the enterprise hiring the farmers (Shepley et al. 2009).

5. Discussion: How Can Biofuels Be Sustainably Deployed in the GMS?

The current energy situation in the GMS is not sustainable. The extensive use of fossil fuels, dependence on oil imports and increasing per capita demand mean that if the GMS is to continue on its current path of economic development and progress, significant changes are necessary within the energy supply and demand dynamics. Some improvement from energy efficiency measures can be expected in terms of reducing energy demand, but alternative sources of supply also need to be identified and developed. In this context, biofuels present an opportunity that GMS countries should take into account.

Currently the production of biofuels varies within the GMS, with the PRC and Thailand, and to a smaller extent, Viet Nam, having well developed biofuels systems in place, and Myanmar, the Lao PDR, and Cambodia currently pilot-testing biofuels production. Based on the assumptions and scenarios in this paper, if biofuels were to be deployed they would be able to meet 3%–40% of the demand for gasoline from the transport sector in 2020, and under 10% of the demand for diesel in 2020 (excluding Myanmar). These figures show that although locally sourced biofuels will probably never be able to fulfill all the demand for transport fuels in GMS countries, they will be able to replace a significant fraction of gasoline and could help countries diversify their current, fossil-fuel heavy, energy mix. Additionally, in countries like the Lao PDR and Cambodia (in which biofuels are seen to have greater potential to replace fossil fuels), as long as countries prioritize the use of biofuels to meet internal demand over export, economic sectors would be less vulnerable to fluctuations in oil prices.

However, biofuel development is associated with significant negative impacts; and if the deployment of this source of energy is not planned and implemented with careful consideration of these impacts, current negative trends in countries will have a real chance of being exacerbated rather than improved. Particularly the issues of deforestation and climate change, food security, and rural development are key concerns for GMS countries at the moment, and, as has been demonstrated by a number of local case studies, biofuels have the potential to both negatively and positively impact these issues. Some recommendations relating to these issues emerging from this review paper are below.

Food Security: Even with the wealth of literature focusing on this issue, the links between biofuels and global food prices (and therefore food security) are not clear. Within the GMS, the situation is even more ambiguous and the balance between an opportunity to gain additional revenues for the agriculture sector and potential risks to food prices must be weighed carefully. The current situation of food security in GMS countries is hampered with issues of distribution and storage of food, as well as underlying prevailing conditions of poverty, and GMS countries will need to put in place integrated policies that target the supply of food and risks related to biofuels, climate change, waste, and distribution. In terms of safeguards related to biofuels, some countries are already taking measures to promote energy crops over food crops for biofuels and utilizing marginal rather than core agricultural land, but better enforcement of these regulations will be needed in the future. Additionally, promotion of second-generation biofuels which rely on non-food crops as feedstock could help reduce some direct pressure on food crop production in the near future (though the indirect impact of these would remain), and more investment in developing so-called third-generation biofuel technologies could reduce this further over the long run.

Deforestation and Climate Change: Current trends of deforestation and forest degradation in GMS countries are significantly impacting biodiversity, threatening local communities that are dependent on forest resources, and are a significant source of GHG emissions.²⁰ For biofuels to have a positive impact in terms of climate change, biofuels policies must include some consideration of current prevailing trends of deforestation and should

include measures to discourage biofuels development on forestland. While GMS countries are making efforts to focus biofuel expansion on underutilized and marginal land, the enforcement of regulations protecting forest areas in these countries is weak, and these areas remain vulnerable to both smallholder and large-scale biofuel development. The development of standards for biofuels and certification systems that take into account land-use change and chain of custody may help in checking the replacement of forests with agricultural land for biofuels. Additionally, increasing production yields and efficient collection of waste crops could substantially increase the volume of biofuel feedstock without expanding cultivation into forestlands.

Rural Development Benefits: The opportunities for rural development from smallholder-based biofuel production in the GMS are clearly significant, but the realization of benefits is dependent on the mode of deployment. There are many lessons to be learned from pilot-testing different models in GMS countries, and it is important that future development builds on them and that GMS countries learn from each other's examples. Irrespective of the model chosen, when promoting biofuels from smallholders, GMS countries will need to invest in developing the supply chain for biofuels, and proper research and development should be carried out prior to introduction of new crops for mass propagation, especially in rural areas with subsistence farming. Countries will also need to invest in developing the necessary skills and capacities needed for smallholders to produce and extract biofuels themselves, which would allow them to capture the largest share of the benefits from the production of such fuels. Capacity development would need to be focused at different levels—institutional capacity to develop and support schemes and local capacity to implement successful enterprises.

5.1 Further Issues to Consider

Though this paper considers the potential to produce biofuels from current resources in the GMS, the analysis given here does not comment on whether GMS countries should allocate these resources to biofuel production. A social cost–benefit analysis which quantifies the trade-off between benefits to the agriculture sector, negative impacts on health and well-being due to changes in food prices and environmental impacts of biofuel production would be able to complement the analysis provided here and may provide more insight into this crucial issue.

²⁰ Land-use change and forestry was responsible for 26% of all GHG emissions in the GMS (excluding the PRC) in 2005 (WRI 2010).

6. Conclusion

This review demonstrates that biofuels could make a significant contribution to the primary energy demand (especially in the transport sector) in several GMS countries, leading to increased agricultural and rural incomes and prospects for regional energy trade, while ameliorating several of the prevailing negative environmental conditions. The extent to which this potential can be realized will depend on the type of production system that is pursued. Expansion in the form of industrial-scale plantations would quickly lead to several of the linked social–environmental–political problems that have been observed elsewhere in Asia and outside Asia, namely food versus fuel conflicts, land grab, destruction of forests, and detrimental impacts on soil and water quality. Expansion involving surplus land, smallholder-based production, and an emphasis on non-food crops and second-generation biofuels could pave the way for sustainable utilization of biofuels in the GMS. However, this latter approach will require significant policy interventions, and dedicated support to the farm sector, much of which is missing currently, and will need to be put in place.

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GLOBAL ENVIRONMENT AND NATIONAL INFORMATION EVALUATION SYSTEM (GENIES) FOR URBAN IMPACT ANALYSIS

Jitendra (Jitu) Shah¹, Peter Ulrich², Yinpeng Li², Wei Ye² and Robert Carr²

Abstract

The urban areas of Asia are growing and will, in all likelihood, continue to grow at a rapid rate. This process could result in unprecedented risks to urbanized populations from climate change impacts, such as sea level rise, storm surge, extreme rainfall and temperature events, and cascading secondary effects.

A toolkit concept to support policy-making and planning based on a Global Environment and National Information Evaluation System (GENIES) has been developed that focuses on the core issues of adaptation, mitigation, risk, and economics of climate change and how they interrelate with aspects of water, energy, the built environment, transport, waste, and ecosystems. While recognizing the plethora of methodological perspectives that pertain to each sector, a system dynamics method is proposed, which lends itself to integrated assessment, given its flexibility and ease of extension and revision as new policy and planning questions emerge. The framework design starts with a clear definition of a problem and then draws together the appropriate models and data, to enable relationships to be defined and processed in a scientifically robust manner to evaluate adaptation and mitigation options.

The tool will be macro in its scale of engagement and represent a “first cut” method for conducting an indicative assessment of risks and potential costs and benefits of different adaptation options that could be applied to the risks posed by climate change. The tool development would have the highest chance for success if it were developed in a staged manner with an initial focus on one or two high priority issues in one or, at most, two cities. The political will of the pilot cities to engage in the process and carry it through to completion would be critical to the initial success of the project.

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1. Introduction

The challenges facing Asia from urbanization are unprecedented—some 1.1 billion people could migrate from the countryside to the region’s cities in the next 20 years. In addition, urban areas are becoming riskier owing to the threat of climate change, characterized by reduced agricultural productivity; urban, rural, and international migration; coastal inundation; and increasing vulnerability and damage from extreme climate events. Urban areas concentrate populations, economic activities, and infrastructure. These can be seen not only as vulnerabilities but also as opportunities to synergize resources for creating innovative risk management strategies. There is, however, a particularly urgent need to recognize such opportunities, develop them, and extend them to the wider urban community. Delays in incorporating climate change into urban development planning will reduce the efficient functioning of urban areas as centers of economic activity and aggravate the negative consequences of climate change.

There are barriers to making and implementing climate change policy in our rapidly growing urban centers. These include the lack of knowledge and uncertainties of climate change impacts and risks, and the absence of tools to guide decision making that integrate climate change considerations into overall urban development planning. This paper lays out the case for an urban policy-making support system to address the planning challenges related to the interplay of climate change, disaster risk management, and urbanization. By integrating various assessment models into a toolkit, a city can be in a better position to identify priority actions and, based on this information, implement policies to guide specific urban actions to improve resilience.

Currently, many models and tools are available related to climate change impact assessment, including risk and vulnerability assessment, and adaptation and mitigation tools. However, these models and tools mainly focus on (i) frameworks, lacking in-depth assessment models; (ii) a single sector, thus lacking integration; and (iii) sector processes, lacking a clear climate risk assessment component. None bring together local climate change projections, multisector impact analysis, and urban systems models to provide a set of integrated tools for urban decision makers to use in comparing adaptation and mitigation options in the context of local development

plans in an open framework³ that applies local, regional and global data. However, existing models do provide a basis for the development of an open framework system as a more comprehensive policy-making support toolkit that can provide an integrated and systematic assessment environment.

2. Objectives

The objective of the toolkit is to become an integrated climate change impact assessment tool for urban policy makers, which will allow them to assess the costs and benefits of mitigation and adaptation measures in light of the local development opportunities and constraints pertinent to the city, including for example, pollution problems and expected climate variability. The Asian Development Bank (ADB) proposes to develop this tool in partnership with international agencies and institutions with expertise in evaluating the environmental and socio economic impacts of climate change such as infrastructure, water security, and human health impacts due to air pollution and climate change, among others.

The deployment of the tool should speed up problem solving with pre-loaded data, models, rapid analysis functionalities, and a user-friendly interface; facilitate interpersonal communication and learning by allowing all groups to work with the same data, platform, and models; reveal new approaches to the formulation of problems and generate new evidence for decisions; and encourage exploration and discovery on the part of the decision maker. The features of the system include:

- modular design to build on and link to existing models and related applications;
- integrated analysis, enabling testing of adaptation and mitigation options against socioeconomic drivers, likely sectoral impacts, and existing goals for sustainable development;
- open framework, allowing multiscale, multidisciplinary impact assessment, which can be customized on a case-by-case basis to suit each city;
- climate change uncertainty analysis, building on General Circulation Model (hereafter GCM) and Regional Climate Model (hereafter RCM) climate change scenarios;

- geographic information system (hereafter GIS) integration, which is not heavily reliant on third-party software;
- visualization and further analysis options for the assessment of results; and
- Integration of risk analysis and cost-benefit analysis tools.

The tool is intended to answer questions like:

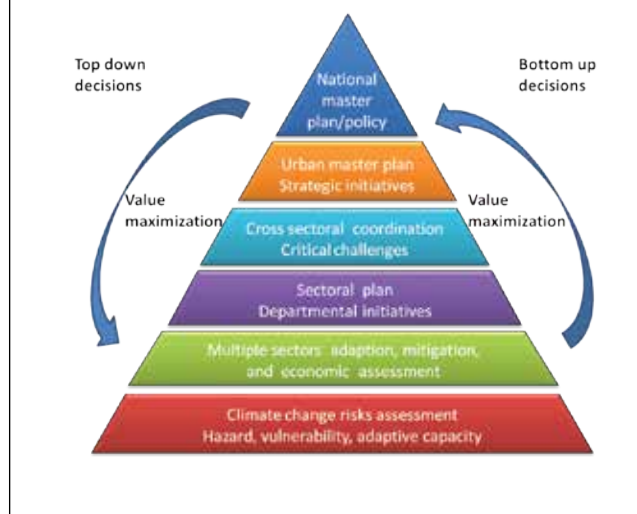
- How to characterize the impacts of climate change?
- Which sectors are likely to be most affected?
- What actions could reduce the intensity of these impacts?
- How could cities evaluate the future costs of such impacts?
- Are other cities experiencing similar impacts and how are they responding?
- What are the expected benefits and co-benefits of an action plan?
- How can this information support adaptation funding and its prioritization?

3. How Can the Tool Help in the Policy-Making Process?

With the raised awareness of climate change challenges, top-down and bottom-up synergetic approaches are eventually adopted by countries (Pulhin 2010, 2011). Based on understanding the key vulnerability caused by climate change at different scales and correlation with other natural and socioeconomic contexts, climate policy can be made from the national to local, urban level. Through a synergetic process—including single and cross-sector assessment—financing, in alignment with the national and local development strategies, can meet the critical challenges (Lawler, *et al.* 2011).

Climate change issues can be addressed appropriately and be mainstreamed into the policy making and planning process for maximizing the values of human well-being (Figure 1). The notion of good governance is related to effective public institutions. At the local level, this involves the development of partnerships between top-down government initiatives and bottom-up local institutions and policies (Urich, Quirog and Granert, 2009). Empowering local citizens and community organizations in the decision-making processes not only increases efficiency but also provides a real possibility for individuals or groups to transform their choices into desired actions and outcomes

³ Open framework is used here to describe a system that permits the end user to either select from a suite of models or add new models and to import local data to run the models in a system that evolves into a customised version of the toolkit for the particular urban environment.

Figure 1: Top-Down and Bottom-Up Multi-Level Climate Change Policy-Making Support and Value Maximization

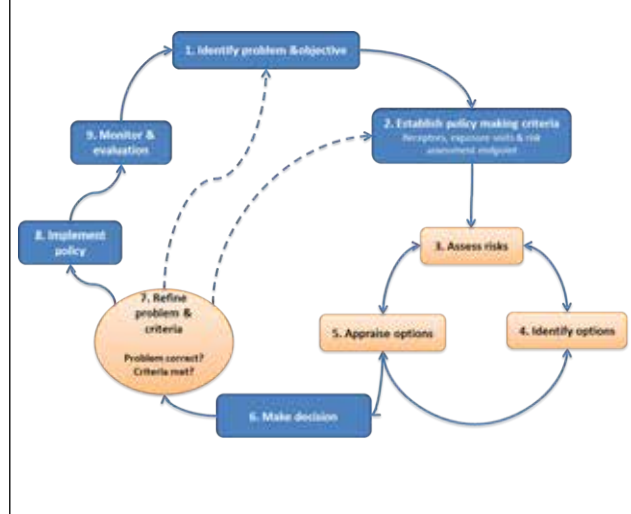
(Pulhin, 2011). The ultimate goal for adopting a synergetic approach is to strengthen the livelihood strategies of both national and urban communities.

Regarding the nature of climate change, for decision making on climate change adaptation actions, a risk, uncertainty, and decision-making framework (RUD) (Figure 2) can be deployed to explain how such a tool forms a decision support system (DSS). RUD enables decision makers to recognize and evaluate the risks posed by a changing climate, making the best use of available information about climate change, its impacts, and appropriate adaptive responses.

The process is circular, emphasizing the importance of the adaptive approach to managing climate change problems and implementing response measures. Decisions should be revisited in the light of new information on climate change and its impacts; for instance, when new climate scenarios are published.

Feedback and iteration are encouraged, so that the problem, objectives, and decision-making criteria can be refined (stages 1 and 2), and further options identified and refined to better reduce and manage climate change risks (stages 3, 4, and 5). Iteration is important to achieving robust decisions.

Certain stages (3, 4, and 5) are tiered. This allows the decision maker to identify, screen, prioritize, and evaluate climate and non-climate risks and options before deciding whether more detailed risk assessments and options appraisals are required.

Figure 2: Risk, uncertainty and decision-making framework (Modified from Willows and Connell, 2003)

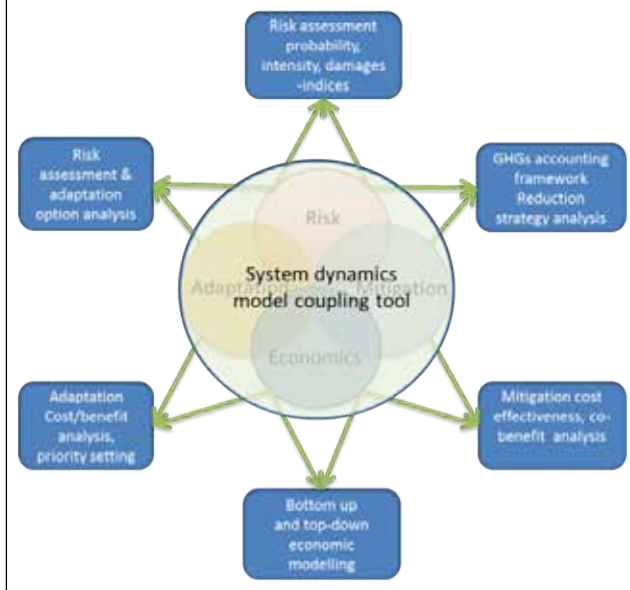
4. What Methodologies can Help Simplify Complicated Systems?

Climate change can affect every sector of an urban system with varied extent and intensity. A decrease in precipitation but increase in extremes can have a series of impacts on water, transport, energy, health, buildings, and other sectors. And by the urban system's nature, all sectors are closely correlated and working as a human life-supporting system. Therefore, for policy and decision making regarding climate change, the sectors also need to be seen systemically. However, to a large extent, climate change is still viewed as an add-on component to the routine of traditional policy making with its management of uncertainty, challenge, and opportunities.

Different from other sectoral DSSs or models, a Global Environment and National Information Evaluation system (hereafter GENIES) is framed by climate change issues, including risk, adaptation, mitigation, and related economic analysis, with a clear expression of urban planning and policy making; all sectors link to climate change issues, although each sector has a potentially long list of risks and opportunities.

During the last few decades, many modeling methodologies and tools have been developed for each climate change topic (i.e., risk, adaptation, mitigation, and economics). Many combined modeling methodologies also have been explored for the relationship among topics. The main quantitative modeling methodologies can be summarized as follows (Figure 3 and Table 1).

Figure 3: Structure of the Modeling Methodology



Other than quantitative modeling approaches, guidance or instructive tools have also been developed by various agencies, including ADB, Clean Development Mechanism, Inter-American Development Bank, international and national nongovernment organizations, the United Nations system, and World Bank.

5. Model Integration Tool

Given the large number of existing but independent models and tools, GENIES would act as a harvesting system that can integrate the existing and emerging technologies to make them work together as a system to

provide better climate change policy-making support. A system dynamics approach and object-oriented system modeling (OSM) can serve this purpose effectively (Box 1), although GENIES would not be a typical system dynamics software.

There is a need for a new framework of model development that can integrate existing and future natural resource models into a common, collaborative, and flexible system. Such a system will maintain modularity, reusability, and interoperability or compatibility of both science and auxiliary components. The system will also recognize the fact that different categories of applications may require different levels of scientific detail and comprehensiveness, driven by problem objectives, scale of application, and data constraints. These functionalities of the system will be obtained by establishing standard libraries of interoperable science and auxiliary components or modules that provide the building blocks for a number of similar applications. Module libraries have been successfully used in several domains, such as the manufacturing, transport, and other systems. The development of an individual model will follow the standard of OpenMI (<http://www.openmi.org/>).

To summarize, an approach for GENIES is needed that will

- reduce duplication of development effort and improve the quality and currency of model codes;
- make natural resource models much easier to build, access, understand, and use;
- facilitate long-term maintainability of existing and new natural resource models;
- lead to greater consistency of modeling for particular problems and scales;

Table 1: Summary of Quantitative Modeling Methodologies

Topic	Methodologies
Risk Assessment	Vulnerability and risk indicators and profiles; past and present climate risks; probability analysis; livelihood analysis; agent-based methods; narrative methods; risk perception, including critical thresholds; relationship of adaptive capacity to sustainable development.
Risk and Adaptation	Cross-sectoral interactions; integration of climate with other drivers; linking models across types and scales; combining assessment approaches/methods; adaptation option analysis; cost-benefit analysis, cost effectiveness, priority setting, and ranking.
Mitigation	Top-down models are most useful for studying broad macroeconomic and fiscal policies for mitigation, such as carbon or other environmental taxes. Bottom-up models comprise three basic types: optimization, simulation, and accounting frameworks. There are various hybrid models that combine elements of these three approaches.
Economics	Top-down and bottom-up economic modeling; integrated assessment models simulate the process of human-induced climate change, from emissions of greenhouse gases to the socioeconomic impacts of climate change; cost simulations across the widest range of possible impacts, taking into account the risks of the more damaging impacts suggested by new scientific evidence; analyzing changes to economies and societies that are large, uncertain, unevenly distributed, and that occur over a very long period of time.

Box 1: System Dynamics Approach

System dynamics is a computer-aided approach for policy analysis and design that applies to problems arising in complex social, managerial, economic, or ecological systems. The approach is appropriate for any dynamic system characterized by interdependence, mutual interaction, information feedback, and circular causality. It emphasizes wholes rather than parts, and stresses the role of interconnections, including the role each person plays in the systems at work in our lives. It emphasizes circular feedback (for example, A leads to B, which leads to C, which leads back to A) rather than linear cause and effect (A leads to B, which leads to C, which leads to D, etc.). It contains special terminology that describes system behavior, such as reinforcing process (a feedback flow that generates exponential growth or collapse) and balancing process (a feedback flow that controls change and helps a system maintain stability).

Source: http://www.systemdynamics.org/what_is_system_dynamics.html

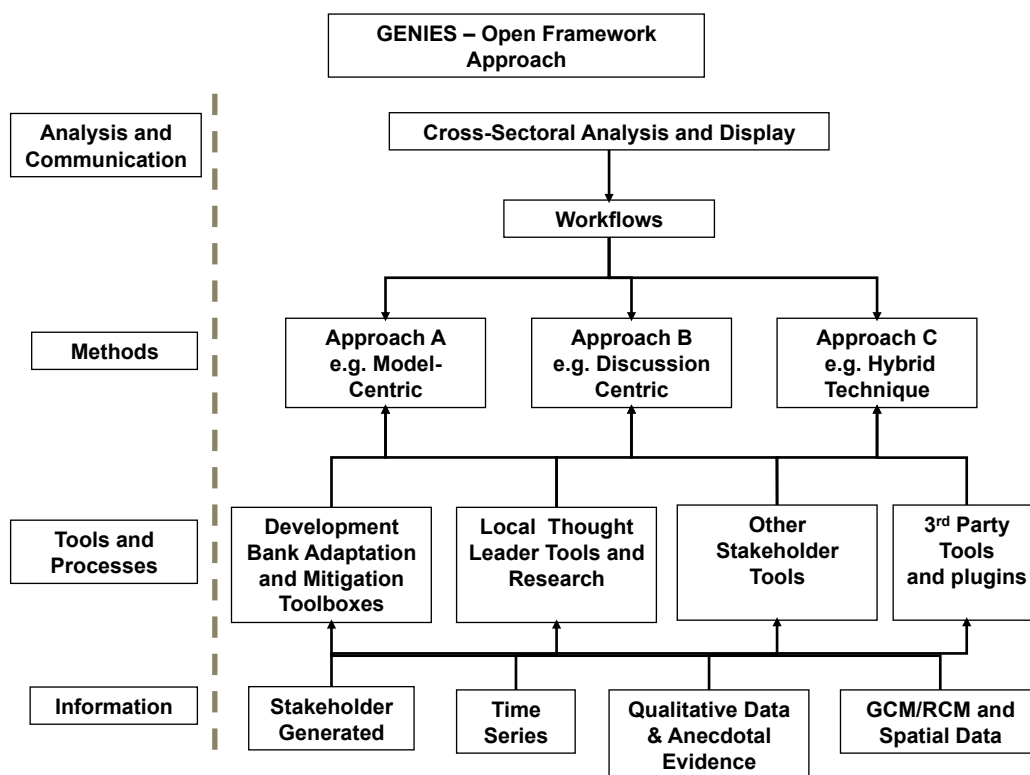
- improve response and delivery times in scientific modeling projects; and,
- ensure credibility and security of model implementations.

Climate change planning can, and should, augment and be integrated with existing planning and development activities across all sectors. All the features of a system dynamics approach can make climate change issues clearer in urban planning and can help us see how to

change them effectively with the aim of overcoming the complexities of decision making.

A unique advantage of applying system dynamics models is the ease of extension and revision as additional questions arise. The system could allow users to add models, input and output of the model, use a visual coupling tool for data conversion, and define, run, and monitor workflows. Figure 4 illustrates the inclusive open framework of GENIES.

Figure 4: GENIES Open Framework Approach



The inclusive framework of GENIES information and model/tools has (i) a layer of different methods or approaches to problem solving—probably tailored to each individual sector (water, transport, health, etc.); hence, they do not need to be generic, and can be different for each outcome; (ii) a layer of tools, in which again each tool is sector and process specific. Where we do not have a tool, one can be built; and (iii) a layer of information.

6. How Will the Toolkit be Developed?

The toolkit needs to focus only on climate change related issues, through a case study approach to define the audience and learning by doing (i.e., not in a one-off project; continuous support from commercial operations is needed). Many attempts to develop integrated climate change impact assessment tools stopped at the blueprint or pilot stage because of the loss of focus and continuous support. The development methodologies and operational approach for this project need to be clearly defined to ensure its completion.

The foundational pieces of this toolkit are the existing integrated climate change impact assessment software SimCLIM (Figure 5) (Warrick, 2009a; Warrick and Urich, 2011). The integration of data, graphic user interface, impact models, and open framework makes SimCLIM a co-evolutionary decision support system that can be upgraded and improved through the interaction between

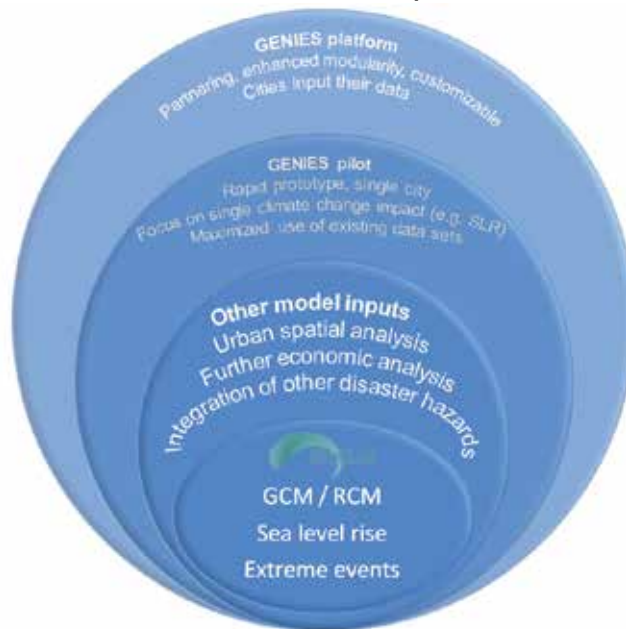
end users and toolkit developers (Li., *et al.* 2009; Li, Ye and Yan, 2011). The main features of SimCLIM are that it allows for multi-scale, multi-disciplinary impact assessment; climate change scenario uncertainty analysis; and, with a built-in GIS tool, visualization and further analysis of the assessment results. A series of models, tools, and datasets have been integrated into SimCLIM (Masike and Urich, 2008; Masike and Urich, 2009; Warrick, 2009b).

7. Agile Development Methodologies

Given the complexity of the toolkit, it needs to be a test-driven development process. We need to release workable software regularly using a staged approach with prompt stakeholder/end-user/developer communication, quickly adapted to new demands/changes, and the process repeated until the strategic goal is fulfilled (Box 2). The stages are as follows.

Stage 1: Develop a broad framework and core models as the foundational piece in the primary stage. SimCLIM and its impact model library already provide a unique platform for the development of GENIES. The methodologies and functionalities that are important but not existing or inadequate can be prioritized for the first stage development. Some of the development needs have already been identified, such as the enhancement of economic analysis, including cost-benefit, co-benefit,

Figure 5: The SimCLIM Core and Relationship with Toolkit Development



cost effectiveness analysis, and development of integration tools using the system dynamics approach. An international technical support group needs to collaborate closely with the policy-making group. Scientists, modelers, and software developers need to work seamlessly with their counterparts in urban policy-making groups. This stage also needs to be relatively short in order to provide workable software for the user to evaluate and to attract funding.

Stage 2: Build up more new models through a co-evolutionary process, projects, and end user demand. Provide inclusive linking methods for other models

following the OpenMI standard. The software needs to be developed continuously and maintained efficiently; therefore, funding for such a toolkit needs to be well sourced, including projects from international financing institutions, and international and national agencies. GENIES has to be a collaborative development initiative of interested stakeholders. Stakeholder engagement needs to be stressed from the beginning. Table 2 provides an example of a stakeholder engagement approach.

Stage 3: The further development and application of the toolkit extends to a broader scope to fulfill the strategic goal of this initiative.

Table 2: Stakeholder Engagement Approaches to GENIES Development

Stakeholder Identification and Analysis	Invest time in identifying and prioritizing stakeholders and assessing their interests and concerns.
Information Disclosure	Communicate information to stakeholders early in the decision-making process in ways that are meaningful and accessible, and continue this communication throughout the project life.
Stakeholder Consultation	Plan each consultation process, consult inclusively, document the process, and communicate with stakeholders.
Management Functions	Build and maintain sufficient capacity within the provider to manage the process of stakeholder engagement, track commitment, and report on progress.
Reporting to Stakeholders	Report back to stakeholders on environmental, social, and economic performance, both to those consulted and those with more general interest.
Discussion and Partnership	For controversial and complex issues, enter into open discussions that satisfy the interests of all parties by forming a strategic partnership.
Concerns Management	Establish accessible and responsive means for stakeholders to raise concerns and demand changes about the project throughout its life.
Stakeholder Involvement in Project Monitoring	Involve directly affected stakeholders in monitoring project impact, mitigation, and benefits, and involve external monitors where they can enhance transparency and credibility.

Box 2: Agile Software Development

Agile development is a different way of managing software development projects. Ten key principles of agile software development illustrate how it fundamentally differs from a more traditional waterfall approach to software development, and are:

1. Active user involvement is imperative.
2. The team must be empowered to make decisions.
3. Requirements evolve but the time scale is fixed.
4. Requirements are captured at a high level; lightweight and visual.
5. Develop small, incremental releases and iterate.
6. Focus on frequent delivery of products.
7. Complete each feature before moving on to the next.
8. Apply the 80/20 rule.
9. Testing is integrated throughout the project lifecycle— test early and often.
10. A collaborative and cooperative approach between all stakeholders is essential.

Source: <http://www.allaboutagile.com/10-key-principles-of-agile-software-development/>

8. Conclusion

A framework for GENIES uses a system dynamics-like approach. It acts as a combined harvesting system that can integrate existing and emerging technologies to make them work together as a system to provide climate change policy-making and planning support. The integrated toolkit will provide an opportunity to maximize the co-benefits of mitigation actions and location-specific adaptation policies at the local level, keeping in mind interactions between sectors. Given the complexity of the toolkit, it needs to be a test-driven development process. We need to release workable software regularly using a staged approach with prompt stakeholder/end user/developer communication, agilely adapted to the new demands and changes in need and climate science. This process needs to be repeated until the strategic goal is fulfilled.

An investment will need to be made to develop the tool to attain its maximum utility, building on existing resources and initiatives, to enable enhanced applications for urban impact analysis. This investment will need to be extended to improve data collection and build local capacities for analysis and planning.

The tool will be macro in its scale of engagement and represent a “first cut” method for conducting an indicative assessment of risks and potential costs and benefits of different adaptation options that could be applied to the risks posed by climate change. The tool development would have the highest chance for success if it were developed in a staged manner with an initial focus on one or two high priority issues in one or, at most, two cities. The political will of the pilot cities to engage in the process and carry it through to completion would be critical to the initial success of the project.

A more global perspective for development and deployment of the software toolkit could be explored with the World Bank, Inter-American Development Bank and African Development Bank. Further sharing of perspectives and tools and integration with programs currently being run by other international financial institutions would be desirable to avoid duplication in such an important area of tool development.

The first steps involve discussing needs of urban policy makers, mapping existing tools, and resources, undertaking a high-level functional design, developing the integrated tool, identifying pilot cities for initial application, and supporting the ongoing development and use of the system by a growing number of interested cities.

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INTERNALIZING THE EXTERNALITIES – STRATEGIC ENVIRONMENTAL ASSESSMENT OF POWER DEVELOPMENT PLANS IN VIET NAM: IMPLICATIONS FOR THE GMS

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Abstract

This paper reviews the experience of developing a strategic environmental assessment (SEA) as an integral part of the preparation of the seventh power development plan for Viet Nam. The implications of the use of SEA in strategic planning of the power sector are discussed in the context of regional power demand trends and in relation to efforts to strengthen strategic planning efforts within the power sector across the Greater Mekong Subregion. The focus of the SEA was on the identification, assessment, and valuation of all principle social and environmental costs and benefits that would be likely to accrue from different power generation alternatives, including thermal power (especially coal-fired generation), hydropower, nuclear power, and renewable energy. The analysis in the SEA provides a basis for the internalization of these factors that have traditionally been treated as externalities. The results of the SEA emphasize the need to strengthen existing efforts to improve energy efficiency and encourage renewable energy if there is to be any significant progress made in mitigating the likely future negative impacts of the increased use of coal in the power generation sector.

1. Introduction

The development of enough power generation capacity to meet demand while minimizing the potentially negative impacts of the power sector on people and the environment is one of the key sustainable development challenges facing the Greater Mekong Subregion (GMS). The ability to meet the rapidly-growing demand for electricity has been fundamental to the subregion's growth and development, but planners face difficult choices in deciding which are

the right power generation sources. Thermal power generation, especially coal but also oil and gas, dominates the generation mix, but hydropower is also significant while the potential of nuclear power is being explored and the potential of different types of renewable energy (especially wind and solar) is significant. Demand management and system improvement are also important, with the power sector in all Mekong countries having great potential for improved efficiency so that real future demand can be met with a slower rate of expansion of power generation capacity.

Each of these generation sources has different costs and benefits in economic, social, and environmental terms. Balancing these different costs and benefits is the key challenge that power sector planners face. All countries in the subregion have a power sector planning system in place. In both Viet Nam and Thailand, this takes the form of power development plans, with new plans produced every 10 years and the plans having a 20 year planning horizon. These planning systems are in general effective in “traditional” terms, being based on projection of future demand scenarios and the identification of the least-cost mixes of generation sources to meet these demand projections. The basis for the identification of generation sources and the calculation of the costs have in the past been primarily based on technical and direct financial costs; however, it is recognized that indirect costs, especially those associated with social and environmental impacts, have not been adequately integrated into the power sector strategic planning systems in the GMS.

Steps are being taken to improve this situation, including the introduction of strategic environmental assessment (SEA) as an integral part of the strategic planning system for the power sector. SEA is increasingly becoming mandatory for strategic planning in the region; the People's Republic of China, Thailand, and Viet Nam have legal requirements for its conduct and the Lao People's Democratic Republic (Lao PDR) is working toward the promulgation of a SEA decree. Experiences of and capacities for undertaking SEAs are limited, however, and international development partners, such as the Asian Development Bank (ADB) are providing active support to the development of such capabilities. This paper presents the outcomes of one such effort, the SEA undertaken as part of the seventh power development plan (PDP VII) in Viet Nam. PDP VII has recently been approved by the Government, with a comprehensive SEA fully integrated into the PDP VII planning process for the first time. The outcomes of the SEA have led to important new thinking for the power sector in Viet Nam, including the

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reconsideration of the best balance of power source mixes, the viability of individual schemes, and, perhaps in the long term most significantly, how to improve energy efficiency and expand the use of renewable energy sources in power generation.

2. Context: The Power Sector in the Mekong Region

By 2025, electricity demand for the GMS is expected to reach 237,000 megawatts (MW), a threefold increase compared to the 77,000 MW used in 2010 (Figure 1). Demand for electricity is predicted to grow in all countries in the GMS in this period, presently a formidable and shared development challenge if overall economic growth and sustainable development goals are to be realized.

Meeting this demand will require substantial financial investments and could potentially cause large social and environmental costs unless effective actions are taken to reduce economical, social and environmental risks to the investments. All power generation options present some risks: the challenge for strategic planning in the sector is to balance the full range of economic, social, and environmental costs in the choices made. The GMS countries are making substantial investments in power development. Figure 2 shows the projected evolution of demand and supply options in the GMS (except Myanmar; Myanmar data only include export oriented projects). These data show that thermal power is the dominant element in regional supply mixes, followed by hydropower. This will

be especially true in the future as demand continues to grow but potential expansion of hydropower is increasingly limited by the lack of viable sites.

The relatively advanced economies in the region are expected to harness all their indigenous supply options and will be increasingly importing power from neighboring countries (Figure 3) and fuel supplies from further afield. The evolution of regional power trade is currently being facilitated by the GMS Regional Power Trade Coordination Committee, the importance of which can be expected to grow in coming decades. A regional power trade agreement has been signed and is expected to increase investments in regional power trade facilitation.

3. The SEA in PDP VII: Approach and Structure

The PDP is the national strategic development plan for power production and utilization in Viet Nam. The PDP VII provides a long-term strategic framework to guide the development of the power sector during 2011–2030. It analyses likely future electricity demand scenarios by sector and takes into account likely future economic and social development trends. It also assesses the most effective, least-cost (taking into account full economic costs) methods for meeting the likely future demand. The SEA's focus was on optimizing the potential contribution of power generation to national development through a strategic planning approach that balanced economic development, social equity, and environmental sustainability. The central

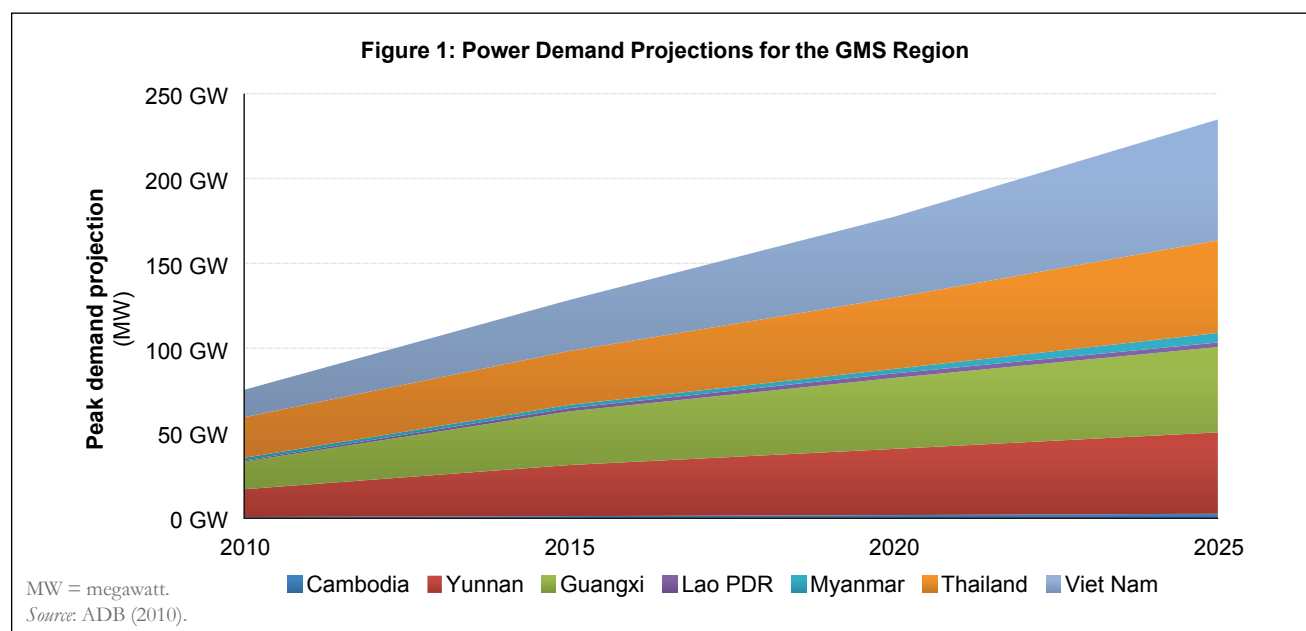
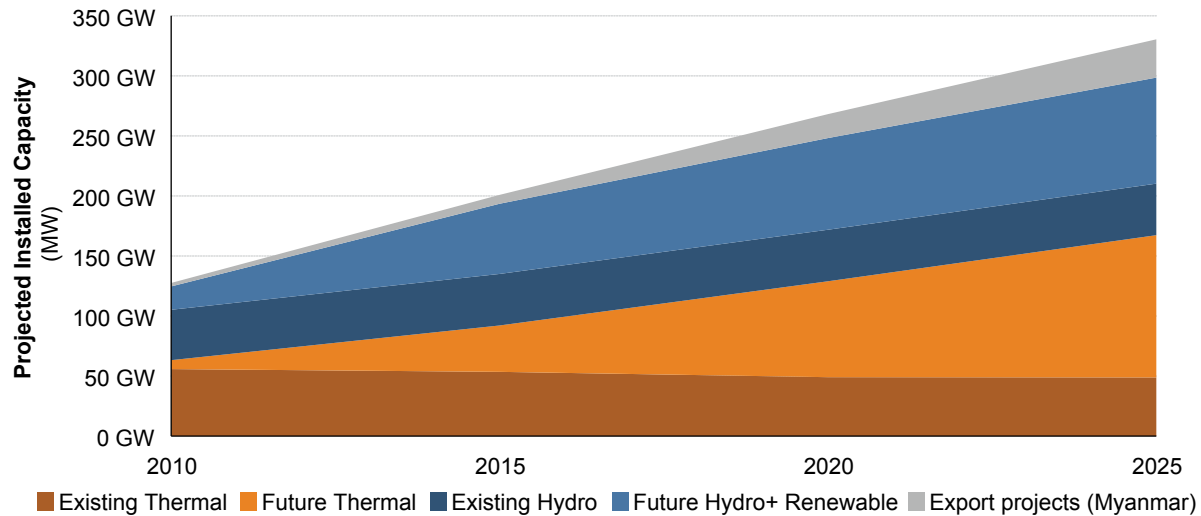
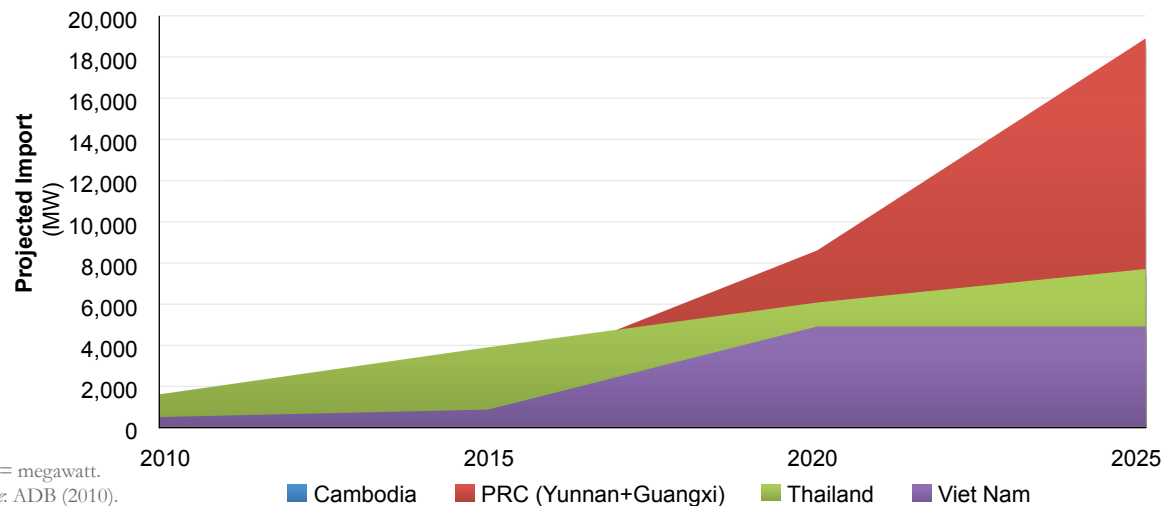


Figure 2: Power Supply Options for the GMS



MW = megawatt.
Source: ADB (2010).

Figure 3: Projected Regional Power Imports



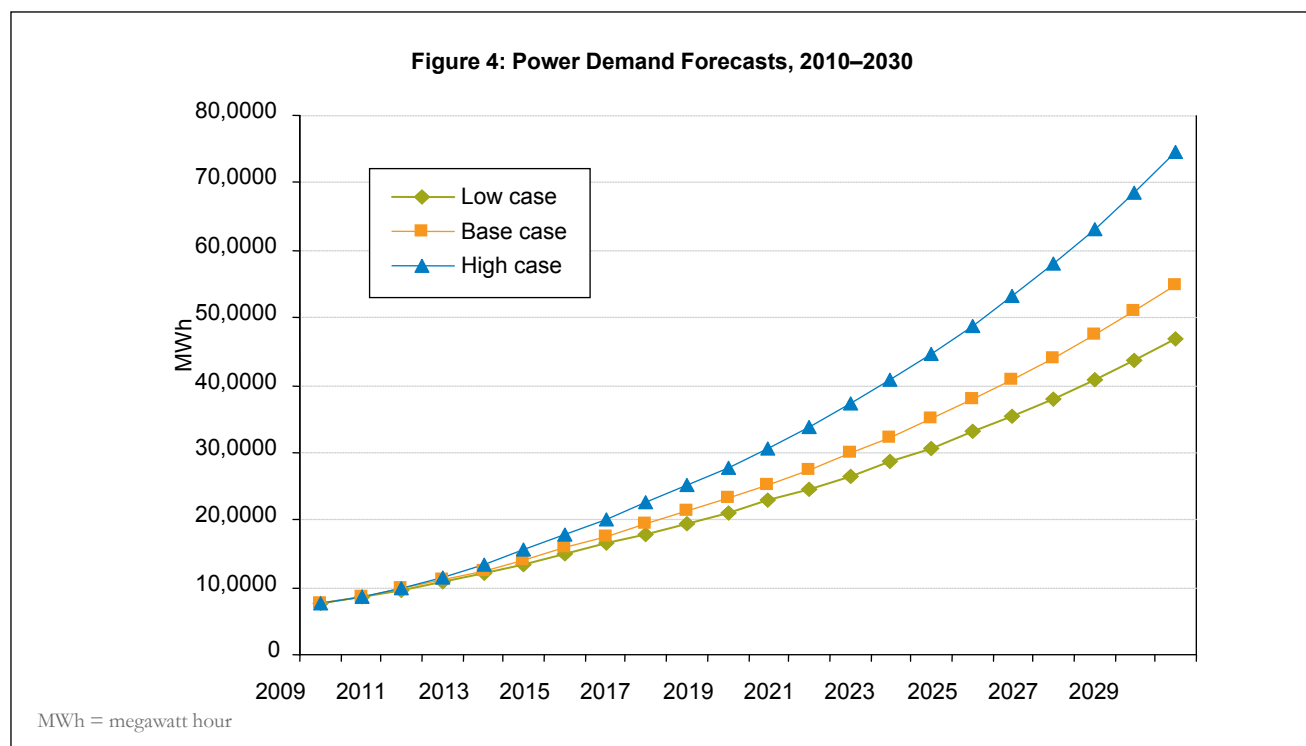
MW = megawatt.
Source: ADB (2010).

goal of PDP VII is to meet future demand through the most effective and responsible strategy for the expansion of generation capacity and the power transmission system, requires trade-offs between the costs and benefits of different types of power generation.

The SEA analyzed the potential social and environmental impacts of the package of generation development options contained in the PDP VII base case, valued where possible in economic terms that could be internalized into the PDP VII least-cost calculations. The assessment of power demand was based on existing power consumption data

for each sector, combined with assumptions on the speed and character of socioeconomic development during the plan period, and on savings from energy efficiency improvements (Figure 4⁴).

⁴ These and most other data in this paper are taken from “Strategic Environmental Assessment report of Vietnam National Power Development Master Plan for the period of 2011-2020 with perspective to 2030, Ministry of Industry and Trade, 2011”.



The PDP estimated that meeting this demand would require an expansion of the country's generation capacity to a projected installed capacity of 75,000 MW by 2020 and 146,800 MW by 2030. The projected financial costs of these expansions are huge: \$69.5 billion by 2020 and \$156.2 billion by 2030.

4. Main Findings of the SEA

4.1 Thermal Power

Thermal power constitutes by far the largest component of the power generation sector in Viet Nam, so it is no surprise that it is also the source of by far the largest social and environmental impacts. The most significant are the impacts of the atmospheric pollution from the combustion of fossil fuels and especially of coal. Under the plans in PDP VII, carbon dioxide (CO₂) and particulate matter releases will increase more than ten-fold during the PDP VII period up to 2030 and those for sulfur dioxide (SO₂) and nitrogen

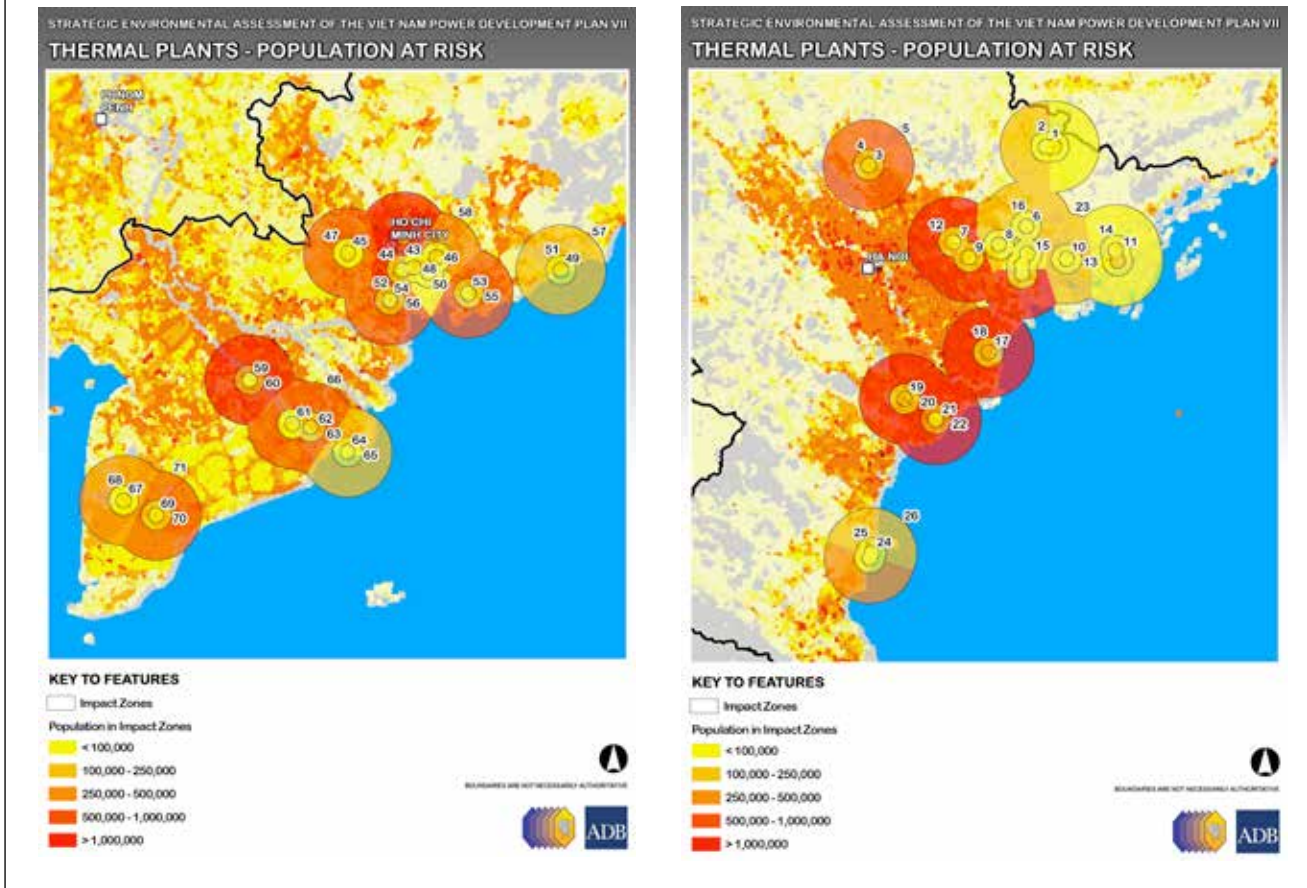
oxides will increase several fold. The impacts of these atmospheric pollutants will be severe and widespread. It is estimated that these impacts will cost Viet Nam nearly \$9.0 billion per annum by 2030 unless actions are taken to reduce the levels of atmospheric pollutant releases from, in particular, coal-fired power generation (Table 1).

The impact of atmospheric pollutants from thermal power is most critical where the stations are planned to near major urban areas, where existing ambient air quality is often poor and, of course, much larger concentrations of people are found. This is particularly true for the planned clusters of thermal stations close to Ho Chi Minh City and, to a lesser extent, in the northern region southeast of Hanoi (Figure 5). These planned clusters lead to a cumulative effect, where the impact of one station may not be so severe but the effects of several stations located close to each other in the proximity of large population clusters is a serious issue that should be addressed in the PDP VII plans.

Table 1: Total Environmental Costs for Each Pollutant (\$ million)

Year	2011	2015	2020	2025	2030
Particulate matter	98.86	134.95	289.57	439.40	710.24
Sulfur dioxide	93.77	148.09	311.85	448.18	728.74
Nitrogen oxides	234.15	274.48	386.09	494.30	638.86
Carbon dioxide	1,215.5	2,190.5	4,118.7	6,075.9	9,071.9

Figure 5: Thermal Power Station Clusters in North and South Viet Nam



4.2 Hydropower

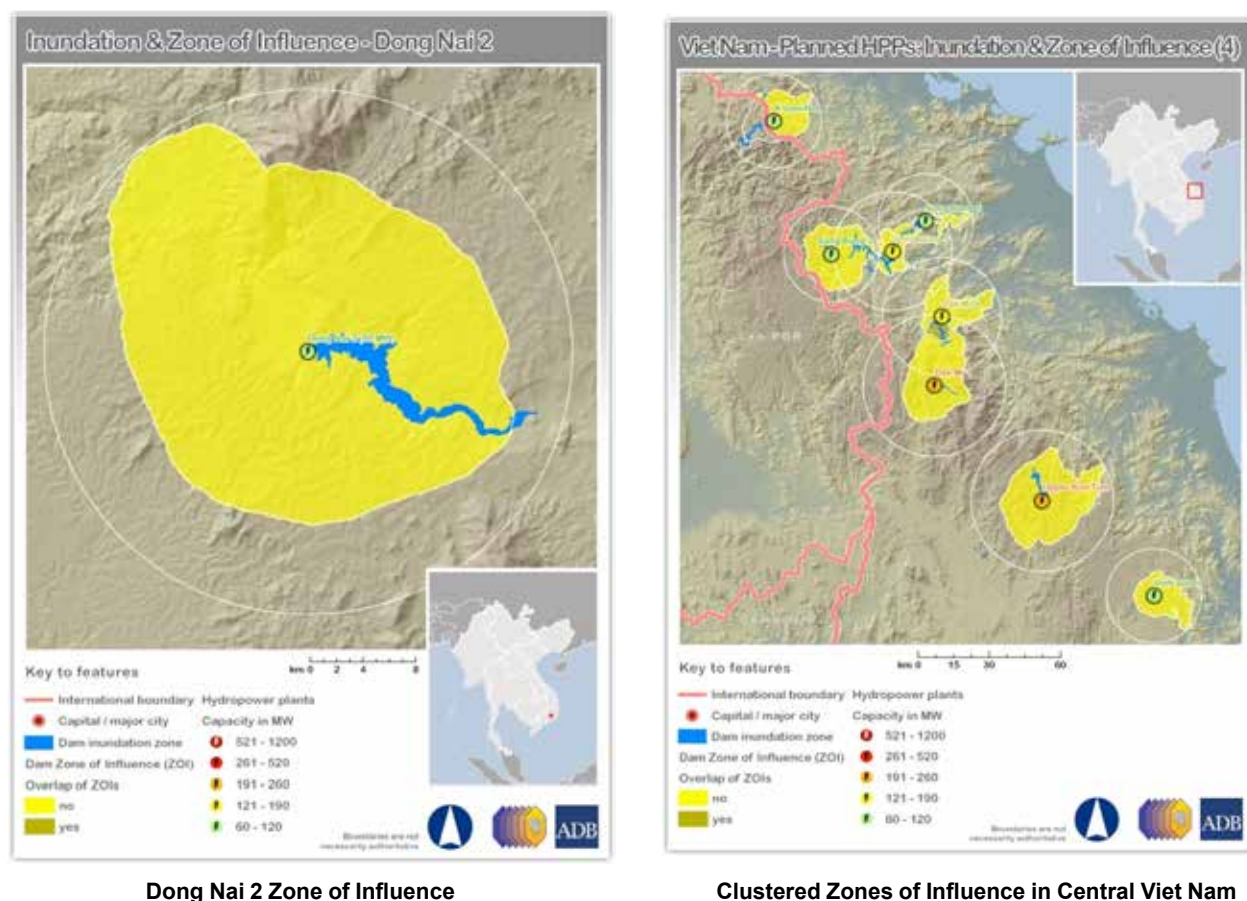
Hydropower can produce adverse social and environmental impacts, including the loss of land and disruption of sensitive ecosystems, the displacement of people and effects on the culture and livelihoods of communities not physically displaced, disruption to hydrological systems and ecosystems that depend on them, and other effects. With hydropower, most of the social and environmental impacts are associated with the development of the scheme. The wider effects on people and the environment are a mixture of both positive and negative impacts, with potential improvements to dry season water flows having positive benefits over whole river basins but several river ecosystems vulnerable to degradation in the immediate vicinity of hydropower schemes.

An area of 25,133 hectares (ha) will be submerged in the 21 schemes in the PDP, with an estimated economic value of goods and services of around \$75 million a year. A total of 61,571 people would be displaced if all 21 schemes are constructed, two thirds of them displaced due to four

schemes with more than 7,000 displaced people each (Ban Chat, Bac Me, Huoi Quang, and Lai Chau). Over 90% of the displaced people are ethnic minorities with a poverty rate well above double the national average. These people are highly dependent on access to natural resources (including forests) for their livelihoods and a close connection to where they live is an integral part of their cultural identity.

4.3 Nuclear Power

Nuclear power will be a new development for Viet Nam. It is a source of power generation characterized by risks of low probability but extremely high in impact, reflecting the extreme hazards associated with radiological materials. It is essential that Viet Nam develops the management systems to handle radiological materials before nuclear power development starts. There are additional predictable impacts that are a cause for concern, especially associated with the use and release of cooling waters. The site selection of power stations is the key issue here: any locations in the proximity of sensitive or high value

Figure 6: Examples of Zones of Influence around Hydropower Schemes

ecological areas must be avoided and the possible impacts of cooling water on riverine and marine ecosystems must be carefully assessed, while recent events in Japan have shown the importance of taking the risk of natural disasters affecting nuclear power stations into account.

4.4 Transmission Lines

Transmission line investments will generate adverse impacts, especially associated with the clearance of land along the routes of the transmission lines. The value of the forests that will be lost in implementing PDP VII is estimated at \$218 million. The line routes will pass through 59 protected areas and 39 key biodiversity areas, with risks of the fragmentation of habitats that could compromise the integrity of high value biodiversity areas. The consequences of the routing of transmission lines need to be carefully examined.

5. Considering Alternatives

5.1. Improved Energy Efficiency

Although challenging, it is possible to significantly improve energy efficiency in Viet Nam. The Electricity of Viet Nam (EVN) demand side management assessment study shows that the savings potential of around 36% could be achieved in the residential sector and more than 20% and 12% could be attained in the industrial and commercial sectors, while the World Bank's Commercial Energy Efficiency Program (CEEP) shows project savings of 15%–30%. This study considered achieving the 5%–8% electricity savings target set under the Vietnam Energy Efficiency Program (VEEP) for 2010–2015, gradually increasing this savings target to 20% of the total electricity demand during 2015–2030. These targets would bring down the country's electricity elasticity (ratio of growth rate of electricity demand and growth rate of GDP demand) from a high of 1.90 in 2010

to 0.85 in 2030, which is consistent with those of many efficient developing and developed countries.

A scenario was analyzed in which the plans in the PDP VII base case were adjusted to increase energy efficiency according to the national strategy. Under this scenario, electricity generation savings increase from 1,639 gigawatt hours (GWh) in 2015 to more than 22,000 GWh by 2030. The reduction of electricity demand would potentially greatly reduce dependency on coal-fired power generation: 16 coal-fired power plants throughout the country that are presently planned to be commissioned in 2027–2030 that are identified in the PD VII baseline scenario will no longer be needed.

The results show the potential of a sustained effort to increase energy efficiency as a key element in reducing the negative impacts of coal-fired power generation. The energy savings would save over 56 million tons of coal a year by 2030 (Table 2). This in turn would reduce CO₂ emissions by over 100 million tons a year, SO₂ emissions by over 72 million tons, NO_x emissions by over 42 million tons, and particulate matter emissions by nearly 10 million tons (Table 3). These reduced emissions would have huge benefits in terms of reduced climate change and acidification impacts and greatly reduced risks to human health from the power generation sector. The economic value of these reduced social and environmental impacts is calculated to be over \$3.3 billion (Table 4), a figure that would be much higher than any likely costs of the energy efficiency measures and investments implemented.

One of the critical factors, in addition to the regulatory and management measures, is financing of energy efficiency activities and projects. An energy efficiency fund could be established to support activities and leverage private sector investments. Similarly, the market for energy efficiency services and the establishment of energy efficiency service companies should be stimulated and supported by the Government.

5.2. Increased Renewable Energy in Power Generation

The second major element of any strategy to reduce the levels of coal-fired power generation needed in the future is to generate the electricity from other sources. Under the existing base case of PDP VII, large-scale hydropower will be close to maximized in terms of feasible hydropower construction sites; nuclear power will be developed at as fast a rate as is feasible for Viet Nam, and both oil and gas will be at levels that are as high as is likely to be economically and technically feasible. This leaves the further rapid expansion of power generation from renewable energy sources as the outstanding option for reducing coal consumption and impacts through substituting alternative power generation sources.

Under the baseline scenario, the share of renewable energies increases from 3.6% in 2015 to 5.8% in 2025 but declines to 4.4 % in 2030 due to the rapid growth of coal-fired power generation. In absolute terms, renewable energy capacity improves from 1,679 MW in 2015 to 6,029

Table 2: Energy Efficiency Scenario: Reductions in Demand for Coal, 2011–2030

Year	2011	2015	2020	2025	2030
Coal (million ton)	10.9	28.2	57.9	89.6	135.1
Domestic	10.6	26.2	39.8	53.2	69.5
Imported	0.34	2	18.1	36.4	65.6
Coal reduction (million tons)	0.6	3.8	19.2	26.9	56.3

Table 3: Reduction of Pollutant Emissions Compared to the Base Case (Carbon dioxide, '000 ton)

Year	2011	2015	2020	2025	2030
Particulate matter	312.91	995.04	3,552.45	4,933.26	9,873.90
Sulfur dioxide	4,538.23	5,837.31	22,184.68	32,609.93	72,868.86
Nitrogen oxides	12,140.97	113,65.97	20,593.53	29,154.38	41,291.30
Carbon dioxide	6,921.10	115,08.16	39,806.59	49,275.07	104,685.02

Table 4: Reduction of Health Costs (\$ million)

Year	2011	2015	2020	2025	2030
Particulate matter	-45.05	9.72	73.19	101.65	203.47
Sulfur dioxide	13.19	17.21	65.59	96.41	215.45
Nitrogen oxides	31.55	36.14	66.38	93.97	133.09
Carbon dioxide	644.40	791.70	1,578.70	2,195.80	3,348.10

MW in 2030. Although significant, these figures can be regarded as conservative and are far below the levels of renewable energy development that would be possible given the potential resource base of these energy sources, especially wind, solar power, and small-scale hydropower.

The increase in the proportion of renewable energy from 4.1% in the base case to 8%–10% has been considered, which would mean a capacity expansion of an additional 7,800 MW by 2030 compared to the base case. The target is to attain almost 5% share in 2015, 8% in 2020 and close to 10% in 2030. This entails raising the capacity from 1,979 MW in 2015 to 13,829 MW in 2030, more than double the level presently found in the PDP VII base case scenario. At present, grid-connected renewable energy is mainly from small hydropower systems, which are projected to increase from 461 MW in 2011 to 3,129 MW in 2030. Wind power generation will increase from a minimal level at present to 2,900 MW by 2030. For this renewable energy scenario, an additional 4,800 MW of small hydropower systems and 3,000 MW of wind power plants are to be installed. This expansion would result in the reduction in use of coal for power generation shown in Table 5 and the reduction in atmospheric pollution shown in Table 6.

These reduced emissions would in turn produce a significant reduction in environmental costs compared to the base scenario (Table 7) of over \$1.7 billion by the year 2030, reflecting the significant reductions in environmental and human health impacts from the power generation sector. These savings would be permanent and sustained and would far outweigh any likely increase in the direct

financial cost of power generation associated with the use of renewable energy in present conditions. It is in any case likely that the relative economics of renewable energy and conventional power generation sources will change in coming decades with technological developments and economies of scale as the global level of renewable energy continues to increase.

6. Recommendations from the SEA

The SEA produced a wide range of recommendations on both the content of PDP VII and the enhancement of the power sector planning process. A key step in the full integration of social and environmental issues into the PDP VII is the internalization of all economic costs into the calculation of the least-cost alternatives for power generation. Important steps toward this have been taken in this SEA but the full internalization into the base case scenario calculations has not yet been possible. This should be developed for future PDPs so that a more rigorous and transparent means to compare the full implications of the different power generation options is available within the core structure of the PDP.

Key recommendations relate to the reduction of future dependency on coal as a principle means to generate electricity. The greatest impacts come from coal-fired power generation, with impacts that will cost several billion dollars per year by 2030. A strategy that combines improved energy efficiency and accelerated renewable energy development would go far to reducing these

Table 5: Reduction in Demand for Coal with Expanded Renewable Energy

Year	2011	2015	2020	2025	2030
Coal (million ton)	11.2	31.9	75.8	111.9	177.5
Domestic	10.8	29.9	46.2	61.9	64.8
Imported	0.38	2	29.7	50	112.7
Coal reduction (million ton)	0	0.1	1.2	4.6	10.6

Table 6: Reduction of Atmospheric Pollution from Expanded Renewable Energy (Carbon dioxide '000 ton)

Year	2011	2015	2020	2025	2030
Particulate matter	-7.03	35.23	223.81	849.02	1,941.73
Sulfur dioxide	377.61	818.72	940.08	4,865.65	13,575.04
Nitrogen oxides	12,356.55	11,253.20	10,166.70	13,561.26	14,575.81
Carbon dioxide	7,440.86	6,635.29	7,056.78	14,736.98	26,264.91

Table 7: Reduction of Health Costs due to Reduced Emissions (\$ million)

Year	2011	2015	2020	2025	2030
Particulate matter	-57.42	-15.65	4.59	17.48	40.00
Sulfur dioxide	0.87	2.34	2.76	14.37	40.12
Nitrogen oxides	31.33	35.43	32.77	43.71	46.98
Carbon dioxide	638.50	694.20	938.80	1,472.50	1,739.90

impacts and it is recommended that such a strategy is elaborated. This would include further assessments of the potential scale and best sites for renewable energy development as well as the means through which greater energy efficiency can be achieved.

For hydropower, specific recommendations include the improvement of the existing package of support and compensation for displaced people, the multi-purpose management of reservoirs to ensure an integrated approach to water resources management, the development of community forestry and protected area plans for the areas surrounding hydropower sites and the preparation of biodiversity management plans in localities of high ecological value. It was further recommended that two planned schemes, at Dak Mi 1 and Dong Nai 5, are actively examined for cancellation because of their likely severe biodiversity impacts in areas of unique ecological significance.

Further recommendations relating to the technical content of the PDP VII include approaches to improve management and operational efficiency; on ensuring that nuclear power is developed in a safe and rigorously managed manner; and on mitigating potential environmental damage from transmission line development.

Taken together, these recommendations will ensure that the development of the power sector takes place in accordance with rules and regulations on environmental sustainability and to reflect wider principles of environmental protection. These recommendations would make a significant contribution to reducing the adverse social and environmental impacts of the necessary expansion of Viet Nam's power sector. Many negative impacts can be reduced and vigorous actions to ensure that this takes place are essential. Of course, all such impacts cannot be eliminated altogether and there should be a transparent recognition of the likely trade-offs needed for the effective development of the sector. Further analysis of costs and benefits and further consultations with relevant stakeholders are both essential and should be continued.

SEAs are a relatively new process in Viet Nam. Experience is growing but their effective integration into strategic planning is still limited. The use of SEA as an integral part of the preparation of PDP VII has demonstrated the utility of this approach, providing a means through which possible issues can be identified and alternative approaches explored before the plan is finalized. The integration of the SEA process also provides a means

through which key stakeholders can be consulted during plan preparation.

7. Implications for SEAs and Power Sector Planning in the GMS

Executing an SEA requires capabilities that are often beyond those found in many planning agencies. Sustained capacity development activities are needed in Viet Nam and in other countries if the experience of the SEA in PDP VII is to be widely replicated. There is great potential for sharing experience and capacities between the institutes of the different countries in such sectors as power development where SEAs are of particular importance. Project environmental impact assessments remain insufficient to evaluate the implications of national, regional, and sectoral development policies, plans, and programs, where SEAs are the most effective approach to ensure the full integration of social and environmental issues into decision making. The SEA of PDP VII was successful in establishing a robust analytical framework consisting of scenarios, alternatives, and valuations leading to clear and transparent re-assessment of the costs and benefits of different generation alternatives.

The revision of the renewable energy and energy efficiency targets was the major recommendation coming out from the SEA of PDP VII. This recommendation will hold true for other GMS countries. It is essential that a limited approach based only on immediate financial criteria is not used. This is where GMS subregional energy forum can play an active role, as a part of renewable energy (RE) and energy efficiency (EE) - subregional plans, as well as looking to remove policy, market and financial barriers.

Environmental Operations Center (EOC), as a regional environmental platform to mainstream environmental considerations in sector development processes, should continue to act as a regional referral center (clearing house) and support countries to build their SEA capacities to conduct scientifically robust SEAs underpinned by enhancing the technical capacities of line agencies, harmonizing SEA methods and producing SEA guidelines and manuals. Support is also needed to strengthen SEA policy and regulatory frameworks in many countries, including enhanced monitoring and appraisal capacities amongst responsible agencies. Finally, investments in information generation and dissemination must be made as an integral part of any process to ensure the potential of SEA approaches in strategic planning in the region is realized.

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STATUS OF ENERGY USE, POWER SECTOR EXPANSION PLANS AND RELATED POLICIES IN THE GMS: CHALLENGES AND OPPORTUNITIES

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and Pradeep J Tharakan³*

Abstract

The economies of the Greater Mekong Subregion (GMS) are rich in natural resources and are witnessing unprecedented growth and transformation. Further growth is contingent on access to additional reliable sources of energy. The total primary energy consumption in the region is expected to double between the years 2010 and 2025. The two main sectors driving this increased energy demand are transportation and electricity generation. It is estimated that 238 gigawatts (GW) of new electricity generation capacity would be needed by 2025.

Currently, the larger economies in the region are net importers of energy (from outside the region), while the smaller economies have sufficient indigenous energy resources to support significant regional trade, once these resources are developed. The varying states of economic development and unequal distribution of energy resources thus provides the ideal setting to increase regional energy trade in pursuit of sustained and equitable economic growth for all nations involved. Specifically, Thailand and Viet Nam could benefit from increased regional imports, while Cambodia, Lao PDR and Myanmar could gain from trading in surplus power. A regionally integrated energy sector thereby provides a key opportunity to reduce the energy dependence of the GMS on the rest of the world.

The development of an optimum regional energy trading policy is however, contingent on several pre-requisites. Each country must strive to fully realize its energy conservation potential and renewable energy potential while participating in regional efforts to identify and support

regional interconnection projects, and improved energy transmission and transport modes that will allow for cost-effective regional trade. Given the overall investment needs in the sector, it is unlikely that governments alone would have the requisite financial resources. The private sector would have a key role to play in any significant expansion of the GMS energy trade.

1. GMS – A Cradle of Transformation

The Mekong River has six riparian states in Southeast Asia: Cambodia, People's Republic of China (PRC), Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, and Viet Nam, which constitute the Greater Mekong Subregion (GMS). Yunnan Province (Yunnan) and Guangxi Zhuang Autonomous Region (Guangxi) represent the interests of the PRC at various GMS forums. In total, the GMS spans over 2.52 million sq.km of land area and sustains a population of about 321 million. The GMS is one of the most dynamic areas of the developing world having exhibited a high growth rate over the last decade. The sub-region is characterized by uneven distribution energy resources, diverse cultures, and distinct Government systems. It has abundant biodiversity but the pace of transformation of the economies, while aided by the rich natural resource base of the region, also exerts immense pressure on human and the fragile ecosystems. The common challenge to all countries of the sub-region is to sustain their economic growth while limiting the adverse environmental impact.

The geographic positioning of the GMS countries, within Southeast Asia offers an opportunity for co-operation in various areas of economic development. Recognizing the potential for synergistic gains that could be achieved, the six member countries, in 1992, formulated the GMS Economic Cooperation Program (ECP). Between 1993 and 2005, GMS witnessed an overall energy consumption growth of 8% p.a. (ADB, 2009a). However, there is an enormous gap between the economic realities of the various states as can be seen from the variation in the per capita electricity consumption levels (Table 1) and ranges from 97 kWh in Myanmar to 2,079 kWh in Thailand. Even when viewed as a whole, the GMS region has a per capita consumption of only 863 kWh, significantly lower than the world average of 2,876 kWh (WDI, 2011).

The varying energy consumption levels between the nations can be attributed to the unequal economic growth and different stages of development. Barring Myanmar,

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Table 1: Land area, population and energy consumption per capita for GMS countries

Country/Region	Land Area (1,000 km ²)	Population (2010)		kWh/capita ^a
		million	Density (people per km ² of land area)	
Cambodia	177	14	80.1	113
PRC ^b				
Guangxi	237	51	205.0	1,771
Yunnan	397	46	115.1	751
Lao PDR	231	6	26.9	429
Myanmar	654	48	73.4	97
Thailand	511	69	135.3	2,079
Viet Nam	310	87	280.4	799
Total	2,515	321		

a Mekong Delta River Wetland Ecosystem Assessment

b Nguyen Tan Phuong, Forest valuation in Viet Nam

Source: WDI (2011); National Bureau of Statistics (2010).

the rest of the GMS countries have relatively established power sector development plan which provides opportunities in the long-term to effect change (ADB, 2009a).

The exploitable hydropower resources in Lao PDR, Myanmar and Yunnan are expected to exceed their own demand and surplus can be exported in the future (ADB, 2008a). A similar case is in the use of fossil fuel sources - large offshore natural gas reserves in Myanmar and Viet Nam when compared to their domestic demand and coal reserves of Yunnan and Guangxi provinces of the PRC (ADB, 2008a; ADB, 2009a). Therefore, it is necessary to have effective cooperation and coordination between the countries in GMS in order to tap into these energy resources combined with technology and knowledge sharing, given the similarities in the implementation environment that exists on the ground.

The distribution of energy resources is varied and uneven among and within the countries that constitute the GMS. As demonstrated earlier, the per capita consumption is extremely low in the GMS and any demand estimation is likely to fall short of the true demand for energy sources, as there is no awareness in the larger population of the possibilities that open up with greater electricity and energy access and supply. Overall, the lack of policies for the aggressive promotion of energy sector development, of effective coordination between various countries in sharing technology and resources, of financial incentives to tap into renewable energy source and the poor standards of environmental legislation add to the plethora of issues that plague the consumers in this densely populated region.

ADB commissioned a study of the energy sector in the GMS, which was carried out by Integriertes Ressourcen Management (IRM), in late 2007. The base scenario of

the study is business as usual with each country pursuing a high growth strategy without any increased levels of cooperation in the energy sector, by way of trade or sharing of resources. The reference scenario used in the model, treats the GMS as one economy with expanded cooperation, through multilateral trading agreements and sharing of resources and knowledge. This report predominantly looks at the needs of the GMS as seen in the base scenario and highlights the advantages of pursuing shared growth as illustrated by the reference scenario.

2. Energy Supply-Demand Outlook in the GMS

Statistical data pertaining to historical demand and supply of energy were obtained from an array of sources ranging from publications within the respective countries (ministry sources), World Development Indicators (WDI) as published by the World Bank, International Energy Agency (IEA) Statistics etc. Data for Thailand and Viet Nam were obtained from the Asia Pacific Energy Research Centre (APEREC). Projections for the future energy demand were obtained from earlier publications by ADB and IRM, with 2010 forming the base year for comparative purposes. IRM used the MESSAGE model to arrive at projections for GMS as a whole. There are different scenarios listed in these reports while making projections, wherein medium growth scenario with business as usual scenario was the base case considered for analysis.

The following sections analyses the existing conventional energy resource base within the GMS, total final energy consumption (TFEC) and (inter alia) transportation and electricity demand in the GMS and finally the total primary energy production within the GMS.

2.1. Conventional Energy Resources within the GMS

The region has a significant resource base when it comes to coal. Viet Nam has large reserves of anthracite coal, but the inefficiencies associated with burning this form of coal do not permit its full exploitation. The coal found in Lao PDR is of high ash content as in Thailand which is also high in sulphur content (ADB, 2008a). Coal resources in Yunnan Province can generate around 32,850 TWh of electricity but the PRC may not open this resource for regional trading, considering its internal energy demand in other provinces.

Most of the oil resources in the region are used to meet transport energy demand, but significant imports are necessitated as the region is poorly endowed when one considers oil. Thailand has the largest natural gas and crude oil reserve base. Cambodia and Lao PDR rely entirely on imported gasoline and diesel (ADB, 2008a)

to meet their transportation energy demand, which can be attributed to the lack of refineries in these countries. Cambodia uses diesel for producing power which is highly vulnerable to international supply and price volatilities of crude oil. This is one of the reasons for high electricity tariffs in Cambodia as compared to the rest of the GMS.

Myanmar has proven gas reserves of 17 trillion cubic feet which are mostly in offshore fields (ADB, 2008a) while Thailand has the largest installed gas based power generation capacity. Table 2 provides a summary of the energy resources in the GMS.

Myanmar and Yunnan have the highest hydropower potential in the region, while only Thailand and Viet Nam have exploited their hydropower resources to a substantial degree. Over the past decade, Lao PDR and Cambodia have started tapping into their hydropower potential, but only Lao PDR is currently in a position to export surplus electricity to Thailand after meeting domestic demand (ADB, 2008a).

Table 2: Energy resources and potential in GMS Countries

Country / Region	Coal	Natural Gas ^a	Crude Oil	Hydro (MW)		Renewable Energy ^b
				P: Potential	I: Installed	
Cambodia	Hard coal: 10 million tons	140 bcm	Reserves: 400–500 million barrels	P: 15,000 I: 13		Biomass: 16.04 GWh/y Wind: 1.73 GWh/y
PRC						
Guangxi	Hard coal: 1,055 million tons	-	-	-		N.A.
Yunnan	Hard coal: 27,123 million tons	Resource: 32 bcm Production: 6 mcm	136 million tonne	P: 90,000 I: 11,980		N.A.
Lao PDR	600 million tons	101.9 bcm	-	P: 18,000 I: 663		Biomass: 33,000 TJ/y Wind: 39,795 MW
Myanmar	Hard coal: 711 million tons	Resource: 569 bcm Production: 13,513 mcm	2.7 billion barrel	P: 100,000 I: 802		Wind: 365 TWh/y Solar power: 51,979 TWh/y
Thailand	1,240 million tons	Resource: 760 bcm Production: 20,023 mcm	0.2 billion barrel	P: 10,000 I: 3,422		Solar PV: 50,000 MW Biomass: 4,400 MW Biomass thermal: 7,400 ktoe Biogas: 190 MW Wind: 1,600 MW Solar PV (off-grid household): 2 MW
Viet Nam ^c	45,000 million tons	Resource: 256 bcm Production: 5,892 mcm	3.2 billion barrel	P: 15,000 I: 4,155		Biomass ^d : 250–400 MW Geothermal: 200–400 MW Wind: 110,000 MW

a bcm – billion cubic meters, mcm – million cubic meters

b Excluding the current operational potential.

c Hydro and renewable energy data was sourced from <http://tel.archivesouvertes.fr/docs/00/59/35/73/PDF/PhDthesiswriting-20110510.pdf>, except solar energy data.

d Biomass includes wood plantations, residues, rice husk, paddy straw, and bagasse.

Source: ADB (2008a), ADB (2008b), ADB (2008c), Beni Suryadi (2005), Shankar et.al (2005), Nguyen, T. Nhan (2011). Programming Sustainable Development in a Developing Country: A Social Optimization of the Vietnamese Power Sector. CIRED/CNRS archives, 2011. Available online at <http://tel.archivesouvertes.fr/docs/00/59/35/73/PDF/PhDthesiswriting-20110510.pdf>

2.2. Total Final Energy Consumption

Fossil fuels (coal, natural gas, crude oil) along with hydropower, biomass and other renewable sources constitute the energy consumption mix (Table 3), today and in the future. The values are provided for the base and terminal years of the analysis period, indicative of the growth that the region is set to witness.

The region will witness a more than doubling of its energy consumption over the fifteen year period. The modelling by IRM suggests that there will be drastic shift in the dependence away from solid fuels in Cambodia and Lao PDR as a result of increased electrification, which in turn

is driven by exploitation of the hydroelectric potential. In contrast, Myanmar will continue to remain dependent on non-commercial fuel wood and shows an increasing trend through the forecast period.

In order to sustain the economic growth that the region has witnessed two specific aspects of energy consumption have to be addressed viz. electricity and transportation fuels.

Transportation Energy Demand in the GMS

Imported energy sources accounted for 21% of final energy consumption of the GMS in 2005. The region is poorly endowed when it comes to crude oil and imports upto 19%

Table 3: TFEC (in ktoe) in 2010 and 2025^a

Country / Region	Coal		Gas		Oil		Electricity		Fuel wood and renewable energy		Total	
	2010	2025	2010	2025	2010	2025	2010	2025	2010	2025	2010	2025
Cambodia	93	24	19	490	607	3,191	103	406	3,377	2,408	4,199	6,518
PCR												
Guangxi	17,171	41,354	1,720	6,888	11,503	43,745	6,927	19,370	9,305	11,885	46,625	123,242
Yunnan	16,667	34,155	375	3,998	4,966	17,873	4,849	12,133	10,024	11,445	36,880	79,605
Lao PDR	227	681	256	380	642	1,722	153	566	1,013	762	2,291	4,111
Myanmar	564	2,455	265	638	1,963	3,466	542	1,975	12,210	19,831	15,544	28,365
Thailand	9,700	18,400	4,200	9,850	47,000	85,950	15,000	35,300	10,600	15,250	86,500	164,750
Viet Nam ^b	6,800	13,900	1,400	3,650	15,000	36,100	5,700	16,500	22,500	22,500	51,400	92,650

a For the purposes of analysis, a common base year was required and used the same source even for the year 2010 though these are projections for the 2008 data source.

b Viet Nam has the plans to introduce nuclear power and by 2025 it is expected to supply about 7,200 ktoe.

Source: ADB (2008b) for Cambodia, PRC, Lao PDR, and Myanmar; APERC (2006) for Thailand and Viet Nam.

Table 4: Transport energy demand in GMS in million liter

	2005	2010	2015	2020
Cambodia				
Gasoline	590	903	1,219	1,729
Diesel	1,375	2,235	3,307	4,396
PRC, Yunnan and Guangxi				
Gasoline	1,979	2,978	4,191	5,404
Diesel	3,898	4,970	6,744	8,518
Lao PDR				
Gasoline	129	208	336	540
Diesel	201	323	521	839
Myanmar				
Gasoline	434	590	1,001	1,656
Diesel	635	702	775	856
Thailand				
Gasoline	7,248	7,417	11,610	27,692
Diesel	19,594	18,480	26,314	64,049
Viet Nam				
Gasoline	3,554	5,095	7,185	10,132
Diesel	7,013	8,533	11,896	14,667

Source: ADB (2008b) for Cambodia; LBEDC (2008) for Lao PDR; EPPO (2011) for Thailand; PRC (2011) for Yunnan and Guangxi; Myanmar and Viet Nam - country data obtained from Ministry.

Table 5: Installed electricity generation capacity in GMS

Country / Region	Installed capacity (MW)
Cambodia (2008)	390
PRC	
Guangxi (2011)	26,257
Yunnan (2011)	37,437
Lao PDR (2011)	2,558
Myanmar (2011)	3,418
Thailand (2009)	29,212
Viet Nam (2011)	23,000
Total	122,272

Source: ADB (2008a), Sanhya, S. (2011), EGAT (2010), EVN (2011), MEP (2011), EDC (2009), CSG (2011).

of its petroleum needs. In addition, the lack of refineries in the region implies that the reliance on refined products is to the tune of 33% (ADB, 2009a). It is also important for the GMS countries to diversify the transportation energy demand through introduction of alternative fuels, promotion of mass transport systems and increasing the efficiency of the same. Biofuels are being considered and produced within the GMS and there is an evolving policy framework to address the long term sustainability of biofuel usage for the region (Tharakan *et al*, 2011).

Table 4 shows the gasoline and diesel energy demand for transportation in GMS countries. Regression analysis was used to forecast the demand of gasoline and diesel consumption based on the current and historic consumption patterns. The gasoline demand from 2010 to 2020 is going to be somewhere in between 1.8 to 3.7 times the consumption level in 2010. Similarly the diesel consumption is going to be increased by 1.7 to 3.5 times the current consumption in 2010.

While biofuels provide an option to tide over the dependency on imports, biofuels development can be

associated with numerous risks if deployed unsustainably. Risks may include food security, impacts on soil and water quality, and biodiversity, which in turn may have negative ramifications for human development (Tharakan *et al*, 2011). The analysis of its viability in the GMS context is outside the scope of the paper as one needs to pursue an economy wide analysis to ascertain the impact on agriculture, food sufficiency and long term sustainability of the approach.

Total Electricity Demand in the GMS

Table 5 lists out the installed electricity generation capacity in the GMS. The MESSAGE model forecasts that nearly 238 gigawatts (GW) of new electrical power generation capacity need to be added over the coming years in GMS i.e. more than three times to the current capacity generation is required by 2025. A substantial portion of the generation capacity required to sustain growth in the future is yet to be constructed.

2.3. Total Primary Energy Production in the GMS (Regional Supply)

Over the forecast period (2010 – 2025), given the doubling of the energy consumption (forecasted demand); it is inevitable that the supply side will also have to be scaled up proportionately to address the consumption needs. The role of biomass (as a proportion) in contributing to primary energy supply decreases over the forecast period whilst the role of renewables increased along with hydropower. However, there is also increased reliance on coal and other fossil fuel resources, refer to the Table 6.

Table 6: TPES (in ktoe) in 2010 and 2025^a

Country / Region	Coal		Natural Gas		Crude Oil		Hydro		Biomass and renewables		Total	
	2010	2025	2010	2025	2010	2025	2010	2025	2010	2025	2010	2025
Cambodia	136	5	0	0	812	5,278	33	33	3,420	2,737	4,402	8,054
PRC												
Guangxi	37,957	88,929	0	0	12,874	57,801	1,564	2,049	10,502	16,619	62,898	165,398
Yunnan	29,185	66,230	208	490	5,302	17,484	2,491	8,149	11,603	15,267	48,789	107,619
Lao PDR	1,433	5,895	1,039	533	908	1,003	5,209	6,518	1,027	1,650	9,616	15,599
Myanmar	583	5,950	750	597	2,341	2,914	609	3,960	12,305	21,049	16,588	34,470
Thailand	15,500	48,800	35,100	61,100	51,500	90,850	1,000	850	11,000	18,150	114,100	219,750
Viet Nam ^b	11,300	27,100	6,800	13,750	15,000	37,650	2,800	5,350	23,200	25,550	59,100	109,400

a For the purposes of analysis, a common base year was required and used the same source even for the year 2010 though these are projections for the 2008 data source.

b Viet Nam has the plans to introduce nuclear power and by 2025 it is expected to supply about 7,200 ktoe.

Source: ADB (2008b) for Cambodia, PRC, Lao PDR, and Myanmar; APERC (2006) for Thailand and Viet Nam.

3. Background to Regional Power Trade Coordination Committee in GMS

3.1. Need for Regional Cooperation in Energy Sector

In order to evaluate the benefits of regional power trade and cooperation, one must look beyond the analysis presented above, which considers a base scenario, where there is no further trade and cooperation in the future than what exists at present. This could be compared against the reference scenario, which allows for cooperation and trading of energy between the GMS countries, which forecasts an additional requirement of 238 GW of electricity generation capacity, and provides an opportunity to save up to 19% in capital investment costs in power plants and other energy sources. The reference scenario, which optimises the energy consumption of the GMS as a whole indicates a savings of nearly 200 billion USD in energy costs (discounted to 2010). World market prices are much higher and hence all imports that happen are at world market prices in the base scenario. In contrast, the reference scenario assumes the possibility of providing reliable supply at a lower cost, with lesser transaction charges throughout the GMS by establishing an energy trading platform. The scenario also forecasts a much higher development of hydropower potential, in light of the opportunity to trade surpluses. This will further enhance the private sector investments for the power markets. Also, there is a scope for information sharing and knowledge exchange between countries in the GMS. There is already established power sharing through bilateral agreements between the countries in GMS, however, such cooperation needs to be expanded to the regional level. This approach will provide enduring benefits over those of bilateral agreements. In order to meet this demand, it is necessary to have dedicated institutions wherein each country of GMS has a role in fulfilling the regions demands as a whole.

3.2. The Existing Set Up and Co-operation Opportunities in the Near Term

Under the framework of GMS ECP, the Energy Power Forum (EPF) was set up in the year 1995. Over a period, this has evolved into two separate institutional structures (a) the Energy Sector Forum and (b) the Regional Power Trade Coordination Committee (RPTCC) a high level body, which coordinate implementation of Regional Power Trade (RPT) & represents the Countries. RPTCC consists of two subgroups i.e. the Focal Group and the Planning Working Group.

Since the establishment of EPF, there were three main achievements i.e. (i) Intergovernmental Agreement (IGA) for power trade within GMS, (ii) formulation of Regional Power Trade Operating Agreement (RPTOA), and (iii) developed Regional Indicative Master Plan on Power Interconnection (RIMPPI) (ADB, 2008a). Currently discussions are under progress for the establishment of GMS Regional Coordination Centre (RCC) to oversee power trade development and report to RPTCC.

When it comes to the power transmission lines, PRC, Thailand, and Viet Nam in the GMS have well established power grids with integrated 230 kilovolt (kV) and 500 kV lines forming the backbone. Cambodia has started developing its power grid and is in the process of establishing 69 kV, 115 kV, 132 kV, and 230 kV transmission lines. A similar scenario prevails in Lao PDR and Myanmar but with better progress (ADB, 2008a). The reference scenario, was estimated that about 238 GW of new electrical power generation capacity need to be added over the coming years in GMS, a larger proportion of this capacity will be added in Cambodia, Lao PDR and Myanmar. That means it provides an opportunity for these countries to develop low carbon energy technologies such as combined power plants, cogeneration, waste-to-energy options with a possibility to introduce new energy systems that are more efficient apart from hydropower (ADB, 2009a).

3.3. Regional Power Trade: A Starting Point

Globally, there have been a few successful regional energy trading regions, which provide a template for the GMS to adopt. European Network of Transmission System Operators for Electricity (ENTSO-E) formed in 2008 that combines the institutions established earlier in Europe. This is providing wider opportunity for power sector development and equitable role for countries in the European Union. South African Power Pool (SAPP) founded in 1995 links the power systems of Angola, Botswana, the Democratic Republic of the Congo, Lesotho, Malawi, Mozambique, Namibia, the Union of South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe. There are other examples such as EAPP (connects 10 countries), WAPP (connects 14 countries), SIEPAC (connects 6 countries) for international regional trade in energy that has led to significant benefits, both financial and otherwise (ADB, 2009a). Certainly, such cooperation between the countries would help individual countries to achieve market competitiveness, electricity prices can be near the level of the marginal cost of power generation and improves the productivity of the power sector as whole.

Bilateral agreements for power purchase constitute a bulk of the regional power trade today. The most significant of these was the one signed between Lao PDR and Thailand for export hydropower to Thailand (ADB, 2008a). GMS ECP is one of the most successful regional cooperation programmes and is now help to diversify cooperation in the other economic sectors particularly power trade. The two factors that contribute to this success are strong political ownership and economic growth of the countries in the region.

3.4. Expected exchange of power within the region

A futuristic scenario of power trade and regional interconnection of power grid in GMS region was executed

under MESSAGE model as GMS integrated scenario. It is expected that Cambodia, Lao PDR, and Myanmar would become the key electricity exporters in the GMS. By far, Thailand and Viet Nam are major importers. Figure 1 show the units of electricity exchanged between now and 2025 in an integrated scenario (ADB, 2009a).

4. Power Sector Development Plans and Policies in GMS Countries

Policies for power sector are developed with certain objectives. Some of those are (a) to meet the country's demand for electricity at the least cost, (b) to uphold the country's commitments under international conventions, (c) encourage private sector participation (d) efficient

Figure 1: Electricity production and exports within the GMS, 2005 and 2025 (GWh)

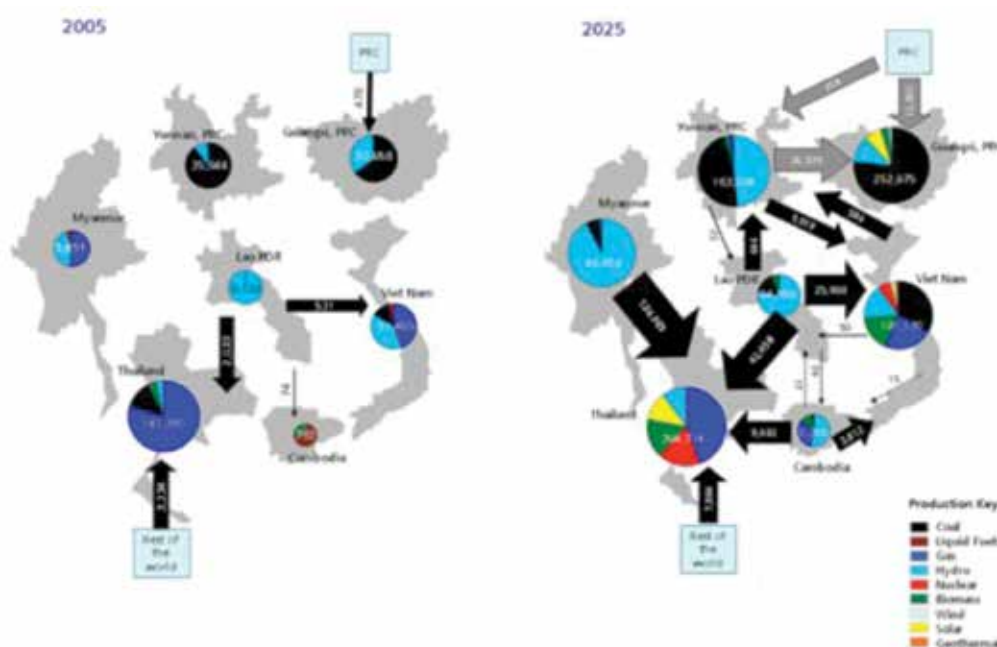


Table 7: Important policy parameters that guide the power sector environment in GMS

Parameter	Power development plans	Private participation in power generation	Private participation in power distribution	Target - 100% rural electrification by	Environmental Impact Assessment (EIA) process
Cambodia	Exist	Yes	Yes	2020	Weak
PRC					
Guangxi	Exist at the national level	N.A.	No	2010	N.A.
Yunnan	Exist at the national level	N.A.	No	N.A.	N.A.
Lao PDR	Exist	Yes	No	90% by 2020	Weak
Myanmar	No clarity	Yes	No	2020	Weak
Thailand	Exist	Yes	No	2010	Strong
Viet Nam	Exist	Yes	No	2020	Weak

Source: ADB (2008a).

use of available resources, keeping in mind the reserve depletion rate and ensuring a sustainable approach to the use renewable energy sources. The overall share of private sector investment in the energy sector remains low in the GMS due to a lack of favourable policies. Table 7 lists some of the important parameters that enable a clear understanding of the existing framework in the GMS countries.

4.1. Cambodia

As per the power development plan, Cambodia has an aggressive policy of total rural electrification by 2020. Nearly 70% of the rural households will have access to quality electricity supply by 2030. The total installed power generation capacity by 2020 is estimated to be 6,000 MW thereby covering the entire domestic demand of 3,500 MW (18,597 GWh) and leaving a surplus of more than 2,500 MW for export purposes (EDC, 2009).

4.2. Lao PDR

The Lao PDR government has a target to achieve rural electrification to the extent of 70% and 90% by year 2010 and 2020 respectively. Lao PDR earns substantial foreign exchange earnings through sale of power and attracts foreign direct investment to fund the projects, which in turn fuel the economy. The country has bilateral agreements with other GMS countries implementation of new projects will have to be accelerated to ensure that the commitments under intergovernmental agreements are honoured. A total of 68 projects with estimated installed capacity of 22 GW are currently under different stages of development (EDL, 2009; Sanhya.S., 2011).

4.3. Myanmar

There are two ministries focusing on power sector development in Myanmar - Ministry of Electric Power-I and Ministry of Electric Power-II with separated responsibilities, with overlap in some areas. Recognising the wide spread energy poverty, the Government has laid down policies to tap into the hydropower potential in the country. About 19 hydropower projects are planned to be constructed between 2010 and 2020. Local investors are allowed to participate in this through IPP agreements for hydropower projects and currently about 284.5 MW of hydro power capacity is under development. Modest targets of 60% rural electrification by 2020 and 80% by 2025 has been set as per the policy (MEP, 2009).

4.4. Thailand

Thailand has a relatively well developed power development plan and provides a greater opportunity for private sector participation in electrical power generation through IPP, Small Power Producer (SPP) and Very Small Power Producer (VSPP) programmes. The power development plan is a step in low carbon development pathway and achieves emission reductions also through the promotion of energy efficiency and renewable energy development. The power capacity additions expected between 2010 and 2020 is about 21.6 GW (EGAT, 2010).

4.5. Viet Nam

The Electricity Law in Viet Nam took effect in 2005 (July) and provides a roadmap for regulatory reform in the power sector, assigns responsibilities for reform and was proposed with a view to promote investments in the power sector and liberalise the same. The nation has ambitious targets for power production to meet the domestic demand. Ground rules for setting of tariffs and for competitive markets to emerge have been laid out. The law further encourages energy savings and renewable energy development (IRG, 2006). Power Master Plan VII was recently approved and there is a strong emphasis on energy security, energy efficiency, renewable energy development and power market liberalisation. There is a change in the targets set for total power capacity additions from 121 GW (plan VI) to about 61 GW (VII) for the period 2016 to 2025 (Dao and Kevin, 2011).

4.6. Guangxi and Yunnan, PRC

PRC has power development plans at the national level, but Guangxi and Yunnan are given special attention due to the low development in these counties compared with other counties in the PRC. Having said this, regional cooperation with GMS provides an opportunity for Yunnan and Guangxi to work with other countries in the GMS to maximize the benefits through greater regional cooperation and integration with GMS. It is expected that in the future, Yunnan will make use of its resources (natural gas) and sources (hydro) for the promotion of relatively clean energy sources in GMS. Though Guangxi is endowed with coal resources, it is expected to largely contribute to the national goals than GMS. The use of high coal consumption in Guangxi has lead to severe environmental pollution and experienced acid rain in many cities of Guangxi (ADB, 2008b).

5. Other Opportunities for Sustainable Energy Sector Development in GMS

While promoting economic development and resource sharing are the focus of co-operation efforts, it is important that environmental and social costs associated with the exploitation of resources are internalised and accounted for. Given the large hydropower potential in the region, and the results from the scenarios, it is clear that a low carbon growth strategy will rely on the extensive tapping of the same. Hydropower projects have detrimental effects on the flora and fauna within the catchment area. The externalities must be accounted for by way of a Strategic Environment Assessment (SEA). The livelihoods of millions of people in the downstream nations of the Mekong depend on the ecosystems associated with the river. Any disturbance will also impact the poor adversely. Therefore, it is imperative that the GMS ECP provides special assistance to RPTCC with regard implementing social and environmental safeguards which are embedded in the SEA (MRC, 2010), while developing power projects. Significant capacity building is necessary at the country level as the existing environmental regulations in the GMS are weak.

As part of power sector development, there are other possible areas of intervention that could lead the GMS economies in low carbon development path without compromising economic growth. The GMS as a whole would be adding significant power generation capacity over the years and in their quest to reduce the carbon foot-print, they would inevitably pursue energy efficiency gains and renewable energy. The following section gives an overview of existing policies in these areas and discusses possible next steps in enhancing the current policies.

5.1. Energy efficiency

The GMS countries are in the varying stages of implementing policies directed at achieving energy efficiency. Thailand,

for example, has in place several mandatory requirements with regard to energy standards and labelling and has even made available a fund to incentivise the adoption of energy efficient technologies. Sharing national experience in energy efficiency, renewable and clean coal technologies, establishing regional best practices and technical standards would greatly help the spread of energy efficiency as a policy paradigm. The prominent barriers for the promotion policies targeting energy efficiency are (a) fossil fuel subsidies (specifically towards diesel, gasoline and LPG) (b) lack of awareness, information and experience in implementation, (c) absence of incentives to end users and producers of energy to adopt efficiency measures (ADB, 2009a).

Table 8 summarises some of the energy efficiency policies prevailing in the GMS and implementation status. Among these, standards and labelling as well as energy conservation programmes are being implemented to an extent than other measures such as financial incentives, building energy standards, and introducing energy service companies (ESCOs) in GMS.

Cambodia is in the process of developing an energy efficiency master plan. There is also a possibility for the promotion of ESCOs as private sector could play a significant role in the power distribution in Cambodia. In Lao PDR there are no formal energy efficiency policies in place. However the country is encouraging voluntary energy audits in buildings and industry. Awareness raising events are being conducted for energy efficient lighting for various stakeholders with the support from ASEAN Centre for Energy. In Myanmar, Ministry of Energy developed an Energy Policy and Strategy, under which it is trying to promote energy conservation in industry (ADB, 2009a).

Thailand is implementing energy efficiency policies successfully. The energy conservation fund (ENCON) in Thailand provides low-interest loans to the designated

Table 8: Energy efficiency policies in the GMS

Policy measure	Energy conservation programmes	Standards and Labelling	Building energy standards	Energy Audit	Financial incentives	Private sector participation (ESCOs)
Cambodia	A few	Planned	Voluntary	Voluntary	N.A.	Yes
PRC				Mandatory		
Guangxi	Yes	Yes	Mandatory	for certain categories	Available	Yes
Yunnan						
Lao PDR	A few	N.A.	Voluntary	Voluntary	N.A.	Yes
Myanmar	Yes	Planned	Voluntary	Voluntary	N.A.	Yes
Thailand	Yes	Partly mandatory	Partly mandatory	Partly mandatory	ENCON fund	Yes
Viet Nam	Yes	Planned	Mandatory for industries	Mandatory for industries	Available	Yes

Source: ADB (2009a).

factories, buildings, and ESCOs, under the specific criteria and conditions, to invest in energy efficiency projects. This fund is also called as revolving fund for energy conservation. Department of Alternative Energy Development and Efficiency (DEDE) is the lead agency responsible for its implementation (DEDE, 2008). Thailand is very successful in promoting ESCOs for energy conservation through performance based contracts. Apart from these, there is a Demand Side Management (DSM) program which integrates (a) energy standards and labelling program, (b) energy audit & load management, (c) incandescent lamps phase-out; and promotes energy efficiency in buildings (Oliver *et al.*, 2001; Nadel and Geller, 1996).

Viet Nam has a national programme for economical and efficient use of energy for 2006-2015. This programme aims to save about 5-8% of the total energy consumed during 2011-2015. Apart from awareness rising among stakeholder, it promotes industrial energy efficiency, efficient use of energy at household level, standards and labelling for certain household appliances and equipment, and energy efficiency in buildings (ADB, 2009a).

In the case of Yunnan and Guangxi, the national policies of PRC are applicable. PRC has a number of programmes for the promotion of energy efficiency at various levels. These would include renovation of boilers in existing power plants, waste heat recovery, energy efficiency in buildings, green lighting to name a few. Energy intensity is being monitored and reported at all levels (ADB, 2008c).

To summarise, three areas need immediate intervention to promote energy efficiency in GMS.

(a) Develop uniform energy standards and labelling for equipment and appliances across GMS. As exchange of goods and services is happening between the countries, such measures will benefit the end users and original equipment manufacturers across the region to compare the energy efficiency of different appliances and encourage promotion of efficient good and services.

(b) Promote the development of ESCOs and other private sector players that guarantee energy savings through performance based contracts.

(c) Promote information sharing and knowledge exchange between countries through dedicated institutions.

5.2. Promotion of Renewable Energy and Low-carbon Technologies

Apart from hydropower, there is a greater possibility for developing decentralised energy systems based on

other renewable energy sources especially solar energy and biomass. Much of the GMS lies in the tropics and is blessed with ample hours of sunshine in a year and can be exploited through concentrated solar power (CSP) or solar-PV technology. Barring Yunnan and Guangxi regions of PRC, the wind energy potential in GMS is limited. Even in the face of available resource, reliable grid connectivity will be an issue, going forward, for wind energy development in the region. Viet Nam is the only country in the GMS that is significantly endowed with geothermal energy resources, estimated to be about 200 – 400 MW of power capacity (ADB, 2008c). The cost of exploiting this is fairly high given current technologies and will present an option for the future, with the right incentive structure.

As in other countries, the options for incentivising renewable energy investments are many and varied. Feed-in tariffs (FIT), Renewable Portfolio Standards (RPS), Tradable White Certificates (TWC)/Tradable Green Certificates (TGC) and financial incentives such as investment tax credits, production tax credits, fixed government investment subsidy/grant, low interest loans and credits form the gamut of options. Most of the countries in GMS have set renewable energy targets considering the fraction of the resource that is deemed exploitable. For instance, Thailand has enacted policy to increase its national share of alternative energy to 20% of total energy supply by 2022.

Renewable energy law in PRC makes it obligatory for the utilities to purchase energy generated from renewable sources, at a price as dictated by the FIT. The National Development and Reform Commission (NDRC) will be responsible for implementing the law. In Thailand, a mix of FIT and RPS is being practiced along with few other policies such as net metering. Thailand introduced net metering in May 2002, which is recognised as Very Small Power Producer (VSPP) scheme. This encourages small-scale renewable energy generators (up to 10 MW) to connect to the grid and guarantees a prescribed price for the electricity supplied to the grid. In addition, there is a subsidy available in the form of “adder” which is over and above the retail price for a given type of renewable energy source for a fixed number of years. The new law creates income opportunities for rural communities based on locally produced, clean and renewable energy and offers significant potential to reduce country’s dependence on imported oil and coal (Greacen *et.al*, 2003).

Cambodia has established the Rural Electricity Fund (REF) in 2005 as part of the Rural Electrification and Transmission project funded jointly by the World Bank

and the ADB. Individual renewable energy projects are encouraged through the provision of a quarter of the total project investment cost in the form of an REF grant. In addition, there is a possibility to obtain concessional loans from private financing institutions, apart from being provided with an operating license from the Electricity Authority of Cambodia.

Table 9 summarises the existing policies for the promotion of renewable energy. Overall, FiTs seem to be the more preferred and successful policy measure for promoting grid connected renewable energy projects. Providing subsidies does increase the number of project proponents in the initial stages, which is necessary to build a critical mass and to create a market for the clean energy. Once the market has matured, sustaining subsidies would not be viable and must be left to the market forces to decide the fate of new and existing investments. Therefore, the option of providing subsidies must be exercised with caution keeping in mind stage of development of the renewable energy sector.

6. Conclusions

Many of the riparian states of the GMS, despite being endowed with a rich natural resource base, are languishing in energy poverty. The GMS is at present composed of countries that are net importers and net exporters of certain forms of energy. This offers a unique opportunity for concerted effort in developing their respective resource bases in an integrated manner to ensure more equitable economic and social development prospects for all the states. The exploitation of resources must however be carried out keeping in mind the fragile nature of the environment and the dependence of the livelihoods of millions of people who depend on it.

The total energy demands of the GMS countries are expected to grow two fold, compared to current levels, by the year 2025. Despite the penetration of commercial

energy sources, biomass and solid fuels will continue to play a significant role in meeting the energy demands of the rural population, throughout the analysis period. Myanmar shows increasing dependence on solid fuels, as the market for commercial fuels is not expected to penetrate, given the current policy framework. Electricity and oil (fuel in transportation) dominate the demand growth in the GMS, like in any developing area. Policies targeting the use and development of these resources are mandated for the countries in GMS. Natural gas provides an alternative to oil in the transportation sector, but much of the natural gas used in the region is also imported. It is then imperative that targeted policies be laid out for a low carbon, resilient growth pathways, to reduce the dependence on imported fuels.

It has been clearly established that there is immense potential for trading energy across borders, specifically electricity, provided there is a sustained effort to augment infrastructure that aids in the transfer. A large portion of the energy resources that the region is bestowed with, namely hydroelectric and other renewable resources have been left untapped. The reasons for this vary from lack of adoption of suitable technologies to insufficient coordination in efforts and sharing national experience in developing them. Hydropower can play a vital role in strengthening regional integration by enabling a more interconnected and resilient power supply amongst the GMS countries. Lao PDR was an early mover in this regard and realised the benefits of trading surplus power with their energy starved neighbour, Thailand. Myanmar and Cambodia have charted out similar a strategy to exploit their hydropower potential. With the growing awareness of the threat of global climate change, GMS countries have now found another strong justification to promote cooperation in the energy sector as regional environmental benefits may also result due to a more efficient use of energy resources, reducing overall need for energy production and thereby potentially reducing carbon emissions, and land use impact from energy-related activities. It is estimated that 238 GW of additional capacity is required to sustain

Table 9: Renewable energy policies in the GMS

Policy measure	FIT	RPS	TWC/TGC	Tax credits	Fixed government investment subsidy/grant	Low interest loans and credits	Net metering
Cambodia	N.A.	N.A.	N.A.	N.A.	Yes	Yes	N.A.
PRC				Partly			
Guangxi	Yes	N.A.	Voluntary	(depends on technology)	Yes	Yes	Yes
Yunnan							
Lao PDR	N.A.	N.A.	N.A.	N.A.	N.A.	Yes	N.A.
Myanmar	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Thailand	Yes	Yes	No	Yes	Yes	Yes	Yes
Viet Nam	Yes	N.A.	Voluntary	Yes	Yes	Yes	N.A.

Source: summarised from various sources including Romeo (2005). N.A - Information not available.

the growth of the region over the next 15 years (as per the GMS Integrated Growth scenario). This scenario was created under the assumptions that optimal production, consumption and trade of energy within the GMS region would be enforced by a robust policy framework.

Addressing the transport energy demand in GMS is a more complicated affair. Given the thriving agricultural sector in the region, biofuels present a feasible alternative but assessing the economy wide implications of such a move is beyond the scope of this paper. Establishing seamless rail-network connectivity and improving road infrastructure in the region would result in more cost effective solutions and result in a significant reduction in the demand for oil as a transportation fuel.

There are other regional power trade examples that serve as success stories for the GMS to emulate. For a start, the countries of GMS have recognised and demonstrated their understanding of the importance of regional cooperation in the energy sector. The existing framework of GMS ECP provides enough space for successful implementation of power trading to happen. Regional upgradation of power-grids and construction of cross border high tension transmission lines is in progress in different countries and provides a measured sense of optimism that the benefits from power trading will be realised sooner than later. It is essential that private sector plays a key role in the power sector at country level. An environment conducive for the emergence of the private sector can be created through transparent policies and simplified procedures that lay stress on preserving and augmenting social and environmental capital. Targeted policies are also needed to incentivise energy efficiency within the economy and to promote low carbon and renewable energy technologies that are resilient to shocks associated with global energy supply chains.

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GREENHOUSE GAS MITIGATION BY HYDROPOWER TRADING FROM MYANMAR TO THAILAND

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Abstract

This paper analyzes the carbon dioxide (CO₂) reduction and economic effects of hydropower development in Myanmar and its power trade with Thailand. These two neighboring countries differ in their energy profiles, particularly in energy sources and requirements. The Myanmar Government's energy policy is to fully exploit enormous hydropower potential and export energy to Thailand in order to increase its foreign earnings while helping Thailand with its power requirements that are becoming an important issue.

To determine the optimal mix of generation planning to meet anticipated electricity demand while fulfilling specified constraints for Thailand, the Wien Automatic System Planning version IV (WASP-IV) was used. The results show how joint resource development is beneficial for both Myanmar and Thailand, financially and environmentally. The study recommends solutions for the attainment of energy security in Thailand and proposes the least-cost effective generation expansion planning to improve the outcomes of hydropower resources trading between Myanmar and Thailand—seen as a win-win solution for both countries.

1. Introduction

Globally, more than half of electricity production is from fossil fuel (natural gas, coal and oil). Nowadays, the emissions from power plants have become a matter of concern, especially carbon dioxide (CO₂) emissions, which are associated with global climate change.

Myanmar and Thailand are neighbors but their energy profiles are quite different. Myanmar relies more on

renewable energy, especially mini hydropower plants with installed capacity 8.35 megawatts (MW), and has high hydropower potential (108,000 MW). In Thailand, the electricity sector is dominated by natural gas (70%) of which 77% is produced in Thailand and the rest is imported from Myanmar; the other 30% of Thailand's electricity is from lignite (20%), hydro power (7%), fuel oil (3%) and less than 1% biomass. In addition, according to the Greater Mekong Subregion (GMS) energy plan, the subregional power grid is to be fueled mainly by hydropower plants. There is concern in the GMS about the rapidly growing electricity demand in Thailand and that producing more electricity by fossil fuel should not be the sole solution. A CO₂ reduction program by power trading between Myanmar and Thailand is an attractive solution. In Myanmar, hydropower has huge potential, more than 108,000 MW. The proposed joint hydropower projects of Myanmar and Thailand can provide revenue for Myanmar and reduce CO₂ emission by Thailand. Moreover, construction of hydropower plants can provide many benefits for irrigation purposes and employment in Myanmar, which is an agricultural country. The outcome would be a win-win solution for both countries.

This paper investigates CO₂ reduction by power trading between Myanmar and Thailand for the planning horizon 2011–2025. Current CO₂ emissions from the various types of power plants in Thailand are calculated and the optimal mix of generation technologies for Thailand is evaluated in line with the country's demand and forecasted constraints.

Comparisons were made of projected CO₂ emissions by Thailand before and after trading power with Myanmar in terms of hydropower resources and the optimal mix of generation technologies using high and low fuel price scenarios.

The paper first discusses CO₂ and local air pollutant emissions of Thailand, then gives an overview of energy-economic indicators of Myanmar and Thailand, power trading, etc. Comparisons of different energy scenarios are next made from an economic and environmental view, followed by some conclusions and recommendations.

2. CO₂ and Local Air Pollutant Emissions of Thailand

In Thailand, emissions of energy-related CO₂ are expected to grow at an annual rate of 4.1%, from 158 million tons (Mt) in 2000 to 676 Mt in 2035. During this period, about 93%

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of total CO₂ emissions will be from the power, industry, and transport sectors. By 2035, 43% of CO₂ emissions will be from coal and 40% from oil. Without mitigation actions, CO₂ emissions in Thailand will increase fourfold between 2000 and 2035. Also, emission of sulfur dioxide (SO₂) may rise from 899 thousand tons (kt) to 5,604 kt and that of nitrogen oxides (NO_x) from 926 kt to 3,413 kt during the same period. In Thailand, energy security is a top national agenda item. In 2000, half the total primary energy demand was imported and this proportion is projected to reach 77% by 2035.

3. Overview of Energy-Economic Indicators of Myanmar and Thailand

Agriculture makes up about 40% of GDP in Myanmar but only 11 % in Thailand, while the service sectors are the reverse, 45% of GDP in Thailand and 12% in Myanmar (Table 1). Thailand's GDP per capita and energy use per capita are far higher than those in Myanmar. GDP in Thailand grew by a factor of 1.45 during 1992–2002 and this was expected to increase to 1.84 during 2003–2016 (Table 2).

4. Power Trading

Power Trading is characterized as “purchase of electricity for resale thereof.” It is a transaction where the price of power is changeable and options exist on trading partners and amounts. It concerns buying and selling electricity between various generators and the state electricity

boards, or other large customers, directly through bilateral contracts, from a central pool, or through intermediaries.

The two main types of power trading are bilateral and pool contracts. A bilateral contract is a direct contract between parties, with optional balancing markets. Generators prepare to dispatch contracted loads. In a pool contract, generators sell electricity into a “pool” and suppliers buy from this pool. Market participants trade in the pool against a defined set of rules. Another type of trading is known as multilateral open market, in which power is traded among three or more parties, agencies, or national governments. Power trade between Thailand and Myanmar is on a bilateral basis, based on long-term power purchase agreements and has promoted hydropower development in Myanmar.

5. Power Generation Expansion Planning Overview

In power system development, power expansion planning is essential. Nevertheless, the optimal power generation planning is not easy and requires selecting which, where, and when new generation units can be built over a long-range planning horizon to meet the expected energy demand. Several problems arise that make the planning difficult. First is the uncertainty of input data, such as forecasts of demand for electricity, economic and technical characteristics of new evolving generating technologies, construction lead times, and government regulations. Second, there are conflicting objectives: equal attention must be given to reduction of the system's cost, reliability, and minimization of environmental impacts. Another planning issue is the high uncertainty in fossil fuel prices and their increasing tendency.

In 2003, more than 50% of the world's electricity production was from fossil fuel sources. The high levels of emissions to the atmosphere have contributed to the adverse greenhouse gas effect. In the United States and Europe, policies have been integrated to reduce the amount of fossil fuel used for generating electricity in accordance with the Kyoto Protocol.

Table 1: Energy-Economic Indicators, 2007

Indicators	Myanmar	Thailand
Population in millions	57.5	65.4
GDP per capita (ppp current US\$)	462	4115
Structure of output (% of GDP)		
a) Agriculture	40.2	10.7
b) Services	11.7	44.7
Electricity use per capita (kWh)	110	1752
Energy use per capita (ktoe)	1084.46	1405.7

ktoe = thousand tons of oil equivalent, kWh = kilowatt hour, ppp = purchasing power parity.

Source: Data from the World Bank; Asian Development Bank; and Ministry of Agriculture and Irrigation. 2008. *Myanmar Agriculture at a Glance*. Myanmar.

Table 2: GDP and Power Demand of Thailand

Thailand	GDP Growth	Electricity Consumption on Growth	Ratio of GDP to Power Demand Growth
1992–2002	1.45 times	2.02 times	1.4
2003–2016	1.84 times	2.39 times	1.3

Source: EGAT's Power Development Plan 2003 and Electricity Demand Forecast Report, January 2004.

Renewable energy (wind, hydropower, solar, and geothermal) is relatively costly and limited in accessibility. However, to mitigate the global environmental damage and the risk of depending on only a few sources of energy, increasing interest in renewable energy sources should be promoted. The option to produce more electricity from nuclear sources is also being re-evaluated by some decision makers.

6. Generation Mix

Electrical power utilities generate power from various sources, such as nuclear power plants, coal powered plants, gas turbines, hydrodynamic plants, and wind turbines. Each source of electrical power has unique power generation costs and capacity, as well as other benefits and disadvantages. These various sources of power are connected to a common power utility grid that distributes electrical power to a large geographic area of residential and commercial energy users. The demand for electrical power from all users on the power grid is used to determine a total power demand from all power sources. The generation of electricity depends on several factors, including economy, availability and accessibility of resources, availability of foreign investment, load duration curve, quality, security, reliability, and lately, public acceptance. According to country environmental analyses by the Asian Development Bank, countries should promote a hydro and thermal generation mixture in the ratio of 40:60.

7. WASP-IV Dynamic Programming

The methodology used in the study was the Wien Automatic System Planning version IV (WASP-IV), which is the latest version by the International Atomic Energy Agency (IAEA) for electricity system planning. The main characteristics of WASP-IV are planning that considers

- constraints on environmental emissions, fuel usage, and energy generation;
- representation of pumped storage plants;
- fixed maintenance schedules;
- environmental emission calculations; and
- expanded dimensions.

WASP-IV is designed to find the optimal generation expansion policy for an electric utility system within user-specified constraints and which is also economically acceptable. It exploits probabilistic estimation of system

production costs, unserved energy cost, and reliability, using (i) a linear programming technique for examining optimal dispatch policy that is sensitive to exogenous constraints on environmental emissions, fuel availability, and electricity generation by some plants; and (ii) a dynamic technique of optimization for comparing the costs of alternative system expansion policies. In the modular structure of WASP-IV, the user is allowed to monitor intermediate results, avoiding large amounts of computer time due to input data errors.

8. Generating System Cost

Whenever a power plant is constructed, calculation of power generation cost must take into account both economic and environmental points of view. There are two types of cost in power generation technology (Figure 2): power generation costs, based on fixed and variable costs; and capital investment costs, which comprise fixed investment based on depreciation, return on investment, other fixed charges, etc. These costs are based in turn on the technologies utilized in specific sectors. For example, fuel cost is a consideration for thermal power plants but for not for hydropower plants.

9. Methodology

WASP-IV simulations were used to calculate production costs for a large number of potential future system configurations and to select the least-cost expansion plan. The planning period was 2011–2025. The detailed methodology is shown in Figure 3.

Objective functions are evaluated in terms of cost functions as in the following equation:

where:

$$B_j = \sum_{t=1}^T (\overline{I}_{j,t} - \overline{S}_{j,t} + \overline{F}_{j,t} + \overline{L}_{j,t} + \overline{M}_{j,t} + \overline{O}_{j,t})$$

B_j : the objective function attached to the expansion plan j ,

t : the time in years (1, 2, ..., T),

T : length of the study period (total number of years), and

I : capital investment costs

S : salvage value of investment costs

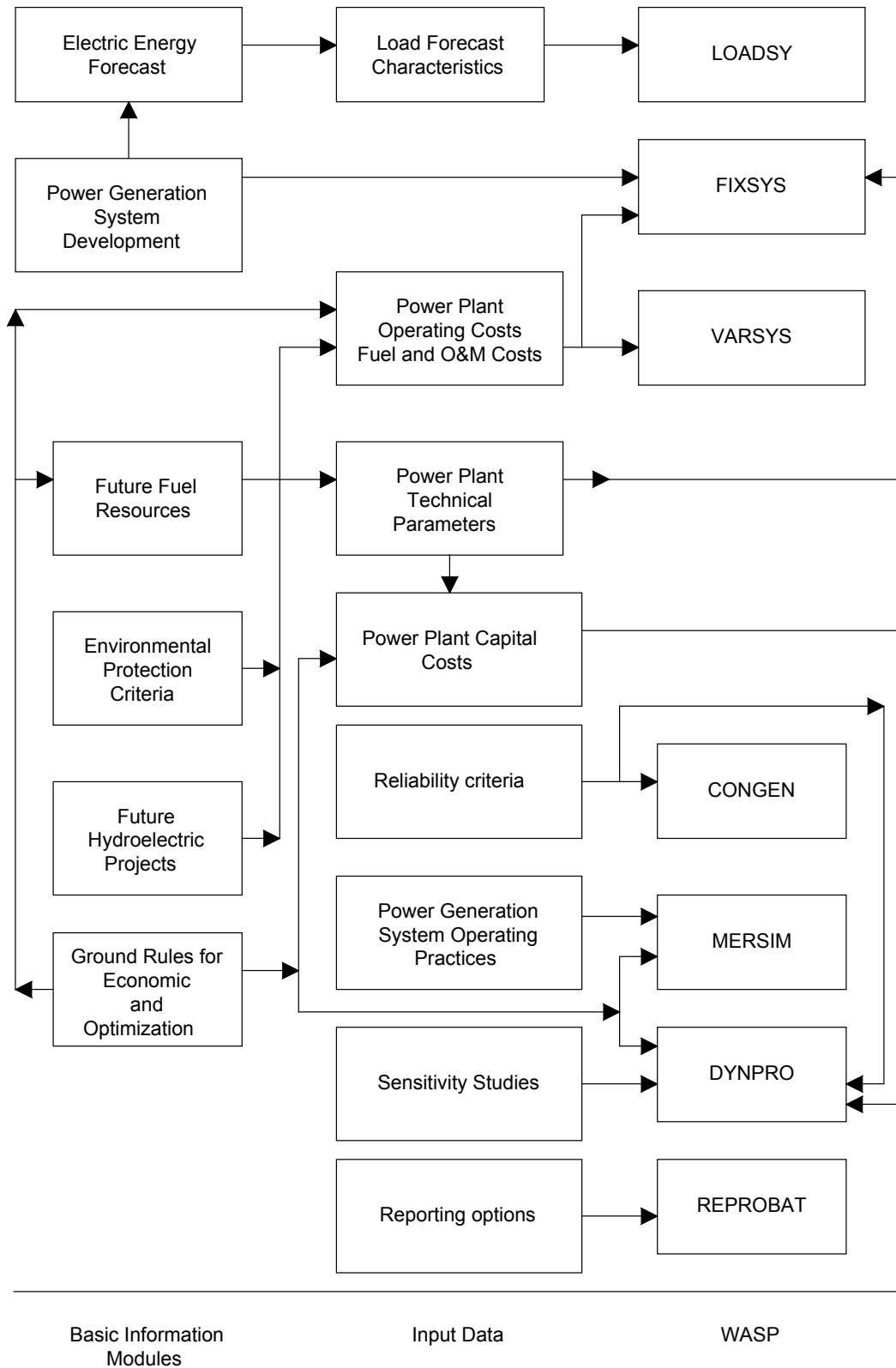
F : fuel costs

L : fuel inventory costs

M : non-fuel operation and maintenance costs

O : cost of the energy not served.

Figure 1: WASP Dynamic Programming Overview



Source: International Atomic Energy Agency (IAEA). 2006. *A Computer Code for Power Generation Expansion Planning, Version WASP-IV*. Vienna.

Figure 2: Cost of Power Generation

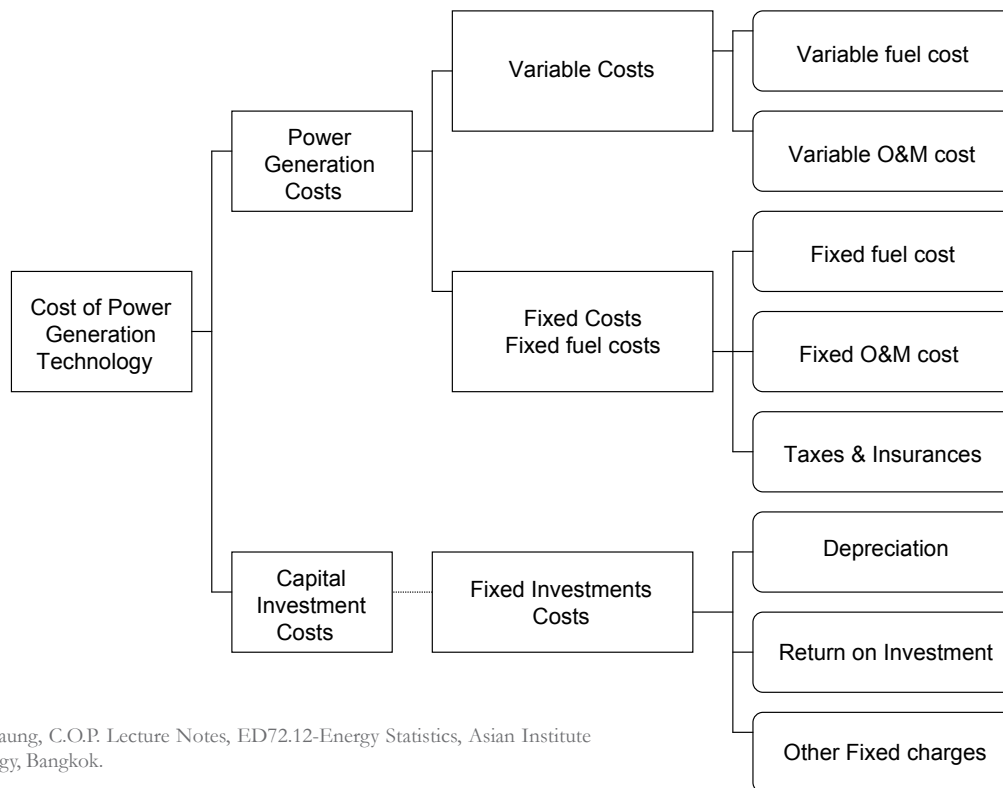


Figure 3: General Framework of the Research

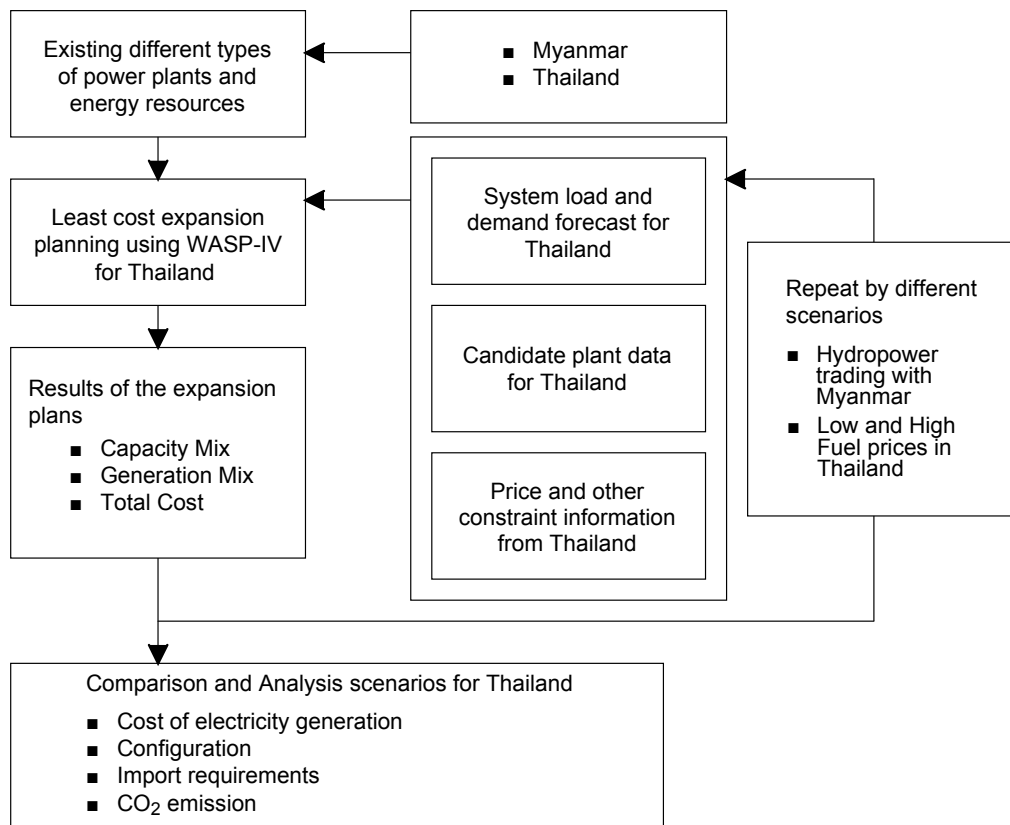
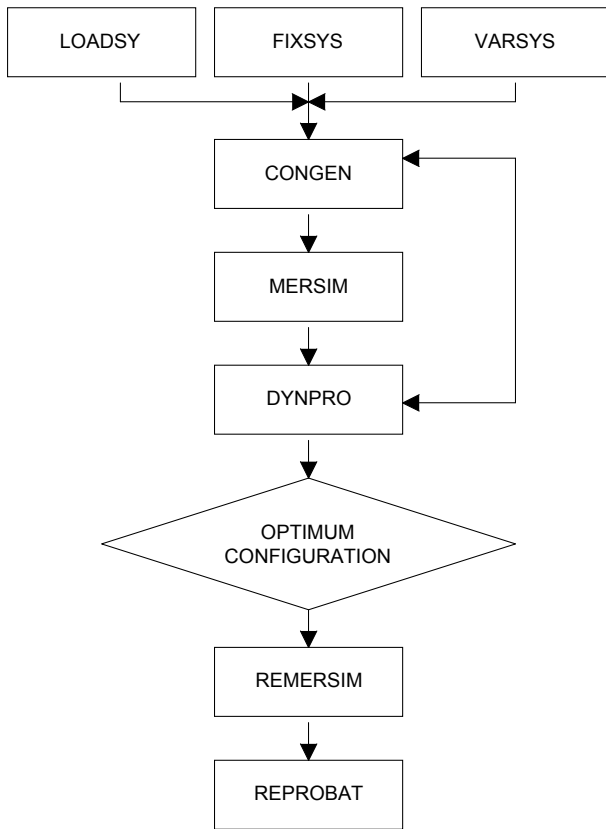


Figure 4: WASP Model General Flow Chart



Source: International Atomic Energy Agency (IAEA). 2006. *A Computer Code for Power Generation Expansion Planning, Version WASP-IV*. Vienna.

To derive the most practical solution for optimizing the power system, limitations on emission and fuel price were used in order to get reasonable outputs. Future demand was calculated based on the population growth rate and economic activities. Different types of fuel resources and other relevant economic issues were employed to select candidate plants.

9.1 Organization of WASP Modules

Figure 4 describes a WASP-IV basic flow chart, which exemplifies the information flow among the various WASP-IV modules, namely LOADSY (Load System Description), FIXSYS (Fixed System Description), VARSYS (Variable System Description), CONGEN (Configuration Generator), MERSIM (Merge and Simulate), DYNPRO (Dynamic Programming Optimization), and REPROBAT (Report Writer of WASP in a Batched Environment).

Module 1: especially used for peak loads annually and periodically, and load duration curves during the study period.

Module 2: processes information about existing systems by considering additions and retirements of power plants during the study period and associated environmental emissions, availability of fuel, and electricity generation capacity. The inputs required for this module are the name, maximum capacity, minimum capacity, fuel type used in specific power plants, heat rates, maintenance days, forced outage rates, and fixed and variable operation and maintenance (O&M) costs.

Module 3: describes the characteristics of the various candidate power generating plants for future power systems.

Module 4: calculates, on a year-to-year basis, possible combinations of expansion candidate additions through iteration to get the best solution. Essential inputs are reserve margin, maximum LOLP and final combined output from FIXYS, LOADSY, and VARSYS.

Module 5: uses the results from the above four modules to merge the existing system with candidate plants that were established and then makes suitable stimulations.

Module 6: evaluates the results according to resultant operating costs. The inputs needed are the capital investment costs of candidate power plants, how much should be assigned as escalation rate and the cost of energy not served, and the discount and interest rate during construction. Probabilistic simulation of the system is used to estimate the associated production. The final outcome provides the best combination of plants to supplement the existing generation system.

Module 7: gives the final result that best meets the objectives.

9.2 Planning Horizon and Candidate Power Plants

CO₂ emission and uncertainties in fuel cost (high/low fuel price) were considered for 2011-2025 to get the most feasible, optimal energy solution for Thailand. For the VARSYS WASP- IV module, the candidate power plants were characterized (Table 3). In the list of the candidate power plants, no additional hydro projects are included because they generate public opposition in Thailand.

Table 3: Characteristics of Candidate Power Plants for Future Expansion

WASP Name	V-CC	V-TH	V-GT	VIGC	VNUC
Fuel	Natural Gas	Imported Coal	Diesel Oil	Imported Coal	Imported Uranium
Capacity (MW)	700	700	220	500	1,000
Heat Rate (BTU/KWh)	7,000	9,260	10,995	7,346	9,208
Maintenance (days/year)	28	42	14	28	42
Fixed O&M cost (US\$/KW-month)	1.49	2.12	0.87	1.27	2.5
Variable O&M (US\$/MWh)	0.6	1.04	0.4	0.73	0.5
Capital Cost (US\$/MWh)	545.6	941.9	545.6	1,420	1,020

BTU = British thermal unit, KW = kilowatt, KWh = kilowatt hour, MW = megawatt, O&M = operation and maintenance, V-CC = Combined cycle, V-TH = Thermal, V-GT = Gas Turbine, VIGC = Integrated Gasification Combined Cycle, VNUC = Nuclear.

Source: Electricity Generating Authority of Thailand (EGAT). 2007. *Thailand Power Development Plan*. Bangkok.

Table 4: Electricity Demand Forecast

Year	2011	2013	2015	2017	2019	2021	2023	2025
Peak Demand (MW)	28,124	31,569	35,467	39,816	44,336	49,213	54,565	60,2500

MW = megawatt.

Source: Thailand Load Forecast Sub-Committee (2007) and authors' assumptions.

9.3 Input Data for LOADSY Module in WASP-IV

The Thailand Load Forecast Sub-Committee (TLFS) has projected the demand for Thailand up to 2012. Demand is expected to increase continuously up to 2025.

10. Hydropower Trading with Myanmar

The governments of Myanmar and Thailand have a Memorandum of Understanding for a power purchasing program. For hydropower trading, there are two main projects: Hutgyi hydropower project with capacity (for trading) of 1,360 MW which will be connected to Thailand at Tha Song Yang district, Tak Province; and Tasang hydropower project, which is expected to connect to Thailand at Mae Eye district, Chiang Mai Province. As the Tasang project has not yet started, this simulation provides the least-cost generation expansion planning for Thailand in terms of hydropower trading based on the Hutgyi project, which will begin operation in 2014. (The total capacity of the Hutgyi project is 3,000 MW of which 1,360 MW would be exported to Thailand).

11. Changes in Fuel Price

Fuel costs play an important role in creating uncertainty. Thus, both low and high fuel prices were used for sensitivity studies. Table 5 summarizes possible fuel price conditions to reflect the situation in the international fuel market.

12. Results

12.1 The Base Case

Thailand's mainly fossil-fuel based power system was taken as the base case. Other sources—nuclear power plants, gas-fired combined cycle power plants, coal-fired power plants, and diesel-based gas turbine power plants—were then considered in order to determine the optimal mix for generation planning in Thailand. Hydropower trading with Myanmar was not considered. Based on configurations and capacities of the various sources, the capacity and energy mix for an expansion plan were then calculated as shown in Figure 5 and Table 6. Hydropower capacity is constant because no more local hydropower

Table 5: Assumptions of Fuel Prices (constant 2011 price)

Fuel Type	Baseline Price (US\$/ million BTU)	Low Price (US\$/million BTU)	High Price (US\$/million BTU)
Natural Gas (Domestic)	6.63	5.42	8.30
Natural Gas (Foreign)(Import)	6.63	5.42	8.30
Lignite	1.55	1.55	1.55
Imported Coal	2.41	2.41	2.41
Fuel Oil	8.82	7.22	11.73
Diesel Oil	16.63	13.61	22.01
Nuclear	0.74	0.74	0.74

Source: Electricity Generating Authority of Thailand data and author's estimates.

projects are planned during the period. Hydropower trading with Lao People's Democratic Republic (Lao PDR) with a capacity of 1,857 MW, storage capacity of 17,894 gigawatt hours (GWh), and inflow energy of 16,267 GWh was included. Starting in 2011, hydropower trading with Lao PDR was considered to be the most feasible optimum solution for power generation expansion for Thailand. In view of the need to minimize greenhouse gas emissions, it is recommended that the load curve providing least CO₂ emission in the country be used in evaluating the optimal mix of power generation.

12.2 Alternative Case

For the case of hydropower trading from Myanmar to Thailand, the proposed 1,360 MW capacity from the Hutgyi Hydropower project from the beginning of its operation in 2014 was used in the model. The capacity and energy mix for an expansion plan were then calculated. Results are shown in Figure 6 and Table 7.

Table 6: Base Case: Expected Generation by Plant Type (GWh)

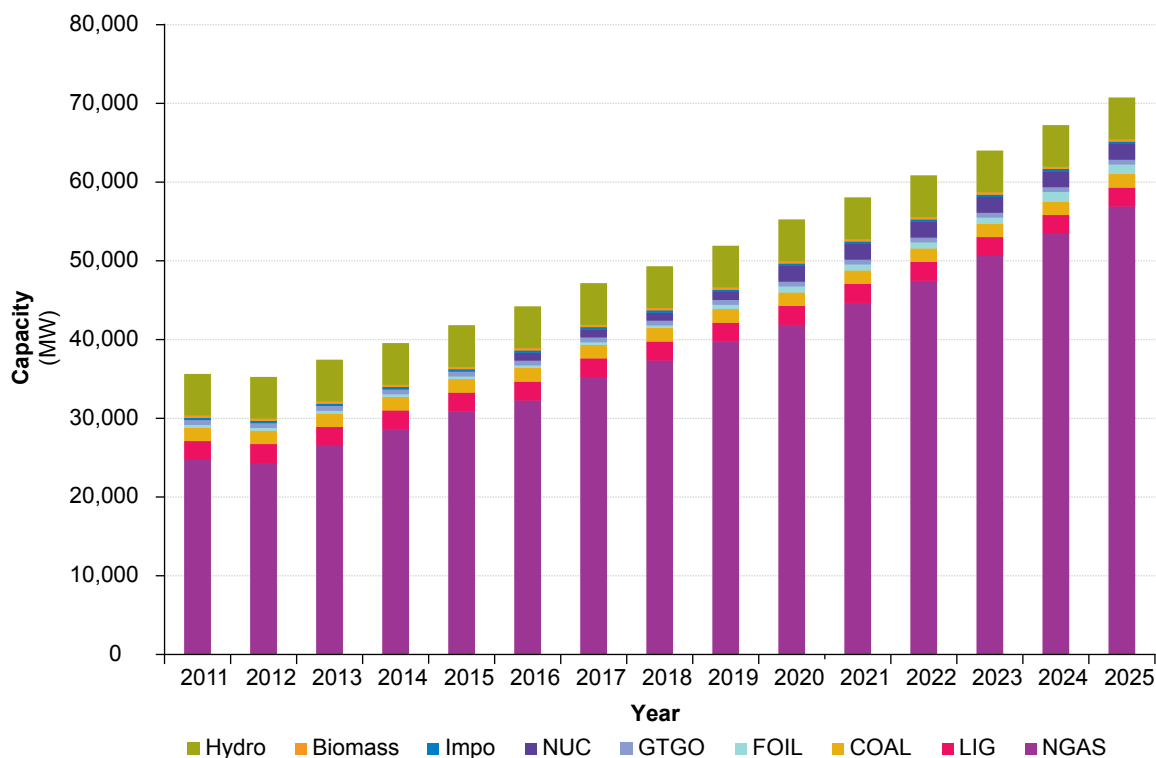
Year	2011	2013	2015	2017	2019	2021	2023	2025
Thermal	133,510	154,634	178,536	205,204	232,920	262,825	295,643	332,035
Hydro	36,911	36,911	36,911	36,911	36,911	36,911	36,911	36,911
Other	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032
Total Energy	172,452	193,577	217,479	244,146	271,862	301,768	334,585	370,978

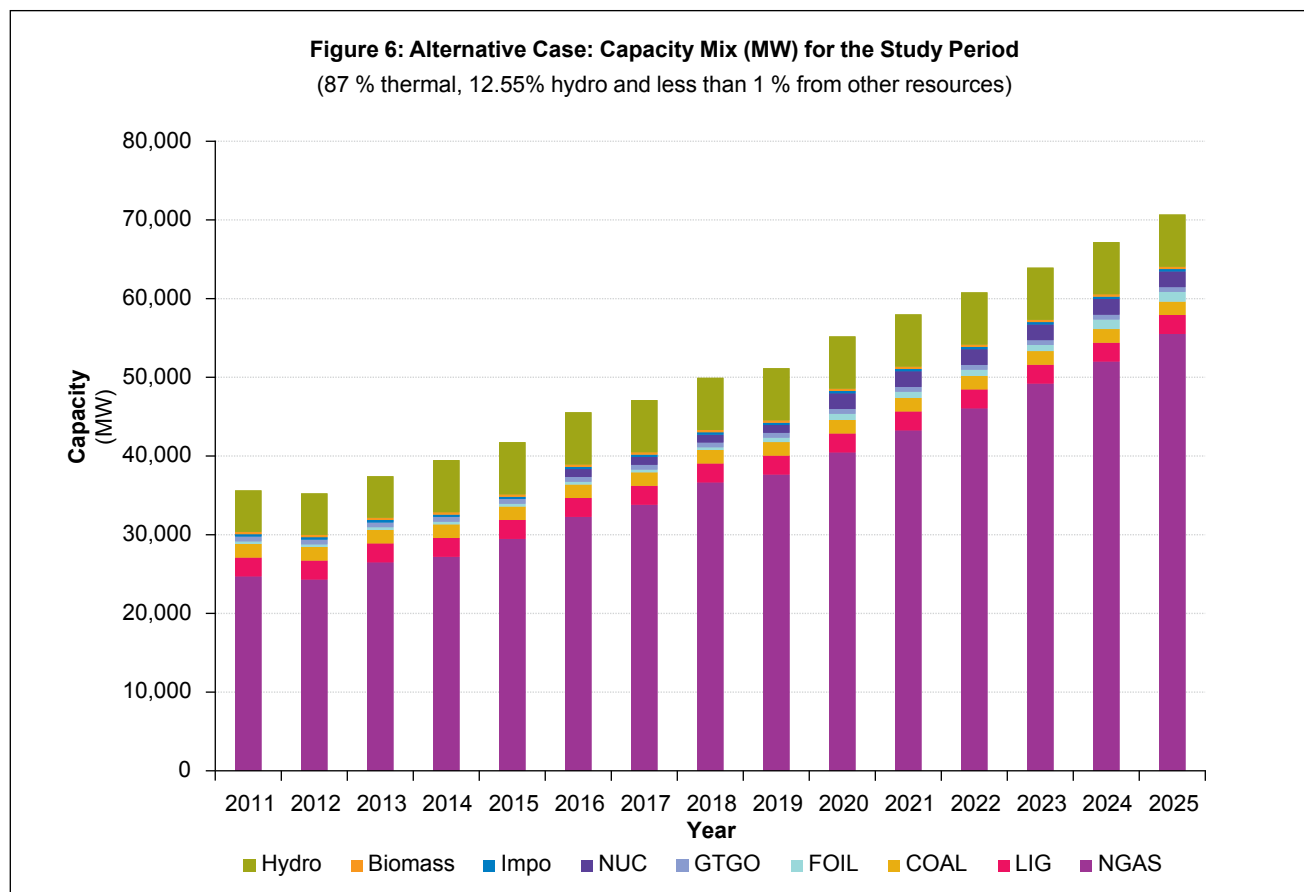
Table 7: Alternative Case: Expected Generation by Plant Type (GWh)

Year	2011	2013	2015	2017	2019	2021	2023	2025
Thermal	133,510	154,634	169,004	195,672	223,388	253,293	286,111	322,504
Hydro	36,910	36,910	46,442	46,442	46,442	46,442	46,442	46,442
Other	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032
Total Energy	172,453	193,577	217,479	244,147	271,863	301,768	334,586	370,980

Figure 5: Base Case: Capacity Mix (MW) for the Study Period

(89 % thermal, 10% hydro and less than 1 % from other resources)





According to the capacity and energy mix of the base and hydropower trading case, it is concluded that natural gas will remain the main source of electricity generation in Thailand during the planning period.

- 57 x 700 MW gas-fired combine cycle plants,
- 4 x 220 MW diesel based gas turbine power plants, and
- 2 x 1000 MW nuclear power plants.

12.3 Simulation Results

In line with the results of the REPROBAT module of WASP-IV, the schedule for addition of new capacities with least-cost generation for Thailand was determined. More than 500 configurations for capacity were considered in covering the study time horizon (2011–2025). The reserve margin used for the planning horizon was between 15% and 25%.

The simulation results suggest that by 2025, without hydropower trading with Myanmar, the optimal mix of these new capacities for Thailand would comprise

- 59 x 700 MW gas-fired combine cycle plants,
- 4 x 220 MW diesel based gas turbine power plants, and
- 2 x 1,000 MW nuclear power plants.

When hydropower trading is included, the optimal mix would comprise

The lowest greenhouse gas emissions and the least-cost generation expansions resulted from the scenarios in which power generation is highly dominated by natural gas. Continued reliance on natural gas for power supply makes the supply mix non-diversified and forces the country to face risks, while a diversification to other fossil fuels would entail an additional environmental burden.

Thailand will not undertake further local hydropower construction due to public opposition although other renewable energy sources could provide cleaner solutions for power sectors. Presently, some of Thailand's electricity capacity is based on renewable energy through its Small Producers Programme. However, this study only considers supply security and environmental impact of bulk electricity supply. It does not consider production of power from these other types of renewable resources. The study concludes that the most viable way for Thailand to reduce CO₂ emissions is to use more hydropower through trading with other countries.

13. Comparative Scenarios of Environmental and Economic Benefits to Thailand and Myanmar

13.1 Environmental Benefits to Thailand

CO₂ emission from the Thailand power sector would be reduced by adopting hydropower trading with Myanmar in 2014. For the base case, total CO₂ emission for the whole study period is 692 million tons and for the alternative case 671 million tons. CO₂ emission reduction and cost saving between base and alternative case during the period are shown in tables 8 and 9, respectively, and the costs and savings using alternative low and high fuel prices are shown in tables 10 and 11, respectively.

All values are discounted to the 2011 base year. The results show total savings for Thailand by hydropower trading with Myanmar for the whole planning period of US\$1.02 billion in both the normal and low fuel price scenarios and US\$1.13 billion in the high fuel price scenario. The opportunity cost of CO₂ is very attractive from the economical point of view but barriers exist for hydropower projects, such as high capital investment cost. In the following section, the economic and environmental benefits for the two countries are considered.

13.2 Economic Benefits to Thailand

The cost function in WASP-IV shows how various constraints can be met by each possible sequence of power units that are added to the existing system. Costs of fuel, operation and maintenance costs, capital cost, and salvage value costs are taken into consideration in this cost minimization function. All economic and technological benefits shown in tables 9-11 of each alternative generation expansion in WASP-IV are balanced and weighted against present costs.

13.3 Environmental Benefits to Myanmar

The potential benefits for Myanmar from an environmental perspective are:

- Water supply and flood control can be manipulated in the region.
- The water from the dams can be used for irrigation.
- Job opportunities are created in rural areas, improving rural development in those areas.
- Hydro-electricity does not emit greenhouse gases or other atmospheric pollutant, unlike most other types of power plants.
- Hydropower is produced by water, which is a clean fuel source.

Table 8: Comparison of Annual CO₂ Emission during the Planning Period (million ton of CO₂)

Year	2011	2015	2020	2025	Total
Base Case	30.344	38.679	50.177	65.802	692.667
Alternative Case	30.344	36.915	48.412	64.037	671.533
Difference	0	1.765	1.765	1.765	21.135

Table 9: Cost Comparison between Base case and Alternative Case (million US\$)

Year	2011	2015	2020	2025	Total
Base Case	7,598.92	3,302.41	2,070.50	633.32	34,837.25
Alternative Case	7,598.91	3,298.43	1,875.12	631.78	33,810.51
Saving	0	3.972	195.38	1.53	1,026.74

Table 10: Cost Comparison between Base case and Alternative Case (Low Fuel Price, million US\$)

Year	2011	2015	2020	2025	Total
Base Case	5,053.80	3,302.41	2,108.91	657.17	34,620.79
Alternative Case	5,053.80	3,298.43	1,900.53	655.64	33,600.03
Saving	0	3.97	195.38	1.53	1,020.76

Table 11: Cost Comparison between Base case and Alternative Case (High Fuel Price, million US\$)

Year	2011	2015	2020	2025	Total
Base Case	6,765.81	3,302.41	2,108.91	657.17	36,332.86
Alternative Case	6,667.19	3,298.43	1,913.53	655.64	35,200.49
Saving	98.62	3.97	195.38	1.53	1,132.37

According to the speech of the Energy Minister in Thailand on 15 February 2010 (National News Bureau of Thailand), the Hutgyi Project has been subjected to environmental impact assessment (EIA) and implementation of recommendations in the EIA would remedy possible construction impacts on the local residents and any violations of human rights.

13.4 Economic Benefits to Myanmar

According to the contract between the Thailand and Myanmar governments, the economic benefits for Myanmar are:

- 1) Free energy for Myanmar
7.5 % (first 5 years)
12.5% (during the following 25 years)
- 2) Tax exemption for first 5 years
- 3) Withholding tax exemption during the contribution period
- 4) Internal rate of return (IRR) on projects of 10.04%
- 5) IRR on equity, 14%

The equivalent results in monetary value (US\$ million) are:

• Free energy	1,206
• Commercial tax	622
• Withholding tax on contracts	0
• Withholding tax on interest	106
• Income tax (project)	81
• Income tax (salaries)	20
• Value of free shareholder	189
• Profit sharing	407

The total benefit to Myanmar over the period is US\$2.67 billion. Thus, both countries could get enormous financial benefits from this hydropower project.

14. Conclusions

The study has examined, for present and candidate power plants in Thailand, various scenarios for an optimum power expansion plan. For the base case, during the study period, the optimum energy capacity mix would be 89% thermal MW, 10% hydropower MW, and less than 1% from other resources; while for the alternative case, it would be 87%, 13%, and less than 1%, respectively. In the base case, hydropower capacity remains unchanged, while for the alternative case, hydropower capacity increases in 2014, when hydropower trading with Myanmar would begin. As a result, thermal capacity decreases from 89% to 87%. This 2% saving in thermal energy is very attractive for the world at present in view of global warming.

In value terms, the US\$1.02 billion–\$1.13 billion, depending on the future price of fossil fuels, that could be saved by Thailand through power hydropower trading with Myanmar is also very attractive, both in satisfying the country's energy demand and in keeping the environment cleaner—21 million tons of greenhouse gas CO₂ would be saved. In Thailand, the government views access to hydropower as an important issue because use of fossil fuels has been opposed due to environmental concerns; it is necessary to diversify the fuels used in power generation; and while nuclear power projects are within Thai national plans, their use still faces some constraints.

In Myanmar, insufficient power supply is the main problem in development. This situation can be overcome by developing hydropower and selling part of the capacity to Thailand.

This kind of study could be extended to other GMS countries, especially Yunnan Province of People's Republic of China, Lao PDR, and Cambodia, which are rich in potential hydropower, to determine the economic and environmental implications for Thailand and those countries. Moreover, comparison of those cases with hydropower trading between Myanmar and Thailand would reveal the hydropower trading scenario that would provide optimal regional environmental and economic solutions. Those results could lead to the evaluation of win-win solutions among all the countries in terms of energy security, economics, and environmental protection, by using the high potential for hydropower trading in the GMS. This could lead in turn to new investments in hydropower projects in those countries.

The largest hydropower resources in the GMS are in Myanmar, Lao PDR, and also in Viet Nam. Thailand has limited mineral and hydropower resources. Cambodia has diverse resources including hydropower and natural gas but is yet to fully exploit them. Hydropower resources are among the best energy options for the GMS power market. The power market should therefore promote hydropower development in the GMS to help optimize investments in power reserves to meet peak demand, reduce greenhouse gas emission and pollutants, and increase consumer access to the cheapest power sources available.

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Panel discussion – Day 1
Scaling economic development and environmental challenges

Facilitator: Dr Nessim Ahmad, ADB

PANEL DISCUSSION – DAY 1

SCALING ECONOMIC DEVELOPMENT AND ENVIRONMENTAL CHALLENGES

Facilitator: *Dr Nessim Ahmad, ADB*

Panelists

H.E. Dr Parisak, H.E. Mr Ros Seilava,

Dr Daovong Phonekeo, Mr Tang Shengyao,

Mr Arjun Thapan, Dr Jeff McNeely, Dr Duong Duc Ung,

Dr Kyoko Kusabe, Dr Mark Rosegrant

Nessim Ahmad: Good morning Ladies and Gentlemen. We are now ready to have our panel discussion on scaling economic development and environmental challenges. I guess that could be reconciling economic development and environmental challenges. The purpose of this panel is to look at the last decade of growth in the GMS and take stock of lessons learned. We are particularly interested to reflect on how we can, indeed, reconcile future growth with environmental sustainability in the context of the food-water-energy nexus. This topic is, of course, important in implementing the GMS Strategic Framework to 2022. But, as mentioned by Vice President Groff this morning, it is a topic that preoccupies the entire world, particularly as we move toward the United Nations Conference on Sustainable Development or Rio+20, which will be taking place in June this year.

This morning we have been fortunate to benefit from a broad spectrum of excellent presentations from internationally renowned speakers on environment, water, food, energy. We have heard that the GMS has seen substantial gains and growth, poverty reduction, and human development over the last decade and whether these gains could be under threat and how future growth needs to be much more environmentally sustainable and inclusive. Jeff McNeely gave us a compelling overview of the ecosystems and biodiversity resources that have underpinned development in the GMS, how these have suffered over the last decade, and how to ensure that ecosystem services, natural capital or natural infrastructure as he calls it, are properly factored into the economic growth equation. Arjun Thapan provided a thoughtful, thought-provoking look at water resource management and the inevitable difficulties that will be faced moving forward; he emphasized the need for rational allocation of water resources, true value pricing, technology adoption, and tough legal and administrative frameworks.

Peter Warr shared with us his analysis of growth and poverty reduction in the GMS and his view on how poverty reduction may increase in the coming decade as a result of structural changes away from agriculture and industry to the service sectors. Mark Rosegrant presented an outlook on water and food security in the GMS to 2030/50, which suggests the need for proactive policies and investments in the face of climate change, higher energy prices, and growing water scarcity. Peter Rogers shared his views on the role of urbanization in the GMS and how this will influence the water and energy demands, with a need to search for greater efficiencies in water and energy use. We have been reminded by Kyoko Kusakabe how gender issues need to be better integrated in development strategies and specifically in the context of cross-border transport development. And finally we had an excellent keynote address on the dynamics of economic growth in the GMS, both retrospective and prospective, delivered by Ms Ladawan Kumpa.

So I think we have a rich basis to reflect on what are some of the key pointers for the next few days of discussion and, of course, for this panel. Now before opening the floor for questions or comments or suggestions to the panelists, I would like to give the opportunity to the country representatives to provide a couple of reactions to what they have heard in the context of their own country's experience, and essentially ground-truthing some of what has been said earlier today.

Ros Seilava, Cambodia: Thank you very much Mr Chair. First, let me thank ADB for the invitation to this very important event. Although I am from the Ministry of Economy and Finance, I find it very useful because I think the way forward for development is a comprehensive not a fragmented, sectoral approach. So that is why I am attending this event. Let me briefly give my feedback on this morning's session. I find the message from all the speakers quite positive, although they highlight the key challenges that we need to deal with properly. We have heard clearly that our success over the past decade with consistently high growth has put a lot of pressure on the natural resources and the environment. The next decade is our challenge; how to address the issues properly. However, quite a number of ideas have been offered to us today; we not only have to fight these challenges head-on but as I put it, it is in the nature of human society going through a crisis that there will be adjustments resulting from the very complex interaction between human development and nature.

In terms of economic growth, I think there is intraregional development going on. Here, in the subregion, we see an important trend in terms of integration; we have the ASEAN connectivity and the GMS economic corridors. These can be seen as second-generation efforts in terms of integration or the evolving development of a production network. What is the implication on future development in the region? Definitely, we need to take care of the environment carefully but in terms of development, I think, there will be a shift from heavy use of resource-based production and industry to broader-based economic growth. Referring to the projections by Peter Warr, the service sector share of the GDP is going to increase, which will take pressure from natural resources.

Let me just briefly talk about the challenges. Cambodia takes the issue of food, water, and energy very seriously. We are one of the rice exporting countries and rice consumes a lot of water. Recently, we issued the Rice Policy, which expects to export 1 million tons by 2015. We have a very ambitious target. My message here is that the Government of Cambodia takes climate change or environmental impacts very seriously. We are now implementing a policy that moves towards rice commercialization but with climate resilience. The study is on-going with discussions and dialogue. On urbanization, key important issues that Cambodia has been experiencing are with regard to the development of the garment industry. We started with a very small industry, which has now grown huge; this has a big impact on urbanization. Over the next decade, Cambodia will move toward industrialization and urban planning will be one of the challenges that will need serious attention. I am sure that we also need to take care of gender issues; we have to think about how to get the community engaged so that we can address the issues more effectively than just to rely on experts. I would like to close by saying that this is a very important agenda, not only for the region but globally; the G20 is taking this issue very seriously and they have commissioned a study and discussion on how to stabilize commodity prices and address food security and energy issues. Thank you very much.

Tang Shengyao, People's Republic of China (PRC): Let me first thank ADB for the invitation to this Conference. I find this event important and very informative. Personally, I have learned a lot from the presentations, in particular, about the connection between food, water, and energy. This food-water-energy nexus has been the concern of many people and also the governments around the world. It is also the case for the Chinese government. You may understand the Chinese experience has been a successful

and good story. But, we do have experience and lessons in terms of agricultural production; we have successfully solved the problem of food security with our own effort using less than 9% of the world's arable land to feed about 21% of the world's population. For eight consecutive years, Chinese agricultural production has had good harvests, increasing year on year. For more than six years, grain production has surpassed 500 million tons; that is almost one quarter of the world's cereal production.

Although it has been successful, personally speaking, the PRC does have some lessons. For example, we face resource constraints: land and water. In terms of water availability, the freshwater availability per capita is only one quarter of the world's average; and the land availability per capita is just one mu (one fifth of a hectare). You can imagine with that land, we have to feed 1.34 billion people now. It is a very, very difficult challenge. We also have problem of land degradation due to frequent and heavy use of fertilizers and chemicals. Every year we have millions of hectares of land lost to non-farm use, for example industrial and other uses. And recently, we have more frequent natural disasters. I don't know if it is due to climate change or not; but it seems we face more every year. Many years ago, the Chinese Government realized the importance of sustainable development; and five years ago, adopted a policy of harmonious development of human beings and nature. I think the core is a sustainable environment. Now we say we have to change the development modality; and five years ago, we stressed development and protection and the importance of economic growth. Now we say, economic development but with quantity and quality. We want to improve the structure of economy, education, health care, rural infrastructure for farmers, and the countryside. I think the GMS 2020 Conference is in line with what the Chinese government is doing. Thank you ADB again for this opportunity and all presenters who have done a wonderful job for us. Thank you very much.

Daovong Phonekeo, Lao PDR: Thank you very much for giving me this opportunity to say a few words about this Conference. As the previous panelist mentioned, this Conference is very important and informative and for our country, it is relevant. The Lao PDR is in a unique position that it can export electricity to neighboring countries. As you know, there is high demand for electricity; so for us, the development of hydropower is crucial and we have started with this policy for some time now to earn revenue and sustain the economy. In terms of development, hydropower is the main attraction for foreign direct investment (FDI) in the Lao PDR so far. With the assistance of ADB, we could

realize the very first successful IPP¹ project, the Theun Hinboun Project, which is a good platform to show the international community that the IPP in Lao PDR is viable.

The Government's policy is to reduce poverty by 2020; this means we have to increase investments in poverty reduction and these investments could benefit from hydropower development, as we have seen with the Nam Theun 2 hydropower development with the assistance of the World Bank, ADB, and the private sector. So the next step for us is the continuation of the development of hydropower. In order to do that, we need good governance and natural resources. For good governance, from our standpoint, we would need capital, good knowledge, and increased capacity building for our country. I believe that in order to maximize the value of natural resources, especially water, we can put in improved technology like re-using the water through cascade hydropower plants, whereby the same water can be used several times and produces more value. It is in our interest to conserve water by sustainable water management as water is our life. Thank you very much.

Duong Duc Ung, Viet Nam: I would like to thank all presenters and speakers for the interesting and comprehensive presentations in this Conference on “Balancing Growth and Environmental Sustainability.” I would like to share my views on the Vietnamese case. As with other countries in the GMS, Viet Nam has in the past decade made big socioeconomic progress. But at the same time, Viet Nam is facing a number of challenges; one of them is the consequence of climate change. If there is a rise in sea level by 1 meter, 105 of the population will be affected; we will lose 10% of GDP; and we will lose land (territory). It will not happen in the immediate future but may happen by 2100; however, we are already feeling some of its effects now. That is why Viet Nam is very interested in quality and quantity of water of the international river.

My message is: I would like to see the countries of the GMS move to a legal framework for the utilization of water, to ensure quality and quantity for countries located downstream. This is particularly important for Viet Nam, as the country is agricultural and 70% of its population is living in rural areas and poverty is concentrated in this area. A large portion of the population depends on agricultural production. Viet Nam has already ensured food security for its people and we also contribute to the food security of the world. Last year, we exported 7 million tons of rice.

The Government adopted a National Target Program for Climate Change and we are integrating this program into the process of restructuring our economy, including market system, public investments, and services. We are moving to a modern economy based on human resources with less capital intensity. We believe that in framework of the GMS economic cooperation and the Mekong Committee, all the subregional countries could share benefits of utilization and exploitation of the rivers in the common interest of the subregion and development of the countries. Thank you.

Nessim Ahmad: We will now open the floor for any comments and suggestions. If you have questions, please direct them specifically to the panelists.

Geoffrey Blate, WWF: I would like to thank all presenters for their excellent presentations, which will help frame the discussion and challenges over the next couple of days. I would like to make a couple of comments to support some of the points that were made so far. The main point is that the GMS truly is at a crossroads, as the presenters this morning conveyed to us. I think there is a sense of urgency in terms of the water challenges, energy challenges, and the biodiversity challenges that we face.

Firstly, the GMS is still, despite all the degradation, one of the most biologically diverse regions on the planet, a truly biologically diverse hotspot. That biodiversity underscores or contributes to the subregion's incredible productivity. Especially in a climate change future, maintaining that diversity is an important risk management strategy; and one that leads to increasing resilience and increasing competitiveness compared to the rest of the region, where we have seen an incredible degradation of the natural environment. And, therefore, productivity is extremely challenging in those other places. I would also like to say that Rio+20 presents an incredible opportunity for this subregion to shift from the current ‘business as usual’ development pathway to really a ‘green growth’, green economy transition. All of the countries in this subregion have either already adopted green growth, green economy policies or national plans or they are in the process of doing so. Moreover, there is hardly any other region in the world that has an economic cooperation program integrated across all of the important economic sectors, with a commitment to actually mainstream environmental considerations across those. Hardly any other region in the world has anything like that. So there is quite a lot to be proud of and to showcase at Rio. All that is necessary is for countries represented in this room, with the support

¹ Independent Power Producer

of development partners, ADB, and others, to articulate a clear, green economy vision and a roadmap to actually achieve that vision. There will be a platform in Rio to secure investments to achieve that vision.

WWF is supportive of this idea. Back in December 2011, the Government of Viet Nam hosted a regional workshop on green economy and natural capital. The key point is that moving to green economy hinges on maintaining natural capital; we can do that collectively by improving the management of the shared resources, enhancing our competitiveness. The delegates at the Viet Nam workshop underscored the importance of a green economy vision and that a roadmap be prepared before Rio. I will be very keen to hear if any of the panelists have any comments about that or any practical suggestions on how we could actually achieve that.

John Kessels, IEA Clean Coal Center: My question is addressed to Mr Thapan. You mentioned in your presentation about the possibility of the flow of water in the Mekong being reduced to a trickle. I have been told about an agreement that the flow will be maintained. So I would like to have your comment on whether the flows will remain the same, or will turn into a trickle, or somewhere in-between?

Archie Beaton, Chlorine-Free Products Association: One of the questions we are trying to deal with today; is water a human right? How do governments balance out private use of water versus the right to water? Or is it a commodity, like coal or gas? Could the countries tell us how they perceive it?

Peter Warr, Australian National University: There is one input into that production story of food-water-energy nexus that we haven't heard mentioned; and that input is knowledge. Around Asia in the countries that I have studied, there has been an alarming decline in commitment to agricultural research. I understand that the People's Republic of China is an exception to that story. But if we are going to produce more food with the same amount of land, with less pressure on the natural resources and environment, we need to expand the supply of knowledge that it takes to do that. And that means research, and research takes investment. I will direct my question to Mark Rosegrant to comment on this please.

Nessim Ahmad: On green growth and the potential to make a difference at Rio+20; there is a zero draft, still work in progress, Probably a Conference like this can

provide meaningful insights that find a way into the process and discussions. On this question, Jeff McNeely may wish to say a few words on the potential for biodiversity ecosystems management to find its way into a meaningful outcome at Rio+20.

Jeff McNeely: The best way to approach this is to think of biodiversity as knowledge. The diversity we see in genes, species, and ecosystems is a result of a few billion years of evolution. And that is learning, that is, either you survive or you die. The species we see today are the ones that survived, the ones who had the knowledge within their genes on how to adapt to changing conditions. What we have heard from all of the speakers is that we are going to see continuing changing conditions, surprises in the coming few years, and the way we are going to adapt to those surprises is to capture the knowledge that is contained in living nature. It will not happen just by some miraculous transformation; we have to actually study, get people to look into these issues. And there is actually quite a lot going on but there needs to be more. We need to apply it to practical challenges. The number one challenge is what we might call decoupling—reducing the amount of resources that are required—water, energy, minerals and so forth, per unit of GNP growth. We have to become much more efficient in the way we use our resources, including our living resources. The capacity to do that is available in the region. What we really need to do is mobilize that capacity and make it happen on the ground. We have a structure within the GMS to make that happen.

Arjun Thapan: The statement I made in my address comes from two sources; one is an internal ADB exercise done in 2005, the other is The Economics of Climate Change in Southeast Asia: A Regional Review (the mini Stern Report) of 2009. Both seem to suggest that flows in the Mekong will increase during the dry season and decrease in the wet season up to a point, and the reverse will be true for the larger part of the year. Over the next 75 years, the expectation is that Mekong flows will decline in overall terms by about 25%. Much, of course, will depend on how the climate change scenarios pan out over the next 60-70 years. And much will also depend on the volume of abstraction that occurs as a result of growth in demand by the various sectors, including, principally, agriculture. But why don't I throw this back to the audience, particularly Jeremy Bird, who has been monitoring this in his previous incarnation in the MRC. Would you like to make a comment on this Jeremy?

Jeremy Bird: Thanks Arjun for putting me on the spot. I like the differentiation between the changes expected through climate change, of which the 25% reduction in Mekong flows may be one extreme value, and the reductions in per capita availability of water due to population increases, etc. The other part of the question is related to what is happening as a result of increasing storage in the basin due to hydropower and nonconsumptive uses, not irrigation storage. We are seeing two different sides balancing out; the modeling that was done for the MRC showed that once storage was completed in PRC, for example, flows at the border with Thailand would increase during the dry season and decrease in the wet season quite considerably. Now there is a benefit there but you also have the downside on the issues of sediment and nutrient storage upstream. A lot of modeling work has been done by MRC, which has been corroborated by work done by institutes in PRC as well. All that information is available in the scenario assessments carried out by the Basin Development Plan of the MRC.

Mark Rosegrant: Peter Warr made a great point there; to meet the kinds of needs we have been seeing for productive and efficient growth that also saves natural resources, the countries in the region will have to very significantly increase their agricultural research. There needs to be not only yield enhancing but sophisticated research, in particular of the new stresses that climate change will make on water resources, scarcity of water, nitrogen use efficiency, drought tolerance, heat tolerance, and greater resistance to insects and disease, as all the models are showing that these stresses will increase due to climate change. There has to be a combination of fairly high-tech research and knowledge generation with greater effort and investment in getting those technologies out to farmers. There has also been a near collapse in some of the countries of their extension systems; we need to build in back-ups to transfer technologies with a combination of, probably, public sector extension services and tap into NGOs and relevant private sector to get those technologies out to farmers. That is another essential piece of the pie.

Kyoko Kusabe: I want to raise for discussion the issue of land, as in many countries of the GMS, private land titling is being promoted. But the process is very slow and has been taken advantage of by some people with negative effects on forest resources. By putting community titling to land would actually solve a lot of problems; the advantage is that there would be large amount of land being managed by one entity, which will allow it to enjoy water rights for the community. It will also allow us to have more flexibility in terms of the use of land as well as creating visibility

so that the community is able to negotiate with other contesting users of forest resources. Of course, there are a lot of challenges in empowering local communities as well as issues of governance. But this kind of community ownership is what we can explore.

Tira Foran, CSIRO, Australia: This question is addressed to Mark Rosegrant: I was surprised by your point presented on child malnutrition rates that in 2005, child malnutrition rate in Thailand was 20%. According to your model, the same is the case in Myanmar; you project, based on food price increases and climate change, that the situation gets much better in Thailand but does not improve in Cambodia and the Lao PDR. I am wondering about the reliability of the results and whether you have had a chance to compare with other sources of data and statistics? Where is child malnutrition concentrated: is it in rural or urban areas? In the conclusion of your paper you call for subsidy regimes to be removed, for example for biofuels; you regard these as economically inefficient. I am just wondering whether your modeling also allows you to estimate the impacts on malnutrition if subsidies are removed?

Mark Rosegrant: The 2005 numbers are actual data, they are not from the models; these are figures estimated by UN agencies. If they are wrong, they are wrong; I have no means of checking the UN figures. The development of food prices is the basis for the projections; we have also estimated long-term investments in female education, clean water, and a measurement of women's status in the household. It could be that we are underestimating progress on those factors for the future. We could look into our estimates on those factors as well. But the key thing is that the higher food prices we project do dampen consumption. I was also surprised at the numbers, given the rapid rate of growth. The key thing will be to double-check our assumptions on those non-food items.

Dr. Parisak: From my understanding and listening to all the excellent papers and discussions, I think as far as achievements are concerned in the last ten years, there are two sides we have to look into. First, it is clear from the papers we have listened to this morning that all countries in the subregion, as part of ASEAN, ASEAN plus 3, or GMS, whatever groupings, have been instrumental in helping the subregion, especially the less advanced countries in the region (called CLMV)², to realize high growth. It is all in the statistics, we have seen that. This is thanks to increased

² Cambodia, Lao PDR, Myanmar, and Viet Nam

connectivity, mobility, and foreign direct investments (FDI) in the region. We have received tremendous investment in cross-border value chains, especially in the agriculture sector, the natural resource sector; this has helped to facilitate cross-border trade. There have been tremendous investments in energy and the mining sector; there has been a transfer in innovation and technology ensuring better complementarity among the countries in the subregion. This has been helpful, especially for the less advanced GMS countries, Lao PDR being one. We have also seen increase of human resource development within the region. Most countries have benefited from this, especially the less advanced countries in the region.

At the same time, what we need to look into is that development in the GMS is uneven and unbalanced. A lot of investments have been detrimental and harmful to the environment. We knew that this would happen but we still allowed it. For example, as far as cross-border value chain is concerned, e.g., maize production in Lao PDR, in the north it has increased by 10-fold or more in less than 10 years. That goes along with increased use of pesticide and machinery in the hilly areas, which has destroyed the top soil. So in the long term it is not helping at all. A lot of investors as well as development partners are involved in this.

Secondly, we were unprepared in terms of capacity. The capacity was not there to manage quality FDIs; we don't even know what that is. So there was an eagerness attract FDI but we were not prepared to get the most out of it in terms of quality performance. We were faced with new challenges, like increased disease breakout; that have created a lot of problems; we still don't know how to manage those challenges. Food safety standards for example are something new; the farmers don't know about that. We have produced a lot of maize; it was sent to the Chinese border and everybody is asking for SPS³; the farmers don't understand what SPS is. We understand what SPS means but we don't have the means to help the farmers. So the capacity was not there.

Thirdly, a lot of development assistance has been uncoordinated. Everybody is talking about sectoral development versus inter-sectoral development. We know about this but we are still promoting sectoral development both from the development partner as well as the Lao side. I think Jeff has mentioned Nam Theun 2, which is the fruit

of a collective effort among dozens of ministries, with involvement of CSOs, NGOs, and private sector. This is a good example but it took too long. I hope we do not have to take 15 years for every development program. Another good example is the Nam Ngum River Basin with ADB. We have brought together the Ministry of Energy and now the Ministry of Environment to work together. We need to promote more of those inter-sectoral programs. Hopefully, ADB will pay more attention to inter-sectoral, collaborative efforts.

Fourthly, development has not been inclusive. Even if we put the term in whatever contractual arrangement, development has been exclusive. There have been efforts to involve the communities but they were not prepared. Investors, development partners, and the Lao side see transfer of ownership to communities as a slow process, as we have to build capacity and this takes time. That goes against the interest of FDI. So we have to balance this; how do we look for an optimal formula?

Last but not least, we need to continue the subregional dialogue. As Viet Nam was saying, and others have pointed out, we need to ensure sustainable subregional development. All countries have to work together to design and align to the same rules of engagement. In our respective countries, we have to try to address our deficiencies, which should have no bearing on the development of other countries. We need to agree on some rules and adhere to a more collective effort of proper resource management in the region. So it is not the rule of country A or B but a regional rule. If not, then we cannot agree on anything at the end of the day. As Kofi Annan said, to move forward in order to engage in collective effort, all sides have to compromise. We need to sacrifice to some extent our interests. We can't continue with business as usual.

The strategy is clear; we have been hearing about this green economy, green agriculture, and other buzzwords. At Rio+20, I don't think there will be something new; they will come up with new buzzwords but they boil down to the same thing—better inter-sectoral work; we need to do it both on the Lao PDR side and the development partner and private sector sides. We have to compromise on all sides (development partners, government, private sector). Thank you.

³ Sanitary-Phyto-Sanitary

SESSION 3: GROUP DISCUSSION REPORTS – DAY 1

A. Food Security Thematic Discussion Group

Chair: *H.E. Dr Parisak*, Lao PDR
Facilitator and Rapporteur: *Dr Mark Rosegrant*

The main question for this group was how to achieve sustainable food security in the GMS. Some of the priority actions identified are: promote productivity and income growth in agriculture and rural development; invest in roads and irrigation in rural areas; help make markets work better for the poor through improved value chains; promote improved diets and food safety; remove biases against the poor in public spending, taxation, trade, and regulation, where there still exists in many countries a bias towards urban and industrial development relative to agriculture; develop human and physical assets of poor people through education and training, one of the big cost-cutting policies; and use market-based or incentive-based approaches to manage water and environmental services, combined with securing property rights for land and water to preserve the ability of farmers to take advantage from their own innovations.

On agricultural productivity, there are three key areas for food security: (i) increasing crop productivity through agricultural research and extension, (ii) farm management, and (iii) rural investment. In the area of research on crop and livestock breeding, the key is to increase investments significantly, including in both biotechnology and local farmers' knowledge and expertise. In the face of excessive use of many inputs and climate change, specific aspects can be targeted, such as nitrogen-use efficiency, abiotic stresses like heat and drought, and such biotic stresses as insects and disease.

At the farm management level, many things can be done to improve the sustainability of agricultural production and to reduce harmful effects of intensification. Some of these are water harvesting and precision agriculture, which allows much better targeting of inputs and management efforts. Three to five years ago it was thought that there would never be precision agriculture in Asia, being too difficult and too capital intensive. However, it is now being used in large areas in India for example, such as land leveling and use of global positioning system (GPS) to help target inputs. Its use will undoubtedly grow in the GSM as well. Minimum tillage systems, integrated soil fertility management, and integrated pest management can also

help reduce the amount of inputs while sustaining growth of productivity. Another key area is to promote policies and investments to reduce postharvest losses. Directly connected to reducing postharvest losses is the need to improve rural infrastructure investment to help improve access to markets, information, credits, and inputs and to provide positive conditions for private investment.

To a large extent in the food sector, good policies for climate change and adaptation are good policies for agriculture development in general. Some of the key areas here are: to implement knowledge, information, and risk-sharing approaches to support flexible farmer adaptation and that is not only related to climate change but also related to variable prices in a changing world climate for agriculture. Greater investments are needed in climate-sensitive traits and protection against climate variability and extremes. Support for open international trading regimes is needed to share climate risk, which also gives farmers in the GMS access to global markets. A large part of that work has to be done by the less economically developed countries (LEDCs) is policies on trade and subsidies. There is a need to improve spatial targeting, with much better data and resource systems to account of highly variable climate change impacts, by crop and location. Another key area related to overuse of inputs is to reduce perverse agricultural subsidies on biofuels, water, energy, and fertilizer that can distort the decision making of farmers and reduce productivity growth.

There is also a need for economic incentives for efficient water use, like establishing firm, tradable water rights for users. Direct water price increases may be punitive to farmers and irrigation users; but Australia and Chile have designed pricing mechanisms by which irrigation users are paid to use water efficiently and they use those payments to organize production more efficiently. The same need arises in the creation of market for ecosystem services as Jeff McNeely noted yesterday. So for watershed management, biodiversity, and other environmental services, there is a need to start valuing those services that are now not measured in the market system. We need to develop markets for agriculture and forest greenhouse gases (GHGs) to generate new values in rural areas through GHG mitigation, such as soil sequestration. These will still need to be coupled with policies for creation of conservation reserves and protected areas.

There is a need to prioritize across these policy options. A big question is: who does what? With these kinds of policy options, to what extent should they be undertaken

by regional organizations, such as ASEAN or the GMS, or at national, subnational, and local levels? There is a need for good governance, including regional integration across the countries, cooperation, and planning. Directly related to that is political and economic stability. The other issue is how to move from policies and plans to implementation; this often appears to be the weak link. There is also a need to improve information and data systems, including use of remote sensing and GIS; to integrate data systems across countries and regions; and establish early warning systems for price variability, famine, and weather forecasting. A strong point made by a number of participants was that we need now to better integrate fisheries, trees, and forests into the agriculture sector; there needs to be much more holistic planning and policies rather than having these in different ministries. And finally there is a need to do explicit targeting of poor and small farmers for the process of technology transfer and support services.

B. Land, Water, and Climate Change Thematic Discussion Group

Chair: *H.E. Mr Ros Seilava*, Cambodia
Facilitator and Rapporteur: *Prof. Peter Rogers*

Many issues discussed in the Food Security group are very salient to the discussions of this group. In particular, the integration aspects of agriculture, fisheries, and forestry with the changing hydrology and ecosystems of the subregion and the choice of appropriate technologies. There is a lack of integration across the different ministries and agencies in these matters. There is uncertainty introduced by climate change. Too much of the effort in the water sector has been on conventional, surface water diversion works, which are very hard to do in a monsoon area; too much is subject to very high rainfall and flooding followed by extended dry periods. It is hard to achieve optimal use in countries that do not have a tradition of management and maintenance of these facilities. The issue is the choice of right technology for the changing conditions in the area. A lot of discussion focused on small farmer irrigation systems as experienced in other parts of Asia, for instance in West Bengal, Bihar, and Bangladesh, where lift irrigation (wells) is done by the small farmers themselves with a huge amount of government support.

Next was the need for ways of forecasting consistent land-use change in relation to the change of environmental and economic conditions. The name of the game in this

subregion and many other parts of the world is land use. How is land use going to change? How is forest going to be changed? How is agricultural land going to be developed? We had a technical discussion on GIS-based land-use modeling as a case study from an area in the GMS showing plausible land-use changes over time. In a similar vein, the urgent need for drought management techniques in a subregion where most of the effort has been on monsoon and flood control and excess water drainage, was mentioned. The GMS does not have meteorological drought like in arid regions, but there are changing rainfall patterns during the monsoon season and also in other rainy parts of the year, leading to dry areas around the subregion. There is a need to zone land areas for drought and flood potential to improve drought and flood management. There was more consideration of the international political context and the resolution of conflicts among the GMS countries and those within countries that have an important set of non-transboundary issues within a transboundary setting, which ultimately affect the rest of the Mekong River Basin.

Four areas were suggested for recommendations: (i) projects, (ii) policy and governance, (iii) institutions, and (iv) research. Monitoring programs could be specific projects getting better data on the performance of various sectors and better data on climate. There are very few serious climate monitoring stations within this subregion compared to Europe and the rest of the world.

More Clean Development Mechanism (CDM) projects, particularly on the transboundary hydropower programs in the subregion were needed as it was pointed out that 90% of the CDM funds go to two countries—the People's Republic of China and India; less than 10% is spread among the other countries. Why don't the GMS countries go after the large funding available for CDM projects? And particularly, since there are a lot of hydropower developments in the subregion, there is a nice trade-off between GHG and positive and negative impacts of development.

The next area of recommendations was policy and governance. Basically the discussion in the group underlined that climate change policy was not mainstreamed in the individual countries or in the GMS itself. We need to encourage climate policy to be consistently addressed in all of the activities of the GMS. Climate change models need to be based on similar sets of data and projections and scenarios; currently there is a wide variation. We should exploit mitigation and adaptation synergy; too often we see these two pitted against each other. Some mitigation aspects related to forestry could help in adaptation of agriculture.

Flexible adaptation approaches are needed, especially by learning from mistakes and being aware of the high risks and consequences of failure in adaptation measures. Unfortunately, we often do not learn from our mistakes. Benefit sharing and costs need to be transparent. An integrated water resources management (IWRM) approach is required but how much is actually applied is unknown.

Legal, institutional, and organizational mechanisms are needed in order to allow progress, for example in dealing with land use, land ownership, property rights, and communal property rights, which are very difficult issues in many countries of this subregion. There were also calls for setting up a GMS working group on water. Apparently, the GMS has working groups on all sorts of things except water. Building capacity for policy making and implementation to attract financing to the subregion need a consistent approach, some it involving transboundary issues. The private sector needs to be assiduously courted, particularly for modernizing agriculture. Precision agriculture, referred to by the previous group, requires capital investment; there are people willing to undertake those investments provided the legal, institutional, and organizational mechanisms controlling concessions, land use, and contract farming provide a conducive framework.

Finally, more scientific research on climate change and impacts in the GMS is needed, specifically down-scaling models and developing models for adaptive management. More studies on policy and implementation are needed, but not just focusing on projects. We also need to know the right costs and benefits.

C. Energy Thematic Discussion Group

Chair: *Dr Daovong Phonekeo*, Lao PDR
Facilitator and Rapporteur: *Mr Anthony Jude*, ADB

The energy thematic group had much discussion on the nexus between food, water, and energy security. In that context, many issues were raised: very clearly, energy demand is growing and will continue to grow within the GMS; some countries are growing at double-digit rates; hydropower is likely to be one of the potential sources of meeting the demand of growth in the subregion. In the context of energy security, how do we manage that? There is a need to undertake a careful planning process. Thailand is highly dependent on gas and it is natural for Thailand to diversify; some of the countries in the GMS are looking at diversifying into hydropower and looking at either Myanmar or the Lao PDR. Those issues will need to be managed properly.

Optimization of hydropower development also needs to be done in the context of mitigating social and environmental issues through strategic and integrated development. Lessons need to be learned from Nam Theun 2 and Nam Ngum 3; Nam Theun 2 took more than 10 years to bring to fruition; Nam Ngum 3 was realized far earlier, in less than five years. Most governments will not like to duplicate another Nam Theun 2. We must try to get other hydropower projects integrated into a river basin management approach.

Most of the energy planning today is looking at how many power plants are being installed, for example x amount of coal-fired or gas-fired plants or oil-fired plants. In that context, the discussion was on how to internalize environmental impact costs. Strategic environmental assessments (SEAs) need to be integrated in the power development planning process. Very little has been done in the GMS except in Viet Nam, which has started internalizing SEA through their Power Development Master Plan (PDP 7); this SEA has been done through collaboration with EOC in the context of the GMS Regional Power Trade Coordination Committee work that is being undertaken. The SEA of PDP 7 indicates that by 2030, the environmental costs of atmospheric pollutants will be about \$9 billion per year. If that is not addressed, we will have serious problems in the future.

There also needs to be coordination between energy planning and the ministries of water resources; there is a lack of planning between these two. The ministries of energy plan hydropower projects but they do not take into account what the water resources ministry has to do in terms of water needs downstream and upstream. There is also a need for clarification about data, information, and methods. In some countries, hydropower is part of renewable energy; IEA also categorizes it as renewable energy but for some countries this is a complex issue; another is whether to use clean coal or cleaner coal technology. Planning methodologies were also discussed and how SEA could be increasingly used and how it could be included in a multicriteria decision-making process.

There is also more need for emphasis on energy efficiency and conservation. Energy conservation and energy efficiency are straightforward to address; but most governments do not push that agenda. In the Philippines, for example, we have champions in the former and the current President; so you see some programs of energy efficiency through lighting and the current electrical vehicle program. Energy efficiency is basically considered as an

orphan because it is not within the energy ministry; it cuts across sectors—industry, agriculture, construction, and the private sector; nearly every sector has to be involved. Now there has to be a clear champion; the only country I have seen within the subregion that plays this card very well is the People's Republic of China (PRC). The PRC has created an agency that takes the responsibility of pushing the agenda. We have seen that in a number of provinces, where energy efficiency both in the industrial and domestic power segments has been pushed through. The other GMS countries need to look at how to promote that.

If hydropower is controversial in some countries because of water and food security, then they have to look at the use of cleaner coal technologies. Some GMS countries are looking at coal as an energy source option. But why use conventional technology? Why not move up the technology ladder to using cleaner coal technologies, for example fluidized-bed combustion (FBC) depending on the type of coal available, or use supercritical and ultrasupercritical technology, which actually reduces the carbon footprint? In the discussions, renewable energy was recognized as an energy option but it is not going to meet the base loads; it needs to play a role in the overall energy planning so that it helps to bring the GMS carbon footprint down.

There was also the issue of lack of awareness; the general public is not aware of increasing efficiencies through the purchase and use of energy efficient appliances. A lot of people are unaware that the market already has a 10,000 or 15,000 hour compact fluorescent light (CFL) but these are not sold. In the Philippines, we pushed a 10,000 hour CFL; most countries use a 6,000–8,000 hour CFL; Indonesia produces a 15,000 hour CFL but it is sold not in Indonesia but in Japan. This is because countries like Japan and the Republic of Korea have policies in place that have imposed benchmarks and industry standards; you do not sell any product below the benchmark or threshold. So why can't the GMS look at better appliance standards. Another is LCD screens; these may consume 140–150 watts of energy in some countries but the same LCD screens sold in Japan and the Republic of Korea consume far less, 40–50 watts. Why can't such energy efficient appliances be procured in GMS countries? These are some of the questions GMS policy makers will need to ask and maybe institute some of these policies in their countries.

There were issues concerning health, environmental, and social impacts of energy projects and how to address these. They are basically examined in the context of environmental impact assessments (EIAs). In the context of ADB-funded

projects, governments will need to look at the health impacts, especially from thermal power plants. As one participant from Thailand pointed out, they will not build coal-fired power plants in Thailand but in neighboring countries; those neighboring countries will have to put in standards and enforce them on the private sector. With changes in wind direction, transboundary impacts will be there also.

Recommendations: There was a recommendation to look at the Bonn initiative of 2011 on the water, food, and energy nexus. The decisions taken in one subsector, whether biomass or biofuels, may have an impact on another sector, for example whether to have plantations for rubber or fuel. Another recommendation was to review and apply the Norwegian model in terms of hydropower. The Norwegian model advocates a quick assessment of the assets that need to be protected, like watersheds and river basins, and development of a master plan to protect these. There is a call to internalize environmental and social costs in terms of the power development planning process (PDP). Most PDPs are looked at from a financial point of view; environmental and social costs are not factored in. How do you bring the full economic costing into the PDP? The governments in the GMS need to push this agenda and not just let the power utilities present a least-cost option from a financial point of view only. If we realize the environmental and social costs, a project is going to be far more expensive; it may not be the least-cost option.

Energy conservation should also be included in the PDP, a win-win solution. Most energy planning within the subregion is done by the power utilities together with the ministry of energy; civil societies are not involved. There is a need to bring civil societies and other stakeholders into a meaningful discussion on the rationale for hydropower, thermal plants, renewables, and energy conservation. These are planning issues in which the private sector and academia could play a role. The energy sector should be harmonized with water resource planning.

Biofuels are here to stay in some countries but have negative effects on water consumption; where biofuel production continues, countries should provide clear policies and guidelines on how this subsector will be managed; if biofuels are used by remote communities, the positive impacts also have to be studied. Subsidies for biofuels should not be provided because biofuels should not create negative impacts on land and food security.

The use of multicriteria decision tools should be enhanced. Recommendations on the institutional side were not

made; these are covered in another session. We need to consider all available or possible energy options (coal, oil, gas, renewable energy, nuclear) and approach the power planning system as a whole. Nationally Appropriate Mitigation Actions (NAMAs) were also mentioned as a tool for addressing environmental concerns in the context of using coal and mitigating GHG emissions.

D. Plenary Discussion

Nay Htun, Stony Brook University, New York: These were three excellent summaries. At least in my group all the major points were captured in the report. I just want to make two comments: the first one is addressed to Peter Rogers. You mention there is a need for cost-benefit analysis. I think this is excellent. I would also like to suggest that we take into account calculating the social cost of carbon. Currently, in the United States they are using a range of \$5–\$45 per ton and the average is about \$25; the United Kingdom is using about \$45–\$50; but recent studies by a group of economists put the real social cost of carbon at \$800 per ton. This comment also applies to the energy group. When we are talking about \$9 billion as damage cost caused by air pollutants, if we were to factor in the social cost of carbon (I am not sure what figure, \$25 or more was used), if we were to use \$800 per ton, the figure would be much more than \$9 billion. It is not only air pollutants but also other pollutants. In this context and relating to the energy group, we did discuss the specific role of very fine particles, those less than 1 micron diameter. Recently, a group of researchers presented some reports that suggest the number of deaths in the United States due to secondary organic aerosols has been very much underestimated; there are at least about 50,000 additional deaths. That needs to be factored in as well. Thank you.

Leeber Leebouapao, Ministry of Planning and Investment, Lao PDR: I have two comments: the first one is on the food security issue. I think the GMS has a huge potential for food production and so far we have not faced problems; some GMS countries are exporting rice like Thailand, Myanmar, Viet Nam, and now Cambodia. But trends are changing; for example, in the Lao PDR, land for food production is declining because of urbanization, infrastructure development, and land needed for establishing industrial park development. This is a number one challenge. Furthermore, the land prices are increasing. This will lead to food price increase in the future. In addition, there are impacts from climate change, floods, and drought. So there is a challenging issue in the future for GMS countries.

On the subject of policy recommendations, we need to have good land-use planning. In the Lao PDR, food production increased at the same rate as population growth. The growth in agriculture sector, including forestry, was 2–3% but if we take only food, it grew about the same rate as population growth, almost 2.0–2.5%. In future, we need to increase food productivity. On the energy issue, the Lao PDR certainly has quite a bit of potential for hydropower but still relies on oil imports for energy. Also in the GMS countries, we rely quite heavily on oil for energy, particularly petroleum products. But Viet Nam, Thailand, and Cambodia have potential oil resources that remain untapped. May be we can factor them into the energy planning. The question is how to balance the potential in the GMS Vision to 2020 and beyond. I think we can share these resources for the common benefit. Also the proposals made relating to renewable energy are valuable.

Peter Warr, Australian National University: I agree with all of the things said by the three rapporteurs this morning and they were excellent summaries. But I want to go further and address something that has not been addressed directly. Behind the title of this conference—Balancing economic growth and environmental sustainability—lies a market failure. The signals provided to decision makers are not consistent with environmental sustainability. That is the fundamental problem. And so I want to see policies designed that address the market failure. Let me give you an example: deforestation. Policies that address the market failure that underlies the excessive rate of deforestation are feasible, such as subsidies to land use in forestry. I have a study with an Indonesian colleague that shows that carbon emissions in the Indonesian context can be reduced through subsidies for retention of land in forestry at a cost far, far less than \$25 a ton using carbon emissions. These are very efficient policies because they are directly focused on the market failure, which is the heart of our problems here.

Satoshi Ishihara, World Bank: I am glad to hear that it is not so much about roads but productivity increase that matters for agricultural development and poverty reduction. I have done some studies some time ago in Africa that assess the contribution of transport costs to prices of agricultural commodities; it turned out to be typically less than 20%. The contribution of road improvement to reduction in prices and increase in competitiveness is much smaller. My conclusion is the same: it comes down to productivity increase and diversification of crops, specializing on some that have a comparative advantage. Another point is about land: there is much discussion about landscape and land use and not so much about land tenure and access to

natural resources. How one uses land depends a lot on land tenure and laws about investments, regulations about economic land, etc. It will be good for future discussions if you can address land tenure systems and regulations about economic investments and forest, mining, and agriculture; these will have a lot of implications on carbon emissions and forest management.

Peter Rogers: There was one specific question addressed to me. On the issue of social cost of carbon, it is very contentious how you arrive at these numbers. We just heard two numbers, \$25 and \$800 per ton; they are not even close, not even in the same ballpark. We have some serious reconciliation to do on these things. I am a great believer in the alternative cost method and I would come out on the lower end of that discussion rather than on the higher end. The higher end numbers come from assigning values to ecosystem services, which are largely hypothetical. Ecosystem economics has some very dodgy assumptions built into it and that is where those high numbers come from. When we talked about benefit-costs in our group, we were not referring to market prices but about social benefit-cost analysis. For those of you who are too young to remember, the United Nations Industrial Development Organization (UNIDO) put out a document in 1971 on social benefit-cost analysis, which is by far the best document that I have seen on that to date. We need to make sure we get the right ranges. I think we are not talking of cost-benefit analysis based on market prices but about social benefit-cost analysis. We are not going to resolve the issue between \$800 and \$25; I would argue very strongly for the alternative cost method, which is outlined in the 1971 UNIDO report. Thank you.

Mark Rosegrant: There are some very good points raised here about the Lao PDR's land scarcity and the need to improve agricultural productivity, I fully agree with that and also the point raised about comparing the value of developing rural infrastructure, particularly roads, with increases in agricultural productivity. I fully agree with Peter Warr's point about market failure. Getting social and environmental markets to be valued and recognized is the key to sustainable development.

Anthony Jude: On the question of cost-benefit analysis raised by Prof Nay Htun, I think we will need to look into it as to how it was done. For the SEA, this could be done in a later session. On the market failures, we have to consider the environmental nexus, the technologies being used, and the lack of policies within the subregion to push certain technologies. Hopefully, in the later session, we can come

up some recommendations on policy. On the Lao PDR and sharing of hydropower energy, I think this will have to be looked at from a basin perspective, and how we can minimize the impacts of hydropower from the tributaries and share the resources. We are not saying that the Lao PDR should not develop hydropower, but to look at how to minimize the impacts. Of course, the power generated will be sold to neighboring countries for revenue and the revenue sharing could also be looked at as in the case of Nam Theun 2 and Nam Ngum 3; how revenues from such projects are set aside for the social and environmental sectors. This is something that can be explored further. On renewable energy in the GMS, there are options but I think these are limited; if we exclude hydropower, the GMS has biomass and solar as renewable energy opportunities; there is not too much wind potential in the subregion. Biomass-based generation using agriculture waste is being done in countries like Thailand through policies for small power plants.

Peter Rogers: Just one comment on land tenure issues. Certainly in the Lao PDR and Cambodia, the issue of large concessions to foreign corporations or foreign state-owned companies is a major issue and environmentalists often call it land grabbing. This depends on whether it is a concession that works or it is land grabbing; it also depends very much on the institutional framework within the government and degree of transparency, etc. To achieve the sort of investments that Mark Rosegrant was talking about in precision agriculture, you need to get foreign direct investment and the private sector has that ability. But the private sector is frightened away by the general attitude that concessions are bad and evil. Recently, I saw a 10,000 hectare concession in the Lao PDR run by a Thai sugar company; that was a wonderful experience, with a high tech agriculture that has created 7,000 jobs, exporting sugar from the Lao PDR to the European Union; also other positive aspects and the benefits of transfer of technology. That is an example of land use, a land tenure concession, carefully overseen by both the Thai and the Laotian governments.

Hasan Moinuddin: The key question for breakout groups in the next session is: Looking to the next decade, what are the responses and recommendations to challenges the groups identified in earlier sessions. The focus will be: (i) What are the key policy responses needed and by whom? (ii) What are the key data, information, and knowledge responses? and (iii) What are the key institutional responses, both at sector and regional levels? I now take this opportunity to thank all three facilitators, who have done an excellent job of conducting constructive and highly participatory group discussions and I think they all deserve applause.

**SESSION 4: CHALLENGES AND DYNAMICS OF
GROWTH IN THE NEXT DECADE 2011-2020**

FOOD-WATER-ENERGY NEXUS: GMS CHALLENGES OF GROWTH FOR 2020 AND BEYOND

David Roland-Holst¹ and

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Abstract

The Greater Mekong Subregion (GMS) holds freshwater resources that offer immense potential for renewable energy and agrofood production. This report examines the long-term economic implications of alternative strategies for developing this potential, including an assessment of the role of climate change. Using a dynamic forecasting model that tracks the five national economies comprising this region and their linkage to each other and the global economy, we find that investments in water infrastructure can indeed promote stronger and more inclusive regional growth, but that a balanced approach to energy and agrofood development is needed to sustain prosperity for all the GMS economies. Moreover, institutional innovation, especially more determined initiatives to promote regional economic integration, will be essential to fulfill the vast economic promise of this subregion for all its inhabitants, especially the poor.

1. Introduction

The Greater Mekong Subregion (GMS) comprises five countries, including two administrative regions of the People's Republic of China (PRC). Although hydropower potential exists across most of the area circumscribed by these borders, the eponymous Mekong catchment area dominates this subregion in terms of hydroelectric capacity and potential. Because it is also an essential shared resource for all the member countries, we focus more attention on it in this study. As one of the world's great rivers, the Mekong traverses six nations along its

5,000 km pathway from the Himalayas to the South China Sea (Table 1). In addition to supporting a vast reserve of regional biodiversity, the Mekong offers three primary economic services to the millions who live along its banks and to hundreds of millions beyond: transportation, renewable freshwater, and (increasingly) electric power.

In all three categories, the GMS is considered to be well below its long-term economic potential. Riverine transport is challenging in this catchment area, but determined national and multilateral investments are integrating it with an ever-expanding web of road and rail transport. Most significant perhaps are the new GMS corridors, and north-south and east-west transept that promise to be a growth bridge between the region and the global economy.

The subregion's unrealized potential for agrofood development and electric power production remains immense and, if properly managed for these uses, the Mekong's water supply can be the guarantor of sustained prosperity for all GMS countries. This subregion's climate and soils are congenial to very high agricultural productivity, but investments in agriculture are severely constrained by low average incomes. The elevation change across the GMS confers enormous hydroelectric potential, but again investments thus far have only realized a small fraction of this. Indeed, the subregion is currently trapped in a low-investment equilibrium, where the majority of the subregion lacks financial resources to animate its rich resource base and rural poverty prevails. More extensive investments that stabilize and more effectively distribute annual water flows, while at the same time harvesting electric energy, could dramatically increase per capita agrofood production and incomes, sustaining the basis for long-term growth and regional economic convergence. This situation presents a strong case for more active policy intervention, promoting public and/or external investment to unlock the subregion's agrofood and energy potential.

This report assesses the subregion's economic potential from the perspective of water use in agriculture and electric power production, policies that can better realize

Table 1: Mekong River Basin Territory and Flow

	PRC	Myanmar	Lao PDR	Thailand	Cambodia	Viet Nam	Total
Area in Basin ('000 square kilometer)	165	24	202	184	155	65	795
Catchment (% MRB)	21	3	25	23	20	8	100
Flow (% MRB)	16	2	35	18	18	11	100

Source: Mekong River Commission (MRC)

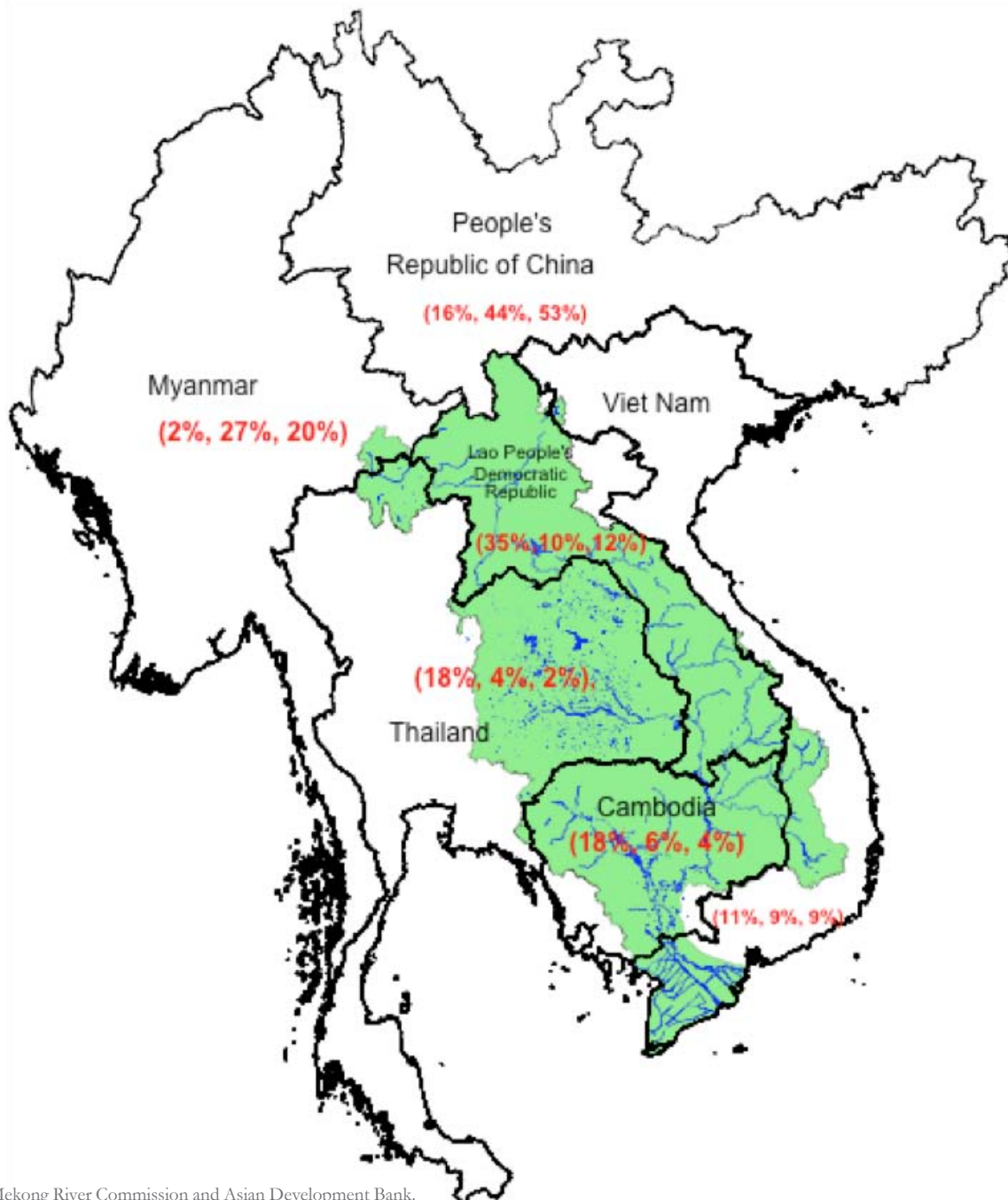
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this potential, and how the risk of climate change may influence these. Generally speaking, our results suggest that optimism regarding the economic potential of GMS agrofood and hydropower is justified, but simply promoting these agendas at the national level, individually and independently, will not realize this potential. Electric power development alone will benefit energy consumers, but producing countries will see the development basis of their economies narrow and their terms-of-trade deteriorate. Agrofood development will improve national

food security, but in isolation the lower income countries cannot fully exploit their agricultural potential and again their development path will be a narrow one. Only by combining water for food and water for energy in a coherent framework of multilateral cooperation can the rich natural resources of the GMS be developed with an appropriate combination of growth catalysts, private investment, and market agency that comes through regional economic integration.

Figure 1: Shares of Estimated GMS Hydroelectric Capacity by Country (Potential, Existing, Planned)



Source: Mekong River Commission and Asian Development Bank.

Finally, we assess the threat to the GMS of climate change, as this would arise from limiting annual average water flows. Our results suggest that, at least for the next two decades, growth policies of the kind just described can more than offset such risks. Water resources are so underutilized in the GMS that the potential for use improvements far outweighs the medium-term risk of Mekong flow attenuation. This means the subregion can focus on cooperative water use solutions and share the bounty of this resource without economic rivalry.

The following section gives a brief overview of hydroelectric potential and capacity in the subregion, followed in the third section by a survey of agrofood development from a water resource perspective. Section 4 presents long-term forecasts of GMS growth and development. The final section offers conclusions.

2. GMS Hydropower

The Mekong's transit from headwaters to delta spans an elevation change of over 5,000 meters, creating enormous potential for hydroelectric power generation along most of its course. In all the river's estimated capacity is about 60 gigawatts, enough to meet nearly 10% of PRC's total electricity demand and larger than the combined electricity demand of all the remaining GMS countries.

The Mekong River Basin, covering more than 800,000 km², is divided into two sections according to geography: the Lower Mekong Basin (LMB) and the Upper Mekong Basin (UMB). The LMB countries are Cambodia, the Lao PDR, Thailand, and Viet Nam and the UMB countries are Myanmar and the PRC (Yunnan Province). At present, however, the Mekong area is far below its hydropower potential, particularly in the Lower Mekong Region (LMR) depicted in Figure 1. Hydropower opportunities in the GMS are largely related to the mainstream Mekong River and its immediate tributaries, but the larger Mekong Basin presents many other opportunities. The Mekong River mainstream, with its 4,400 km of flow and average discharge of 15,000 m³/second, provides a major source of energy potential throughout its basin. The Lao PDR contains the largest portion of the Mekong River within its borders at 35%. Cambodia and Thailand each contain 18% of the Mekong River while Viet Nam contains 11%. In the UMB, the PRC contains 16% of the river while Myanmar contains only 2%. As with most watershed issues, UMB river management decisions are particularly important to LMB neighbors.

The PRC has invested most heavily in expanding and planning new capacity, Viet Nam is about at the regional average of capacity development, but three countries that comprise 72% of subregional (Mekong Basin) potential still represent only 18% of existing capacity. The Lao PDR, sometimes referred to as the "battery of Southeast Asia," has the largest unrealized potential. Both Cambodia and Thailand, however, are just as far below their hydroelectric potential in relative terms, and there appears to be design potential to triple capacity in all three countries. It should be noted that the PRC, Thailand, and Viet Nam have substantial potential and existing capacity outside the Mekong Basin. The Guangxi Zhuang Autonomous Region of the PRC, also part of the GMS, has existing capacity comparable to Yunnan, but draws this power from water resources largely confined to Chinese territory. The distinctive feature of the Mekong Basin is being a primary subregional source of power derived from shared water resources, and it possesses the largest potential. For these reasons, we focus discussion on the Mekong's catchment within the GMS.

Hydropower projects in the Mekong Basin were first constructed on a limited scale during the late 1960s and early 1970s in Thailand and the Lao PDR. After this initial phase of development, no further projects were completed until 1990. The second wave of development extended through the 1990s, including more projects in The Lao PDR and Thailand, but also projects in PRC and Viet Nam. By 2000, approximately 15 significant hydropower projects were in operation in the GMS. With the exceptions of Myanmar and Cambodia, the period between 2000 and 2010 saw a major expansion of regional capacity. For example, Viet Nam alone completed more than twenty projects over the course of that decade (Table 2). An inventory of hydropower projects constructed and planned for the GMS is presented in Table 2. The total potential for hydropower generation in the GMS has been estimated to be as high as 250,000 MW (ADB, 2010). However, only a portion of this potential will be both economically and environmentally feasible. Nonetheless, even if only half of this potential were realized, it would amount to five times today's total generation capacity of the subregion (ADB, 2010).

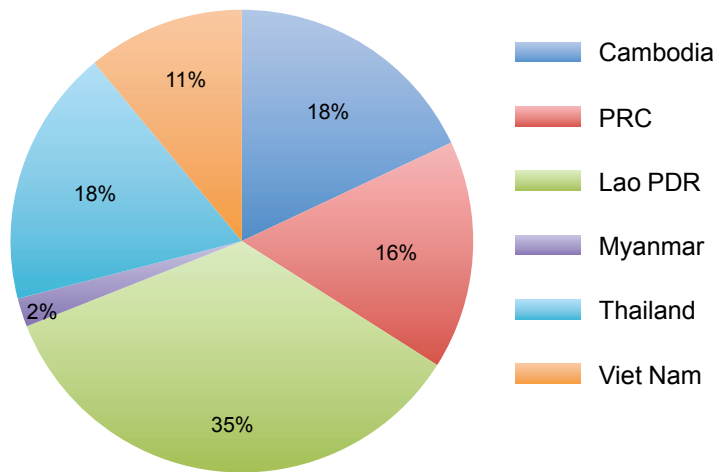
Estimated hydroelectric capacity by country is shown in Figure 3. The four LMB countries have an estimated combined hydropower potential of 50,000-64,750 MW, about half of which is directly related to the Mekong River (MRC, 2010). However, it is the UMB, comprised of Myanmar and PRC, which together represent more

than 70% of the subregion's hydropower capacity (Figure 2b; Figure 3). In the Lower Mekong Basin, approximately 3,000 MW of capacity have already been built, largely in the last decade, while an additional 3,000 MW are under construction and more projects are undergoing feasibility studies or are planned for the future (Table 2). In total, more than 85 hydropower projects are now underway or completed in the GMS and approximately 180 new projects are in the initial planning stages (King

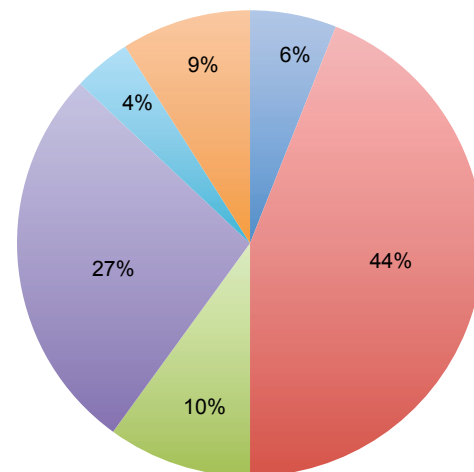
et al, 2007). The Mekong River Commission estimates that presently planned construction on the Lower Mekong will effectively exhaust the river's hydropower generation capacity for the lower portion mainstream of the Mekong River (Mekong River Commission, 2005). Collectively, the planned construction of hydropower projects will mean that the subregion's cumulative generation capacity is expected to increase quickly over the course of the next decade (Figure 4).

Figure 2: Percentage of Mekong River Flow and Hydropower Capacity by Country

a. Mekong River Flow within Borders

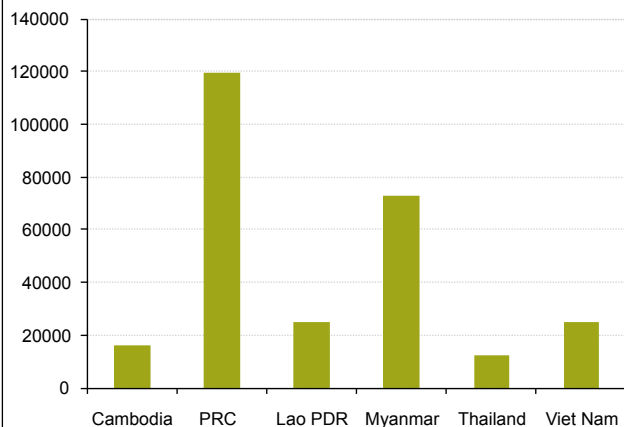


b. Hydropower Capacity



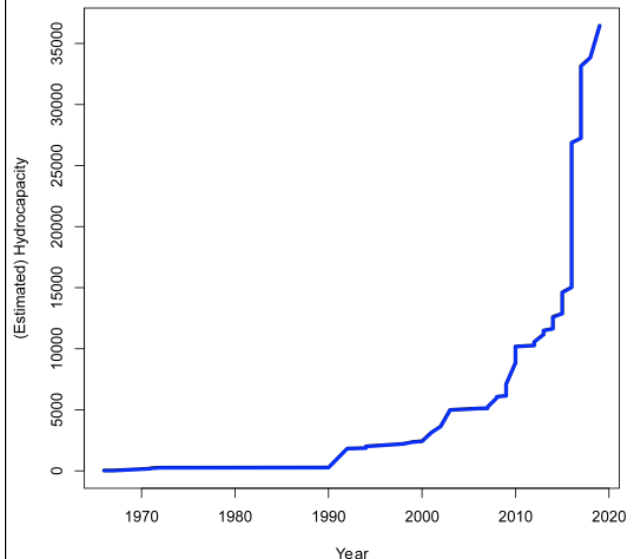
Source: Mekong River Commission (2010); ADB (2010).

Figure 3: Estimated Hydropower Capacity by GMS Country (Megawatt)



Source: Nangia and Schrattenholzer (2006)

Figure 4: Cumulative Hydropower Capacity in Mekong Basin (including projects with announced planned completion date)



Sources: World Bank (2010); Mekong River Commission (2010); King *et al* (2007).

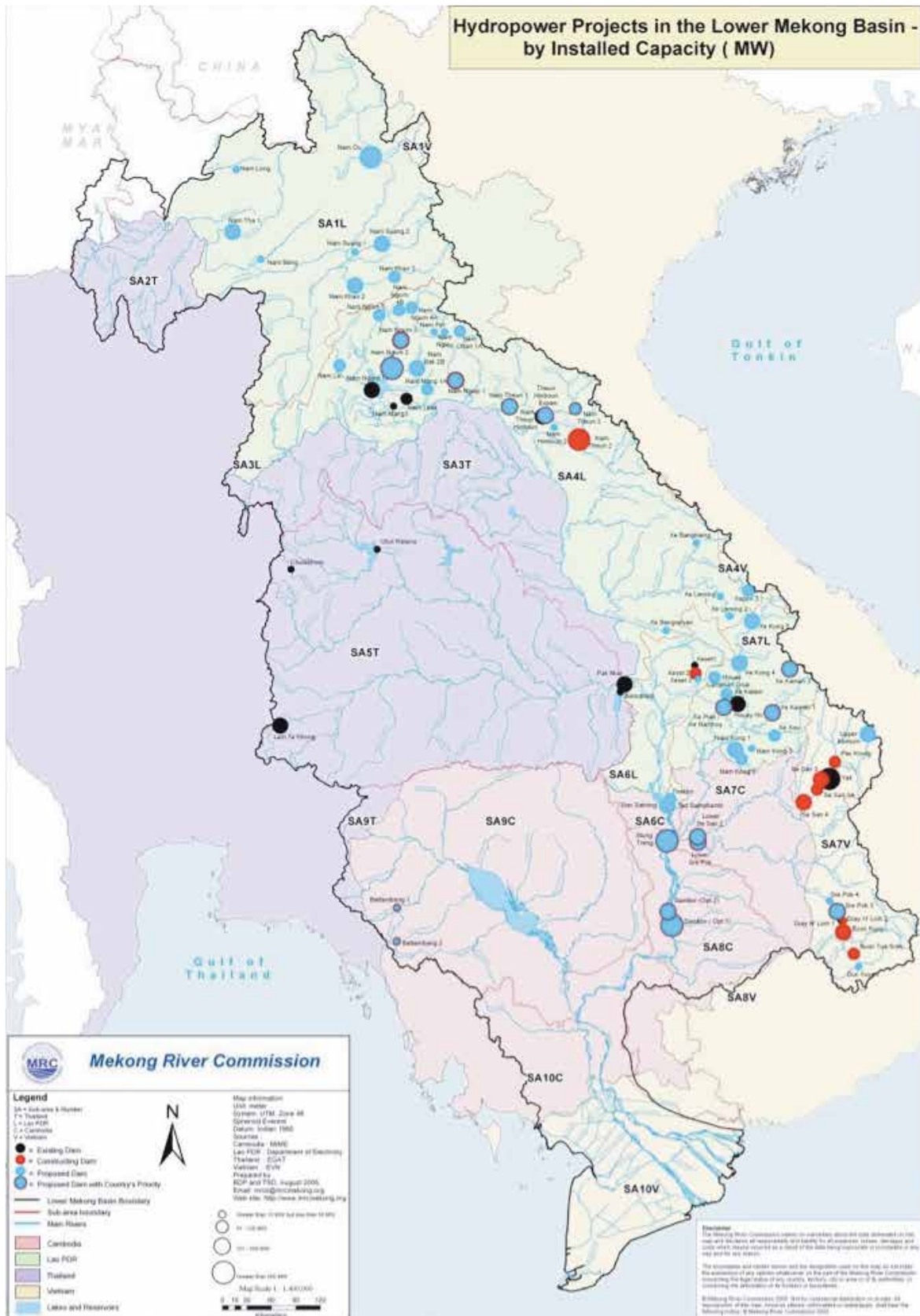
Table 2: Overview of Hydropower Projects in the Greater Mekong Subregion

Country	Project Name	(Planned) Capacity in Megawatts	(Planned) Completion Date
Cambodia	Lower Sesan 1	90	2012
	Lower Sesan 2 +	420	2016
	Lower Srepok 2		
	Sesan 3	375	2017
	Sambor	2,600	2019
	Lower Srepok 3	330	TBD
	Lower Srepok 4	235	TBD
PRC (Yunnan)	Stung Treng	980	TBD
	Manwan	1,550	1992
	Dachaoshan	1,350	2003
	Gongguoqiao	750	2008
	Jinghong	1,750	2010
Lao PDR	Nuzhadu	5,850	2016
	Nam Ngum 1	155	1971
	Se Xet 1	45	1994
	Theun Hindbourn	210	1998
	Housay Ho	150	1999
	Nam Leuk	60	2000
	Nam Mang 3	40	2004
	Se Xet 2	76	2009
	Nam Theun 2	1,088	2010
	Xekaman 3	250	2010
	Theun Hindboun Expansion	280	2012
	Nam Ngum 2	615	2013
	Xekaman 1	322	2013
	Nam Mo	150	2014
	Nam Ngum 3	440	2014
	Nam Theun 1	523	2014
	Nam Ngiep 1	278	2015
	Xepian – Xemanmoy	390	2015
	Nam Ou	1,100	2015
	Don Sahong	240	2015
	Pak Lay	1,320	2016
	Luang Prabang	1,410	2016
	Xayaboury	1,260	2016
	Pakbeng	1,300	2016
	Sanakham	700	2016
	Pakchom (joint with Thailand)	1,079	2017
	Ban Koum (joint with Thailand)	1,872	2017
	Lat Sua	700	2018
	Xekong 4	600	TBD
	Nam Kong 1	150	TBD
	Xekong 5	400	TBD
	Nam Bak 1	80	TBD
	Dak E Mule	130	TBD
	Xekaman 4	155	TBD
	Xekong 3	150	TBD
	Nam Ngum 4A	60	TBD
	Nam Ngum 4B	60	TBD
	Nam Xam	750	TBD
Myanmar	Lower Ta Sang	200	TBD
	Ta Sang 1	4,977	TBD
	Ta Sang 2	4,977	TBD
	Hutgyi	1,200	TBD
	Ta Pein 1	240	TBD
	Shweli 2	460	TBD
	Shweli 3	260	TBD
	Tanitharyi	600	TBD
	Upper Thanlwin	4,000	TBD
	Lower Thanlwin	500	TBD
	Ywathit	800	TBD
	Maykha Basin	13,600	TBD
Thailand	Ubol Ratana	25.2	1966
	Lam Phra Phloeng	?	1967
Viet Nam	Srindhorn	36	1971
	Chulabhorn	40	1972
	Pak Mun	136	1994
	Hua Na		?
	Lam Ta Khong	500	2002
	Dray Hinh 1	12	1990
	Yali Falls	720	2001
	Can Don	72	2003
	Spok Phu Mieng	54	2006
	Sesan 3	79	2006
	Dray Hinh 2	16	2007
	Sesan 3A	96	2007
	Tuyen Quang	342	2007
	A Vuong 1	210	2007
	Quang Tri	70	2007
	Dakr Tih	72	2007
	Thac Muoi	53	2007
	Na Le	90	2007
	Coc San – Chu Linh	70	2007
Thailand	Plei Krong	100	2008
	Dai Ninh	300	2008
	Ban La	300	2008
	Thac Mo	75	2008
	Eak Rong Hnang	65	2008
	Sesan 4	360	2009
	Buan Kuop	280	2009
	Buon Tua Sra	86	2009
	Sre Pok 3	220	2009
	Song Tranh 2	162	2009
	Song Con 2	57	2009
	An Khe + Ka Nak	173	2009
	Ban Chat	200	2010
	Son La	2400	2010
	Dong Nai 3 + 4	510	2010
	Song Ba Ha	220	2011
	Thuong Kon Tum	220	2011
	Huoi Quang	560	TBD
	Lai Chau	1,200	TBD
	Dak My 4	210	TBD
	Nam Chien	175	TBD
	Hua Na	195	TBD
	Song Bung 4	200	TBD
	Ban Uon	250	TBD
	Dong Nai 2	80	TBD
	Dong Nai 5	100	TBD
	Song Bung 2	126	TBD
	Bac Me	280	TBD
	Dak My 1	210	TBD
	Duc Xuyen	100	TBD

Future projects are planned in every GMS country except Thailand, and they call for rapid acceleration of subregional capacity. The nature of planned projects differs across countries. In particular, the capacities of Cambodia, the Lao PDR, and Myanmar remain largely undeveloped and suggest many opportunities for future expansion (Table 2; Figure 5). The Lao PDR, with the greatest portion of the Mekong within its borders, has the opportunity to develop several projects along the mainstream Mekong (Figure 5). However, Myanmar and the PRC have the greatest potential for expanding the subregion's hydropower generation capacity.

Sources: WB (2010); MRC (2010); King *et al* (2007); VUSTA (2007).

Figure 5: Hydropower Projects in the Lower Mekong Basin



Source: Mekong River Commission (2010).

To illustrate, most of the projects planned for the Lao PDR have an estimated capacity of less than 500 megawatts (MW). However, eight proposed projects would have a capacity of greater than 1,000 MW, with the largest (Ban Koum) delivering 1,800 MW (Table 2). In contrast, Myanmar has fewer proposed projects, but four being considered would each have a generation capacity of at least 4,000 MW (Table 2). Similarly, the Nuzhadu project planned in the PRC is expected to have a capacity of 5,850 MW. Consequently, while expansion of hydropower capacity in all countries will contribute to subregional capacity, the largest share of incremental Mekong Basin hydropower capacity will currently come from Yunnan (PRC) followed by Myanmar, the Lao PDR, and Viet Nam in decreasing order (ADB, 2010).

3. Water and Agrofood Production

The Mekong Basin may be defined with respect to a single waterway, but is actually comprised of a rich mosaic of watersheds and tropical landscape that include some of Asia's most productive farmland. As is apparent from Figure 5 above, hydropower projects may be concentrated along the main stem of the Mekong and low on its leading tributaries, but this river's drainage encompasses extensive systems of high and lowland areas with diverse but generally favorable growing conditions. Indeed, historical migration patterns, extending from the UMB to LMB, have brought people from the Tibetan Plateau and northern latitudes into these fertile valleys for millennia. Despite a long history of local agriculture, however, GMS agrofood potential, like hydropower potential, is a promise that remains far from fulfillment.

Across the subregion, differences in agrofood potential are much smaller than differences in yields, primarily because of different levels of local income and attendant patterns of agricultural investment. All five GMS countries have smallholder household production systems as their majority agricultural enterprise. In this context, it can be difficult to realize agrofood potential because poor farmers cannot make investments in irrigation and other agricultural technologies. In countries with higher average incomes, such as Thailand, higher income urban demand can improve smallholder value and facilitate income growth, and more advanced agrofood production and distribution systems can also increase average yields, directly through their own investment and contracting, and by example. Agricultural development policy can support these kinds of productivity and livelihood improvements, but private

agency plays a primary role. One area where there is a strong case for public investment to support agrofood capacity, however, is management of water resources. Like transport infrastructure, improvements in water retention, supply stabilization, and conveyance will all contribute to agrofood enterprise profitability. Because of this they facilitate higher rates of investment and technology adoption and, ultimately, more complete and uniform utilization of agricultural potential. As we have already seen in the case of hydroelectric capacity, the GMS has rich average water endowments, but these are very unevenly distributed and intermittent on a seasonal basis. For precisely the same reasons, renewable freshwater for agriculture is historically unequally distributed spatially and inconsistent temporally. This significantly lowers agrofood potential by reducing average yields and increasing risk, which in turns lowers investment and further undermines capacity development.

Benefits supporting the case for public intervention to store and deliver consistent water supplies to agriculture are very apparent in the following four figures.³ The first two depict existing commitments to irrigation infrastructure in two ways, extent (Figure 6) and intensity (Figure 7). These show clearly the link between average local income levels and this agricultural technology. Locales with higher national and urban incomes can support public and private investments of this kind.

It is well known that by providing stability and continuity in water supplies to crops, yields can be increased substantially. This relationship is obvious in the next two figures, higher agricultural yields (rice, Figure 8) and total output (Figure 9). Lower income populations and markets cannot support such investments independently, so agrofood capacity falls well below potential in comparable areas that may be only separated by a border fence (e.g., eastern Thailand and northern Cambodia). Because extensive rural poverty persists in the GMS, the subregion will remain far below its agrofood potential without some combination of public intervention or regional integration of agrofood investment and/or trade. In the former case, domestic governments can take the initiative, with or without external donor support, to increase private agrofood profitability by investing in water infrastructure. In the latter case, regional and international agrofood investors can finance similar investments from private external savings, just as has been done in urban industrial development across the subregion.

³ Unfortunately, we were unable to obtain comparable high resolution GIS data for Yunnan or Guangxi, so the following discussion focuses on the LMB.

Figure 6: Irrigation Projects

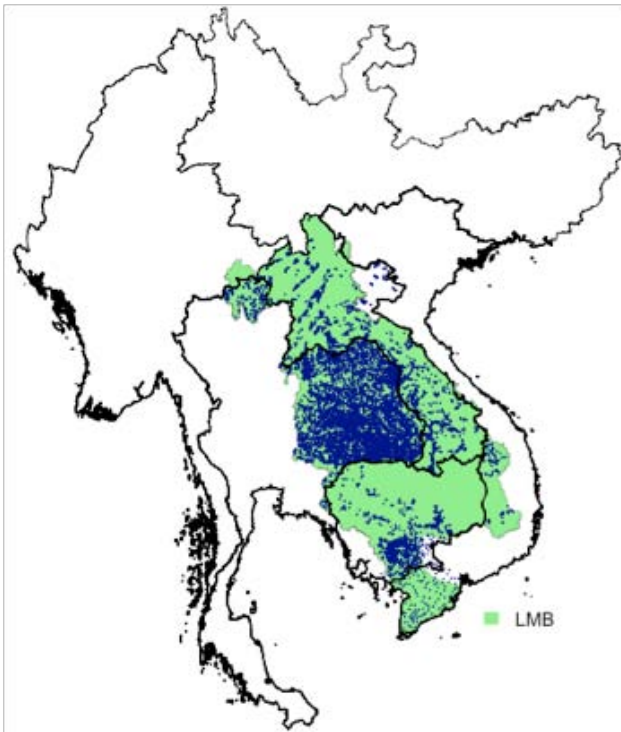


Figure 7: Irrigation Projects, Weighted by Average Monthly Water Diversion

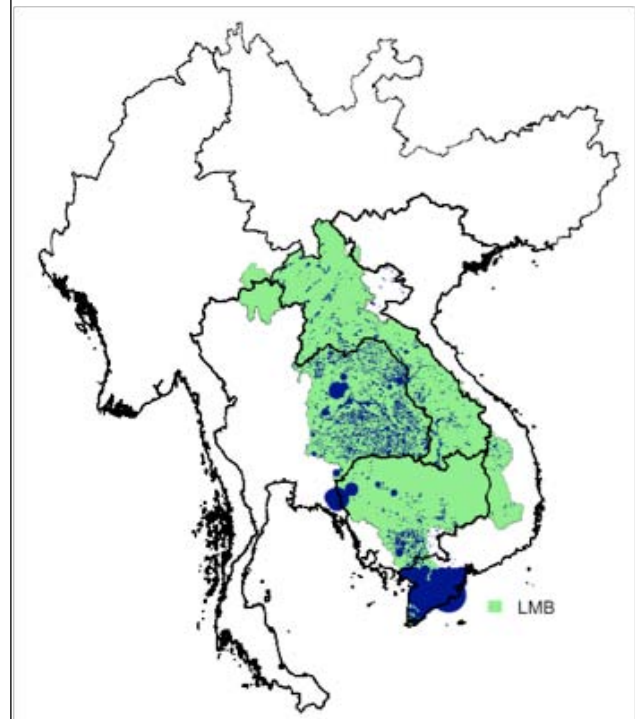
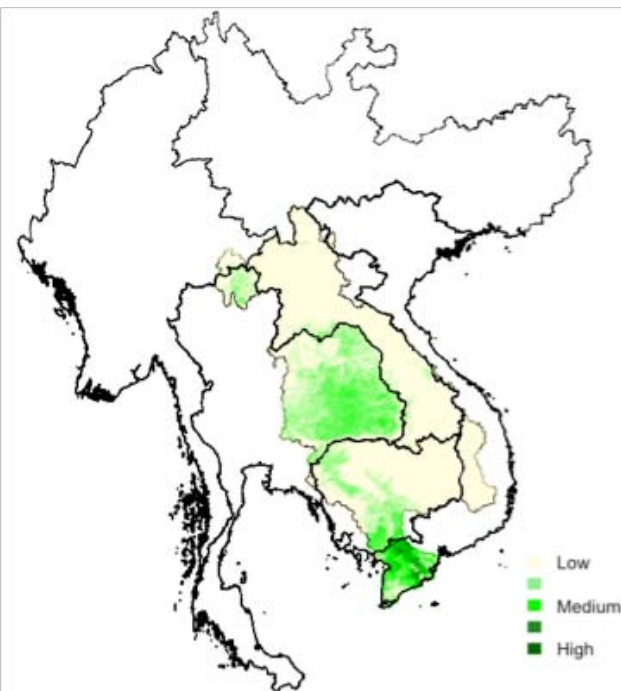
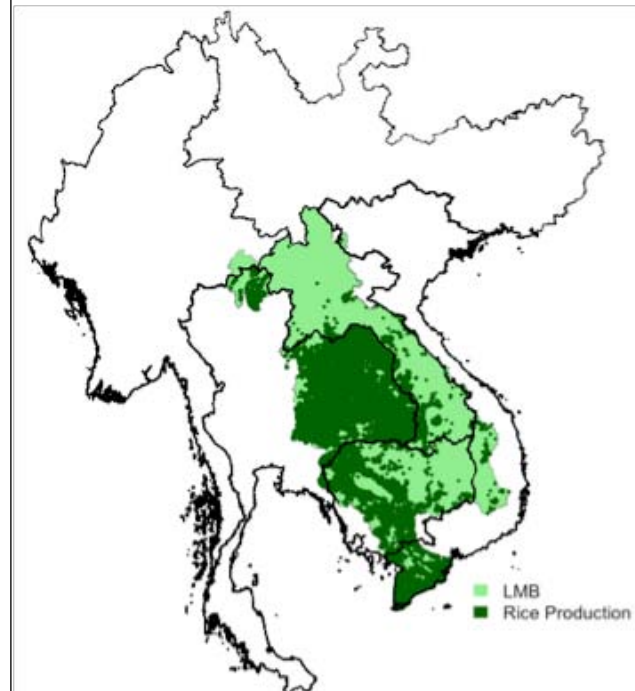


Figure 8: Rice Yields



Source: Author estimates from the Mekong River Commission database.

Figure 9: Annual Rice Production



The foreign direct investment (FDI) approach could be complemented by regional agrofood market integration, conferring three essential advantages on agrofood producers in lower-income countries in the GMS. These are external savings, technology transfer, and market access. Outside investors, whether from neighboring or far away countries, have surplus funds to help overcome local investment constraints. Moreover, through direct (productive investments), contracting, and other local commitments, they can transfer technology to lower income agrofood producers. Finally, these foreign counterparts can use their own supply chains to link low-income producers to higher-income markets and export platforms in neighboring countries. All three of these benefits of FDI can translate into higher rates of yield and income growth in the less productive, lower-income parts of the GMS, promoting economic convergence through subregional integration.

4. Long-Term Scenarios for GMS Water and Energy Development

A. Scenarios

As the preceding discussion makes clear, the economic development of the GMS will depend critically on how its water resources are utilized, particularly in the context of agriculture and energy. In this context, both natural forces and policy institutions can be influential. In the former category, weather variability has been a perennial source of risk, and today we face a longer-term threat of irreversible changes to the global and regional climate. In the policy sphere, GMS member governments have before them a broad spectrum of national and multilateral policy options.

As we have already seen, the economic potential of subregional water, agrofood, and energy suggests that these issues should be foremost in the minds of policy makers. To provide a stronger basis of evidence for public as well as private GMS stakeholders and their trade partners, we conducted a series of scenario experiments on long-term prospects for developing the Mekong catchment's agricultural and energy capacity via investments in water storage, distribution, and hydroelectric generation capacity. We also considered the role of climate risk in a relatively simple context of attenuated annual renewable water flows across the subregion. Our assessment of the economic impacts of these scenarios for each GMS country and the subregion as whole are presented in this section.

Our empirical results were obtained with a global dynamic computable general equilibrium (CGE) model, calibrated to the GTAP 8 database and a baseline macro time series reflecting a business-as-usual (Baseline) scenario over 2010–2030.⁴ This Baseline comprises consensus forecasts for real GDP obtained from independent sources (e.g., International Monetary Fund, Data Resources International, and Cambridge Econometrics). The model is then run forward to meet these targets, making average capital productivity growth for each country and/or subregion endogenous. This calibration yields productivity growth that would be needed to attain the macro trajectories, and these are then held fixed in the model under other policy scenarios. Other exogenous macro forecasts could have been used and compared, but this is the standard way to calibrate these models.

4.1 Climate Change

Evidence is mounting that we face long-term and irreversible changes in the earth's climate systems. The main direct implications of this for the GMS are three: higher average temperatures, rising sea level, and higher seasonal variability of stream flow emanating from the Tibetan Plateau (i.e., the Mekong River). In this report, we take account only of the third factor, increased variance of seasonal river flow because of reduced snow and ice storage capacity in the Himalayas. Ice and snow are the planet's second largest storage mechanism for renewable freshwater, after groundwater. Without offsetting human-made storage, (temporally and spatially) reduced freezing conditions in the GMS headwaters will lead to attenuation of annual water availability across the entire catchment, with corresponding risks for environmental and human water needs. Over the next two decades, FAO estimates that annual water availability could decline by as much as 30% in some areas. Although the subregion is planning to expand water storage capacity for hydroelectric development, agriculture, and other uses, these additions could not significantly offset such a decline.

For this reason, we begin our scenario analysis with an assessment of how the subregional economies would be affected by a 20% reduction in renewable freshwater resources over 2010–2030. This scenario is indicative of the cost of doing nothing in response to adverse natural forces, but it also suggests the consequences of changing water availability that might arise from competition for water. Dams can offer a variety of economic services, including flood control and electrification. They also offer

⁴ The model is fully documented in a separate technical report, available from the authors upon request.

the potential to stabilize water supplies and, with respect to seasonal runoff, increase them. Whether or not these later benefits are realized depends on management of water storage facilities, in particular the extent to which they are used for another function, diversion of water from legacy drainage systems. To the extent that water might be diverted, to other areas for other uses, altering historic water allocation, legacy areas could experience reduced availability. The costs of such arrangements, on a national basis, are also implicit in the climate risk scenario.

4.2 Hydroelectric Power Development

What is the potential for electric power from the Mekong and its tributaries to promote growth of the GMS economies? The answer, of course, depends on the scope of hydropower development, both in terms of overall extent and national locations. As we have already noted, the subregion generally is far below its capacity, with current and planned projects targeting less than 10% of estimated hydroelectric potential. Moreover, existing and planned investments are very unevenly dispersed, and when currently committed projects are all in place, the countries of the GMS will still be very unequal in the extent of their hydropower development. To a significant extent, the result will still resemble today's situation, a low-level investment trap that prevents poorer countries in the subregion from realizing the economic potential given to them by nature.

In this study, we want to contrast this future with one of more ambitious electrification, more uniformly distributed across the region. In other words, we want to assess the economic effects of larger hydropower investment commitments, accelerated in countries with greater excess potential and ultimately doubling electric power capacity with respect to that currently planned. Our results suggest that these commitments would, with the right complementary policies, strongly support subregional economic growth and convergence of living standards, where the poor countries grow faster as a result of natural resource development.

4.3 Water Policy for Agrofood Development

The discussion of section 3 makes it clear that, like most agricultural regions, water resources are critical to the food security of the GMS. More significantly in the present context, water use technology, including storage, conveyance, and irrigation, is very important determinant of differences in subregional agricultural yields. In particular, it is clear that lower-income countries, with less capacity to invest in these technologies, are farther

below their agrofood potential and thereby denied an essential source of livelihood improvement in countries with substantial rural poor majorities.

Enhanced water management infrastructure could contribute substantially to higher subregional agrofood production and promote economic convergence by accelerating yield growth most in the poorest countries. To assess the potential significance of this development strategy, we conducted long-term forecasts for the GMS under the assumption that water "productivity," the contribution of existing water resources to agricultural yields, rises consistently in response to investments in storage and conveyance infrastructure.

4.4 Regional Economic Integration

As we saw in the assessment of agriculture and water resources, GMS growth and livelihood disparities are to a significant self-fulfilling. In other words, low-income regions are trapped by insufficient local demand and low savings-investment constraints. For the same reasons, their public institutions have low revenue potential and limited capacity to provide public goods and services needed to promote resource and market development.

The GMS is a very diverse area, however, comprising both low- and middle-income economies, extensive poor rural areas and thriving mega-cities. This diversity can help overcome investment traps in low-income areas via economic integration. We have seen, for example, that agricultural yields change sharply across national borders. Of course, this has nothing to do with resource endowments, but with market access, available technology, and investible funds. Reducing institutional barriers to trade and investment will expand the horizon of profitable resource use and thereby diffuse both investment and technology into areas that are underinvested. This can be facilitated by policies that remove trade barriers, but also by public goods and services that reduce trade and transport margins, improving the terms of market access for all private agents.

In these ways, public agency can enlist private agency to escape from low investment traps such as that extending across the GMS. Lower-income regions are by definition saving constrained, which in turn limits the progress of development by restricting investment in productive assets and enterprise expansion. The era of globalization has changed the nature of this constraint, however, with the advent of transboundary or foreign direct investment (FDI) that permits low-income countries to leverage foreign

Table 3: Policy Scenarios

- 1) **Baseline:** Calibrating the regional economies to a detailed global database, we project forward using consensus estimates for “Business as Usual” policies.
- 2) **Climate Change (CC):** In this scenario, we assume that seasonal availability of regional water resources is constrained by reductions in winter ice and snow storage in the Tibetan Plateau. Subject to existing constraints on downstream water storage, we assume this reduces annual Mekong water available to agriculture by 20% in 2030.
- 3) **Accelerated Hydroelectric Power Development (Hydro):** Current plans for the GMS call for a regional average growth in hydropower capacity of 3.7%, reaching about 8% of total regional hydro potential by 2030. In this scenario, we assume at two-fold target of regional convergence to 20% of hydropower potential. To achieve this, average capacity would have to expand 7.6% annually across the region, but more rapidly in some countries than others.
- 4) **Increased Investment in Regional Irrigation Infrastructure (Agro) –** We assume that accelerated investments in water storage and conveyance achieve increases in irrigated agricultural capacity of 5% per year across the GMS region.
- 5) **Regional Economic Integration (REI):** In addition to Scenario 4, assume that, the GMS countries the stock of FDI rises to at least 10% of GDP by 2030. We further assume that barriers to trade in electric power and agrofood products are removed within the region.

Notes: Scenarios are inclusive from 2-5.

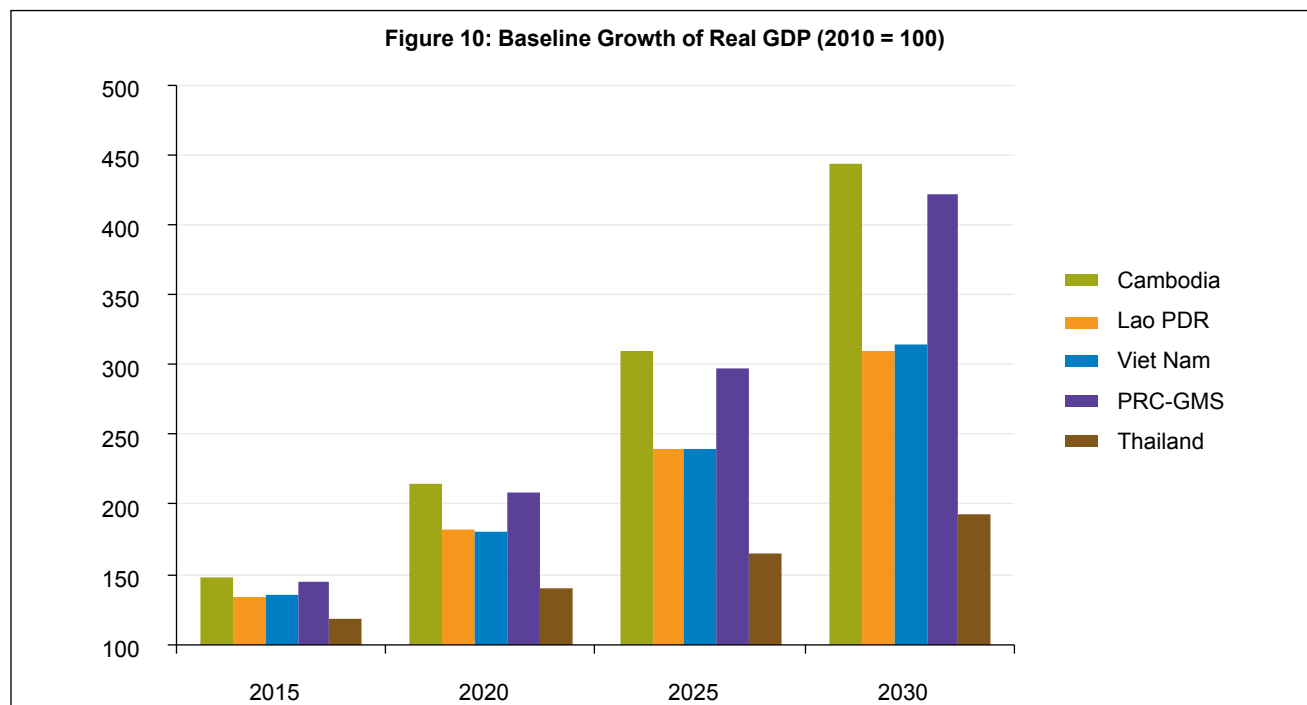
savings for domestic investment, technological change, and growth. To help low-income GMS economies achieve their economic potential in the timeliest fashion, FDI can be an essential catalyst. The same logic applies to rural poor enclaves within middle-income GMS economies. Savings disparities between urban and rural areas are only partially mediated by migrant remittances and public rural development schemes. Improving domestic market access and smallholder productivity could accelerate private investment from urban to rural areas, and from large to small agrofood enterprise development.

Table 3 summarizes the five archetype scenarios we consider – a reference case, one representing an

external shock, and three subregional development policy packages. After detailed examination of baseline subregional growth characteristics, these are thought to best represent the salient policy issues addressed in the present study.

B. Scenario Results

Before examining the counterfactual scenarios, we provide an overview of the reference or Baseline over the dynamic scenario period 2010–2030. As the real GDP indexes in Figure 10 suggest, it is important to recognize that we are studying one of the world’s most dynamic economic regions. Even though the PRC has posted growth rates



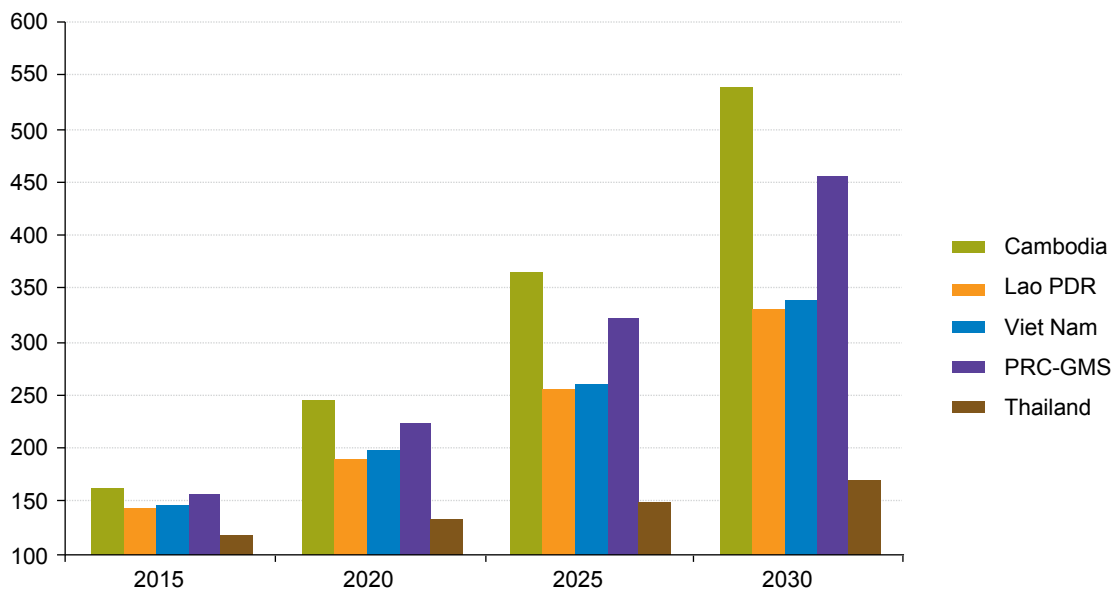
averaging more than 9% for the last two decades, we assume more modest growth (7.5%) for the next two decades in our baseline. Despite this conservative approach to the PRC and its GMS neighbors, we estimate that real GDP would be substantially higher by 2030.

In terms of overall economic impact, all three types of policy can contribute to GMS economic expansion, but in varying degrees. Table 5 summarizes our results for GDP growth, and we see substantial heterogeneity by

both country and policy category. As Figure 11 suggests, baseline growth of electric power capacity will generally keep pace with real GDP in the Baseline scenario.

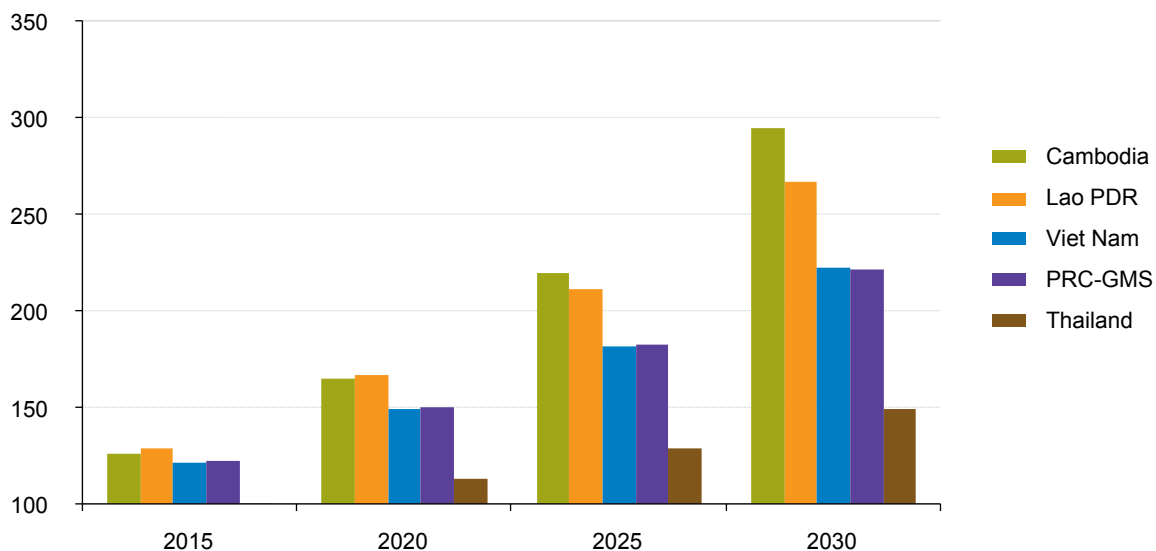
Results for agrofood growth are more modest, suggesting that, without more determined resource policies, the subregion's economies will continue their structural change toward industrial and urban development. Given the large rural majorities in lower-income GMS countries, this poses risks for equitable growth and food security.

Figure 11: Growth of Electricity Output (2010=100)



Notes: In this and subsequent tables, countries/regions are listed in order of increasing per capita income.
Source: Author estimates.

Figure 12: Growth of Real Agrofood Output (2010=100)



Source: Author estimates.

We now turn to the counterfactual experiments, the macroeconomic impacts of which are indicated in Table 4 below.

Table 4: Real GDP by Country, Percent Change from Baseline in 2030

	CC	Hydro	Agro	REI
Cambodia	-14	2	40	79
Lao PDR	-21	-9	66	134
Viet Nam	-6	33	67	111
PRC-GMS	-7	18	39	49
Thailand	-7	5	38	79
All GMS	-8	18	49	81

Agro = agrofood, CC = climate change, Hydro = hydroelectric power, REI = regional economic integration.

Source: Authors' estimates.

These justify careful interpretation because of their heterogeneity, but a few salient observations can be made at the outset:

- Since the Baseline and all four counterfactuals are defined in terms of trend variables, the terminal year assessment is representative of the overall economic impacts across 2010–2020.
- It is apparent that climate risk would significantly impact the GMS if adaptation policies were not enacted in response. Promoting more extensive and intensive water resource development via increased hydroelectric and agrofood investments

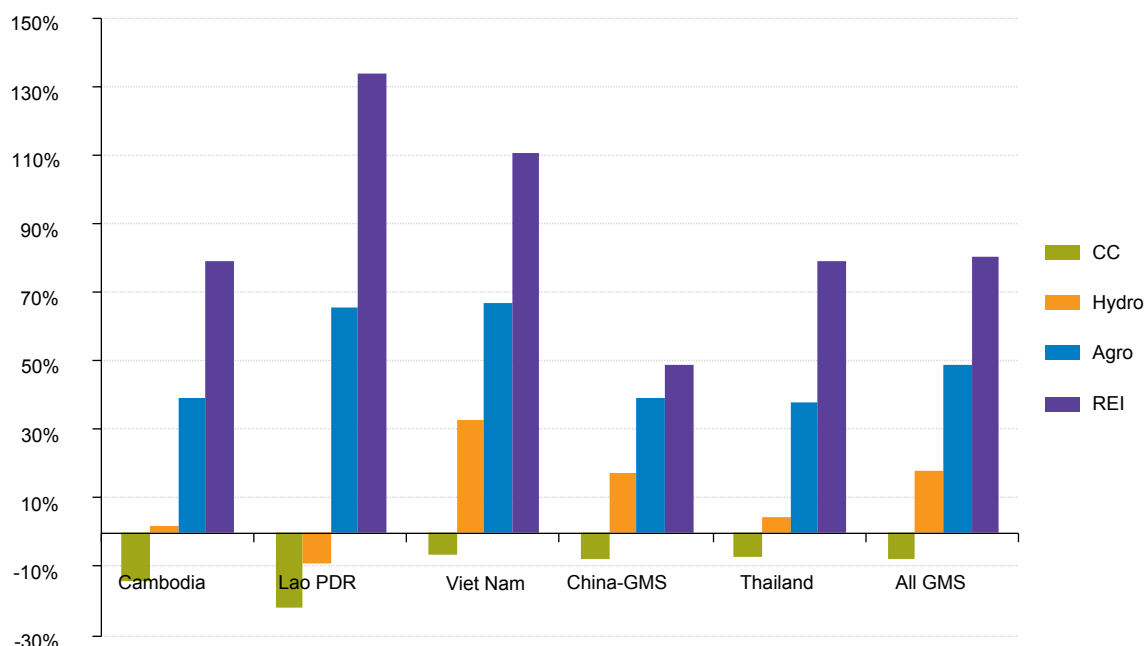
can be a potent growth strategy, and more than offsets climate risk at the subregional level.

- The benefits of hydroelectric development alone, without complementary water development for agriculture, are mixed.
- Combining water development strategies more than doubles the benefits of hydro alone for each country, and increases them fivefold on a subregional basis.
- Policies that facilitate subregional integration by implicating private agency, including enterprise investment and supply chain integration, significantly amplify the gains from more focused resource development strategies, nearly doubling them across the GMS as a whole.

Now we turn to more detailed interpretation of individual scenarios. Tables 5-8 give more detailed macroeconomic results for these. Results for the climate change (CC) scenario are in Table 5.

In an agrarian economic region like the GMS, attenuated water supplies must adversely affect the overall economy. The results in Table 5 support this reasoning, and indeed the more agrofood dependent the economy, the more adverse the outcome. These findings are hardly surprising, but it is worth focusing on the composition of macroeconomic impacts to fully understand their implications. In particular,

Figure 13: Real GDP by Country, Percent Change from Baseline in 2030



Agro = agrofood, CC = climate change, Hydro = hydroelectric power, REI = regional economic integration.

Source: Authors' estimates.

Table 5: Climate Change Risk, Macroeconomic Impacts (Percent Change from Baseline in 2030)

	GDP	Output	Exports	Imports	Cons	CPI
Cambodia	-14	-10	0	-1	-19	4
Lao PDR	-21	-21	3	-10	-32	12
Viet Nam	-6	-2	4	1	-10	2
PRC-GMS	-7	-3	12	9	-12	0
Thailand	-7	-3	0	-1	-8	-1
All GMS	-8	-3	5	3	-11	1

Cons = consumption, CPI = consumer price index

Source: Authors' estimates.

household real consumption is harder hit than real GDP, and this translates into more adverse welfare effects. Increased water scarcity drives up food prices, and this undermines real household income and consumption (Cons), more so in the lower-income GMS economies. In this way, climate risk can be seen to increase the economic vulnerability of the poor and will have serious socio-political implications unless corrective measures can be taken.

Results for the second counterfactual scenario are particularly interesting. Despite the fact that all GMS countries are well endowed with hydroelectric potential, policies that target this sector for development will not benefit all and might even be detrimental without complementary measures. The subregion as a whole will gain from expanded capacity, but the Lao PDR, often touted as the “battery of Asia” for its relatively rich potential, would actually see its GDP growth slow in this scenario. The reason is a simple case of the often seen “resource curse,” where monolithic investment in a resource-intensive export industry shifts the real exchange rate against a country’s other emerging economic activities, reducing overall competitiveness and undermining balanced development. Meanwhile, energy prices fall steeply across the subregion, increasing real incomes for net energy importers.

The results of the next scenario offer an encouraging alternative, combining water development for both hydro and agrofood production. All the GMS economies have the potential to increase agrofood yields, and combining expanded hydroelectric capacity with infrastructure

for more extensive and consistent water conveyance/distribution can realize a significant amount of this potential. Furthermore, real output gains in these countries are only part of the benefit, as declining food prices (in terms of consumer price index) improve real incomes for all and most so for poor majorities. It should also be noted that an integrated approach to water resource development promotes regional economic convergence, i.e., the poorest countries benefit the most in terms of percentage real GDP growth.

When the subregional economies promote parallel energy and food capacity, aggregate gains far outweigh an energy-only development strategy. This has both domestic and multilateral implications. To realize their economic potential, each country needs complementary approaches to utilizing Mekong water resources, but it is also apparent that any country whose access to water resources is compromised could be denied an essential buttress to its growth and food security.

Overall, the results of the combined water policy experiment highlight the importance of balanced development strategy, especially in the context of essential commodities. They also make it clear that countries with agrofood potential and extensive rural poverty have as much or more to gain by securing water services for food security. It is fine to develop electrification and external energy revenue as secondary water policies, but hydro development strategies that subordinate or actually compete with agriculture use are economically and politically risky in regions with low average incomes. The reason is that food costs far exceed

Table 6: Hydroelectric Power Development (Hydro), Macroeconomic Impacts (percent change from baseline in 2030)

	GDP	Output	Exports	Imports	Cons	CPI
Cambodia	2	1	10	4	4	-14
Lao PDR	-9	-13	13	-6	-16	-3
Viet Nam	33	28	21	13	45	-25
PRC-GMS	18	22	43	20	18	-10
Thailand	5	7	9	6	8	-9
All GMS	18	18	25	13	23	-15

Source: Authors' estimates.

Table 7: Water for Energy and Agrofood (Agro), Macroeconomic Impacts(percent change from baseline in 2030)

	GDP	Output	Exports	Imports	Cons	CPI
Cambodia	40	29	8	4	62	-21
Lao PDR	66	44	41	24	80	-12
Viet Nam	67	35	22	14	89	-25
PRC-GMS	39	30	8	-5	58	-10
Thailand	38	21	26	13	40	-6
All GMS	49	30	18	7	64	-14

Source: Authors' estimates.

Table 8: Subregional Economic Integration, Macroeconomic Impacts(percent change from baseline in 2030)

	GDP	Output	Exports	Imports	Cons	CPI
Cambodia	79	55	31	35	124	-21
Lao PDR	134	92	121	69	153	-8
Viet Nam	111	53	61	52	147	-20
PRC-GMS	49	37	15	9	77	-9
Thailand	79	44	71	43	80	2
All GMS	81	46	47	35	105	-11

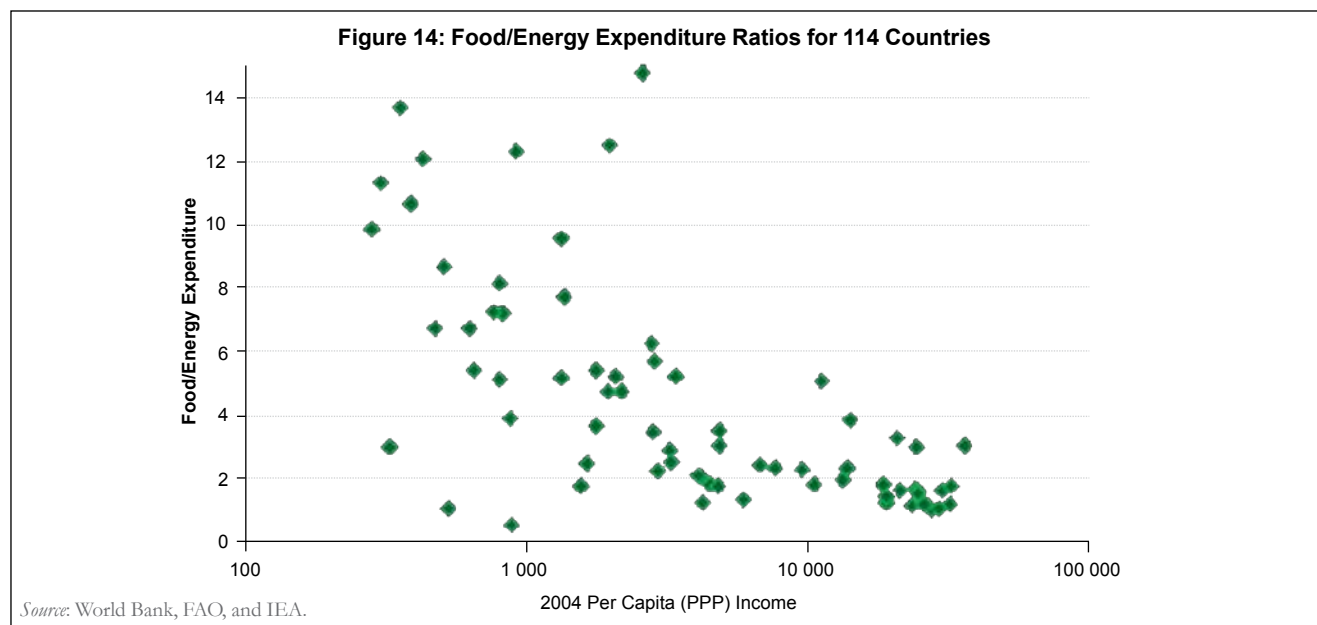
Source: Authors' estimates.

energy costs in the household budgets of the poor. For most low-income countries (Figure 14), households spend 4-12 times as much on food as on energy. This can make diversion of water or water services, between uses or places, a very sensitive issue.

The final policy scenario addresses an essential GMS subregional issue, the extent to which private flows of goods and services can freely interact across national borders. As we have emphasized from the outset, today's GMS is still characterized by vast differences in level of economic development, with attendant differences in incomes, infrastructure, and enterprise systems. In such a coherent geographical region, these differences are only to a very limited extent the result of fundamental inequality of initial conditions like resource endowments. On the

contrary, most of the impetus of modern globalization strives to overcome such differences by extending supply chains and achieving more efficient division of labor and other resources.

The primary explanation for disparities among GMS countries today is institutional. Indeed, there is probably less difference geographically and demographically across the GMS than there is across Europe. The latter has achieved economic convergence through economic integration, and integration holds the same potential for the GMS. The fifth and final scenario gives an indication of the rewards of more open trade and investment across the subregion, and these gains appear to be substantial. In terms of real GDP, benefits of combined water development would nearly double for the higher-



income countries and increase by multiples for the poorer ones. The reason for this pro-poor effect is obvious, as the lower-income countries are the most investment constrained. If Cambodia, the Lao PDR, and Viet Nam could achieve their resource development objectives with private counterparts, instead of having to commit scarce and valuable public or private domestic savings, the real growth benefits would more than double incomes by 2030. As any experienced enterprise developer can tell you, a good banking relationship is much better for growth than financing investment from retained profits.

5. Conclusions

A watershed famously defines the GMS, where river flows hold vast capacity for environmental services to support, among other things, renewable energy and food production. In both contexts, however, the GMS remains far below its potential. On current trends, GMS hydroelectric capacity will be less than 10% of potential by 2020 and average crop yields across the region are probably 25%–30% of potential. Since these two commodities are essential to basic needs and potentially leading contributors to subregional economic growth, they are high priorities for development. The primary constraint in both cases is investment resources. The GMS landscape comprises a mosaic of diverse economies, but is dominated by low-income rural populations. This leads to a low-level investment trap, where domestic and especially local savings are insufficient to develop and maintain water infrastructure for hydroelectric power or more effective irrigation systems or even micro-hydro schemes. Governments of low-income countries face similar constraints, with limited capacity to raise revenue and many competing priorities for scarce public funds.

The advent of greater subregional cooperation, including multilateral transport initiatives and cross-border energy and water management agreements, heralds a new era of opportunity to develop these essential growth resources. This study examined the long-term economic potential of such strategies, using a dynamic forecasting model to evaluate growth prospects over the next two decades. Our results suggest that more determined commitments to water infrastructure can accelerate national and subregional growth dramatically, but only if a balanced approach is taken to water's potential for producing both energy and food. In particular, we find that monolithic investments in hydroelectric development would benefit subregional energy consumers, but have limited benefits

for low-income countries in the subregion. Thus the Lao PDR, for example, could actually be worse off because of the “resource curse” of real exchange rate appreciation. This is particularly regrettable since the poorer GMS economies also have substantial unrealized agrofood capacity, and food costs are much more important to the poor than energy costs.

A more balanced investment strategy, which combines energy development with water infrastructure that stabilizes and more effectively distributes water supplies, could turn the subregion into a major food producer/exporter, with the lower-income countries benefitting most in relative growth and income terms. We also find that these investments can protect the subregion against reasonable climate risk, but using existing or even diminished water resources more productively. Combining these investment programs with institutional reforms that accelerate subregional economic integration would amplify these benefits even further, as private agency is enlisted to finance a large part of the needed investment and to extend subregional supply chains, conferring unprecedented market access on the lower-income GMS economies. Finally, integration will accelerate capacity use for the flagship transport infrastructure assets in the subregion, including the transport corridors, bringing the subregion much closer to its potential and sustaining hope for economic convergence and shared subregional prosperity.

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Panel Discussion – Day 2
Scaling Challenges and Scoping Opportunities
for the Next Decade

Facilitator: Arjun Thapan

PANEL DISCUSSION – DAY 2

SCALING CHALLENGES AND SCOPING OPPORTUNITIES FOR THE NEXT DECADE

Facilitator: *Arjun Thapan*

Panelists

*Prof Nay Htun, Jeremy Bird,
Dr Mark Rosegrant, Jean-Pierre Verbiest,
Prof David Roland-Holst*

Arjun Thapan introduced the session and called for short, sharp, and crisp questions and comments. First he asked the panelists to set the stage by reacting to David Roland-Holst's presentation in statements no longer than 3–4 minutes. The first panelist is Prof Nay Htun.

Nay Htun, SUNY: Thank you very much. With your permission, I may take five minutes, the reason being that I have five points to make and I would like to stir up the discussion a little. That was an excellent presentation by Prof David Roland-Holst. I would like to take this opportunity not only to talk about scaling-up but also think out of the box. Firstly, there are the changing demographic dynamics in the region: 33% – 40% are below the age of 15 and there is an ever-increasing aging population. This has tremendous implications. Secondly, we have heard about urbanization, that is urbanization in the coastal areas of between 66% and 80% in the next ten to twenty years, if not already more in some countries—with tremendous consequences from climate change: sea level rise, typhoons etc.

There is another phenomenon as more and more people move into urban areas: increasing numbers of urban poor. But the urban poor are not the poorest. They are probably earning about \$2–\$3 a day living in slums and may hold jobs in five-star hotels and they see that a bottle of water or a can of soda costs \$5. You look at your laundry list and you can see that cleaning a shirt costs \$5; if you go out you can buy five shirts for \$5. As they see a can of soda for \$5 and they earn only a few dollars a day, believe me, there is a tremendous amount of unhappiness. The disparity between the urban poor and the more affluent is growing and is a very important social indicator.

A third phenomenon is social networking; we have seen it more in the United States, Europe, and in the Middle East, and it is going to be here and we will be seeing more of this.

The last two points are my favorites relating to climate change. We hear a lot about greenhouse gases, but I would like to mention the following: while the international community and the Intergovernmental Panel on Climate Change (IPCC) has been talking about a future 2 °C degree temperature increase, there is now talk of a 4 °C increase. Last year, the Royal Society in London published 12 papers about the consequences of a 4 °C increase and how countries should be gearing up to cope with this increase. We are not even prepared to face a 2 °C degree increase but now we are talking about a 4 °C increase.

We have not heard much about ocean acidification. Last year, the National Science Foundation prepared a report to the US Congress showing that over the last 100 years the rate of acidification has been the highest in human history and it has tremendous consequences for social and economic human security. Along with ocean acidification comes soil acidification. When the carbon dioxide becomes carbonic acid and nitrogen oxides become sulfuric acid, not only do these precipitate over the oceans, they also precipitate on land and freshwater. How will that affect our rivers, lakes, and soil? It will have tremendous implications for agriculture and food security. We need to hear more and look into this. There is also ocean hypoxia, which are increasing spots in the ocean where oxygen is being depleted and almost nothing lives. What is happening to our coasts and water bodies needs to be examined. When we talk about water and land, we need to address these matters.

Finally, another passionate subject of mine is alien, invasive species. We hear a lot about melting of the permafrost and so much release of methane; but when the permafrost melts, it is not only methane that will be released but a lot of microorganisms that have been dormant. What affects will they have on our soil, water, food, and health? All these impacts need to be examined for our food security and food safety. All have tremendous implications if they come together. The central driving force of all these is carbon in energy production.

David Roland-Holst, University of California, Berkeley: I think these matters are very relevant; they are not in the scenario that I presented as I wanted to isolate just one dimension of climate risk. I am perhaps not as pessimistic

as the average person on adaptation requirements. I am very bullish on technological capacity. But I do believe we have to address these issues as quickly as possible. I think the main challenge is to get the public to take climate risk seriously and to make it real. An example I use with audiences when I speak in California is seismic risk; that is something we know is real as we get gentle reminders in the middle of the night a few times a year in California. So we are changing our behavior; in the Bay area we are building a new bridge and it has not fallen down because we have internalized that risk and there is a multibillion dollar industry in California for retro-fitting because of internalizing risks. Climate change has not really aroused that kind of adaptation response yet but it is very necessary. I hope we do not wait too long so that we are already in a crisis before we begin to adapt.

Arjun Thapan: Before I ask anybody else on the panel to react, is there anybody in the audience who would like to comment on Prof Nay Htun's interventions and Prof Holst's initial reaction.

Javed Mir, ADB: I refer to Prof Nay Htun's comments on the gaps in our coverage in this conference, especially on marine resources, which need special attention. I do agree that in many of our GMS countries, marine resources, particularly supply and safety of fish resources, are important issues of food security. The acidification of soils has been an issue in the past; I am not aware how big a problem it is right now in the region and how big a problem it is likely to become. But that is something obviously we need to get a better hold on; and all I can say is in our programs, we are trying to benchmark the conditions in the particular landscapes and farmlands. We need to look at most efficient ways of how to do it. Are we deploying the latest technologies to monitor, detect and diagnose these issues? Thank you for those interventions; I do think these are relevant.

Mark Rosegrant, IFPRI: Let me start with some specific comments on the paper: I like a lot of key conclusions that were enlightening; I have never seen so clearly demonstrated in a quantitative sense the synergies between hydropower development and integrated water development for agriculture. I would like to know if there is a freshwater fisheries sector in the scenario analysis because a lot of literature indicates that the level of hydropower and irrigation development could possibly have severely damaging impacts on freshwater fisheries. How would you predict that one? Another key point you could elaborate on is this powerful effect from

the combination of regional economic integration and foreign direct investment. Could you tell us what kind of functional relationships and assumptions are there in this context? The question posed to the panel is what are the scaling challenges? It would seem to me that for scaling-up sustainable growth, investments are needed that have broad, positive externality, such as investments in education, that bring people into this modern sense of globalized economy that integration would bring. These investments should have strong backward and forward linkages in rural economies, such as getting agricultural productivity growth moving, linking inputs and long-term commodity markets. Another area that will be very valuable is getting legal and institutional structures in place; to have land rights, water rights, and contractual arrangements becoming more consistent and strong across the subregion. Another area is public goods investment in rural infrastructure that helps make it feasible for private investment to come in to generate substantive benefits.

David Roland-Holst, University of California, Berkeley:

I am very grateful to have these clarification queries and I will be happy to talk more about these results. The fisheries issue is a very interesting one; unfortunately, that is a blind spot in this analysis and the reason is that the hydro specifications are not project specific. We are really not looking at individual projects and we cannot capture those spillover effects (no pun intended) of the dams. So we probably have underestimated the average effects that dams might have on fisheries productivity, and we are looking at a crop-oriented irrigation strategy. In terms of the foreign direct investment amplification effect, this is a really appealing component of the results. It is a great selling point for an integration agenda. The reason it works is because disparities in productivity across the GMS are so acute. It is startling to compare agri-food productivity in higher-income, more technology-intensive countries with subsistence production in isolated rural-poor areas. There is acute inequality in terms of productivity. So if you can overcome that in, I think, about two decades, it is realistic to assume that agri-food technology and resources could be diffused to a reasonable extent; we are only assuming 4% growth per year, which is not unrealistic by post-green revolution standards. In some areas I think, it could be even more dramatic simply because initial conditions are so remarkably unequal. Here, again, I apologize to our colleagues from Myanmar; unfortunately, were unable to include Myanmar in the modeling because we couldn't identify sufficient data to calibrate that economy and make it comparable to other countries in the subregion. We would like to do that because we think we will see a huge dividend

to transboundary engagements in the agri-food sector and other sectors. Fortunately, the policy environment seems to be pointing in that direction.

Before we move on, let me concede a very significant weakness in my modeling that has not been brought up yet—institutions. As economists we have to assume that markets are going to be the prevailing determinant of resource allocation, and frankly speaking, this is a potential that I am showing and the results are indicative, but they depend on institutional initiatives and functioning that often do not realize the hopes of economists. So we do really need to be sure of the institutional framework and support for these economic efficiency measures.

Arjun Thapan: Thank you. I think that point about institutions is extremely important and, in fact, we are asked to look at that element in the context of the overall policies and recommendations that this conference might wish to consider.

Jean-Pierre Verbiest: Let me first comment about Myanmar; Myanmar is twice the size of Viet Nam and a quarter larger than Thailand. Half of its agricultural land is not used and lies fallow at the moment as irrigation has fallen apart. Thus, the country has a huge potential for agriculture and we know that also from history. Myanmar is going to change the GMS and it is going to change ASEAN over the next 10–15 years. I think we are at a point of no return in terms of reforms. It is also a country with huge energy capacity; by 2014 it is set to double its gas exports and there are proven reserves at the moment for 50 years; and that is only one part of it. Water resources, by and large, have not been tapped. So that is going to be a major change. On institutions, I am involved with the Asian Development Bank Institute on a study on ASEAN 2030, and while ASEAN institutions are probably not the strongest ones, GMS is even weaker because GMS does not even have an institutional framework. We are looking at a longer-term perspective relating to these issues and in such areas as energy and environment; basically, there will be an ASEAN energy authority or an ASEAN environment authority, which deals with climate change, priority transportation, and so on, similar to the European Union (EU), which has a policy in place on green logistics. All transportation in the EU looks at climate change and is optimized to minimize impact of climate change. Whether in the GMS or in ASEAN, we are nowhere near that; it is not even in the vocabulary. There is a tremendous need for things to be done in this area. And of course, water management should be part of it. Also, the ASEAN

context fits better in building up institutions where you have common agreements on energy. Now energy, I think, is going to be the major issue in the future; if you look at the GMS, the CLM countries—Cambodia, the Lao PDR, and Myanmar—have become large exporters of energy. And countries around these—PRC, Thailand, and Viet Nam—are energy-deficient; so there is going to be huge demands on the CLM countries.

So, coming back to the institutional question, how, as a country, do you deal with geopolitical pressures: on an individual basis or as part of a regional entity? That is why it will be better for countries to have common policies. They do not have to surrender sovereignty, but they may have a common position on how to use their energy. And we have not even touched upon the South China Sea, which is another potential area of conflict.

Arjun Thapan: Thank you. I think these comments have touched on something very important, some of which has been missing in some of the discussions held over the last day and a half. It is very tempting to look at a number of these issues concerning water, energy, and food at country level and expect rather simplistically that these will aggregate into a subregional position; I do not think that is either correct or appropriate; I think it is time to start looking at some of these issues at a GMS level, like food security. Is the GMS a single food security zone or is each country going to be food secure on its own? May be there is an enormously high price to be paid in terms of pursuing severely nationalistic goals as opposed to pursuing a subregional agenda. So is there anyone here who would like to comment on that aspect in terms of the outcome that David's research has yielded, the institutional elements?

Geoffrey Blate, WWF: One comment I would like to make about climate change is the potential for mass migration due to inundation of low-lying areas, especially the Mekong Delta. The rationale for a regional approach to dealing with climate change is one important area; the countries have to deal with mass movement of people and WWF supports the idea of a regional approach to tackle such issues. We would support some kind of a regional agreement to deal with climate change, mostly on the adaptation front, but also to ensure that activities focusing on mitigation do not undermine the resilience of neighbors. Thank you.

Myo Thant, ADB: On the regional aspects, in the middle of last year ADB was approached by Indonesia hosting the ASEAN Summit last year to prepare a paper on what ASEAN can do collectively on agriculture and food security.

The potential of GMS to act collectively on many of these issues came up very prominently in this paper; it is much easier for the GMS to cooperate on food security than ASEAN because ASEAN is split between food importers and food exporters. We have got the big importers like the Philippines and Indonesia on the one side and the exporters on the other side and their interests are not always the same. But for the GMS there is lot of potential and some of the issues we touched upon like common standards, ensuring connectivity, and trade flows, are important for enhanced food security. One of the important issues is collaborate more on agricultural research. For 20 years the amount of funding going to research has been declining; we have seen some uptake in, for example, the International Rice Research Institute (IRRI), but that has happened basically through funding from the Gates Foundation. The countries have to do something collectively as well. Each country has to resolve the issues individually, but there is a lot that can be done collectively. And in the future I hope we would focus on what we, six countries collectively, can do as consumers, producers, and researchers.

Leeber Leebouapao, NERI, Lao PDR: I would like address my question to Prof Holst. In your presentation, you showed that climate change will negatively affect water availability for agriculture in the Lao PDR. The Lao PDR is aiming to graduate from its current status of a least developed country by 2020 and one of the criteria for graduation is the so-called economic vulnerability index. The index shows a widening of impacts on the Lao PDR and increasing vulnerability. But how does your scenario show an improved agriculture production scenario in the Lao PDR in spite of increasing vulnerability from climate change impacts?

David Roland-Holst, University of California, Berkeley: Thank you for that insight on Lao PDR. Vulnerability is increasing inequality in the subregion; it is also leading to declining yields in subsistence areas; but the scenario I presented is based on the idea of factor productivity growth in food production and that I think would be the strongest stimulus to reducing vulnerability for smallholder households. The challenge is, institutionally to get those innovations down to the smallholder level and that is a very big challenge. Extension services, technology transfer, infrastructure and public goods and services for agriculture would be essential to make this assumption of the scenario of a 4% growth in agricultural productivity over 20 years; that is the hard part. I can estimate what the benefits of that would be numerically, but the institutional requirements

to deliver that are very significant. I just hope that when government sees the prize—how big the potential gains are—they will make the necessary commitments and that I believe would be the most effective way to reduce economic vulnerability in the rural sector.

Jeremy Bird, former CEO, MRC: I will start with a question to Prof Holst and then give some more general comments. I shared his initial surprise when I saw the results of the hydropower scenario in Lao PDR—this idea of the resource curse or the Dutch disease. Is this inevitable or is it a risk that needs to be managed? Is it definitely going to be the outcome? For example, we have seen in the Lao PDR over the last 8–10 years that there is revenue coming in from major mining activities that have been flowing into the national budget. Now has that caused this resource curse phenomenon or not? I think the Nam Theun 2 project was also mentioned this morning where mechanisms are put in place to direct revenues toward social or livelihood oriented activities. So that is my first question. The second relates to the title of the conference and how that links to the nexus considerations that Prof Holst presented. The results presented were demonstrated in terms of GDP impacts but he also mentioned the imperative of looking at it from a livelihood perspective and we saw yesterday in Peter Warr's presentation of links between economic growth and poverty reduction, and malnutrition was mentioned by another speaker. I have a concern when I look at the title of the conference in terms of the word "Balance" because balance to me conjures up issues of trade-offs. It is important to know how you calculate the benefits and what externalities are incorporated into that calculation. If the positives outweigh the negatives then we just go ahead with the positives and is that trade-off going to lead to a series of losers? I am not advocating that you can always end up with win-win solutions; that may be utopian. But if we look at it from the point of view of "balance" with benefit sharing as a requirement and maybe integrating economic growth and environmental sustainability, that is to me a more acceptable way of using the term "balance". Another point is the nexus: this nexus idea was presented at the Bonn Conference in November 2011; it is also highly prominent in the recent report of the high-level UN Panel on Global Sustainability. The Bonn conference came up with six key messages and most of those were very relevant to the work of the present conference; policy coherence was the first one and I think that has come out very strongly from many of the speakers here—to make sure there are no pervasive subsidies or incentives that distort development decisions, whether biofuels or hydropower. Others included accelerating

access, which comes back to the concept of benefit sharing and making sure that the available revenues (and there incredibly high revenues) are used to address such concerns as poverty and lack of access to basic services. Other Bonn messages were on creating more with less and ending waste; I think this included new technological advances, efficiency gains, demand-side management, etc.; one of the hydropower issues is the possibility of rural energy using hydro kinetics in small streams and irrigation canals to generate hydropower for rural communities.

Coming back to the development modeling and scenarios, I wanted to raise awareness here of the work by the Mekong River Commission (MRC) in the last 2–3 years on a set of interlinked scenarios: baseline, definite future scenario, climate change, dams in the PRC, hydropower potential, and irrigation; and all that material is available on the MRC website; I think a strategy that has emanated was also approved by the Council of Ministers last year. Looking around the room, I wish to echo what Dr Parisak has mentioned about silos—not only silos within development organizations and within governments, but also silos within regional organizations. The people in the audience here are not all the same people I saw in the MRC meetings that led to that strategy development. So I think there needs to be a stronger cross-fertilization of those issues.

David Roland-Holst, University of California, Berkeley: I do not have the capacity to respond to all those comments, particularly institutional issues, although I am in considerable agreement with most of your comments. But on the resource curse or Dutch disease, there are ways out of the dilemma and one of them is proposed in the third scenario, which is to have integrated water development with a deliberate strategy for utilizing water services more completely across the economy. There is only one cautionary comment I will make about using revenues from resource-intensive industries based on my experience in development. It is very important that those resources be invested in productive infrastructure or activities and not simply be dissipated in public services or entitlement-oriented royalty payments to the general population. This really intensifies the so-called Dutch disease problem: real exchange rate overvaluation reducing competitiveness for other activities. In the United States, Alaska has a serious case of this problem; they have converted resource royalties into welfare payments to the general population with no discernible effect on real growth in the economy. The other option is keeping those resources offshore; some oil producing countries like Cameroon have done that but of course that would not help in a low-income

environment. It is very important to put those royalties to work but I want to caution that it is essential these revenues go into increasing domestic factor productivity so that the economy can get the maximum growth leverage from the resource base. I do still advocate integrated approaches to realizing the potential of water services. On other points, I really want to second the recommendation that you look more extensively into the contributions of the Mekong River Commission into public and private understanding of resources in the region and not just the data resources, which are abundant now, but also the value added in terms of research that has already been undertaken under MRC sponsorship. This is a great model for improving public awareness and informing the policy dialogue; I would like to see it extended to the GMS. I think it is essential that we support more evidence-based approach to regional policy dialogue.

John Soussan, SEI: Looking at the big picture, we have major infrastructural development and regional integration processes but I am missing the people in this. Nobody becomes prosperous from agriculture alone; if we look at the nature of rural development as opposed to agricultural growth, rural development is much more about diversification of livelihoods. That includes, for example, rural-urban migration where parts of the household are in the city sending back remittances and providing services from urban areas. And yet, across the region there are all sorts of barriers to diversification, including tax incentives, perverse incentives, barriers to enterprise development, problems of access to credit for enterprise development, lack of services support, and so on, because there too much focus on the equation: rural development equals agriculture; agriculture equals field crops. Field crops are generally less than a quarter of the value of rural incomes and livelihoods in most parts of the region. This perspective of understanding the dynamics of household livelihoods and how to get prosperity at household levels means diversification. The big picture is important but will not alone create desirable dynamics of livelihood development. I seek comment on that.

David Roland-Holst, University of California, Berkeley: Thank you. I am really grateful for those comments; they echo much of the discussion in our working group session on food security yesterday. I hope that Dr Rosegrant also has something to say about this. It is absolutely essential in agriculture-led growth processes to get beyond the high-density subsistence population and increase not just food production but also food value, improve livelihoods at rural household levels, and, thereby, create the opportunity to

liberate labor from the rural sector and animate more productive employment and intensive urbanization. The agriculture-led growth process, which is now familiar from dynamic economies of Japan, Republic of Korea, and Taipei, China, began in these countries with agri-formative growth in the beginning of their rapid growth phase as I am sure you are well aware. But again it is about institutions; overcoming the market access barriers and transferring technology are more about the microeconomics of agri-food development. We had a lot of discussion about that in the food security session yesterday.

Mark Rosegrant, IFPRI: Yes, you increase employment when you have diversification of higher value crops, higher knock-on effects through processing industries, and generation of higher valued processed foods. I think those really are key components of this kind of development.

Nay Htun, SUNY: With institutions and regional integration, it is a chicken or egg situation—which comes first. In my previous work, there was always a problem to identify within a government a certain ministry that is willing to take ownership an institution that will help support regional integration. The task is usually spread out between many ministries and very few of these want to take ownership; that is the problem. Without a good, strong coordinating institution, it is very difficult to promote greater regional integration. I think regional integration, given the history of the GMS, is important because it will be an extremely important platform for global integration, which is happening more and more, whether we like it or not. There is a tremendous opportunity to build up capability and capacity at the national level to help support an institution that will promote more comprehensive regional integration rather than sector-based approach. My second point is about Myanmar. My comments here are being made on a personal basis; during the last three months I have been back in Myanmar three times; most of the time was spent in Nay Pyi Taw having informal conversations with ministers. Several messages were very clear: following the inaugural address of the President of the Republic of the Union of Myanmar, the country will strive for economic development and growth in parallel with environmental conservation and that this development will be inclusive and participatory. Other words were added, like equitable. Subsequently, Parliament endorsed this and it provided a very good policy direction for all the line ministries, which are trying their level best to see how this could be put into ministerial policies. Currently, Parliament is debating the Law on Environmental Protection and Conservation, which is expected to be passed with a lot of strengthening, and

will formally establish the new Ministry of Environmental Conservation and Forestry. Every one of the ministers I have talked to is very keen to have economic growth in parallel with environmental conservation with inclusiveness, public participation, etc. So I believe as the country will now open up; the increasing influx of investors has already led to scarcity of hotel rooms. Bilateral, multilateral, and private sector organizations are all gravitating to Myanmar. My personal advice is that there is need to take into account not only economic growth and economic investments but also environmental conservation, inclusiveness, and equity. The country has tremendous natural and human resources and welcomes the investments and cooperation.

Arjun Thapan: I think a very interesting point to focus discussions on is the knowledge foundation. Is the knowledge base we have today, and as it evolves, sufficient for us to take the right kinds of steps, such as policies and institutional change, that will be needed to achieve what Prof Holst has suggested in terms of water driving both hydropower potential and food production potential of the subregion. Are there any comments on that? Are there any questions on the adequacy of the knowledge base that we currently have, the manner and direction in which it will evolve, and the speed and rate at which we should be bringing it up to scratch?

David Roland-Holst, University of California, Berkeley: It is an extremely important question. I am optimistic that existing knowledge or extant knowledge can make an enormous contribution to realizing the potential of water services, the livelihoods potential, and the sustainability potential. The fundamental challenge is to share that knowledge across the subregion. The state of technology is very advanced in terms of potential; the most advanced economies are very advanced in agri-food technologies but there are incredible disparities in access to that knowledge and the financial capacity to implement it across the subregion. I am very hopeful that regional integration can achieve a leveling of the field.

Jeremy Bird, former CEO, MRC: I would like to comment on hydropower, which is one of the biggest drivers of change in water resources, not only in the Mekong River basin but also in some of the other basins in the GMS. We know that there are some uncertainties and gaps in knowledge, particularly on the linkages between infrastructure interventions in the river systems and livelihoods; we heard some of that yesterday. So in some respects, taking a low-risk approach—using the precautionary principle to identify projects and move

ahead rapidly on those where there are lower risks—will be an important strategy. And when it comes to institutional and regulatory environment, the question is whether the independent power purchase (IPP) model at the moment, being used in a relatively unregulated way from a social and environmental perspective, is actually delivering on that precautionary principle or low-risk strategy. A lot of discussion has been on sustainability but how do we really get a handle on what sustainability is and what mechanisms and processes need to be put in place to ensure that dialogue takes place within the countries to lead to optimal solutions. The hydropower industry itself has moved a long way over the last four or five years in trying to implement a sustainability assessment protocol, which is a project-based activity to set up mechanisms; and the Mekong River Commission has added to that by looking at a basin-wide assessment tool. I think all these things do provide a framework within which discussions across the different sectors and ‘silos’ can take place.

Ian Makin, ADB: My role is to look at irrigation and how ADB engages with irrigation and agriculture water management. I think we are going to see a major structural transformation in agriculture; people are no longer relying on agriculture, as mentioned earlier, as their primary source of income. Seeing comments about migration from rural to urban areas, we are faced with a lack of rural labor. The transformation, as we heard yesterday, is a reliance on services that is driving the economy. I come from England and we have not done terribly well relying on a service-based economy. What I would like to know and understand better is that as this transformation takes place, hydropower and mining are important, but agriculture has to continue because we will need food—how is all that going to play out? Are we going to see increased commercialization? In Thailand the big agribusinesses are successful but we have not seen that transformation in other countries yet. If commercial agriculture is going to take off, where are the people going to go, where are the opportunities? The Philippines, for example, which has put a lot of store on service-based support, has a very small, well educated segment of the population in services like call centers, etc. But there is still migration from rural to urban areas that is building up a social tension that needs to be addressed. So Prof Holst, with respect, it is just not numbers; there is a lot of transformation underneath that needs to take place, and I am not sure that we have addressed that properly yet.

Arjun Thapan: Let me just add that in your paper Prof Holst, you suggest the GMS currently exploits 20%–25% of its food production potential. And I have heard many

others here talk about expanding irrigated agriculture, rain-fed agriculture, crop diversification, and so forth. But I did not hear anybody talk about reducing food waste. And I do not know what that number is for the GMS; and I do not know if any of us here does. But there are numbers out there for other parts of the region 30%, 40%, what do you say about that? Is that a feasible proposition?

David Roland-Holst, University of California, Berkeley:

On the food waste issue, food waste is essentially proportional to income. I am sorry to say that coming from a high-income country. In developing countries and in rural areas where the poor are subsistence producers, there is not really a lot of waste. It is always good if we can reduce waste but I think in terms of unrealized potential; it is really the kind of things that John Soussan, and Mark Rosegrant, and Ian Makin have been talking about, which is overcoming market access barriers for the poor in rural areas. The gateway out of poverty in almost every developing country is market access; it is either to urban labor markets via migration or to agro-food markets—marketing specially processed products like fruits and vegetables and meat that have higher income elasticity and allow the poor to move toward more efficient modalities of production. This is essential; it has to overcome a very broad spectrum of market failures and obstacles for the poor; yet, if we do not do that, there will just be increasing marginalization and inequality as urban areas essentially grow away from rural areas.

Anna Marie Oltorp, Counselor, Embassy of Sweden:

You mentioned the sharing of knowledge in the subregion, which I think is really important. But then, who are the drivers of change, that actually make change come about? We know that politicians are quite conservative and there is probably need for some bold decisions and bold policy making in order to address some of the things we are talking about today. I had a discussion with a former senior dignitary in ASEAN asking him about the environmental priorities with ASEAN and what role ASEAN could play. His response was that in order to achieve change in this region we need to look at civil society and look at what the people in these countries demand from their decisions makers. It will be interesting if you could reflect on that.

Jean-Pierre Verbiest: This is a point I wanted to make earlier. The hydropower potential in Thailand is zero; you are not going to build any dam in the foreseeable future neither will you be able to build a coal fired power plant, even if it is a clean technology because of civil society and the way social networking goes. Let me give you an

example: we are talking about Myanmar and as some of you know probably, there is going to be a highway and pipeline built from Rakhine State to the PRC. People in Rakhine State are using Facebook to complain and raise their voices. It is interesting to see that in moving forward, Myanmar has tremendous potential but civil society is going to be more powerful than it used to be five or ten years ago. That kind of change is going to influence the way we go about the use of water and energy and food production. So I think that has to be factored in as it is an important aspect. But it is amazing to see people who live in remote areas and have been isolated for a long time already using Facebook and better at computers than I am.

Muanpong Juntopas, SEI: It would be useful to look at food security from a food purchasing power perspective as in some pockets there may be food insecurity (although GMS overall has food security) and as people move to urban areas seeking employment as laborers. So it will be interesting to look at where the growth nodes will be—now there are about 2 million Burmese in Thailand—and how this labor interacts in the different growth nodes. Also what about food safety? It will be interesting to look into the future development of growth nodes given that Myanmar will be coming into the scenario. Will it be that refugees will move back to Myanmar or will the growth nodes be in Bangkok and other areas? In terms of food access, the question is whether income from labor is enough to purchase the food, and secondly will the government have enough capacity to regulate about food safety?

Peter Warr, Australian National University: I want to follow up on one point discussed by Prof Holst in his presentation and Dr Leiber of the Lao PDR also followed up on this: what are the benefits of hydropower development? As pointed out by Prof Holst, the benefit of hydropower development rests on the revenues from sale of electricity accruing to the government; so the benefits in terms of GDP, poverty reduction, environmental improvement, or any other indicator depend on what we assume about the way the government uses those revenues. That is the crucial, underlying point behind David's presentation. It is possible for those revenues to be wasted completely and there are so many examples from around the world where that has happened with petroleum exporting countries; monument building, corruption, and unproductive transfer of payments can waste all of those benefits. If those benefits are invested productively in necessary infrastructure, education, and health, the benefits can be vast.

David Roland-Holst, University of California, Berkeley:

We are in significant agreement about this; the actual technical assumption in this model was “business as usual” for government expenditure patterns because I was not going to prescribe government spending scenarios; business as usual is what created a Dutch disease problem because too much of the revenue went to the service sector without directly productive spillovers. I think we all aspire to the same goal.

Apichai Sunchindah, Development Specialist, Thailand:

The GMS has been running for twenty years; I think the GMS program has made tremendous strides and achievements; the subregion has benefited at the macro level. But in economics we also need to go down to the micro level to make a balance and this is what is missing. Certainly, there are always winners and losers and the GMS is no exception; but where is balance in place, in time, and in population groups? From a policy making point of view, it is important to know how to zero in on specifics like impacts on women, impacts of spread of HIV, or other development issues. As the conference makes projections to 2020, we are not asking for immediate answers but we hope we can work on these answers in the next 8 years and perhaps get something like a Google map, where we can zero in and find out particulars.

David Roland-Holst, University of California, Berkeley:

I wish I had a budget for a satellite program to build in my models with billions and billions of dollars. Let me just say we can and we should focus on those kinds of detail because we know from international trade theory that countries can benefit without anybody else in the country benefiting. There are more details available and if we had the time and resources, we could get more into it.

Vedini Harishchandra, ADB: Olivier De Schutter, the UN Envoy for Food, talks about distributional aspects of food to partially address the food security issue, apart from productivity increase, etc., being raised at this conference, I have not heard anybody mentioning the distributional part of food in the context of food security. So I was wondering how GMS countries should address this aspect in their policy options.

David Roland-Holst, University of California, Berkeley:

I would certainly encourage them to do so but in this context we need to make an important distinction between public and private sector support for distribution. Public sector support for distribution is appropriate where there are capacity failures, such as in Africa; but the GMS has

tremendous capacity to produce and also distribute food. And here again, opening borders and allowing for supply chain integration will take full advantage of very advanced logistic and marketing skills in the higher income GMS countries. This is essential and will be a fringe benefit of greater integration.

John Ward, CSIRO: Thank you for the really insightful presentation and ensuing discussion. One of the institutions we have not discussed is entitlement and the assumption that there is a set of enforceable and specified rights vested with individuals. This is particularly important in the areas Prof Holst has highlighted that have potential for hydropower and irrigation, where the rights of the current users are highly tenuous and certainly not specified and certainly not enforceable. I wonder if that initial assignment of entitlement would perhaps influence the outcome of the analysis and does the panel have any thoughts on the political economy of how those rights may be assigned?

Mark Rosegrant, IFPRI: That is an excellent point. We have stressed in some of our presentations that one of the absolute keys to this kind of development is going to be the establishment of secure rights to water and land; and where those rights are not existing it is not an easy thing to do. The administration and assignment of those rights are crucial to the equity outcome.

Geoffrey Blate, WWF: I would like to address my comment on the word “balance” in the conference title. We think about environmental sustainability underpinning economic growth and that is the essence of the green economy. On the question of whether we have sufficient knowledge to move toward this, I would say both yes and no. On the ‘yes’ side: yesterday we heard from Jeff McNeely that biodiversity provides resilience and productivity and the subregion is very rich in biodiversity. We have knowledge that productivity will depend on investments in protecting and enhancing that natural capital. On the ‘no’ side, we have poor knowledge of the ecosystems and what services they are delivering. So the idea of a master plan that was brought up earlier should come after producing such a map of the subregion. What WWF has proposed is to develop an ecosystem function map of the Mekong River itself; this was identified in the strategic environmental assessment as a gap. This would be to me a high priority. On knowledge, we heard yesterday that there is rich, local ecological knowledge of crops; we heard that there were 10,000 rice varieties that were cultivated on a regular basis in the subregion and now we are down to just probably a few. So how do we mobilize that knowledge and take advantage of it.

Jeremy Bird, former CEO, MRC: One of the things I saw in Jeffrey McNeely’s presentation yesterday was the mention of four principles for development and those included developing areas of low risk and low biodiversity impact; he talked about connectivity in the biodiversity corridors program, which is looking primarily at terrestrial ecosystem connectivity. I was a bit surprised that one of the principles when we talk about hydropower is not the same principle for aquatic ecosystems integrity and connectivity. One of the items under the MRC agreement is notification requirements for projects, which ask whether the tributary is significant or not. That was developed in the early 1990s; the concept of significance related to hydrological significance; how much did that tributary contribute to the overall flow of the river system. Over time that has now evolved; there is a study ongoing on a whole series of parameters and one of those would be connectivity of ecosystems. WWF and MRC are working in a similar direction on that.

Arjun Thapan: Thank you all. This has been a very rich discussion and I am sure it is not the last discussion on the subject but it would not have been possible without hard work done by Prof Holst and his team. Thanks to all of them.

**SESSION 5: RESPONSES TO CHALLENGES
OF THE NEXT DECADE IN THE GMS**

Group Discussion Reports – Day 2

A. Food Security

B. Land, Water, and Climate Change

C. Energy

D. Private Sector - Emerging Role

On Day 2, the thematic groups focused on the following three questions:

- i. *What are the key policy responses needed and by whom?*
- ii. *What are the key data, information, and knowledge responses?*
- iii. *What are key institutional responses, both at sector and regional levels?*

A. Food Security Thematic Discussion Group

As key policy responses were already dealt with in the Group's Report to the Plenary on Day 1 (Session 3), the discussion was on key issues relating to food security, foreign direct investments coupled with land tenure, regional agricultural research, and hydropower impacts on fisheries.

Food Security: It was suggested that regionally ASEAN +3 should be the platform for food security issues as its members comprise both food exporting and food importing countries. However, the ASEAN Secretariat has limited resources to carry out activities and the GMS is seen as a dynamic region that can work effectively on food security through cross-border trade. Food security is not just about quantity but also about access and food safety. According to the FAO definition, food security is about access and affordability and about having enough to eat today and being confident to have enough for tomorrow. Compared to five years ago, more people feel food insecure today. International food prices are again rising as they did in 2008; and some policy responses undertaken then were not always very helpful. Especially in urban areas, as rural-urban migration continues, poor people need sufficient purchasing power (affordability) to buy food. Are GMS governments prepared to tackle this dimension of food insecurity, which could be exacerbated in times of crises? The new GMS Strategic Framework underlines the importance of developing backward and forward linkages. At a national level, the Lao PDR, Thailand, and Viet Nam are food secure but pockets of food insecurity remain. Hence, there is a need to improve purchasing power. In this way, people who do not own land to produce their own food or who have migrated to the city can be empowered to find other non-farm occupation to earn an income and buy food. The idea of food self-sufficiency was seen by some as an inefficient way of tackling food security. There is a need for reducing market interference, but at the same instruments like buffer stocks and funds to finance short-

term measures have been known to respond to food price crises in the region.

Foreign Direct Investment (FDI): On the question whether smallholders and workers can benefit from foreign investments without being overexploited, the general response in the group was that governments should be careful with foreign investments as there is a danger of land grabbing. Thus, foreign investment deals relating to land for agricultural production need to be well structured and designed with institutional oversight that ensures existing security of land for the poor who depend on it for their livelihood. International agricultural partnerships will add significant risk leading to local marginalization (making the poor very vulnerable) unless government protects the people and domestic interests. There are many examples of countries that have suffered from similar situations, e.g., Mongolia, which is having problems at the domestic level with large-scale partnerships because these affected the livelihoods and the interest of the poor. In general, however, governments need to regulate domestic investors as well, who have long-term investments on the land; in many cases foreign investors go through domestic entities for investing in the land. It is important to strike a balance in allowing FDI that offers investments in technology and know-how with an institutional regulatory framework that protects vulnerable and poor groups. Insecurity of land tenure is a significant issue in some countries of the GMS. For instance, farmers cannot use land as collateral and are chased off their land without adequate compensation by private interests, which are granted concessions.

Regional Agriculture Research: It was suggested that there was need for a "regional center of excellence in agricultural research" in the GMS, which is equipped with up-to-date technology and can handle bio-informatics, genetic research, and biosafety, and contribute to harmonizing food safety and phytosanitary standards. It was also suggested that such a center could be hosted in Thailand as long as it had a "subregional or regional character." In recent years, commitment to agricultural research has dropped in the GMS countries and private investments in agricultural research are not complementary. Countries may be exploited by having to depend largely on multinational companies; there should be collective action among the GMS countries to avoid this kind of exploitation. Hence, public investment is important and should go together with the private sector to avoid marginalization of smallholders. There could be synergy between ASEAN and GMS in such a venture making it important and beneficial. However, there was

also disagreement in the group about setting up such a regional center, as many countries like the PRC and Viet Nam are quite advanced in agricultural research. It was felt more important to network these research centers and provide mentoring and strengthening of the national research centers. Organizations like IFPRI already have regional offices. So it will be better to strengthen these facilities and establish a well-functioning network rather than create a new regional center.

Fisheries: In general, it is recognized that hydropower (big or small) will have an impact on fisheries. Viet Nam has been successful in segregating fisheries and other agricultural activities from hydrological development, but most of these strategies were not done in close proximity and the social groups benefiting may not have been the poorest groups. In Myanmar, as fisheries are mostly subsistence, hydropower development will have impacts, such as structural impact, loss of species, changes in sediment flow, nutrient flow, etc. There is a possibility of minimizing these impacts, but large hydropower dams will have big impacts; cost-benefit analyses will be important. It is essential to look at fisheries as a critical component in the food security equation of local people; loss of access to capture fisheries without any substitute affects nutrition and livelihoods. The “full values” of fisheries have not been determined. This kind of valuation is important because it also takes into account employment generation in sector.

B. Land, Water, and Climate Change Thematic Discussion Group

Key Policy Issues

The discussions resulted in identification of three key policy issues that needed attention in the GMS:

- Integration and harmonization of water resources across sectors
- Mainstreaming drought, flood, and sea level rise in national planning
- Land tenure and benefit sharing mechanisms.

Integration and Harmonization across Different Sectors: It is essential that different sectoral agencies are coordinating and working together. There should be more integration within existing institutions in the countries to bring about synergy among various ministries and cut through ‘silo’ thinking, as water resources are crucial for

many sectors and sustainable growth and development. Governments and owners of reservoirs need to have very clear water allocation and sharing rules; for example, in many countries the owner of a reservoir manages it for a single purpose, not integrated purposes. Legislation and clear rules might be needed on how to optimize reservoir management for several purposes. Regarding agriculture, fishery, and forestry, adaptation toward drought and flood management and disaster risk reduction (DRR) has to be mainstreamed into all development policies. Integration will lead to optimal use of water resources for agriculture, fisheries, livelihoods, water supply, and power generation. For example, northeastern Thailand is using 100% of its water resources locally for agriculture and power generation using weirs and dams, leaving little fish migration between the main stem of the Mekong River and that area. Yet, capture fisheries production there is the highest in the basin and the annual capture fish production is reported to be higher than even in Tonle Sap in Cambodia. This has to do with an integrated system of canals, drains, rice fields, and ponds. The devastating floods of 2011 in Thailand have again underlined the need for closer coordination and integrated planning and management of water resources. The Lao PDR is taking a basin-level integration approach in setting up basin management committees.

Mainstreaming Drought, Flood and Sea Level Rise: Two types of hydrological changes are taking place: human-induced change by operation of hydropower dams and uncontrolled changes that are expected through climate change. There is a need to distinguish between the two because the timeframe for these changes is quite different; hydrological changes due to hydropower development will happen within 4–5 years of dam construction and commissioning; changes due to climate change are longer term: 20–40 years; management of land and water resources needs to be cognizant of these two perspectives. There is an urgent need for management of drought, flood and sea level concerns. Flooding is a serious problem now and there is an urgent need to address floods given Viet Nam’s and Thailand’s vulnerability to sea level rise. All sectoral strategies or national development plans should aim to mainstream these considerations (drought, flood, sea level rise) in their planning with adequate resources in terms of budgeting for implementing mainstreaming actions at the operational levels. These actions are usually context specific; in a policy document it is easy to mention them; but in terms of budgeting and implementation, it is more challenging to reflect climate change impact. In the Pilot Program for Climate Resilience in Cambodia, government is trying to see how the budget at national, provincial, and

commune levels can really reflect considerations for coping with climate change impacts. We have to go forward step by step. Kiribati has mainstreamed options at four levels: what can be done by communities, by local governments, by national government, and through international assistance. Each sector has prioritized interventions and the government has made these actions mandatory within a legislative framework. Once local governments have identified an action that can be undertaken, all local governments are required to take that action. There are many ways to implement and there is no single prescribed route.

Land Tenure and Benefit Sharing: There is talk of mainstreaming land use but there is weak land tenure that does not provide security or title to smallholders. In some countries, an adequate legal and regulatory framework for land use is lacking. In the context of land access and natural resources, there is a need to find technical ways to secure access to land and natural resources for smallholders. Viet Nam provides land use rights; Cambodia is investing in rural land registration and granting private ownership. With land tenure also comes the issue of benefit sharing. Mechanisms for sharing benefits from hydropower schemes are inadequate, although productive use of such revenue can enhance productivity and sustainability. In Viet Nam, a decree stipulates use of a small portion of revenue from hydropower operations for watershed and forest resource protection by communities. This needs to be further explored and institutionalized within a basin management approach.

Key Data, Information, and Knowledge Responses

The MRC has a vast library covering over 50 years of research; there is a portal that allows access to data and there are other databases that may not be well known; a lot of information is available. For example, ground water information was researched and data collected in 1970s, 1980s, and early 2000s; there may not be most recent updates but the data could form a basis to update. Information on hydrological acceleration and hydropower development is available on a number of basins; missing, however, are accurate and comprehensive data on fisheries. Research can be promoted by providing incentives to national universities and national institutes to focus on issues beyond agriculture. However, there is a reluctance to share data. Ministries hesitate to release good data. Technical agencies realize that fundamental water monitoring data relating to surface water are essential for reliable forecasting; there is a need to invest

in management information systems, research, and data gathering, but central agencies may be reluctant to undertake such investment. A data clearinghouse within the GMS would be useful, which can list existing information, provide easy access to data, and network with other data holding institutions in the region. There are still areas that need further research—not only fisheries, but also vulnerability assessments, climate change impacts, and ecosystem services from forests, watersheds, and wetlands.

Key Institutional Responses

River Basin Approach: Basin-level integration and establishment of basin organizations is now being pursued by the Lao PDR. The Nam Ngum River Basin organization has been recently established and this process will expand to other river basins in the Lao PDR. However, there is a need to link basin initiatives with national water resource use objectives. Having a central institution to follow up what is happening in the basins is important because at the district level, national goals seem to dissipate. There needs to be stronger intersectoral coordination, and ADB and other development partners could support this process. Translation of data into decision making is still weak. In the Lao PDR, investments in water resources are ongoing but assessment, monitoring, and project management capacity are weak or lacking.

GMS-wide Working Group: At the initiation of the GMS Economic Cooperation Program, water resource related issues were expected to be covered by the MRC. The reality is that the Mekong River is only one of many river basins in the GMS and the MRC mandate does not allow it to work outside the Mekong basin. Furthermore, the MRC covers the lower Mekong basin leaving out two countries of the upper Mekong basin. It was suggested that a GMS-wide working group on water be established for integration and harmonization across different sectors. But this was rejected. It is an institutional mechanism that has been examined and proposals have been made and the GMS members have decided that is not an approach they want. However, there is a need for GMS arrangements and the different working groups to address water as a development issue because it does impinge on agriculture, environment, transport, and hydropower. Water is a cross-cutting issue that impacts on all developmental aspects. Yet, the prospects of establishing a GMS working group on water in the foreseeable future are dim. Another idea is to establish a GMS working group on climate change, which would integrate issues all across different working groups and must include water. Given the situation that it will be

difficult to establish any kind of new working group in the GMS, it was suggested that there could be a GMS strategy or vision statement on water. There is a GMS Transport Strategy and Economic Corridor Forum and strategic action plans but there is none on water transport, including navigation. A clear vision and strategic framework exists covering overall development, but a green economy vision is also missing.

Capacity Building: Private sector operations will increasingly gain in importance and the public–private partnership (PPP) model will gain strength. However, private participation in infrastructure development, such as hydropower, is financially more rewarding than water provision. PPP could play a role in the Lao PDR on maintenance of roads, especially through hydropower and mining investments. Pure PPP in the road sector in the Lao PDR is difficult because of low traffic volumes; but road maintenance contracts to hydro and mining concessionaires are an attractive proposition, which may have some poverty alleviation impact through employment generation. Capacity building through PPP ventures needs to be explored. Identifying champions and promoting the concept of leadership is important. In this context, the Network of Asian River Basin Organizations has recently established a leadership program, in which Indonesia and Malaysia are making their water champions available to other countries to learn how they are implementing river basin management. Institutional capacity for assessing investments, decision making, and appraisal for investments is needed. Also needed are strengthened capacity for proper economic analysis and proper project management capacity to handle concessions in forestry, mining, irrigation, and agriculture, and to oversee private participation.

Transboundary Cooperation: Apart from the Mekong River basin, the Red River basin, with 40% of the water coming from the PRC, needs to address such issues as regulation of seasonal water flows in the dry season and during droughts, and pollution control that requires transboundary cooperation between the PRC and Viet Nam. Currently, there is no agreement on data sharing or any sort of cooperation between the two countries on the management of the water resources of the Red River.

C. Energy Thematic Discussion Group

Recommendations	Policy Responses Needed	By Whom	Key Data, Information, Knowledge Responses	Key Institutional Responses (sector)	Key Institutional Responses (regional)
Energy policies need to be focused and long term	Assess effectiveness of current energy policies	Ministries of energy	Resources (fossil fuel, renewables) data – mapping, lack of information Use of multi-criteria decision technique	Sectoral (energy, transport, industry, etc.) agency efficiency improvements	RPTCC, subregional energy forum
Internalize environmental and social costs in PDP planning	Ensure that important stakeholders understand EIA, internalize environmental & other impacts Legislation supporting SEA (cf. case of VN) Corporate Social Responsibility (CSR) policies Ensure social, economic, and environmental feasibility of projects, including conduct of EIAs NAMAs	Relevant ministries (e.g. energy, environment), project developers, civil society	Valuation of ecosystem services Resource information Cost-benefit analysis	Energy, water, forestry, agriculture, rural development Use existing EIA process especially at the policy level Consider SEA	MRC, RPTCC, SEF, Working Group on the Environment, GMS EOC, ASEAN (ASOEN, Energy Center)
Energy efficiency/ DSM should be considered in PDP	Review PDP Legislation (e.g. building codes, industrial/applied standards Off-grid electrification	Relevant ministries (e.g. energy, industry, trade/ commerce, construction, transport)	Efficiency ratings/standards, labeling, incentives (e.g. rebates) Conservation supply curve (McKinsey Industrial efficiency agreements between governments	All sectors	IEA, Knowledge sharing with ASEAN+3, GMS Authority, Asian Environmental Compliance Enforcement Network
Maximize the participation of civil society in pushing for energy reforms	Increased consultations with civil society Involvement in EIA policies including health issues	National governments	Project knowledge (i.e., EIA, social safeguards reports, etc) Transparency Least-cost modeling Economic and social costs National media	Websites Government to fund local civil society organizations to disseminate information Independent regulators	ADB and development partners Regional media

Recommendations	Policy Responses Needed	By Whom	Key Data, Information, Knowledge Responses	Key Institutional Responses (sector)	Key Institutional Responses (regional)
Energy sector planning should be harmonized with water resources planning	IWRM strategy Increased coordination with water authorities Regional water quality monitoring Establish water quality standards	Relevant ministries (e.g. energy, water resources, meteorology, hydrology, planning and investment, irrigation, fisheries, agriculture)	Water input analysis Water balance geographic information systems Current water policy practices	energy, water resources, meteorology, hydrology, planning and investment, irrigation, fisheries, agriculture	GMS Agriculture and Environment MRC
Biofuels: countries should provide clear guidance on how this industry is to be developed and managed	Review potential for biofuels and provide guidance for biofuels development Renewable fuel standards	Relevant ministries (e.g. agriculture, energy, transport, science, and technology)	Market demand for biofuels Requirement for water, land, other resources SEA Information on subsidies Policies Resource/land use mapping	Relevant ministries (e.g. agriculture, energy, transport, science, and technology) Life cycle assessment Consultative analysis	ASEAN
Subsidies for biofuels should not create negative impacts on land and food security					

ADB = Asian Development Bank, ASEAN = Association of Southeast Asian Nations, ASOEN = ASEAN Senior Officials on the Environment, EIA = environmental impact assessment, DSM = demand-side management, EOC = Environment Operations Center, GMS = Greater Mekong Subregion, IEA = International Energy Agency, IWRM = integrated water resource management, MRC = Mekong River Commission, NAMA = nationally appropriate mitigation action, PDP = power development plan, RPTCC = Regional Power Trade Coordination Committee, SEA = strategic environmental assessments, SEF = Subregional Energy Sector Forum, VN = Viet Nam

D. Private Sector - Emerging Role

Kewal Thapar, Consultant, ADB and Facilitator: I would like to set the broad framework as to what the role of the private sector can be and the increasing emphasis that is being laid by the Asian Development Bank and by other multilateral agencies and governments on private sector participation. We live in a turbulent world, especially the financial world, and public financing for projects is slowly drying up. We can see this happening in Europe and the USA and the fallout is also witnessed in these regions. Private sector participation and funding therefore become a very important aspect of project financing, especially environmental and projects in sustainable development. We will hear today from Mr Tak Sriratanobhas, Vice President, Project and International Trade of the Mitr Phol Group and Acting Managing Director, Petro Green Company Thailand, about how they have created the sugar distribution chain and the supply management system, and how this is to be sustainable.

Mr Tak Sriratanobhas, Vice President, Mitr Phol Group, Thailand: I do not have a fancy presentation today but we have an information brochure available for participants. Our sugar mill is just 50 years old, formed by sugar cane farmers in Thailand; it grew quite fast over the last five decades. When you hear about sugar mills, you probably think about water pollution, waste, dumping of molasses and waste water, and smoke from burning bagasse; but we are entering into a new era of the sugar industry. Sugar is not only the sweetener; it is comprehensively used in the food supply chain. Our mill is Thailand's largest sugar producer and the second largest in the PRC through its joint venture company East Asia Sugar. In addition to Thailand and PRC, Mitr Phol has operations and investments in Cambodia, the Lao PDR, Viet Nam, and most recently Australia. Its key business units include sugar, ethanol, biomass energy, fiberboards, logistics and paper. Mitr Phol works from the plantation fields right up the production line to the sugar on the table; but along the way we have utilized all the by-products. I do not want to use the term "waste" here and prefer to use the term "by-product" and we maximize and create the value chain of the by-product. When sugar cane is delivered by the farmer to the mill, we separate the juice from the fiber known as bagasse. In the past, bagasse was burned and poorly generated electricity to the turn the steam turbine just enough to operate the sugar mill. We are now using an improved model with high pressure for the boiler and turbine in a closed system with a scrubber that collects all the dust for re-use and only steam evaporates through the chimney;

this tripled the generation of power output leaving us with a surplus of power that we can export to the local grid or communities. We can generate from 5,000 tons of cane crushed about 15 MW of electricity of which 6-7 MW are used by the plant and the rest is sold to the Electricity Generating Authority of Thailand (EGAT), which it sells to the community. The plant in Khon Kaen supplies 50 MW of electricity to the city and most of the household in Khon Kaen are using electricity generated from the sugar mill. Apart from generating electricity from bagasse, we use some of it to produce particle board that can substitute use of wood. In our investments in Guangxi in the PRC, we produce pulp and paper from the fiber/bagasse although the quality of the paper is not that of office stationary; it is more like cardboard paper. In the past, the residue from processing the sugar cane syrup called molasses was dumped in the river contributing to pollution; today, molasses is no more a waste product as it is converted into ethanol, while the by-product of filtering the sugar leaves behind the filtering cake, which is rich in micro nutrients, is used as fertilizer in the sugar cane fields. In the process of refining ethanol, we get vinnasse, which can be used as a liquid fertilizer, enriching the soil nutrients or recycled in the power plant boiler.

Besides creating the value chain of by products from sugar cane processing we are also concerned about limited land availability. Usually the argument from anti-biofuel advocates is that ethanol production competes with staple food production. I must counter this argument because we are extracting ethanol from the by-products of sugar cane, which is a food item needed by society and the ethanol production can be attributed to the same amount of land as the sugar cane output, retaining food as well as producing energy from the molasses. Mitr Phol has also set up research and development facilities to increase yield from sugar cane varieties so that less land can be used for increased output for the farmer. Basically in Thailand, the output of sugar cane is about 8-9 tons per rai (6.25 rai in 1 ha) or about 50 tons from 1 ha; Mitr Phol is promoting varieties that can yield up to 12 tons/rai or 75 tons per hectare, using rai irrigation project and organic materials as fertilizers. Current experiments are showing an output up to 20 tons per rai, (175 tons per ha), double of the current average productivity, which is our goal in the future provided there is efficient use of inputs. Last but not least, we put in a lot of effort in the community and we provide lot of support in irrigation, ponds for water and aquaculture, home gardens, and other livelihood activities supplementing their incomes. So that is a brief presentation of Mitr Phol's zero waste and environmentally

friendly production with contribution to community and social responsibility.

Kewal Thapar, Facilitator: Thank you very much Mr Tak. What we have heard in this session is a real life experience, a real life product, an integrated, sustainable development project that has all the elements we would like; you have got corporate social responsibility, profits, and returns commensurate with market levels; you have got an example that is replicable. Mitr Phol has actually done investments abroad. Congratulations. Now we can move on to Dr Khaing, who will speak on public-private partnership in Myanmar. We have heard in the morning about the growth of Myanmar and the fact that hotel rooms are not available to accommodate all the investors and visitors. So let us hear about the role of the private sector in Myanmar and how that can develop.

Dr Ohnmar Khaing, Country Coordinator, Food Security Working Group, Myanmar: My presentation (see paper) describes gaps between the public and private sectors and identifies initial steps for closing the gaps and improving the public-private partnership development framework through capacity development and institutional strengthening to balance development and environment. I have briefly reviewed the impacts of economic growth and environmental awareness in the GMS—especially on livelihoods, income, and access to food—and indirect impacts on ecosystems and water resources. Current problems in public-private partnerships are described, giving Myanmar as an example, pointing to the need for commitment of policy and political will; the lack of technology transfer and dissemination to the public; and lack of awareness at all levels. Capacity development and institutional strengthening efforts are needed in order to help people's livelihoods become more resilient. Possible actions and resources are described, such as development of national strategies and multi-stakeholder consultation for monitoring livelihood resilience, linking social responsibility and the importance of long-term private-public partnerships.

Kewal Thapar, Facilitator: Dr Khaing has given us a very strong and forceful presentation on aspects relating to regional cooperation and the role of the private sector. Typically, as we are all aware of, the private sector arrives well before the government. And it is the private sector that actually first sets up and creates the bonds and the regulatory frameworks as we have seen in Viet Nam and we will see now in Myanmar. That is how it happens: the private sector follows money, initiative, and

innovativeness. Now we will move on to Mr Archie Beaton, who is the Executive Director of the Chlorine Free Products Association of Illinois, USA.

Archie Beaton, Chlorine Free Products Association, USA: In the GMS, the Pulp and Paper Industry has an opportunity to create a period of dynamic paradigm shift in adopting sustainable technologies. Over the past 15 years many advances in computerization, nano technology, chemistry, substrates, and processes have made it more economically feasible to retrofit a mill creating a “closed loop” or TEF (totally effluent free) facility. On the economic front, not only can the mills in the GMS eliminate big amounts of chlorinated toxins, increase green energy production, decrease water consumption immensely, decrease GHG emission, and produce high quality pulp and paper products, but also increase profitability through the upgrades. Many mills around the world are developing additional revenue streams via solar, wind, steam, etc. I visited a plant that was not only TEF but it had 5 revenue streams. Debarked wood is chipped and fed together with the cooking chemicals into digesters. The bark is burned and recovers energy in the form of steam. After cooking, the cellulose is washed and bleached with hydrogen peroxide in the closed loop water system. The bleached cellulose is then dried and delivered in bales. The whole process takes approximately 40 hours. During cooking the digesters, hemicellulose and lignin are released. The hemicellulose is fermented and distilled into ethanol. The lignin is refined and with the subsequent ultrafiltration processed into lignosulfate. It is then dried and packed. The cooking chemicals are then recovered and energy in the form of steam is used during the process. It is now possible to eliminate waste water filled with a chlorinated toxic soup, containing chlorine compounds such as dioxin, furans, PCBs, etc., thus helping aquatic and dairy farmers. Implementing of TEF technologies will reduce exposure to known human carcinogens, reduce human health costs, and help to implement advanced water recycling and water treatment. Increased profitability must take place while bleached kraft market pulp and paper products are at profitable levels, well above operating costs. With regional support, elimination, or tremendous reduction, in the effluent discharges from bleached kraft pulp mills (via the elimination of chemical wastewater discharges) is an important way of reducing operating costs, improving environmental impacts, and reducing negative effects on natural resources.

Kewal Thapar, Facilitator: Thank you Mr Archie Beaton. We will now go to the last speaker of this session, Dr

Kalyanamitr (popularly known as Audi), President of ENERCEL and Senior Advisor on the National Science Council.

Dr. Chieanchuang (Audi) Kalayanamitr, Advisor National Science Council, Thailand: With your permission, I have two topics to talk about: The first is on energy, showing why the private sector is going to make a big impact in the GMS. There are developments taking place outside the country as well as inside Thailand. In two-and-a-half years the ASEAN Economic Community (AEC), like the EU will be established, easing trade flows between its member states. Customs barriers will be lifted. Full market integration is aimed for 2025. As a law maker, I am involved in reviewing and abrogating seven different Acts in order to comply with conditions of a common market. The second is about the signing of an MoU and agreements with the PRC, bringing about large infrastructure investments in Thailand; the PRC has the money, the power and the human resources. The projects cover bullet train, water resources, power sector, human resources, and sea and ocean, with a commitment of Yuan 70 trillion. This will have a big impact. The PRC will take most of the business. The third is about Myanmar, which is opening up and this is also a big impact for Thailand. There may be a 100,000 MW power deal between Myanmar and Thailand. Dependence for power on Myanmar alone will be sufficient to cover the needs of Thailand. Right now, Thailand only generates 40,000 MW; with Myanmar opening up and supplying power to Thailand, it will be more than double.

In Thailand, the law makers are amending the law on establishing special economic zones and passing the public-private partnership (PPP) law. In the past it was either 100% government or private sector investment; we had a joint venture law but this will be replaced by the PPP, promoting similar to investments as in Nam Theun 2 in the Lao PDR. The subway in Thailand is a PPP venture. Earlier, ADB was working closely with government agencies; in future, PPP mechanisms will replace sovereign borrowing and it could be threat to institutions like ADB, unless it re-orient itself to finance PPPs. Another problem, internally, is government policy on minimum wage. Some investors, like me, are moving factories to neighboring countries like Cambodia. In Thailand, the minimum wage, due to political agitation, is set to increase to more than Baht 300; with rising labor costs, investors will look elsewhere. By moving out my electronics factory to Cambodia, I pay Baht 80 per day, immediately increasing my profit margins. I nearly moved to Myanmar but the economic zone does not have

enough power, unlike Cambodia. Any country in the GMS politicizing the economy will force an exodus of the private sector to more competitive bases of production. In the energy sector, power will be decentralized and it is likely that there will be small producers of power promoting clean air technologies. As the economies in the EU and the USA are hit and there is low demand, growth will be focused in Asia as the region will create the demand, displacing exports outside the region. Myanmar, particularly, is indicating decentralized demand and Thai investors are already involved in infrastructure contracts, particularly in port construction and operation with long-term leases. Also the industrial zones and port projects in Myanmar are 10 times in size of that in Thailand. Myanmar is the gateway to the Indian Ocean and it is only 270 km from Bangkok, slightly further than Pattaya. On environmental sustainability, Thailand is aiming at emission reductions by converting diesel trucks to liquid propane gas, with also an eye on exports to the USA and gaining carbon credits. This could save up to 65% on diesel imports in Thailand and also reduce emissions. In the USA, a law is providing road tax rebates as incentives to convert from diesel to propane as well as making it mandatory for government vehicles in city limits to either use gasoline or natural gas; they are also subsidizing installation costs.

ELIMINATING TOXIC EFFLUENTS FROM PULP AND PAPER INDUSTRY: CREATING GREEN JOBS AND SUSTAINABLE ECONOMIES IN THE GREATER MEKONG SUBREGION

Archie J. Beaton¹

Abstract

In the GMS the Pulp and Paper Industry has an opportunity to create a period of dynamic paradigm shift in adopting sustainable technologies. Over the past 15 years many advancement's in computerization, Nano technology, chemistry, substrates, and processes have made it more economically feasible to retrofit a mill creating a "Closed Loop" or TEF (Totally Effluent Free) facility.

On the economic front not only can the mills in the GMS eliminate mass amounts of chlorinated toxins, increase green energy production, decrease water consumption by billions of m³, decrease GHG emission and produce high quality pulp and paper products but also in the upgrades increase profitability. Many mills around the world are developing additional revenue streams via solar, wind, steam, etc. and I visited a plant that was not only Totally Effluent Free (TEF) but it had 5 revenue streams. Debarked wood is chipped and fed together with the cooking chemicals into digesters. The bark is burned and recovers energy into the form of steam. After cooking, the cellulose is washed and then followed by bleaching with hydrogen peroxide in the closed loop water system. The bleached cellulose is then dried and delivered in bales. The whole process takes approximately 40 hours. During cooking the digesters, hemicellulose and lignin is released. The hemicellulose is fermented and distilled into ethanol. The lignin is refined and with the subsequent ultrafiltration processed into lignosulfate. It is then dried and packed. The cooking chemicals are then recovered and energy in the form of steam is used during the process.

The opportunity to dramatically reduce the environmental degradation of the lands in the GMS is at hand. It is now possible to eliminate waste water filled with a chlorinated toxic soup, containing chlorine compounds such as dioxin, furans, PCBs, etc. Saving the aquatic and dairy farmers

products from being laden with hormone disrupters, protect the people from these toxins entering their bodies from the food, air and water they ingest. Focus on reduction of harvesting old forests, or development of a monoculture forest, by growing and utilizing bamboo as a feed stock which requires far less processing, offers small and large farmers an opportunity to harvest and sell to the mills. Green Jobs – Green Economy based on local resources.

Implementing of TEF technologies will reduce exposure to known human carcinogens, reduce human health costs, help to implement advanced water recycling, and water treatment. Increased profitability must take place during periods like now where bleached kraft market pulp and paper products are at profitable levels well above operating costs. With regional support, elimination, or tremendous reduction, in the effluent discharges from bleached kraft pulp mill (via the elimination of chemical wastewater discharges) is an important way of reducing operating costs, improving environmental impacts, and negative effects on natural resources.

Successful recycling of bleach plant filtrates has been long recognized as the last major technological requirement in achieving the goal of Effluent-Free pulping. During the last 10 years, dramatic successes have been achieved in the recycling of bleach plant filtrates.

All of these advancements include the increased use of "environmentally benign" chemicals for pulping and bleaching, and a greater consideration of the life cycle of the forest. Many producers are considering the best steps to take now, in the face of economic uncertainty, to successfully retrofit an existing facility for Effluent-Free operation.

1. Introduction

This paper responds to the people's statement for Rio+20 with regard to sustainable development of the pulp and paper industry in the Greater Mekong Subregion (GMS), using examples from the industry in other regions.

On the 17th August in Bangkok Thailand² a statement was signed by 52 women and men from 18 countries – Bangladesh, Burma, Cambodia, China and Hong Kong SAR, India, Indonesia, Kyrgyzstan, Lebanon, Mexico, Pakistan, Philippines, Sri Lanka, South Korea,

¹ Executive Director, Chlorine Free Products Association.

² Peoples Statement on Sustainable Development and Rio +20 Peoples Statement on Sustainable Development and Rio +20 www.iboninternational.org/page/whats_new/96.

Spain, Thailand, Timor Leste, USA, and Vietnam – and representing peasants, agricultural workers, fisher folk, indigenous peoples, workers, women, youth and students, refugees and stateless persons, academia, environmental and support NGOs and networks met in Bangkok, Thailand.

The multi-faceted, yet interconnected crises encompassing the economic, political and ecological spheres are causing unparalleled suffering all over the world. Worst afflicted are people from poor countries, most especially women and indigenous peoples.

This crisis of global capitalism further propels profit-driven and unsustainable development that causes irreversible damage to the world's environment. This crisis results in the global climate meltdown, the appropriation of natural resources and the destruction of lives and livelihoods, especially of ecologically sensitive indigenous and traditional livelihood systems.

Rio+20 in 2012 thus comes at an opportune time, when the world's governments and peoples are obliged to think of alternatives to the current development model with its ever-increasing failures. It presents opportunities to push urgently and comprehensively the agenda for genuine people-centered sustainable development. Indeed, solutions exist. And they are in our hands, the people, who in our communities, workplaces, farms and forests, make the building blocks of genuine people-centered sustainable development.

The time has come, and actually it is way past due, that no wastewater discharge should be permitted from any Bleached Kraft Pulp Mill (BKPM). The long term goal of a TEF Effluent-Free operation is technologically and economically feasible with available technology³. There are today BKPMs who have turned this goal into a reality. These companies, guided by corporate objectives, are aided by the scientific literature⁴ and by published TEF Effluent-Free successes in pulp and paper processes⁵.

Over the past 15 years since the first comprehensive concept for an Effluent-Free bleached kraft pulp mill

(BKPM) was presented, there is one Greenfield BKPM in operation which will be capable of Effluent-Free operation⁶; there are two existing BKPMs presently modifying their process systems for Effluent-Free operation⁷; and there are eight BKPMs which have taken significant steps toward eliminating their wastewater discharge⁸. Active interest in the introduction of reduced effluent and effluent-free processes must be taken up by government.

2. Human Health

The health effects of the pollutants produced by pulp and paper mills are as follows.⁹

Chlorine and Chlorine dioxide¹⁰:

Chlorine is a severe short and long term respiratory irritant at levels above 1 ppm (odour threshold 60-200 ppb); chlorine dioxide is a severe short and long term respiratory irritant at levels above 0.1 ppm (odour threshold 100 ppb). Both compounds kill at high levels. The characteristic response to short term chlorine and chlorine dioxide exposure is Reactive Airway Dysfunction Syndrome (RADS), airway inflammation and bronchial hyper-responsiveness, which may last for three years and can result from one acute exposure.

Nitrogen Oxides (NO_x)¹¹:

NO₂ is acute respiratory irritant at 1 ppm for 15 minutes. It is a harmful air contaminant, a precursor to smog, ground level ozone, fine particulate matter and acid rain.

Particulate Matter¹²:

The lungs and respiratory tract can expel large particles and therefore are not a great risk. The greatest health impact is felt from particles with smaller sizes – designated PM 10 (microns) or less, and especially PM 2.5 – which penetrate the lungs and can stay there for extended periods of time. PM 10 is linked to serious health impacts including chronic bronchitis, asthma, and premature deaths. PM 2.5

³ Ken L. Patrick, Jim Young, Kelly H. Ferguson and Andy Harrison, Closing the Loop, Pulp & Paper, March 1994, Supplement - The Editors, La Papeterie, October 1994, p 48.

⁴ Richard J. Albert, The Effluent-Free Bleached Kraft Pulp Mill, 1992 TAPPI Pulping Conference, November 1992.

⁵ Fred Martin, John Nepote, Kirk Girard, and Anton Jaegel, Toward Mill Closure: Lesson Learned TAPPI-Minimum Effluent Mill Symposium, January 1996.

⁶ Diana Aminoff Sandstorm, Rauma- World's Largest Totally Chlorine-Free Plant Papermaker, October 1994, p 20.

⁷ Donald G. Meadows, TCF a Step Toward TEF, Continual Modernization Puts Ostrand in Forefront of Pulp Mills, TAPPI Journal, November 1994, p 51, and p 55.

⁸ Andrew Mitchell, Metsa-Botnia Moves Into Ozone at Kaskinen Pulp & Paper, International, June 1994, p 32.

⁹ <http://paper.c2hcl3.com/health-effects>

¹⁰ ibid.

¹¹ ibid.

¹² ibid.

has been recognized to have the potential for the greatest health impact on a larger segment of the general public.

Sulfur oxides (SO₂, SO₃ and solid sulfates)¹³:

Sulfur oxides are irritants to the eyes and respiratory system at 5 ppm for 10 minutes. SO_x is a precursor to fine particulate matter formation. Sulfuric acid is implicated in bronchitis, emphysema, eye, nose, and stomach irritations, and possible lung cancer in exposed workers. Total Reduced Sulfur compounds, including hydrogen sulfide, methyl mercaptan, di-methyl sulfide, and di-methyl disulfide

These can cause an extraordinarily foul-smelling, toxic gas. H₂S Irritates eyes at 50 ppm, and causes death at 100 ppm. The human nose detects it at about 1 ppb, and the sense of smell can be permanently damaged.

3. Water

A precious and scarce resource is a critical factor to alleviate poverty and hunger, for sustainable development, for environmental integrity and for human health.¹⁴ The GMS has an abundant fresh water resource that needs protection and monitoring. The GMS must set into place the kind of protection that ensures that all mankind in the region has available fresh clean water and that rivers run clean with fish that do not threaten human health via the toxic chlorinated or halogenated poisons embedded in the flesh.

It is my understanding that recent access to water (a basic necessity for all life) is continuously being threatened by privatization and shortages in some states. There is a restructuring of the water industry in Malaysia, because of an immediate solution to water rationing and water shortages faced every year. If water conservancy is the goal, then new and adapted regulations are warranted.

I am not sure how the water is controlled in the GMS or what it will require to bring all interested parties into the discussion. But in the US there are about 53,000 water agencies, getting all of them along with businesses to come together and develop a coherent point of view about water management isn't going to happen all at once. The challenge of water conservation around the world will require that we balance out all of these needs and develop a global perspective.

¹³ <http://paper.c2hcl3.com/health-effects>

¹⁴ Loga Sunthri Veeraiah Consumers Education, Representation and Participation in Integrated Water Resource Management and Conservation-Malaysia.

The motivation around the world is high to minimize water usage in paper mills, meeting stricter governmental regulations, combined with the focus to reduce costs through more efficient water and energy consumption. Many paper mills are actively pursuing plans to significantly reduce fresh water use and to return water to rivers cleaner than it arrived. Our organization can attest to that with more than 200 audits of many different types of mills.

4. Eliminating Toxic Pulp Mill Effluents

An example: The water quality of three pulp mills in the GMS is a comparison of the bleaching plants that are the largest toxicity source in terms of Toxicity Emission Factor (TEF). BAPACO was high on TEF, but not in COGIDO where the discharge of black liquor is the largest contribution of toxicity. For this reason, the total toxicity discharged from COGIDO with TEF>6000 was much higher than BAPACO with TEF of 750. For the Thai mill, the TEF of the pond system effluent alone was already much higher than TEF of the other two mills¹⁵. These TEF levels from the mills would not meet the minimum standard to be certified under the Sustainable Manufacturing Initiative¹⁶.

In the US the State of Louisiana Department of Environmental Quality recently put a Bogalusa paper plant on notice that it is liable for a massive fish kill¹⁷ in the Pearl River, setting in motion the legal process for potentially issuing penalties and fines, DEQ issued a compliance order and a notice of potential penalty to Temple Inland for its role in the incident that clogged the Pearl River through Washington and St. Tammany Parishes with thousands of dead fish.

In reviewing the key trends in key environmental areas including air and water quality, water availability, GHG emissions, and climate change all stand out as negative side effects of this growth in the GMS.

Technology has now combined with public demand, environmental regulation, and economics to permit the construction of Greenfield BKPMs which will operate Totally Effluent-Free and to the permit retrofit of existing BKPMs to operate Total Effluent-Free.

¹⁵ Resources, conservation and recycling, Source 1996, vol. 18, no1-4, pp. 87-105 ISSN 0921-3449, Elsevier Science

¹⁶

¹⁷ Katie Urbaszewski, Bogalusa paper mill admits fault as dead fish flow to Lake Pontchartrain, The Times-Picayune, Wednesday, August 17, 2011

The need to be sustainable in the pulp and paper market has come as a natural consequence of the following:

1) The US has closed¹⁸ **2004 – 2007 equaled 228 – 2008 equaled 140 – 2009 equaled 248 – 2010 equaled 41 all based on chlorine technology**

2) Effluent-Free BKPM technology are in operation now for more than 10 years producing market brightness pulp at lower capital and operating costs than those for a standard reference BKPM¹⁹.

3) It is now technically possible to retrofit an existing BKPM to operate Effluent-Free, produce market brightness pulp and reduce operating costs²⁰.

4) The public has a perception that our products and mill discharges contain harmful chemicals, and consumer demands for “Environmentally Friendly” products and processes continue to escalate in intensity.

5) Environment regulations in all countries are moving steadily toward total elimination of wastewater discharge in existing and new BKPMs.

The first requirements for Effluent-Free operation are to use chemicals which are inherently recyclable, or react to form air, water, and process make-up chemicals; and to provide a means for removal of the non-process elements which enter the system. These requirements are most easily satisfied by the use of TCF bleaching chemicals; although there are the possibilities of Effluent-Free operation using ECF bleaching chemicals. One major producer, SAPPI, Ltd., had developed an ECF bleaching system which included recovery and removal of non-process elements, but abandoned this concept and has installed a system which will initially reduce effluent discharge by 35%, and later permit Effluent-Free operation with TCF Bleaching²¹. BKPMs who retrofit their bleach plants for TCF operation will be the first to convert to a TEF.

The innovative technologies of the SAPPI, Ngodwana Mill, however, permitted this facility to be designed, constructed and operated as the most water-efficient mill in the world, with a discharge of only 11.6 m³ per ADMT of product²².

Many of the internal process water recycling technologies which are in operation at this facility have yet to be adopted for water conservation in BKPMs constructed in subsequent years.

The following discusses the background of pulping, bleaching, and progress toward Effluent-Free production; one of the reasons why, for many, ECF was a misstep; and the direction of future pulping processes. The environmental and market conditions in major pulp producing countries are presented, along with their response in the production of TCF pulps.

5. Background

Chlorine chemistry use in pulp bleaching has been, and is widely used today, to complete the delignification of pulp after cooking, and to facilitate the removal of lignin in subsequent bleaching stages. Issues of toxicity of bleach plant effluent have been raised through the years, and chlorine is strongly linked to toxicity. Nevertheless, chlorine, and now chlorine compound based chemicals continue to be the principle bleaching agents. In the late 1990's change among pulp producers were adjusting to new realities of the marketplace, the environment, and the availability of new, lower cost technologies²³.

Since 1975, the effluent quantity per ton of pulp from a typical bleached kraft pulp mill (BKPM) has been reduced by more than 50%²⁴. The effluent quality, as measured by toxicity, BOD, COD, color, odor, and foam has steadily improved through this period²⁵. These improvements were made largely as a result of increased government regulation of effluent quality²⁶, as well as the energy crisis of the 1970's²⁷. During this time, the cost of treating and

¹⁸ <http://www.pprc.info/html/millclosures.htm>

¹⁹ Richard J. Albert, Technical and Economic Feasibility of the Effluent-Free Bleached Kraft Pulp Mill, 1993 International Non-Chlorine Bleaching Conference, March, 1993.

²⁰ Richard J. Albert, Building Block Technologies Which Build Toward Effluent-Free Operations, for Retrofit of a Bleached Kraft Pulp Mill, Including Technology and Economics Canadian Pulp and Paper Association, 81st Annual Meeting, January 1995.

²¹ A.G.J. Volk, TAPPI 94, February 1994.

²² B. Coetzee and C. D. Davies, F. E. Mera and L. K. Swift, Practical Steps Leading Toward the Effluent-Free Mill, TAPPI Journal, April, 1985, p 82.

²³ Helge Eklund, CEO Sodra Cell, TCF- Will it Stay or Go?, Global Conference on Paper and Environment, Brussels, June 93.

²⁴ Reid Miner and Jay Unwin, Progress in Reducing Water Use and Wastewater Loads in the U.S. Paper Industry, NCASI Technical Bulletin No. 603, February 1991.

²⁵ Brian T. Harrington and Richard J. Albert, New Color Abatement Strategies Include End-Of-Pipe Treatment, Pulp & Paper, September 1989, pg 119.

²⁶ Kelley H. Furguson, Process Changes, Regulatory Knowledge Necessary to Meet Dioxin Challenge, Pulp & Paper April 1991, p 61 - Mark A. Luttner, EPA's Pulp and Paper Cluster...Scope Purpose and Implications for Pollution Control Initiatives, TAPPI 1992 Engineering Conference, pg. 63.

²⁷ Ronald J. Slinn, Emerging Problems and Opportunities for the Pulp and Paper Industry, TAPPI Journal, October 1982, p 51 - R.J. Ellerbe, Of Bricks and Mortar, TAPPI Journal, August 1983, p 49 - Stacy L. Hammond, and Fred G. Habeishi, A Case Study-Fast Work in Chesapeake on a Wastewood Boiler Project, TAPPI Journal, August 1983, p 49.

heating large quantities of process water was continuously evaluated against the cost of using new technologies to reduce effluent flow and to recover valuable chemicals.

Today, a typical BKPM in the United States has a water supply of 133 m³ of water per ton of pulp and discharges effluent at the rate of 110 m³ per ton. The latest Greenfield BKPM in the United States has reported a water intake equivalent of 113 m³ per ton and effluent discharge of 69 m³ per ton²⁸. The most water-efficient BKPM in the United States reports an effluent discharge of 54 m³ per ton. The typical mill uses such large quantities of water because of the process design of the facility, use of chlorine chemistry and processing equipment limitations.

6. Technologies which lead to Effluent-Free Operation

This purge is necessary because of the process design which includes chlorine and chlorine compounds in the bleaching process. Nevertheless, this design demonstrated the practicality of operating with low effluent flows and pointed to future further reductions. At the time of the original design, contingency plans were proposed to eliminate effluent from the bleach plant in the future, either by closing the filtrate loop within the chlorine based bleach plant; or by converting to an Oxygen-Ozone-Peroxide bleach plant and recycling filtrates through the recovery system. In 1996, as a further building block toward effluent-free operation, a new Ozone bleaching stage was added. The process following the existing Oxygen stage will permit an additional 35% reduction in effluent.

In January 1992, an Effluent-Free TCF bleached chemithermomechanical pulp mill started operation in Canada. This facility has been in continuous operation with complete reliability of its Effluent-Free process, producing high quality pulp. With a total water supply of 2 m³ per ton, all incoming water exits with the pulp, sludge, or to atmosphere through evaporation. Although this facility has no provision for process chemical recovery, the ability to complete closes a pulp mill water circuit, and to operate totally chlorine-free, with zero effluent, has been and continues to demonstrate the value of TEF technology²⁹.

²⁸ Charles E. Swann, Weyerhaeuser Starts up a New State of the Art Pulp Mill, *American Papermaker*, Dec 1990 pg.26.

²⁹ Jerome A. Concel, Millar Western Continues to Innovate With Zero-Effluent Chlorine-Free Mill, *American Papermaker*, January 1992, p 14.

In mid-1992, a United States pulp and paper manufacturer started up the first North American Bleach Plant utilizing ozone as a principle bleaching chemical³⁰. Operating results have satisfied their expectations for chemical usage and fiber properties. Although this bleach plant continues to use chlorine dioxide in the final brightening stage, lab data from this facility reportedly shows that an effluent flow of 7 m³ per ton is possible.

7. Pressures for Change

Since the US EPA Promulgated the Cluster Rules the Pulp and Paper Industry had settled into a routine, that it is accustomed to, responding methodically to new reports of undesirable elements in BKPM effluent. An individual company or the industry will evaluate the new information and then make appropriate process and/or equipment changes. Not much has changed here in North America.

Since the first dioxin study and numerous subsequent studies, consideration and implementation of new pulping and bleaching technologies have been proceeding at a faster pace than at any time in the past. The rate of change appears to be accelerating again as the public focus is on sustainability issue like water uses, GHG, forestry, etc. that are driving change.

Public awareness and concern about chlorine toxins, chemicals discharged to public waters or present as residuals in the mill's products and solid waste were added to the traditional pressures for environmental improvement. These have led to new interest in developing and applying non-chlorine bleaching, modified pulping, and other technologies to further reduce chemical discharges³¹.

The Pulp and Paper industry realized that simple process and equipment changes would not solve these problems, so they began to focus on more comprehensive improvements. The issue of sessions and is an important factor in corporate decision making. This issue has

³⁰ Kelly H. Ferguson, Union Camp Begins Ozone Pulping Drive with New Kraft Bleaching Line at Franklin, VA, *Pulp & Paper*, November 1992, p 42 - Jim Young Union Camp Lead Ozone Pulping Drive in North America Pulp and paper, November 1992, pg 42.

³¹ John Bettis, Bleach Plant Modification, Controls Help Industry Limit Dioxin Formation, *Pulp & Paper*, June 1991, p 76 - Rudra P. Singh, New Developments in Bleaching, *TAPPI Press-The Bleaching of Pulp*, 3rd Edition, Revised 1979, p 569.

precipitated an industry revolution in thinking and has prompted consideration of the following alternatives:

- Change the process
- Change the method of introducing chlorine
- Lower the chloride
- Change the chemicals to chlorine-free
- Treat the effluent
- Treat the product

Following technologies are available to reduce both the total quantity of BKPM effluent and the quantity of undesirable elements in the effluent:

Pulping

With present BKPM designs, organic and inorganic chemicals which enter the bleach plant are discharged to waste treatment along with the bleaching chemicals. To the extent that pulp can be further dignified in the digester while maintaining final pulp properties, lesser quantities of bleaching chemicals will be required and the discharge of organics and inorganics will be reduced. Typically, mills dignify in the digester to kappa number 32 for pine and kappa number 29 for hardwood. Oxygen delignification is the most widely implemented step in reducing the amount of organic and inorganic compounds remaining to be treated during bleaching and in reducing the amount of organic/inorganic compounds to be discharge. Oxygen stage filtrate is routinely returned through the chemical recovery cycle.

Bleaching

Bleaching process modifications included the use of various levels of chlorine dioxide as a substitution for elemental chlorine. These efforts were directed toward “environmentally compatible” production processes. High chlorine dioxide substitution reduced the discharge of detectible high levels of dioxin in the effluent and reduced the measured AOX. The next modifications eliminated the use of any elemental chlorine. This step further reduces, but does not eliminate, the discharge of toxic compounds³².

BKPMs are responding to those demands by experimenting with, and using ozone, peroxide peracids, enzymes, and other chemicals to further reduce or eliminate the use of chlorine containing compounds³³.

This current impetus for change arises from a new force felt by the industry, that of the consumer. The public is demanding products and effluent that bear no potential environmental or health risk.

8. A Paradigm Shift

What we see, is not merely more of the same slow evolutionary accommodation to new realities, but rather a fundamental shift in the paradigm, or rules under which our business will operate. There is frequently confusion when such a fundamental change occurs. In this case, however, the new rules are quite clear, environmental regulations and consumer demands will affect operations. In the case of pulp mill effluents will be under scrutiny until there is no longer any effluent³⁴.

In the long term for BKPMs to survive in the end it must convert to chlorine-free and Effluent-Free. Those who see this now, and plan accordingly, will be successful. Some who understand this new paradigm shift are taking action to establish themselves for these new conditions. Those manufacturers who realized there was an opportunity to sell TCF pulp, enjoyed a premium price for their product during the first five years; found they could sell full production during the cyclical downturns of 1990-1993 and 1996-1999; and realized the operating cost advantage of using lower cost TCF bleaching chemicals. To those who wait there is the likelihood of becoming the marginal producer; last on-line during up times and first off-line during down times.

9. Environmental Issues in Sweden, Finland, Europe, Australia/Asia

Sweden has been recognized as a leader in environmental progress. It is interesting to note that operating performance of Swedish mills shows substantially lower AOX discharge than their regulations require. The Swedish Environmental Protection Agency confirms the Scandinavian laws of 15 Kg per ton COD and 0.2 Kg per ton AOX. The typical Swedish mill effluent averages less than 15 Kg per ton of COD, 0.5 Kg AOX per ton.

Finland has effluent discharge regulations which are similar to those in Sweden, in that they are based on Best Available Technology, and that cooperation, rather than

³² J.J. Brunsvik, R. Grundelius, R. Kordes, and B. Swan, Environmental Compatible Bleaching of Chemical Pulp, TAPPI 1989 Pulping Conference, p 411 M.B. Van Hook, W. Peter, P. Sligh, R. Malinen, and D. Pryke. Regulatory Issues by Country, Pulp and Paper Non-Chlorine Pulping Conference, March 2, 1992.

³³ Howard Deal, Environmental Pressure Causes Change in Bleaching Technologies, Chemicals, Pulp & Paper, November 1991, p 110.

³⁴ Richard J. Albert, Restrictive Environmental Regulations Drive Mills to Operate Effluent-Free, Pulp and Paper, December 1993.

confrontation is sought between the regulatory agencies and the mills.

Because Finish mills are heavily dependent upon export for their viability, they are supplying ECF and increasing quantities of TCF pulp to satisfy this growing market. The world's first BKPM capable of Effluent-Free operation is now in operation in Finland. This facility is located at Rauma, on the south-eastern coast, had its start-up in Mid-1996. The mill is based on displacement batch cooking and TCF bleaching.

EU and especially the German speaking countries are providing the greatest demand for chlorine-free pulp and paper products. Coordination of environmental regulations is extremely cumbersome in Europe because of the many competing national interests. An ambitious five year study has been undertaken in an attempt to coordinate this effort and resolve potential conflicts of interest. However, since this region already has more than 30% of the TCF mills, the issue may well be decided before the study is complete.

The European market has clearly stated that, for a given paper product specification, there is a strong preference for TCF pulp. The pulp and paper industry is learning that comparable TCF products can be manufactured at lower costs than with chlorine-based technology. To those in the pulp and paper industry who made the changes early, there was a market price premium for TCF products, which helped to compensate for the capital costs of conversion to TCF Technology. This same premium may be an incentive to those operating in the GMS.

Australia and Asia in the past have shown little published activity in the area of TCF production. Environmental issues are receiving increasing concern in Australia with *the Gunns Pulp Mill taking the headlines* which will now require the mill produce TCF pulp and paper products or even a TEF mill³⁵. The Australian guidelines for new bleached eucalyptus kraft pulp mills are now being updated. There is some information which indicates that any new mill in Australia would have to be both TCF and perhaps Effluent-Free in order to be licensed. A new mill will most certainly use the latest technology that has been developed in the northern hemisphere.

Environmental issues in Asia appeared to have little impact on the early design or the operation of its pulp and paper facilities. There is, however, an awakening interest

in environmental issues in Asia. The first designed to be easily converted to low effluent, ECF or to efficient TCF processes.

Plan of Action for the mills in GMS

If the long term objective is to continue manufacturing and implement a sustainable pulping plan, not following the path of the US who will never see another Greenfield Mill built. Then it is clear that facilities will eventually be operated Effluent-Free.

Each company should:

- First: Obtain a complete picture of the existing facility. A through study of the processes and equipment should be undertaken. This study should include pulp, water, chemistry, chemical heat, and energy balances.
- Second: Prepare a new process design including pulp, water, chemical heat, and energy balances for the facility as it would be, when operated Effluent-Free. This should be based on a TCF bleach plant which may include Oxygen, Ozone, and Peroxide. Detailed capital cost estimates should be included for constructing the required new facilities, and for upgrading existing facilities.
- Third: Develop a logical program, using a "Building Block" approach, to get from the existing, to the ultimate configuration. For example, when new environmental guidelines or regulations are imposed, there will be certain costs incurred for minimal compliance. If minimal compliance systems will later be abandoned, they become avoided costs in comparison with those environmental investments which result in the same environmental improvement but also become Building Blocks toward the ultimate mill configuration. Alternatively, as existing systems require replacements due to obsolescence or excessive maintenance costs, the replacement systems can be installed in accordance with the master plan.
- Fourth: Execute the development program, with implementation in phases to satisfy new regulations as they arise, or to meet potential cost/benefit criteria.

If each company follows these procedures, they will have a logical plan to stay in compliance with environmental regulation. They will be more likely to invest in TCF technology today for Effluent-Free operation in the future, than to invest in technology which must later be abandoned.

³⁵ Gunns Ltd. proposed Pulp Mill on the Tamar river - The issue discussed - www.tamarpulpmill.info/ Updated 19/9/2011.

The Support and Governments of the GMS

In the entire region the Pulp and Paper Industry is considered vital to its economy. Should GMS consider proposing financial incentives be granted to BKPMs which make environmental improvements greater than the basic requirements.

10. Economics of the Greenfield TCF/Effluent-free BKPM

The **most important factor** in the effective pursuit of sustainable development is **'getting the price right'**. Unless prices are assigned to air, water, and land resources that presently serve as cost-free receptacles for the waste products of society, resources will tend to be used inefficiently and environmental pollution will increase³⁶.

Capital Costs are estimated to be \$35 Million less for a TCF/Effluent-Free Greenfield BKPM than for a new ECF BKPM. Principal incremental savings arise from elimination of the waste treatment plant and chlorine dioxide plant. Principal incremental costs arise from the larger evaporator system, and cooling towers.

Operation Costs are estimated to be \$30 per ton less for a TCF/Effluent-Free Greenfield BKPM than for a new ECF BKPM. Principal incremental savings are for bleaching chemicals, makeup cooking chemicals, and the effluent treatment plant operation.

Basis of Design and other data have previously been presented, as a guide, for individual use in making an independent evaluation of these alternatives. This evaluation may become of academic interest only, however, if no one would, today, build a Greenfield ECF BKPM.

11. Retrofit of an Existing BKPM for Effluent-free Operation

Initially, low KAPPA pulp cooking followed by oxygen, ozone, and peroxide bleaching will likely become the standard for pulping and bleaching processes. Advances in pulping chemistry, greater experience with bleaching techniques, and closed cycle operation will permit higher yields and lower operating costs.

Ultimately biological technologies will replace chemical processes. Some work has already shown that these technologies are potentially more selective in preserving cellulose and more cost effective.

Life Cycle Approach

Life cycle approach to the forest products industry has dictated that solid materials, now considered waste from the pulping process, be returned to the forest to replace the nutrients which were removed with the wood.

11. Conclusion

The time is here now where governments can regulate a no wastewater discharge being permitted from any BKPM. Environmental regulations and public demands will continue to converge until the only possible result will be to operate an environmentally begin, Effluent-Free BKPM.

On the Green Economy

We must make sure that we do not allow the corporatization of the Green Economy agenda. Technological fixes and market-based incentives are false solutions to the ecological and climate crises and will not advance sustainable development.

For sustainable economies to develop, it is crucial to democratize ownership as is done in the EU communities, control and decision making over productive resources and assets. The GMS should consider a move from a capital investment model towards an appropriate mix of more democratic modes such as cooperative, community-based and driven, commons or public forms of ownership to ensure that economic activity provides sustainable livelihoods and meets the developmental goals of the community and society.

- Public enterprises should remain in public control and privatization should be reversed.
- Promote sufficiency-based economies (i.e. catering primarily towards meeting local needs and demands, developing local capacities, based on available resources, appropriate technologies and resource sharing).
- Manufacturing should promote closed-loop production where products are designed with minimum use of energy and materials, longer life-spans and with maximum reuse and recycling of parts and components.
- Promote mass public transportation systems.

³⁶ Stewart Elgie, Faculty of Law University of Ottawa, Achieving a Low-carbon, High-octane Economy- The Wealth of Nature: how fixing the economy can save the planet <http://www.slideshare.net/Fedcan/stewart-elgie-on-achieving-a-lowcarbon-highoctane-economy>

- Implement genuine agrarian, aquatic, pastureland and forestry reforms; and promote biodiverse ecological agriculture that benefits small producers, especially women and indigenous people.
- Stop profit-oriented exploitation and destruction of natural resources that destroy lives and livelihoods.
- Stop industrial corporate agriculture and fisheries that do not adhere to advanced sustainable activities.
- No to renewable energy that depends on monoculture and biomass extraction.
- Respect and promote community-based and farmer-driven efforts in organic agriculture, seed banking and on-farm improvement of crop varieties and animal breeds.
- People-centred sustainable economies should promote the rights of indigenous peoples and local communities in accordance with UNDRIP including rights to land and resources, and free, prior and informed consent (FPIC).

- Producers must have a clear vision of their ultimate mill process configuration, when operated Totally Effluent-Free, in order to build toward this plan, and avoid making capital investment in processes which increase their current risk, and will be later be abandoned.

Even with a reduction in research and capital appropriation expenditures, there has been rapid development and implementation of technologies that will eliminate the discharge of BKPM process wastewater. The first Greenfield BKPM, capable of Effluent-Free operation, started up 10 year and is meeting initial design expectations.

The first BKPM, retrofit for closed cycle, from bleach plant to recovery, has been in operation for 10 years. This mill demonstrates the elimination of process effluent to be achievable with available technology, and to be economically feasible.

THE PUBLIC-PRIVATE PARTNERSHIP ROLE IN DEVELOPMENT AND ENVIRONMENT: CAPACITY DEVELOPMENT FOR SUSTAINABLE PUBLIC-PRIVATE PARTNERSHIP

Ohnmar Khaing¹

Abstract

The paper describes gaps between the public and private sectors and identifies initial steps for closing the gaps and improving the public-private partnership development framework through capacity development and institutional strengthening to balance development and environment. The paper briefly reviews the impacts of economic growth and environmental awareness in the GMS, especially on livelihoods, income, and access to food, and indirect impacts on ecosystems and water resources. Current problems in public-private partnerships are described, giving Myanmar as an example, pointing to the need for commitment of policy and political will; the lack of technology transfer and dissemination to the public; and lack of awareness at all levels. Capacity development and institutional strengthening efforts are needed in order to help people's livelihoods become more resilience. Possible actions and resources are described, such as development of national strategies and multistakeholder consultation for monitoring livelihood resilience, linking social responsibility and the importance of long-term private-public partnerships.

1. Introduction

Public-private partnership (PPP) implies a common understanding of shared goals, a willingness to repartition responsibilities for their achievement and a continuing public-private dialogue on what needs to be done to promote their realization, and a supportive policy and institutional framework. Partnership goes beyond business concerns, and extends into all policy areas, including education, health, human rights, immigration and citizenship, science and technology, foreign relations, arts and culture. There is a widespread trend to broaden participation in governance by strengthening the interface

between the state and nonstate actors and people-centered sustainable development.

The Greater Mekong Subregion, made up of Cambodia, the People's Republic of China, the Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam, is endowed with a rich and diverse natural resource base. The Mekong River itself has historically supported economic development and sustained rural livelihoods. However, differing political, economic, institutional, and cultural circumstances across the countries of the subregion have resulted in uneven progress toward sustainable development.

Public-private partnerships are expected to increasingly form the cornerstone of the implementation plans for sustainable development. Innovative partnerships—including within countries from decision to the community levels as well as at transboundary and regional levels—that bring together various partners from different sectors, are expected to be the key to the long-term sustainability of balance between development and environment (UNEP, 2011).²

The purpose of this paper is to provide some preliminary thoughts on ideas and issues in this regard for consideration and further action. The paper looks at partnership in the pursuit of balancing subregional development with environmental goals, with a focus on some innovative examples of PPP, and some of the main issues arising, notably increasing opportunities in the private sector, giving an agricultural business example from Myanmar.

The paper is divided into three main sections, which deal respectively with impacts of economic growth and environmental awareness in GMS especially the impacts on livelihoods, income and asset to food and indirect effects, impacts in ecosystems and water resources; the current constraints and gaps between private and public partnership by giving the example of Myanmar, need commitment of policy and political will; lack of technology transfer and dissemination to the public; lack of awareness at all levels; and capacity development and institutional strengthening efforts include increasing opportunities in the private sector, the business-enabling environment, promotion of cooperative social responsibility regulation, and a final section which briefly touches on the role of the regional community with regard to the foregoing.

¹ Food Security Working Group, Yangon, Myanmar.

² United Nations Environment Programme (UNEP). Sustainable Development Strategy of the Greater Mekong Subregion; Consultation document.

2. Impacts of Economic Growth and Environmental Awareness in the GMS

Subregional trade has increased but, because road corridor projects and trade facilitation measures under the GMS Cross-Border Transport Agreement are not fully developed, the total intraregional trade (in 2006), taken as a percentage of the sum of GMS countries' total exports (6.5%), was still low compared with the 52%, 59%, and 52% intraregional trade shares, respectively, of Asian (as a whole), European Union, and North American countries (in 2006) (ADB, 2008).

A system of transnational rail and road routes that links transport systems, power grids and markets across and beyond the sub-region is being created to stimulate and take full advantage of economic opportunities arising from fuller integration in the regional and global economy. This extensive infrastructural structure integrating all GMS countries into an unique "growth area", is one of the most tangible signs of the rapid pace of regional integration in development, and one that deeply affects people's mobility, facilitating in-country and—in tandem with visa harmonization and cross-border transport facilitation—intraregional travel.

2.1. Impacts on Livelihoods

Infrastructure development and the related growth of the transportation sector in the GMS, besides facilitating movement and migration, also directly creates job opportunities for mobile work forces, including bus and truck drivers and migrant construction workers.

However, in some cases, infrastructural development is a "push" factor, causing people to move by impinging on their environment and affecting their livelihoods. New roads and bridges connect villagers in remote and isolated communities to a world where their agricultural skills do not easily transfer and where few coping mechanisms are available, landing them into conditions of poverty and motivating them to seek alternatives. Construction and other development projects also at times imply displacement and resettlement of local communities, especially ethnic minority populations, which may result in migration of those who have lost their land and other sources of livelihood, or who find their new places of residence untenable or unacceptable (AMC and MMN, 2005).

The expansion of trade and liberalization and initiatives put further pressure on environmental sustainability in the subregion. The sustainable use of water and natural

resources in the Mekong basin is directly and inevitably related to human and survival in the subregion. The promising development of hydropower and setting up regional power grids to support regional power trade are models for future development.

Economic corridors are meant to attract investment and generate economic activities along an area, usually with the aim of providing livelihood for people. They are meant to provide two fundamental attributes for development: lower distribution costs and improved supply of land for economic activities.

2.2. Ecosystems and Water Resources

Achieving a balance between trade, investment liberalization, and environmental conservation is one of the key challenges facing the members of the GMS. Environmental protection awareness is an urgent need since growing development affects ecosystems and water resources. Illegal trade in the subregion, particularly of wildlife and timber products, is also undermining the sustainability of the GMS environment (Dosch, 2010). Illegal wildlife trade involves hundreds of millions of individual plants and animals and tens of thousands of species across the GMS.

The most important concern for GMS is poverty, which is probably the main cause of watershed and ecosystem degradation. There is not much reliable data to indicate whether poverty is more acute in lowland areas than elsewhere in the subregion. Poverty-driven expansion of cultivation in upstream areas can destroy watershed resources. At the same time, rapid growth of agribusiness has been seriously threatening the region's environment. Land tenure is an important socioeconomic factor that greatly affects farmers' decisions regarding land use, land conservation, and farm development.

At present in Myanmar, there are more than 53 watersheds with dams that provide crucial water supplies. These watersheds cover a total land area of 3.56 million ha. The natural resources in catchments that supply water for irrigation, hydropower, and industrial and domestic uses will need sustainable management to maintain and continue a stable ecological balance between people and the ecosystems. Although exact data on the extent of degraded lands in these watersheds are not available, there is evidence of widespread soil erosion, formation of gullies and landslides, increased sediment deposit in the dams and reservoirs, irregular stream flows, and decreasing

crop yields. A time will ultimately come when the upland environment becomes inhospitable for sustainable living.

3. Current Constraints and Gaps between Private and Public Partnership

While governments in most countries of the Mekong subregion have been gradually adopting laws to create a simple and transparent rules-based private sector environment in a market oriented system, protection of the environment and sustainable use of resources have regularly taken a back seat in the industrialization process. Economic growth and social development remain a priority in the fight against poverty throughout the region. Yet the ecological footprint shows that, despite the fact that a significant part of the GMS population lives in absolute poverty, the subregion is already living beyond its ecological carrying capacity (World Bank. 2006).

The constraints to the development of partnerships are mainly attitudinal and organizational. The prevailing culture of each GMS government may include risk avoidance, secrecy, and suspicion of the private sector. Reorientation training can displace this established culture and bridge the gap between public and private sectors, but widespread change is a long-term process, particularly in the former centrally planned command economies in which entrepreneurial activity has only recently been decriminalized. Productive interaction with the private sector may be used to reinforce responsiveness, transparency, impartiality, objectivity, and accountability as major professional values of the civil service. GMS governments need a regional governance framework for effective PPP in the subregion to balance development and environmental protection.

The constraints on government spending and the focus on tackling national debt will increase the requirement for substantial volumes of private sector capital to meet essential infrastructure needs and goes on to suggest that the proposed establishment of a National Infrastructure Bank in Myanmar will support PPPs and help reduce borrowing costs on essential infrastructure projects.

3.1 Commitment of Policy and Political Will

Political will is very important by having realization on community's livelihood resilience by decision makers; raising awareness on development, its advantages, disadvantages, and cooperation among all stakeholders; and raising awareness on countries' involvement in

regional and global forums to balance recent development with environmental concerns.

Traditionally, environmental concerns have not been a primary policy focus of the subregion's governments. Regarding coordination and collaboration among GMS countries, where the government performs a balancing role, looking after the interests of such groups as customers in the area of utility tax regulation as well as business, the relationship with the private sector should be at arm's length rather than cozily cooperative. Otherwise, there is the risk that civil servants and big business collude in their own interest at the expense of the general public, or at the expense of such groups as small and medium-sized enterprises, which are left out of the mainstream of collaboration.

There needs to be more clarity across diverse regulatory frameworks in different states to enhance the efficiency of the PPP process. Additionally, more consideration must be given to the structuring of PPP deals to encourage sustainable investment, such as using a cooperative social responsibility approach to development. Government support is fundamental to the functioning of a strong PPP market. This support can take the form of clear and consistent regulatory and legal frameworks, as well as the creation of an infrastructure project pipeline to improve transparency and encourage private sector investment.

A new report (RICS 2011) highlights that the potential PPP market has not been adversely affected by the global financial crisis and is, therefore, in a relatively strong position to help finance infrastructure development in the GMS. Cooperation between government and the development industry will be needed in order to deal with such problems as the lack of a clear framework for projects, absence of rigorous contracts, and weak regulatory support. Additionally, steps need to be taken to encourage institutional investment, for example, from pension funds for public sector staff, to help provide additional funding for projects.

3.2. Lack of Technology Transfer, Awareness and Dissemination to the Public

Poorly-planned and executed development activities, such as road construction, logging, mining, and big hydropower projects in fragile watershed areas, impair streams and pollute the environment. No reliable statistical data are available in Myanmar in this regard. Inadequate institutional and organizational arrangements as well as lack of technical expertise and information sharing have made watersheds worse in Myanmar over the years. Expansion of gullies in

depth and width is revealing the serious level reached in watershed and water resources degradation.

The major handicaps in Myanmar watershed management are the insufficient number of professionals and lack of a proper policy framework. Myanmar needs a good PPP mechanism in this important issue to improve relationships between all stakeholders. Experience in many developing countries has shown that watershed management or soil conservation projects can only develop when trained and experienced personnel are available. Since watershed management is based on a multidisciplinary approach, government institutions from various disciplines should cooperate and work together to survey, design, and implement watershed management activities. A central institution and interdepartmental coordination at all levels are required to minimize duplication of effort and to promote effective implementation.

In the absence of a cooperative work among government departments, unplanned and decentralized upland rural development is likely to accelerate environmental degradation, making the population in the watershed highly vulnerable to natural disasters, such as floods and landslides. In highly active or heavily populated watersheds, torrential mountain streams often cause heavy damage to nearby villages and downstream areas, including heavy deposits of sediment in storage reservoirs and irrigation channels.

4. Capacity Development and Institutional Strengthening Efforts

The main constraints to strengthening institutions are lack of appropriate regional inclusive policies for balancing development and environment by applying firm, clear rights for people. Lack of resource allocation and equitable beneficial between policy and regulation and decision maker and citizen by individual government also observed. Inclusiveness of multi stake holders is a real need to put in policy formulating process.

For information sharing in the GMS, the channel is only disseminated by the Government, not inclusive consultation from private and public concern. National budget from each GMS country should include regional collaborative private- public efforts and forums.

In the case of Myanmar, National Plan of Action for development projects does not include input from scientists, policy makers, and implementers, and technical inputs and expertise are very limited. Sometimes, incomplete

infrastructure makes life and livelihoods in affected communities more vulnerable. Lack of standards and guidelines has resulted implementing poor quality systems in development projects; transparency also is greatly needed. Social aspects and sense of ownership are ignored by the authorities, which is threatening to local people.

The whole GMS needs a proper coordination channel at every level, including that of communities. In all sectors, a key element of capacity building is the establishment of revolving funds for self-reliant groups, to be managed within communities in each country and on a subregional basis.

4.1. Development of National Strategy and Multistakeholder Consultation

In order to secure future private investment and development, particularly from institutional investors, the construction industry needs to communicate more clearly the investment potential of infrastructure as an investment asset class, including risk-return characteristics and diversification benefits. Additionally, it is essential to improve the transparency of infrastructure investment markets to enable performance benchmarking across asset classes and to create innovative investment vehicles to best match investor risk profiles and investment capacities. At the same time, it is very important to include public concern on projects.

It is observed that most frameworks in GMS countries have started as useful or voluntary guidelines and a number are progressing into international standards or legislative frameworks. The GMS countries must include some very important elements, such as a “Do No Harm” framework. Equally important, private and public efforts must be inclusive in a national framework and strategy, involving all stakeholders as equal partners and transparent in their functioning and in their accountability.

4.2. Livelihood Resilience, Linking Social Responsibility

Promotion of Entrepreneurship and Small Enterprises. There are a number of unique features in “small” enterprises, including micro, small, and medium-size enterprises (SMEs) that can play a key role in a nation’s economic success. Although entrepreneurship is important for all types of enterprises, it is especially important for SMEs, which typically constitute the bulk of total enterprises by number. In many countries, enterprises in these categories account for more than half of industrial employment and as much as a third of the national product and export earnings.

They tend to be highly innovative, make excellent use of scarce capital and skills, and provide a range of services and goods to the large corporations. In countries where economic units are often too large to be economically efficient, many new small units are needed because they are responsible for a great deal of technological progress. The lack of small-scale entrepreneurs, especially the “missing middle” (small and medium-sized entrepreneurs), is a handicap to economic progress.

Multistakeholder engagement and dialogue are the most important factors in making progress in these areas, since much of the development has come from interactions between public, private, and civil society sectors, as part of improving governance, transparency, and right to operate for corporations. Much more attention on rights of citizens and their livelihood and the co-responsibilities of governments and business are also critical to sustaining progress.

Job Creation in the Nonfarm Rural Economy in Myanmar is in urgent need. There is a need to create jobs targeting the landless poor, through investments in small-scale social, economic, and environmental infrastructure schemes and by supporting rural nonfarm enterprises through capacity building in entrepreneurship, skills training, and product development.

United Nations agencies and nongovernment organizations can contribute their assessments of the non-agricultural rural economy and opportunities for development interventions, as well as cost-benefit analysis of possible interventions. Many organizations are seeking ways to create short-term and seasonal jobs for the landless poor and marginal farmers through social infrastructure projects: rural roads and footpaths, irrigation channels, health centers, schools, and community buildings. Private–public relationships in this regard are crucial to decreasing unemployment among the population in Myanmar.

The Myanmar Government has prioritized developing livelihood options for the rural poor through community-based infrastructure schemes, the development of agrobusinesses, and private-sector abattoir and meat-processing enterprises. However, the Government should review all the regulations and rules to ensure benefits for local people.

4.3. Long-Term Private-Public Partnership

Most GMS governments have realized that the rural poor can enhance their food security and increase their incomes only if project designs and activities are built on their production systems, alternative livelihood strategies,

environmental protection awareness, and proper allocation of resources. To be effective, therefore, development to reduce poverty must be linked to a proper understanding of poverty processes and environmental protection—how these affect different groups of poor people across the GMS. To this end, GMS governments need to increase effective collaboration with the private sector—toward corporate social responsibility—as well as with local stakeholders in developing programmatic and their implementation. Through experience, GMS governments are acquiring a wealth of knowledge and skills on the processes that contribute to the generation and perpetuation of poverty, and how to reduce poverty by balancing development and environment.

Regional cooperation and collaboration on balancing development and environment should be strongly supported by each country through PPP, with primary concern on improving livelihoods and ensuring long-term sustainability. GMS forums must urgently initiate dialogue involving all stakeholders, covering clusters of each group from each country, to obtain diverse inputs toward regional cooperative and collective mechanisms that will improve trust building and synergy on balancing development and environment.

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SESSION 6:
SEIZING OPPORTUNITIES – THE WAY FORWARD

Panel Discussion – Day 2
Seizing Opportunities: The Way Forward

Facilitator: James Nugent, ADB

PANEL DISCUSSION – DAY 2 SEIZING OPPORTUNITIES: THE WAY FORWARD

Facilitator: *James Nugent, ADB*

Panelists

*Dr. Parisak, Prof Nay Htun,
Mr. Hans Guttman, Mr. Antti Inkinen,
Ms. Ulrika Akesson,
Dr. Chieanchuang (Audi) Kalayanamitr*

James Nugent: Good afternoon ladies and gentlemen. I am very impressed to see so many with us this afternoon after very busy but productive two days. On the first day, we looked at the development of the Greater Mekong Subregion (GMS) over the past two decades and today, we focus on the future program, especially putting the GMS on a sustainable platform. If there is one take-away message from the conference, it would probably be that environmental sustainability in the GMS is imperative; it is no longer an option, it is an absolute must. With this in mind, this session is going to focus on the way forward for the next decade and beyond. To guide us on this we have quite a large panel of distinguished experts. We have identified four specific areas, which are the thematic messages for discussion:

1. The food security challenge will intensify in the coming decade.
2. Water will increasingly become a constraining factor for food and energy security.
3. Private sector participation is critical for the transitions and transformation to a sustainable development pathway.
4. Development coordination and cooperation need to be rationalized and intensified to deliver the 2012-2022 GMS Strategic Framework.

We will ask different panelists to focus on a specific message. The first message is in the context of food security and how it will intensify in the coming decade. So my first question is addressed to Dr Parisak, who is no stranger to this, coming from the Ministry of Agriculture and Forestry in the Lao PDR. So Dr Parisak, in consideration of the importance of food security, share with us some of the main policy, institutional, and investment options that you see as critical to food security and managing the food security, water, and energy nexus over the next decade.

Dr Parisak, Vice Minister, MAF, Lao PDR: First of all, let me start by saying that it was great privilege and pleasure for me to be here and I would like to thank ADB and the organizing committee of the conference; I and the Lao delegation have learned a great deal of knowledge and even know-how in this conference. With regard to the food security challenge, I fully agree with what has been presented. The challenge is how to address all those obstacles to achieve sustainable food security. As I mentioned on the first day, in terms of policy, our government has a policy that supports sustainable development. But the issue in the country is, as I mentioned before, capacity in terms of human capital and resources. For example, thanks to connectivity and cross-border value chain and trade, we have increased our maize production ten-fold but we used destructive technology and a lot of pesticides that have degraded our topsoil. We know that there are a lot of conservation technologies and we have been piloting these with the Consultative Group on International Agricultural Research (CGIAR) in the north of the country, but there is no capacity to scale-up such technologies. A huge investment is needed and we also need credit to support the farmers to make use of the technology. We know what needs to be done but we have all those limitations that we need to address.

What is also important, as you rightly said, when we talk about food security, is that not only the Ministry of Agriculture is involved; we need to work with other ministries; there was a recommendation that the Ministries of Agriculture, Environment, and Energy have to work together. In the case of Nam Theun 2 and Nam Ngum river basins, we are working closely with the Ministry of Energy and Ministry of Environment. But although we come up with beautiful plans, when it comes to local and grassroot levels, it is difficult to implement them. In order to empower the people we need to provide the means to them. I think we cannot move at the pace we would like but we are heading in the right direction. We need to continue with our regional cooperation and try to harmonize cross-border action and assistance. Complementarity is important. We have been receiving a lot of assistance from our neighbors within ASEAN, which has helped us address the technical and technological divide. Along the borders there is a great deal of knowledge that has been passed on to farmers and we have to find ways to intensify such cross-border knowledge sharing.

Regional dialogue is important because certain investments in food security will have both positive and negative impacts. We need to continue this regional

dialogue and work together to find common ground and a common action plan that will serve not only subregional interests but also address national priorities. I will go back with a lot of old and new knowledge and we have discussed this in the Lao delegation; what we have learned here will help us polish our policies and will provide references for us to continue to work with the Asian Development Bank (ADB) and our development partners and to check the programs we have prepared already for 2015 up to 2022 and see what adjustments are needed to ensure that we have more cross-sectoral programs that respond both to regional needs and national interests. I would like to thank ADB and development partners for the support provided to Lao PDR and also to the GMS in general. And thanks to GMS partners who have helped the Lao PDR to advance in achieving increased productivity in the agriculture sector. We have seen tremendous advances in the past decade but now we need to work together to ensure that what we do together will also serve subregional sustainability and that this is also good for the national interest.

James Nugent: Thank you very much Dr Parisak. You have touched on some of the themes we have heard over the last two days. One such theme you mentioned is capacity; having the depth and resources to scale-up and you used the example of your maize production increasing by ten-fold; another theme, which came across throughout the conference was the importance and challenges of several sectors working together; and the third is deriving synergies not only at national but also at subregional levels, promoting the optimization of experiences that we can learn from—you used the example of cross-border learning. So I think those are three very good policy points for us to focus on. Now going on to the second specific issue regarding water, my question addressed to Hans Guttman is: what do we need to do so that water does not become a constraining factor to food and energy security within the GMS and perhaps more broadly than that?

Hans Guttman, CEO, MRC: If we look in terms of water as an enabling resource for energy and food, there is a common thread in terms of management. There are a number of potential constraining factors. It all boils down to how the policies and strategies that are put in place actually account for the different types of uses. It was pointed out earlier that in the energy sector, one supply source is hydropower; looking at it from an energy perspective, other users of or dependencies on water may not be taken fully into consideration when the mix of energy choices is put together for energy security of the country. Likewise, other potential competing uses

may not be taken into consideration when agricultural and irrigation strategies are being drawn up. What the MRC has been charged to do in its remit in working on the Basin Development Strategy (BDS) is to try to ensure that the different potentially competing uses can be incorporated and the preferred choices can be made in a proactive manner to achieve the aims that have been set up in various sectors, looking at the whole picture and not just one single sector. However, I would like to highlight two difficulties: one is equity in development. More care and information are needed in many cases to know who benefits from particular initiatives and plans and how they benefit. When we are referring to the broader aspects of cost-benefit analysis and looking into the bigger picture presented by modeling scenarios, we do not get the full picture of who is benefiting or losing out in the development process. Further work on how planned benefits and anticipated costs accrue on different segments of society will be critical in order to move the planning processes for the GMS and within the MRC cooperation framework. A good example is national food security; compared to Africa, the countries in the GMS are well off; however, as was reported, there are still high incidences of child malnutrition in some areas. So how does this match up, with achievements in food security and yet clear statistical evidence of inequity?

The other point is the overlapping portfolios of various agencies involved in making decisions, which makes follow-up in some cases very difficult. As Jeremy Bird pointed out earlier, the people in this meeting are not necessarily from the same government agencies as those attending MRC meetings on similar issues. Perhaps ADB and MRC can work together to share results of meetings to avoid duplication and increase synergies.

I want to wrap up with an opportunity. Going back to what Dr Parisak referred to as a gap in capacity, MRC and our cooperation framework are in a good position to help member countries with development assistance in water and related resources and can provide capacity we have from member countries. There is an opportunity wherein MRC can be used to help build capacity in implementation, reporting, and financial management in all aspects of all implementation. This perhaps could be something the GMS portfolio could look to support; MRC has the remit to provide this and do it in a regional context. Under the Basin Development Strategy, which has been approved by at least four of the six GMS countries, there are opportunities for member countries to ensure successful implementation of GMS prioritized initiatives.

James Nugent: Thank you Hans. This morning Dr Nay Htun mentioned he had four other observations to share with us this afternoon.

Nay Htun, SUNY: I will address specific issues of water first and then go to the other observations. I think all of you are familiar with these water-related issues but please allow me to reiterate: first, is access to water—quantity, quality, availability, and pricing. The poorest are already paying a very high price and they are willing to pay for quality and reliability. The second issue related to water use for agriculture and domestic consumption is saving water—efficiency and conservation. There is still an awful lot of wastage in the agriculture sector. Up to two thirds of all water is used for agriculture; there are tremendous ways to ensure efficiency. The third and final issue related to water is climate change. Within it, there are subsets; climate change, as the international community talks about, is within a 30–40 year timeframe; we are beginning to see extreme weather, changing precipitation patterns, too much water, too little water, drought, floods—breaking all historical records year on year. Within that subset is climate variation; the inter-seasonal variations from year to year are important for many farmers. The ability to predict this variation is extremely important as farmers are teetering on the brink of bankruptcy. Now allow me to come back to my passion: surely, we have got to move forward but is moving forward the same as “business as usual”? I think we need transformational paradigm changes. More of the same is not enough. Incremental changes are not enough because of the major challenges I mentioned earlier. The confluence of these challenges is almost reaching a perfect storm. Like many of you, I see a lot of evidence-based data from reliable sources and we want to link up the dots.

I see four opportunities and each opportunity is a revolution: the first is a low-carbon revolution; the carbon content of energy is the problem; the greatest challenge is how we can reduce it. A McKinsey report recently said there must be a tenfold increase in carbon productivity in the next thirty years. The US economy took 130 years to achieve ten-fold labor productivity. Can a ten-fold increase in productivity be achieved in 30 years? Yes, technology and financial resources are there; the only thing needed is political will. This is the biggest challenge and opportunity for mankind. The economies that are going for low-carbon productivity will become the most competitive. The second revolution is the resource revolution: we are overusing resources, misusing them and not using them efficiently and effectively. Again, another McKinsey report recently

said we can easily extend availability of resources by 30% at very low cost, which is a low-hanging fruit. But within the resource revolution, the most important element is the biochemical revolution, which allows us to produce energy with bioproducts that are less energy intensive and more resilient and sustainable. Some of the most exciting research going on is how to change photosynthesis in plants; two of the most efficient are sugarcane and banana. The third is the connectivity revolution; we are more and more moving into a wireless world; connectivity between remote areas is emerging wirelessly without big transmission lines. Wireless energy transmission can also be an option for Asia-Pacific countries, thus saving resources on transmission lines. The fourth and last is with all the money, technology—political will. If our behavior does not change, it is still “business as usual,” the status quo. There needs to be behavioral revolution. This where social networking and wireless and information technology will help to change behavior. Today mobile phones give us real time updates of the stock market; in the future, these gadgets can tell us to switch off our lights, reduce our carbon footprint, and make us more conscious about scarcity of resources and need for efficiency. Through these devices our behavior will change. This will be the fourth revolution.

Apichai Sunchindah, Development Specialist, Thailand: I agree in general and there is no big debate on these basic issues; it is important to address these challenges and opportunities. In the final analysis, it comes down to political will, which is largely determined by governments and politicians. How do we make politicians more responsive and accountable bearing in mind that if they are democratically elected they only have a fixed term? Their timeframe is may be only four or five years; how do we make all these long-term plans meaningful for them to take action? With that in mind, I was also interested in developments that have been touched here regarding Myanmar relating to environmental aspects; the Myanmar government suspended one of the dam projects that the PRC Government was going to construct; more recently they also delayed the construction of a Thai coal-fired power plant. Six months ago, this could not have even been imagined but somehow it happened. It seems overnight the Myanmar Government has become very pro-environment and pro-people. In terms of governance, can we sustain this kind of decision making? From the environmental and people’s perspective, this is good. How do we ensure governments in this region become more responsive and accountable?

Dr. Chieanchuang Audi Kalayanamitr, Advisor, National Science Council, Thailand: When it comes to the private sector, I volunteer to answer that. We have realized as the private sector that there are lot of rules and lot of regulations coming up but few are working. We take decisions, we pollute, we are the factory owners. But the polluter pays principle is not working. However, In Thailand we were hit hard last year due to flooding; my factory was flooded; one of them is closed; one has been moved to Cambodia. We begin to realize that the rules and regulations issued by the Government are meaningless. Candidly, we do not listen to them anymore; we are doing and surviving by ourselves. Basically we have reached a crossroad in Thailand now. We cannot depend on the Government.

Muanpong Juntopas, SEI: This is a question addressed to Khun Apichai: On one hand, we want to have a government that cares for people and the environment but on the other hand we have different kinds of investors increasingly from this region. How do we ensure that they are good investors who take people's concerns and environment into consideration? Would we depend on government alone to regulate these investors? Or would we depend on the efforts of civil society, a regional body, or national body (watchdog) to keep on taking up issues and flagging to government? In this context I want to ask whether ADB or other organization has supporting mechanisms for civil society so that they can keep a close watch on investors and their social responsibilities. What are the strategies to ensure that they are doing good, not only to maximize profits but also for the people and environment?

Javed Mir, ADB: In response to the question on what ADB can and is doing in terms of involving civil society, there are several levels—project, program, and corporate. ADB formulates its sector or corporate strategies that will determine and guide our support to countries, it is a multistakeholder process of engagement with different parts of civil society, researchers, academia, and nongovernment organizations (NGOs); so that is on the corporate level. At the project and program levels, we also have engagement with civil society, academia, and NGOs. At the GMS, we have NGO partners helping us design and implement the program. While at the design and implementation stages, we seek out and we have, for example in the GMS Core Environment Program, NGO partners helping us design the program and implement it. Even in major infrastructure projects, we have significant involvement of civil society in preparation, implementation, and the post-implementation stage, where more and more

monitoring is necessary. For example in Nam Theun 2 or other projects, we have sought engagement and involvement of communities as well as NGOs in helping executing agencies in the countries to monitor compliance with what has been agreed under the environmental and social impact assessments. At each stage, we are seeking partnerships with non-state actors including NGOs to help in monitoring the social and environmental impacts. None of the state or market institutions have the capacity to do all by themselves; it is a necessity in many countries that we have to engage and work with partnerships that involve communities, civil society, and NGO actors.

James Nugent: Thank you Javed. So far we have just covered two points so far; the third point relates to private sector participation and this also came out in the model presented by Prof Holst. It is absolutely critical for the transition and transformation to a sustainable development pathway. So in this context I would like to request Dr Kalyanamitr to comment on specific green technologies in the context of the GMS.

Dr. Chieanchuang Audi Kalayanamitr, Advisor, National Science Council, Thailand: It is an honor that the private sector is allowed to express its point of view. We realize that this particular year is very significant, what we call a crossroad year. First, the private sector is increasingly participating in the industrial and financial sectors and within two and half years the era of corporate mergers will start under the ASEAN Economic Community. It will create a borderless connectivity between Thailand and the Lao PDR, like in the European Union. Customs barriers will be removed and immigration will have less work to do; in- and outflow of raw materials will be easier. Second, two months ago, Thailand signed an historic agreement with the PRC. The PRC is very different now as they are wielding power, money, and human resources. We signed six big contracts on infrastructure, which will change many things. Immediately following the flooding in Thailand in 2011, the first state guest visiting Thailand was the next President of the PRC, who signed agreements on 22 December 2011 to assist Thailand. This assistance is related to the master plan for water resources, irrigation and flood control. Third, Myanmar is opening up; recently the Prime Minister of Thailand and the opposition leaders visited Myanmar. We are looking toward power supplies from Myanmar as Thailand cannot venture into nuclear energy or coal-fired power plants; we are already relying on the Lao PDR for our power supply.

The whole investment system has changed and I think ADB recognizes that. In the past, the public sector invested in infrastructure and turned these into state-run enterprises; for the future, there is emphasis on public-private-partnership (PPP). Increasingly, private sector funding will flow into PPP infrastructure projects, such as between Thai, Australian, and French companies. The law in Thailand is being amended to accommodate PPP. Last, regarding national politics in Thailand, we are not concerned so much in the private sector because it has been swinging toward the left, and then to the right; the private sector is concentrating more on economic policies and development. Regarding food security, market demand for organic products is increasing and Thailand is positioning itself as a processor of organic foods with raw materials coming from neighboring countries like Cambodia, the Lao PDR, and Myanmar. There will be increased contract farming on government land with local, decentralized power. Countries like Thailand need power and this will come from the streamlined transmission lines and power highway integrated with neighboring countries. In the future, the private sector will play an increasing role in food security, quality foods, agriculture, water, and the power sector.

Geoffrey Blate, WWF: I appreciate all those comments and I think the crystal ball is probably quite accurate, especially in regard to Thailand. One of the conclusions of a workshop we were involved with in Viet Nam in December 2011 was the importance of engaging the private sector in shifting to a green economy. Could you comment on specific things the private sector can contribute to ensure sustainable development?

Nay Htun, SUNY: I hope I did not hear you wrong; I thought I heard you said that private sector now is supreme—does not care about national laws and regulations; if the private sector wants it a certain way, it is going to be that way. I hope this is not what I hear. I know of no country in which, no matter how powerful the private sector is, it has supremacy over national laws and legislation. If that is the new attitude of the private sector in this country and the GMS governments, personally I believe there will be a lot of misunderstanding and a lot of disappointment.

Ancha Srinivasan, ADB: We all know that the private sector role is important; but it is also important to maintain the competitiveness of the private sector for its own sustainability. To what extent is the private sector really aware of the emerging challenges, such as climate change impacts and the sustainability of the private sector itself?

To what extent is the private sector really mainstreaming those concerns? There was one program called Business Leadership for Southeast Asia organized by the University of Cambridge and the National University of Singapore and in that we looked at three sectors: real-estate, power, and food and beverages. The World Resources Institute (WRI) has done a very good study on how these three sectors are going to be impacted in Southeast Asia. But when we talk to the CEOs of various Southeast Asian companies, including from the GMS, they are hardly aware of the potential impacts and they have also admitted that they have not really mainstreamed those concerns yet. So to what extent does private sector need support to mainstream those concerns?

Dr Parisak, Vice Minister, MAF, Lao PDR: Normally, I should say this as a final remark: wherever I go, I keep on hearing about political will and good policies. It seems that is the main obstacle, the main impediment to achieve sustainable development. I do admit that across ASEAN and GMS and in other parts of the world, governments are different; there is a great diversity of politics; there are good and bad policies and politics. I think this goes for everyone: private sector, development partners, not just governments. In my own experience, a good policy is not enough; good or bad policies do not come only from policy makers. Some do. For example, in the case of cash crop production like sugarcane in hilly areas in the Lao PDR, where a lot of investment came from Thailand, investors are using technologies that are not allowed in Thailand, such as using bulldozers in hilly areas. We came out with a policy to stop the practice. We have to scale-up conservation agriculture in hilly areas. That is a good policy but when it came to implementation, it was more difficult as there is no private sector propagating or selling conservation technologies. For mechanization by contract farmers, the private sector is providing long-term credit that farmers have to pay back. But no one is bankrolling conservation technology. So a good policy sometimes does not work. We know that we are rich in biodiversity. We cannot beat our neighbors in quantity, but we can beat them in quality. For example, we have thousands of varieties of rice; so let us work on organic rice. We found out that developing organic rice is much more difficult than genetically modified organisms (GMOs). In the case of organic rice, farmers find the conditions for certification too complicated. Policies have to go with lot of parallel interventions. Government is not enough—we know that; we need the private sector; we need communities to empower themselves so that they can partner with the private sector in some form of PPP. What we need to

do if we have a good policy, and this is where ADB and development partners can help, is to connect with private businesses, to find quality investment that will assist in implementation of good policies.

Dr. Chieanchuang (Audi) Kalayanamitr, Advisor, National Science Council, Thailand: Admittedly, as the Vice Minister has clarified, having a good policy in place is not good enough if the government cannot enforce the policy. We found in the past 30 years that we, the private sector, are playing cat and mouse, running away from government officers or hiding somewhere. It is not going to work and many businesses have actually closed down and government has lost taxes. Hence, the enlightenment that is coming is the increased use of the PPP mechanism, with government and private sector at the same table. The outcome is a partnership; no more games to be played between us. This is the era that is changing. It is a system that ADB can facilitate a great deal. ADB as a financier can assist in facilitating understanding between the private sector and government. For example, in organic farming, private investors need land to conduct contract farming and do quality control of organically produced goods; use of chemical fertilizers and pesticides will kill the export markets in Japan and the EU. So there is mutual benefit in such a partnership and cost is not the main parameter as food safety must be a priority.

James Nugent: Thank you for that. Obviously we have different views on the roles of the private and public sector and we are not going to resolve all the issues today. I think we are being given a lot of information that we can digest and take the dialogue forward. With that I will move to the fourth message and invite a couple of our development partners with respect to development cooperation and coordination, particularly in the context of the GMS Strategic Framework 2012–2022.

Antti Inkinen, Counselor, Embassy of Finland: Finland has been engaged in the Mekong region for many years with a multitude of interventions in different countries as well as subregionally. We build our cooperation on three main themes: renewable energy, sustainable natural resource management, and rural development. The overarching theme and philosophy of what we do is exactly in line with title and topic of this conference. We are one of the largest donors to the Mekong River Commission and have been engaged there for a long time. We have now committed additional funding to the GMS Core Environment Program. We also support the Mekong Water Dialogues and some other regional initiatives, such

as the Energy and Environment Program (EEP), which provides grant financing to innovative renewable energy projects in Cambodia, the Lao PDR, Thailand, and Viet Nam. In addition, we work with the Regional Community Forestry Training Center (RECOFTC) on forestry research and knowledge development. At the national level, we work in the Lao PDR and Cambodia; in the Lao PDR we are involved in the forestry sector, particularly production forests, and recently started a mapping and geographic services project. Very importantly, we are working with the newly established Ministry of Environment on mainstreaming environmental concerns into overall planning across the sectors. In Cambodia, we are involved in land registration and cooperate with ADB on Tonle Sap development. The overall financing on an annual basis is about EUR 20 million. We have just approved the new development policy guidelines. We have a very strong focus on the issues being discussed at this conference, including tackling climate change and ensuring environmental sustainability, but there is a new focus on a rights-based approach in everything that we do. We are also in the process of drafting a 4-year regional strategy for the lower Mekong.

If you allow me some reflections on the conference, there have been some tremendously interesting discussions. It is clear now that environmental mainstreaming or balancing environmental concerns with economic growth is not an option but a must. Political will is ultimately necessary. How does one address the responsiveness of politicians at the national level? Changes do not come from outside; they have to come from within the country. Often experience shows that to get an issue in the development agenda, it is useful to do a proper cost and benefit analysis and scenarios: what are the medium- and long-term costs of business as usual? Governments cannot wait for research. Environmental concerns should be integrated in planning. Finland in this broader context is very focused on the role of water on economic growth. There is so much happening in the countries in the subregion. There is agriculture-led industrialization; there is rapid urbanization; and there is a high proportion of the population is rural. What is the economics of water in the different plans of the countries? How do you get the different sectors to work on it together? It doesn't require new institutions but new systems, structures, and procedures. The challenge is that as you waterproof construction, you should also waterproof economic growth. A recent economic assessment of water in Jordan had significant impact on how investments are to be made. Water resources are embedded in all of these processes. The nexus of water and energy

and deliberations at Bonn are crucially important. As development partners, we have a lot of responsibility. We should do our utmost to coordinate, harmonize, and synergize on the different interventions. I strongly support closer cooperation with the MRC.

Ulrika Akesson, First Secretary, Embassy of Sweden:

Sweden has a long history in supporting GMS cooperation since 1992. We have a strong commitment in the subregion. What is guiding us is our regional cooperation strategy for Asia 2010–2015, with a focus on Southeast Asia and the GMS countries. Our budget for the region is approximately EUR 25 million (US\$32 million per year). We focus on three main areas of work: (i) environment, climate change, and natural resource management; (ii) democracy and human rights; and (iii) renewable energy and urban planning. Under the first, we support the GMS Core Environment Program, the Core Agriculture Support Program, MRC, the Adaptation and Knowledge Platform, Mangroves for the Future, and many others; under the second, there is a lot of civil society support toward freedom of expression and anti-corruption; under renewable energy and urban planning, we fund ADB and the World Bank on finance facilities. We also have cross-cutting support in the research area, including environmental economics networks in the region. We have done this now for 20 years and it needs to be mentioned in this conference as it is an area we have not touched on in detail.

On donor coordination, in our support to the GMS Core Environment Program we assist jointly with Finland; in our support to MRC, we work closely with a number of development partners. Donor coordination at the regional level is much more difficult than at the bilateral level. It is something we need to consider and work out ways on how to improve that. Sweden works on the aid effectiveness agenda; we try to give core support and try not to earmark funds and try to work jointly with other donors. I would like to stress the importance of coordination between GMS programs and sectors. We are trying to strengthen synergies between the GMS Core Environment Program and the Core Agriculture Support Program. In particular, the GMS Core Environment Program 2012–2016 aims for achieving an outcome of pro-poor environmental management and climate-friendly measures being adopted by the GMS Economic Program. That is a very ambitious outcome and there are many challenges to achieving this. We think it is important to involve diverse stakeholders—civil society, private sector, and decision makers at all levels—in proper consultation processes to establish real ownership. Regarding political will, it is important to

stress that there needs to be good incentive structures for increased sustainability toward green economic development. But also we need to take into consideration environmental economics in socioeconomic planning that can demonstrate need for investments toward sustainable development. It will be good to take forward what has been discussed here during the last two days at Rio+20, which is coming up in June and is a platform where GMS countries could show commitment on green economy and sustainable development.

Hans Guttman, CEO, MRC: I want to take this opportunity to make you all aware of the Mekong-to-Rio event, organized by the MRC on 1–3 May 2012 in Phuket to address the three areas of the nexus; MRC has invited a number of river basin organizations from around the world. We will discuss nexus items in a transboundary water context. We are working with ADB and perhaps some of the outputs from this event can serve as an input into the Mekong-to-Rio event.

James Nugent: As our development partners have pointed out, partnerships are the operative principle. The fact that we had this diverse group of individuals participating in this conference and having such an open dialogue for the past two days demonstrates that. There is no question that there are challenges, whether at the national or the subregional level; but we hope that we continue to have dialogue like this in the future and that we move forward with the principles that we have outlined this afternoon with respect to getting that proper balance of inclusive economic growth and environmental sustainability. And with that, I would like to end this session. Thank you very much everybody.

SESSION 7: CONFERENCE CLOSING REMARKS

CAMBODIA

Mr. Chuon Chanrithy,
Director & GMS-WGE National Coordinator,
Department of Natural Resource Assessment and
Environmental Data Management,
Ministry of Environment

Excellency, the Ministers of the GMS Countries, the Asian Development Bank, Distinguished Delegates of the GMS Countries, Development and Implementing Partners, Ladies and Gentlemen.

It is our great pleasure to deliver the country remarks on behalf of the Cambodian Delegates at the closing of the International Conference on the GMS 2020 under the theme of “Balancing Economic Growth and Environmental Sustainability.”

Please allow me to extend our deep appreciation and sincere thanks to all distinguished GMS country delegates for sharing useful insights related to the conference theme, the Asian Development Bank for organizing and supporting this very important event, the Ministry of Natural Resources and Environment of Thailand for hosting such an important event, and all development partners for your continuous support and participation.

During this two-day event, we have had a number of presentations and papers, and I think we have got a very good picture and insights relating to the emerging issues, development pressures on food-water-energy nexus and challenges faced in having efficient and effective utilization of water. In particular, there is a need to improve the knowledge base of three inter-related thematic areas to address the balancing of economic development and environmental sustainability.

For years, Cambodia has experienced spectacular progress in social, economic, and environmental aspects. While national economic growth has boosted the country's economy and lifted many out of poverty, the environmental degradation, decline in natural resource base and ecosystem services, coupled with transboundary issues like water scarcity, pollution, and floods and drought resulting from climate change are of great concern.

Fully aware of development pressures on natural capital and the challenges to environmental sustainability, the Royal Government of Cambodia has taken significant steps to reduce poverty in rural areas, ensure environmental safeguards and increase efficiency in natural resource

use. Besides, our government has developed the Green Growth Roadmap to harmonize national policies, helping facilitate the transition to a green economy.

Before concluding my brief remarks, I would like to leave some thoughts with all of you. It is really important to stress how important it is to have the themes of our two-day Conference taken into account in the policy formulation process at national level. The factors that are important for sensitizing top policy makers about the nexus, formulating a related strategic plan, and finally implementing priority actions are the following:

- Need to have the national government's buy-in
- Need to convince relevant sectoral ministries/agencies to acknowledge importance of the nexus
- Need to apply a multisectoral approach to deal with nexus-related policy interventions
- Need to set up an appropriate institutional mechanism to draw up, implement and monitor a related strategic plan
- Need to build national capacity.

Thank you very much and I look forward to seeing you all at the next event.

PEOPLE'S REPUBLIC OF CHINA

Mr. Wang Ling,
Deputy Director,
International Department, Ministry of Finance

Chair, Distinguished colleagues, ladies and gentlemen.

First of all, we would like to express our sincere thanks to the GMS Working Group on Environment and ADB for co-hosting this event. And also thanks go to the participants from GMS countries and all other participants for their great contributions to this event.

Balancing Economic Growth and Environmental Sustainability is the theme of the Conference. We think it is the common challenge we are facing now. Over the past two days of discussions, we have had fruitful outcomes, which are very useful to confront the challenges and to move the GMS cooperation forward.

Rich in water and biological and other natural resources, the GMS has enormous economic potential and development prospects. The GMS countries have been working for economic reforms, industrial restructuring and greater

openness to the outside world. Accelerated economic and social development has become their shared goal. In the past 20 years, thanks to the joint efforts of the ADB and all the countries, subregional cooperation has moved steadily forward, borne rich fruits, and played an active role in eliminating poverty and promoting economic and social development of the GMS countries.

In December 2011, in the Fourth Greater Mekong Subregion Summit, the new Strategic Framework for cooperation covering the next 10 years has been approved. The new Strategic Framework has focused on eight priority areas, which are crucial to the future development of the countries. In order to realize the goal of the Strategic Framework, we should pay more attention to sustainable development.

The People's Republic of China and ADB have had good cooperation during the past years and our country stands ready to work with ADB and other GMS countries to ensure implementation of various cooperation initiatives so as to take the cooperation in all fields to greater width and depth, and contribute to the common development and prosperity of GMS countries.

Thank you.

LAO PEOPLE'S DEMOCRATIC REPUBLIC

Ms. Keobang A Keola,
Director General,
GMS National Secretariat-cum-ASOEN¹ -LAO
Chairperson, Ministry of Natural Resources
and Environment

Good afternoon Distinguished GMS Participants, Resource Persons and Panelists, Ladies and Gentlemen.

It is a great pleasure for me on behalf of the Lao Delegation to express our sincere thanks to ADB, especially the Environment Operations Center, for organizing this very important conference today.

Resource persons as well as panelists have addressed many important issues, relevant to our region both theoretical and practical, operational aspects and shared experience with us during this conference. This conference enhances our knowledge, awareness, and better understanding about resource efficiency, its importance and necessity, and the opportunities, challenges, and productive harmony

between the water, food, and energy sectors. Most of the resource persons and panelists are very familiar with the challenges facing resource use, economic growth, and environmental sustainability and opportunities. Hence, many recommendations made with regard to economic growth and environmental sustainability on a number of priority areas, especially capacity building, need to be identified by us and taken up as quality investment projects or integrated into implementation plans.

Therefore, the individual GMS countries should come up with implementation plans as early as possible, as there is a need for this platform to benchmark these issues. We have just held a GMS Summit in last December and it is timely for us to have this conference providing us a good platform and guidance to move forward. But we should also have a platform approach or mechanism to discuss how to implement this kind of work, reflecting the real situation in different countries. We need to ensure development of a proper approach, especially as the countries have unequal development; we have large and small countries, advanced and less advanced. It is quite difficult for us to have the same kind of approaches across the subregion. And we would like to request the advanced countries in the GMS to help those who are less developed. We would like to request ADB to advise us on how to take advantage of this opportunity, how to meet the challenges that we have ahead of us, and how GMS countries can help each other more in improving capacity. This is, I think, very important.

In terms of agriculture and energy themes mentioned during this two-day conference, we also need to identify for ourselves what level of assistance we will require to implement technology that lowers our environmental impacts. We also need to scope out what kind of information will assist policy makers in choosing the most appropriate technology that is suitable to the needs of the country. Regarding water, we also have the Mekong River Commission. What are the current policies with regard water management in the Mekong River Commission and how can we upscale and integrate these into the GMS programs.

We also need to look at the existing policy and practices that balance water use and increase its sustainability. In general, the GMS countries have to identify the kind of support we need to establish good governance structures, supporting economic and quality investments. In order to work together to unify our efforts to balance our economic development and environmental protection for poverty reduction in the subregion, we are looking forward to continuing close participation in the new Strategic Framework 2012–2022

¹ The ASEAN Senior Officials on the Environment

by taking necessary action and responsibility to contribute to developing quality investments, as mentioned by the panelists today, and to facilitate the GMS moving closer toward subregional integration.

We clearly understand that the new Strategic Framework initiative will be more complex, dealing with both hardware and software, multisectoral investments, and difficult trade-offs between conservation pressure and development aspects, environment, and climate change. We will develop more knowledge-based and analytical thinking in the region. At the national level, we will review the recommendations and information on opportunities and challenges received from this conference, and how to digest them and to work together with the relevant ministry at central and local levels, including private sector and civil society, to develop a national implementation plan as well as a master plan to incorporate into those of other GMS countries as Subregional Plan 1. This is a difficult exercise awaiting us.

I thank you.

MYANMAR

Ms. Kyi Kyi Mint,
Assistant Director,
Ministry of Environmental Conservation and Forestry

Distinguished Guests, GMS Participants, and Ladies and Gentlemen.

First of all I would like to thank ADB and the Environment Operations Center for organizing this Conference.

Regarding food security, this is an issue important for all GMS countries. The agriculture sector is of strategic importance for the GMS Economic Cooperation Program. My point is that diverse drivers of change will influence agriculture over the coming decades—not just climate change. So we need to consider the major drivers of food security. There are six major drivers: (i) population growth; (ii) dietary change; (iii) urbanization; (iv) trade and globalization; (v) biofuel production, which competes with crop production; and (vi) climate change. We should consider the implications for food security from these drivers, to minimize the risk to people in the GMS countries in the future. In addition, an essential component of an effective solution should include adequate transfer of foreign direct investment, technology, and know how.

I thank you.

THAILAND

Mr. Chudchawan Suthisrisilapa,
Expert on Convention/International Cooperation,
Ministry of Natural Resources and Environment

Excellency, Ladies and Gentlemen.

On behalf of the Thai participants, I would like to take this opportunity to express my sincere thanks to the organizers, who selected Thailand as a venue for such a conference and to congratulate you on the success and fruitful outcome of the conference.

I appreciate the conference very much and I sincerely believe that it has been very informative and useful for implementation of activities related to economic development and environmental challenges. The knowledge and experience gained from the GMS Conference enables us to see how other GMS countries have developed towards achieving sustainability. We hope that ideas generated in this conference can reflect our needs at the United Nations Conference on Sustainable Development or Rio+20, which will be held in Rio de Janeiro, Brazil, on 20–22 June 2012.

I wish all participants a safe trip back home. Thank you.

VIET NAM

Mr. Duong Hung Cuong,
Official,
Foreign Economic Relation Department,
Vietnam Ministry of Planning & Investment

Excellencies, GMS Delegates, Ladies and Gentlemen.

For and on behalf of the Viet Nam delegation, I would like to express our sincere thanks to ADB, the Environment Operations Center, and Thailand as the host country for inviting us to attend this very important Conference.

This year, the GMS community will celebrate 20 years of cooperation. During this time, the GMS program has gained many achievements and successes in comparison with other regional cooperation initiatives.

During these two days of intensive discussion and sharing, we have gained a lot of useful and fruitful information. GMS countries will face a variety of challenges in the future.

These are: water scarcity, energy shortage, food security, environmental degradation, and climate change. I think the message is clear. Balancing economic growth and environmental sustainability is a must. Business as usual is not an option.

Ladies and Gentlemen, in order to achieve sustainability in the region, the study of solutions and measures to tackle emerging issues is essential. More importantly, strong cooperation and support among GMS countries are critical. We believe that with support from ADB, the development partners, and active participation of the private sector, the GMS countries will continue to contribute to the prosperity of the region.

Once again, I would like to thank the organizers for an excellent conference; thank you very much facilitators and speakers for your great work. The results of the conference will play an important role in the decision-making process relating to food-water-energy nexus.

I wish you all health and success. Thank you very much.

Asian Development Bank

Mr. James A. Nugent,
Deputy Director General,
South East Asia Regional Department

Excellencies, Distinguished Guests, Ladies and Gentlemen.

Our colleagues from each of the GMS countries have done an excellent job in terms of summarizing the deliberations over the course of the past two days and delivering the message of the importance of following through with the measures that have been outlined with respect to achieving inclusive economic growth and environmental sustainability. So I will be brief with my comments.

ADB has facilitated development of the GMS framework that will provide the operational platform for implementing the green economic agenda. In this context, the deliberations in the past two days have really outlined the challenges involved in managing the food, water, and energy nexus in the GMS. Also, affirming that environmental sustainability is imperative to inclusive growth was pointed out by a number of speakers over the past two days. The discussions have also identified key messages for facilitating policy dialogue and institutional

convergence for environmental sustainability in the GMS. The conference will take these policy recommendations forward as part of the Action Plan to be implemented through the GMS Economic Cooperation Program, but they are also important to the GMS Summit in 2014. I will highlight four specific actions that ADB will take in the course of the next two years.

The first is, by the GMS Summit in 2014, the GMS countries and policy makers will aim to arrive at common principles of cooperation and coordination on addressing the overall food-water-energy nexus for the mutual benefit of the subregion.

Second is that food-water-energy nexus issues will inform the next GMS Strategic Framework and the GMS Regional Investment Framework, which represents the next generation of investment projects, or the pipeline. This will help us identify the proper placement of projects going forward for the next decade.

Third, ADB will coordinate and cooperate with GMS countries and development partners to address knowledge and information and institutional gaps required to manage the nexus in the context of the Strategic Framework and the Regional Investment Framework formulation. A number of speakers pointed out that there is still fragmentation, there are still gaps and we need to get harmonization and alignment; we need to move forward with this agenda.

And fourth, the GMS Core Environment Program and the Biodiversity Conservation Corridors Initiative Phase II as well as the Core Agriculture Support Program II will carry forward the recommendations from the conference in terms of institutional, policy and financial options to address this nexus as part of their operational plans for the next five-year period 2012–2016.

Finally, I would like to thank all the participants for your valuable inputs including the GMS country representatives, development partners and partner institutions, and in particular, our hosts the Ministry of Natural Resources and Environment and NESDB, Thailand. I would also like to thank the Environment Operations Center and the GMS 2020 Conference Team for their excellent coordination arrangements during the past two days. I know there is a lot of work to get 240 people into a room to have this level of policy dialogue.

So congratulations to all and with that I will stop here and declare the Conference closed. Thank you very much.

APPENDIX 1: CONFERENCE AGENDA

INTERNATIONAL CONFERENCE ON GMS 2020: BALANCING ECONOMIC GROWTH AND ENVIRONMENTAL SUSTAINABILITY

20 - 21 February 2012

Conference venue

Royal Orchid Sheraton Hotel & Towers, Bangkok

Conference Agenda

Theme/Event		Presenter/Speaker
Monday, 20 February 2012		
08.00 – 08.30	Registration	Conference Secretariat
08.30 – 08.40	Welcome	Craig M. Steffensen, Country Director, ADB Thailand Resident Mission
08.40 – 08.50	Official Inauguration	Mingquan Wichayarangsaridh, Deputy Permanent Secretary, Ministry of Natural Resources and Environment, Thailand
08.50 – 09.00	Opening Remarks	Stephen P. Groff, Vice President (Operations 2), ADB
Session 1: Decade of Development, Growth and Impacts 2001-2010 in the GMS		
Chair: Dr Phouangparisak Pravongviengkham		
09.00 – 09.20	Key Note Address 1: Environmental Impacts: Current and Future Challenges in the GMS	Jeff McNeely
09.20 – 09.40	Key Note Address 2: The Future of GMS Water: Is it History?	Arjun Thapan
09.40 – 10.00	Economic growth and poverty reduction	Peter Warr
10.00 – 10.15	Morning refreshment break	
Session 1 continued		
10.15 – 10.30	Water and food security in the Greater Mekong Subregion: Outlook to 2020/2050	Mark Rosegrant
10.30 – 10.45	Sustainable Urbanization in the GMS?	Peter Rogers
10.45 – 11.00	Gender and regional economic integration in GMS: Role of cross border transportation development	Kyoko Kusakabe
11.00 – 11.15	Key Note Address 3: Dynamics of Economic Growth in the GMS: retrospective and prospective views	Arkhom Termittayapaisith / Ladawan Kumpa
11.15 – 11.30	Group Photo	
11.30 – 12.45	Panel discussion: Scaling economic development and environmental challenges Panelists • H.E. Dr Parisak • H.E. Mr Ros Seilava • Daovong Phonekeo • Tang Shengyao • Arjun Thapan • Jeff McNeely • Duong Duc Ung • Kyoko Kusabe • Mark Rosegrant	Facilitator: Nessim Ahmad
12.45 – 13.45	Luncheon Talk: Corridors Linking Our Community and GMS	Noritada Morita
Session 2: Food – Water – Energy Nexus		
13.45 – 14.00	Introduction to Thematic Group Discussions	Hasan Moinuddin Conference Facilitator

	Theme/Event	Presenter/Speaker
14.00 – 16.45 with Refreshment Break	Theme 1: Food Security	Chair: Dr Parisak Facilitator: Mark Rosegrant
	<ul style="list-style-type: none"> • Policies for Long Term Food Security in the Greater Mekong Subregion • The future of GMS forestry in the context of the food-water-energy nexus • Climate Risks to Agriculture / Food Security in the GMS countries and Early Warning Systems in the context of Food-Water-Energy nexus 	David Roland-Holst Jeremy Broadhead SVRK Prabhakar
	Theme 2: Land - Water and Climate Change	Chair: Ros Seilava Facilitator: Peter Rogers
	<ul style="list-style-type: none"> • Water for food and energy in the GMS: issues and challenges to 2020 • Development and Application of a land-use prediction model for future water resources management in the Greater Mekong Subregion • Challenges Facing Cooperation and Sustainability on Water Security and Hydropower Development in the Mekong River Basin: The GMS Response • Climate change adaptation and Disaster Risk Reduction 	Peter McCormick Akiyuki Kawasaki Suzanne Ogden Rajib Shaw
	Theme 3: Energy	Chair: Daovong Phonekeo Facilitator: Anthony Jude
	<ul style="list-style-type: none"> • Mekong energy metabolism: connecting energy demand into the nexus of food- water-energy security • Water resources management in the Greater Mekong Subregion: linkages to hydropower planning for a sustainable future • The role of Clean Coal Technologies in the Greater Mekong Subregion • Global Environment and National Information Evaluation System (GENIES) for urban impact analysis 	Tira Foran, John Ward Jeremy Bird J.R. Kessels Jitendra Shah
16.45 – 17.45	Rapporteur Meeting: Preparation of Group Discussion notes for plenary presentation	
18.00 hrs	Cocktails hosted by GMS Countries	
Tuesday, 21 February 2012		
08.30 – 10.00	Session 3: Recap of Day 1 with Reports from Discussion Groups Chair: GMS	Facilitator: Javed Mir, Director, Environment, Natural Resources and Agriculture Division, Southeast Asia Department, ADB
10.00 – 10.30	Morning refreshment break	
	Session 4: Challenges and Dynamics of Growth in the next decade: 2011 - 2020	
10.30 – 10.50	Keynote Address 4: Food-Water-Energy nexus: GMS challenges of growth for 2020 and beyond	David Roland-Holst
10.50 – 12.15	Panel Discussion: Scaling Challenges and Scoping Opportunities for the next decade Panelists: <ul style="list-style-type: none"> • Nay Htun, SUNY, USA • Jeremy Bird • Mark Rosegrant, IFPRI • Jean-Pierre Verbiest 	Facilitator: Arjun Thapan
12.15 – 13.30	Lunch	

	Theme/Event	Presenter/Speaker
13.30 – 15.00	Session 5: Responses to Challenges of the next decade in the GMS	
	Food security	Facilitator: Mark Rosegrant
	Water demand	Facilitator: Peter McCormick
	Energy	Facilitator: Anthony Jude
	Private sector: Emerging role	Facilitator: Kewal Thapar
	<ul style="list-style-type: none"> • Archie Beaton, Executive Director, Chlorine Free Products Association • Ohnmar Khaing, Public-Private-Partnership in Myanmar • Mr Tak Sriratanobhas, Vice President, Mitr Phol Group, Thailand • Dr Chieanchuang Kalayanamitr, Board of Director, Partner PSCC.CO. LTD. (Diesel Gas Technology), Advisor, Sub-Committee Greater Mekong Subregion • Mr Voravit Potisuk, Senior Executive Vice President, Electricity Generating Public Company Ltd (EGCO) • Ms Boonjira Thongpravati, PTT PLC 	
15.00 – 15.30	Afternoon refreshment break	
15.30 - 16.30	Session 6: Seizing Opportunities: The Way Forward	
	Panel Discussion / Panelists:	Facilitator: James A. Nugent Deputy Director General SERD, ADB
	<ul style="list-style-type: none"> • Dr Parisak, Vice Minister for Agriculture and Forests, Lao PDR • Mr Hans Guttman, CEO, MRC • Mr Antti Inkinen, Counsellor, Embassy of Finland • Ms Ulrike Åkesson, First Secretary, Embassy of Sweden • Prof Nay Htun, SUNY, USA • Dr Chieanchuang Kalayanamitr, Representative from private sector 	
16.30 – 17.00	Session 7: Conference Closing	
	Closing Remarks by GMS participants	GMS Country Representatives
	Conference Closing	James A. Nugent, Deputy Director General SERD, ADB
17.30 – 18.30	Press conference	
	Representatives from the GMS and senior management, ADB take questions from media representatives	GMS Country Reps, ADB

APPENDIX 2: LIST OF PARTICIPANTS

No.	Name	Designation and Organization
GMS COUNTRIES		
Cambodia		
1	H.E. Dr. Yin Kim Sean	Secretary of State, Ministry of Environment
2	H.E. Mr. Thavrak Tuon	Director General, Ministry of Planning
3	H.E. Mr. Chan Darong	Director General, General Directorate for Technical Affairs, Ministry of Rural Development
4	H.E. Mr. Ros Seilava	Deputy Secretary General, Ministry of Economy and Finance
5	Mr. Touch Eng	Deputy Director, Department of Investment and Cooperation, Ministry of Economy and Finance
6	Mr. Chuon Chanrithy	Director & GMS-WGE National Coordinator, Department of Natural Resource Assessment and Environmental Data Management, Ministry of Environment
7	Mr. Touch Vina	Deputy Director & EPA National Coordinator, Department of Natural Resource Assessment and Environmental Data Management, Ministry of Environment
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