Application of spatial analysis in natural resources and environment management

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1. Introduction: What is spatial analysis?

- Spatial analysis is a set of techniques for analyzing spatial data.
- It is studying objects and their arrangement, their geometric and geographic properties.
- The results of spatial analysis are dependent on the locations and the characteristics of the objects being analyzed.
- Spatial data tell us **what is where**, and how it is interconnected and related to each other.
- In land-use planning and environmental management, spatial data and its analysis can provide a crucial information base to make decisions.
Land-use planning (aiming to improve Natural Resources Management)

Spatial Data:
Natural resources, landforms, land cover and use, soil, geology, geomorphology, climate and climate change, hydrology, infrastructure, socio-economic and cultural settings

Land resources assessment

Analysis

Land suitability

Analysis

Land-use potentials and limitations

Identification of areas for specific types of land use. Identification of management and intervention options

Socio-economic development plans and other plans and plannings
2. The use of Geographic Information System (GIS) to support spatial analysis

Spatial data is stored in digital layer formats:
- Points
- Lines
- Polygons
- Raster

GIS software is applied to integrate, to process, combine, tailor and spatial data, and to display them as maps or tables.
• GIS is using coordinates and attributes of objects or features to compute their:
  – Spatial location
  – Spatial distribution / positioning / patterns
  – Spatial form / shape / size
  – Spatial relationship between objects or features

• Using GIS allows the integration of a wide range of environmental and socio-economic criteria.
• Potential options, alternatives, and also limitations can be defined, displayed and presented as maps and tables.
• These maps and tables serve as input to apply Multi-Criteria Analysis (MCA) techniques for comparative assessments of alternative options or intervention measures.
3. Example: Identification of potential land-use units

- Project “Improvement of Crop Yields on Marginal Land in Northern Thailand” (1992-1995)*
- Institute for Physical Geography, Frankfurt University, Germany
- ITC Enschede, The Netherlands
- Chiang Mai University (Dept. of Geography, Multiple Cropping Centre (MCC), Dept. of Chemistry, Dept. of Political Science)
- Funded by supported by the European Commission under the program "Life Sciences and Technologies for Developing Countries #3 (STD3)"

Main Objectives:
- Improvements of crop yields by analyzing their key parameters
- Inventory of natural resources
- Classification of potential land-use units
- Providing a database for further development of the area.

Input data collection and processing:
- Cadastral and Topographical Maps 1:10 000, 1:50 000, 1:250 000
- LandSat 7 TM image
- Aerial Photographs 1:15 000 (stereo pair)
- Field survey: soil, geology, land use, water resources, interviews with farmers
- Climate data
- Laboratory analysis: soil samples
- MCC: Demonstration Plot

- Data tables (dBase4, Excel)
- GIS data layers: ILWIS 1.4
GIS data layers produced:
- Elevation
- Slope
- Soil
- Geology (Tectonics and Stratigraphy)
- Geomorphology
- Land use 1992 and 1994
- Base map incl. infrastructure and all land plots 1:10 000
- Water resources, incl. reservoirs
- Socio-economic data
- Farmers’ perceptions and opinions
- Land use history

High proportion of unused (fallow) land: 31.5 % => 37.38 %; why?

<table>
<thead>
<tr>
<th>FAO Soil Unit</th>
<th>Area km²</th>
<th>Area %</th>
<th>Possible obstacles for land use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haplic Alisol/Acrisol</td>
<td>2.21</td>
<td>29.66</td>
<td>Distance to reservoir; economical</td>
</tr>
<tr>
<td>Gleyic Alisol/Acrisol</td>
<td>0.53</td>
<td>7.11</td>
<td>Flooding during the rainy season</td>
</tr>
<tr>
<td>Stagnic Ali./Acrisol</td>
<td>0.38</td>
<td>5.10</td>
<td>Distance to reservoir; economical</td>
</tr>
<tr>
<td>Dystric Plinthosol</td>
<td>0.57</td>
<td>7.65</td>
<td>Gravel and laterite at the surface, soil poorly developed</td>
</tr>
<tr>
<td>Albic Plinthosol</td>
<td>1.53</td>
<td>20.54</td>
<td>Distance to reservoir; low fertility, shallow soil development</td>
</tr>
<tr>
<td>Calceric Regosol</td>
<td>0.03</td>
<td>0.40</td>
<td>Coarse-textured soil; soil poorly developed</td>
</tr>
<tr>
<td>Ferralic Cambisols</td>
<td>0.15</td>
<td>2.01</td>
<td>Distance to reservoir; economical</td>
</tr>
<tr>
<td>Albic Arenosols</td>
<td>0.95</td>
<td>12.75</td>
<td>Low fertility, distance to reservoir</td>
</tr>
<tr>
<td>Gleyic Arenosols</td>
<td>1.09</td>
<td>14.63</td>
<td>Low fertility, distance to reservoir</td>
</tr>
<tr>
<td>Gleysols</td>
<td>0.01</td>
<td>0.13</td>
<td>Flooding during the rainy season</td>
</tr>
</tbody>
</table>
Options to improve water supply: reservoirs or wells?

- GIS data layers produced:
  - Elevation
  - Slope
  - Soil
  - Geology (Tectonics and Stratigraphy)
  - Geomorphology
  - Land use 1992 and 1994
  - Base map incl. infrastructure and all land plots 1:10 000
  - Water resources, incl. reservoirs
  - ++++

  - Socio-economic data
  - Farmers’ perceptions and opinions
  - Land use history

High potential: Ground water table of 2-6 m below surface (in the dry season) [Area = 5.48 km², 21.07%].

Medium potential: Ground water table of 8-15m below surface (in the dry season). [Area = 2.17 km², 8.34%].

Unsuitable: hard laterite ground-water levels >20 m, existing reservoirs [Area = 18.38 km², 70.59%]
<table>
<thead>
<tr>
<th>TMU No.</th>
<th>Name</th>
<th>Description</th>
<th>Limitations</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Forest</td>
<td>Already forested areas located outside the LRD plots</td>
<td>Poor soil quality makes this area unsuitable for field crops as well as for fruit-trees</td>
<td>2.47 km², 9.50%</td>
</tr>
<tr>
<td>2</td>
<td>Unsuitable for agriculture</td>
<td>Previously fallow land on Dystric Plinthosols</td>
<td>Poor soil quality makes this area unsuitable for field crops as well as for fruit-trees</td>
<td>0.68 km², 2.61%</td>
</tr>
<tr>
<td>3.1</td>
<td>Animal farm (livestock)</td>
<td>Already established pig and cow farms &lt; 400 m from reservoir</td>
<td>Poor soil quality makes this area unsuitable for field crops as well as for fruit-trees</td>
<td>0.01 km², 0.03%</td>
</tr>
<tr>
<td>3.2</td>
<td>Animal farm (limited suitable)</td>
<td>Already established pig and cow farms</td>
<td>&gt; 400 m from reservoir</td>
<td>0.09 km², 0.36%</td>
</tr>
<tr>
<td>4.1</td>
<td>Undemanding field crops with shallow root systems</td>
<td>Previously fallow and field crop areas. Albic Plinthosols with low soil-moisture capacities and fertility rates; &lt; 400 m from reservoir</td>
<td>Laterite in 40-60 cm depth can limit the root development</td>
<td>0.87 km², 3.34%</td>
</tr>
<tr>
<td>4.2</td>
<td>Undemanding field crops with shallow root systems</td>
<td>Previously fallow and field crop areas. Albic Plinthosols with low soil-moisture capacities and fertility rates.</td>
<td>Laterite in 40-60 cm depth can limit the root development; &gt; 400 m from reservoir; unsuitable for reservoir or wells</td>
<td>1.68 km², 6.47%</td>
</tr>
<tr>
<td>5.1</td>
<td>Orchard</td>
<td>Already established orchards or intercropping systems (mango and longan mixed with field crops, e.g. soya) on various soil types; &lt; 400 m from reservoir</td>
<td></td>
<td>1.17 km², 4.49%</td>
</tr>
<tr>
<td>5.2</td>
<td>Orchard (limited suitable)</td>
<td>Already established orchards or intercropping systems (mango and longan mixed with field crops, e.g. soya) on various soil types; &gt; 400 m from reservoir</td>
<td></td>
<td>6.03 km², 23.15%</td>
</tr>
<tr>
<td>6.1</td>
<td>Field crops, orchards (intercropping), agroforestry</td>
<td>Previously fallow, field crop and intercropping areas on Haplic or Stagnic Alisols and Acrisols &lt; 400 m from reservoir; most suitable cropping area.</td>
<td></td>
<td>0.75 km², 2.87%</td>
</tr>
<tr>
<td>6.2</td>
<td>Field crops, orchards (intercropping), agroforestry (limited suitable)</td>
<td>Previously fallow, field crop and intercropping areas on Haplic or Stagnic Alisols and Acrisols &gt; 400 m from reservoir</td>
<td></td>
<td>4.24 km², 16.29%</td>
</tr>
<tr>
<td>6.3</td>
<td>Field crops, orchards (intercropping), agroforestry (perched ground water)</td>
<td>Previously fallow and field crop areas on Gleyic Alisols and Acrisols</td>
<td>Frequent flooding during the rainy season can damage crops</td>
<td>1.02 km², 3.91%</td>
</tr>
<tr>
<td>7.1</td>
<td>Field crops, orchards (intercropping)</td>
<td>Previously fallow and field crop areas on Arenosols &lt; 400 m from reservoir</td>
<td>Sandy soil</td>
<td>0.22 km², 0.86%</td>
</tr>
<tr>
<td>7.2</td>
<td>Field crops, orchards (intercropping), limited suitable</td>
<td>Previously fallow and field crop areas on Arenosols &gt; 400 m from reservoir</td>
<td>Sandy soil, &gt; 400 m from reservoir</td>
<td>2.97 km², 11.41</td>
</tr>
<tr>
<td>8</td>
<td>Public and residential areas</td>
<td>Already established public and residential areas</td>
<td>Water-holding capacities could be improved by covering the bottom with plastic sheets</td>
<td>0.79 km², 3.02%</td>
</tr>
<tr>
<td>9</td>
<td>Reservoir or pond</td>
<td>Already established reservoirs and ponds</td>
<td>Water-holding capacities could be improved by covering the bottom with plastic sheets</td>
<td>0.49 km², 1.88%</td>
</tr>
</tbody>
</table>

Combination of all relevant layers and information => Identification of Thematic Units for Potential Land Use (TMU) and their attributes.
4. Concluding Remarks

- STD3 project results were considered by MCC, LRD, and farmers.
- Cooperation between academic institutions, government departments, and the rural population can be very beneficial.
- Any land use planning should reflect suitability aspects based on physical and socio-economic conditions.
- Spatial analysis is a step-wise process, it needs expertise in the subjects concerned (GIS, natural resources, economy, etc.) to select the right criteria for the desired output. Thus it requires multidisciplinary cooperation.
- It is a dynamic process. For instance in the previous example, by adapting the input parameters of the model - e.g. after improving water supply - the effected land plots can be reclassified into other thematic units.
- GIS is a useful support tool to compute huge amounts of data, but the interpretation of results is done by humans.
- Numerous Geoinformation Systems and Databases already exist in Vietnam (E.g. Ha Tinh Coastal Zone Database, GIZ-EbA Vulnerability Analysis Database Ha Tinh and Quang Bin, Soils and Fertilizer Research Institute, GIZ ICMP, FORMIS, +++ ).
- How can the data be utilized efficiently to support decision-making in environmental management, land-use planning, land allocation, and Strategic Environmental Assessment?
- What are the technical issues concerning software, data compatibility, accuracy and accessibility?
- How can technical experts can provide useful outputs to support decision-making?
THANK YOU for your attention!

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