Application of GIS in natural resource management

ERASMUS Intensive Program
GIS’EM 2013 at Eberswalde

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GIS in NRM

ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS (GIS) FOR INTEGRATED ASSESSMENT AND MANAGEMENT OF MINERAL RESOURCES IN NORTH-EAST ASIA

MINERAL RESOURCES ASSESSMENT, DEVELOPMENT AND MANAGEMENT SERIES

VOLUME 7

UNITED NATIONS
Concept of the course

- This course aims at GIS applications and spatial analysis techniques for the analysis of natural resource information, including sources and capture of spatial data.

- You will characterize, transform, analyze and present results of spatial data; and spatial analysis to solve real-life resource management problems.

- Students will learn about the concepts of NRM in lecture, will individually apply GIS capacities and will practice the relevant spatial data skills by completing an individual project.

- The goal is to provide students an opportunity to become proficient in using GIS for environmental problem solving through understanding of how these skills and concepts can be applied to problems in natural resource management.
Learning Outcomes of this course:

- Increase hands-on GIS experiences proficiency using up-to-date GIS software to access, manipulate, and present all types of spatial information in a complex GIS project environment.
- Assess differences between spatial and nonspatial data
- Value GIS research and spatial information for decision support
- Design your individual and relevant GIS project
- Understand the usefulness and limitations of GIS and related analytical techniques
- Illustrate the impact of scale, projection, and topology on our understanding of the world.
- Generate maps using existing spatial data and justify a chosen map design
Working steps and skills

- Understand how to approach an individual spatial question
- Develop a clear spatial question
- Evaluate and obtain data needed to answer the question
- Assess the appropriate scale at which to answer the question
- Perform the tasks necessary to answer the question
- Discuss the impact of scale and topology on your problem/question.
- Apply basic proficiency using GIS software to access, manipulate, and present spatial information
- Obtaining and processing individual data including aerial photographs, satellite data and pre-processed statistical data
- Performing spatial analysis functions in GIS
- Analyze and solve spatial analysis problems with GIS software
- Generate maps using existing spatial data and justify a chosen map design
- Prepare written and oral reports detailing this process and its results.
Suggested Content of this course:

- Applications of GIS and spatial analysis techniques in a real life project work (group work on next Thursday and Friday)
- A few lectures about the spatial concepts behind GIS in NRM
- Class discussions about spatial project topics

- Acquisition and collection of spatial data;
- Presentation and analysis of natural resource information
- Practice relevant GIS skills and apply certain methods
- Characterizing, transforming, and map displaying spatial data
- Apply spatial analysis tools
- Application of decision support tools base on GIS
GIS: A Framework for Understanding and Managing Our Earth

- Geographic Knowledge
  - Creating
  - Measuring
  - Organizing
  - Analyzing
  - Modeling
  - Holistic
  - Comprehensive
  - Systematic
  - Analytic
  - Visual

- Applying
  - Planning
  - Managing
  - Acting
GIS application in NRM

GIS is being applied around the world across many disciplines, professions, and organizations.

Becoming an instrument of evolution

Source: ESRI, 2011
Potential GIS project application
GIS is constantly evolving (rapidly)

Projects since 1990
Systems since 1998
Networks since 2002

Integrated
Coordinated
Cooperative

Societal

Today ->

Source: ESRI, 2009
From Data to Information to Knowledge

- Information compilation
- Knowledge generation
- Knowledge transformation

Data

Information

Knowledge

Wisdom
What’s about Natural Resource Management

NATURAL RESOURCES MANAGEMENT IN AFRICAN AGRICULTURE
UNDERSTANDING AND IMPROVING CURRENT PRACTICES

Edited by
C.B. Barrett
F. Place and
A.A. Aboud

LEGEND

© CABI Publishing 2007

Natural Resource Conservation Project
Gulai - Abbottabad

HNE Eberswalde (FH) 06/03/2013

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GIS and NRM
INRM, CBNRM, Biodiv Conservation, CDM

- **NRM** = Natural Resource Management
- **INRM** = Integrated Natural Resource Management
- **CBNRM** = Community based NRM
- **CDM** = Clean Development Mechanism

**Resource** = The total means available for economic and political development, such as mineral wealth, labor force and political capacities.

**NR** = Natural resources (economically referred to as land or raw materials) occur naturally within environments that exist relatively undisturbed by mankind, in a natural form.

In contrast to **RM, INRM** is also being promoted with community groups and, in some cases, even with individual farmers through community-based natural resource management of common-property, open-access, and privately owned resources in micro-catchments, typically only 5–50 km².
NRM – some definitions

- Natural Resource Management refers to the management of natural resources such as land, water, soil, plants and animals, with a particular focus on how management affects the quality of life for both present and future generations.

- Natural resource management is congruent with the concept of sustainable development, a scientific principle that forms a basis for sustainable global land management and environmental governance to conserve and preserve natural resources.

- Natural resource management specifically focuses on a scientific and technical understanding of resources and ecology and the life-supporting capacity of those resources.

- The term Environmental management is also similar to natural resource management.

NRM – characterization

- **Biotic** = Biotic resources are obtained from the biosphere, such as forests and their products, animals, birds and their products, fish and other marine organisms. Mineral fuels such as coal and petroleum are also included in this category because they are formed from decayed organic matter.

- **Abiotic** = Abiotic resources include non-living things. Examples include land, water, air and ores such as gold, iron

- **Renewable resources** = are ones that can be replenished or reproduced easily. Some of them, like sunlight, air, wind, etc., are continuously available and their quantity is not affected by human consumption

- **Non-renewable resources** = are formed over very long geological periods. Minerals and fossil fuels are included in this category. Since their rate of formation is extremely slow, they cannot be replenished once they get depleted.

POTENTIAL UNRAVELING OF CIVILIZATION

Corporate Growth
- exponential growth
- economic growth
- expansion

Economic Growth
- free market
- economic growth
- consumption

Population Growth
- growth
- increase
- expansion

Global Capitalism
- expansion
- growth
- economic growth

Pollution
- air pollution
- water pollution
- land pollution

Peak Oil
- depletion
- exhaustion
- end of oil

Climate Change
- global warming
- climate change
- environmental change

Fossil Fuels
- coal
- oil
- gas

Rising Temperatures
- global warming
- climate change
- environmental change

Threats to Food Security
- food insecurity
- hunger
- famine

Depletion of Resources
- resource depletion
- environmental degradation

Collapsing Fisheries
- overfishing
- habitat destruction

Species Extinction
- loss of biodiversity
- species loss

Impact on Ecosystem Services
- loss of ecological services
- ecosystem degradation

Poverty
- economic disparity
- social inequality
- lack of access

Impacts of Environmental Degradation
- habitat destruction
- loss of biodiversity
- loss of ecosystem services

UNLIMITED GROWTH ↔ FINITE PLANET

Source: Design of a conceptual Map by Fritjof Capra, based on Plan B 3.0, by Lester Brown
Depletion of Natural Resources

Part of complex resource management questions

- Water Scarcity
  - farmers vs. cities
  - falling water tables
  - rivers running dry
- Soil Erosion
  - advancing deserts
  - lakes disappearing
- Depletion of Resources
  - deforestation
  - habitat destruction
  - overfishing

- Species Extinction
  - damage to coral reefs

Impact on Ecosystem Services
- water purification
- pollination
- flood control, etc.

Source: Design of a conceptual Map by Fritjof Capra, based on Plan B 3.0, by Lester Brown
Potential Impact of Integrated Natural Resource Management

This website provides access to the knowledge and products developed by the DFID Natural Resources Systems Programme (NRSP) from 11 years of research on the integrated management of natural resources. The research covers the social, economic, institutional and biophysical factors that affect people’s ability to use and sustain their natural resource base. NRSP’s research knowledge and products provide practical means to enable and achieve improved livelihoods for the poor.

Source: http://www.nrsp.org/
Entities or continuous field?

- Pragmatic decision, determined by the application,
- In administration rather entities, in science more often continuous fields
- Examples:
  - Administrative information
    - Planning zones
    - Land register
    - Utility lines
    - Geodetic survey points
    - Subsoil surveys
  - Geo-hydrological information
    - Terrain elevation
    - Soils
    - Rivers
    - Groundwater levels
    - Boreholes

Conceptual models...
Ecosystem services

- Biodiversity
- Genetic resources
- Non-timber forest products
- Water; air; landscape
- Non-renewable resources
- Medicine/pharmaceuticals
- Traditional knowledge
- Agrobiodiversity
- LAND
- Home
- Energy
- Food
- Sacred place
- CARBON
- Timber (legal and illegal logging)
Wind energy potential in forest stands
Critics about windmills in forest stands
NRM requires Land Tenure Security
GIS wind energy project concept

- Regional Wind energy potential
  - Constructed wind mills
  - Corine land cover
  - Technical construction limits
  - Social and political considerations
  - Actual potential area for wind mill constructions
    - Technical construction limits
    - Ecological and nature protection
  - Realistic Wind potential
    - Restricted area buffer
      - DLM –DE Buffer
        - Realistic potential area for wind mill constructions
          - Technical construction limits
          - Ecological and nature protection
GIS wind energy data resources

Raster data sets
- DWD – regional wind data: scale 1km x 1km
- Corine landcover data: 100m x 100m

Vector data sets
- Forest cover map: 1:25.000 – 1:100.000
- Basis DLM-DE: 1:25.000 – 1:250.000
- FFH- Gebiete: 1:100.000
- Nature Protection Zones: 1:50.000 – 1:250.000

Selected buffer zones according ecological or political restrictions and suggestions

Forest cover and forest quality

Potential land allocation in federal and private properties
Groundwater pollution causes

- Low flow rates
- Low oxygen
- Bacteria infiltration
- Cold temperatures

- Coal strip mine runoff
- De-icing road salt
- Pumping well
- Waste lagoon
- Accidental spills
- Water pumping well
- Landfill
- Unconfined freshwater aquifer
- Confined freshwater aquifer
- Groundwater flow
- Hazardous waste injection well
- Buried gasoline and solvent tank
- Cesspool septic tank
- Sewer
- Discharge
- Leakage from faulty casing
- De-icing road salt
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Coastal zone management

Shoreward Edge of Vegetation

1999

2001

Landward Retreat of Vegetation

Shoreward Edge of Vegetation

1999

2001

Landward Retreat of Vegetation

Legend:
- Unvegetated
- Waterline on shore
- Grass
- Grass with sparse vegetation
- Water
- Forest/shrub
Main water user sectors in Viet Nam

Challenges in the Mekong Delta area
The Mekong Delta in Vietnam offers natural resources for several million inhabitants. However, a strong population increase, changing climatic conditions and regulatory measures at the upper reaches of the Mekong lead to severe changes in the Delta. [Source: DLR- Wisdom Project Viet Nam 2008]
The Mekong River Information System

The concept of an integrated information system

- Remote sensing data
  - Landuse, Vegetation, ...
- Meteorological Data
- Socio-economic
- Infrastructure
- Additional Model Data
- Topography
- Core Data
  - Modelled Inundation
  - Watermask
  - Water quality
  - People affected by flood
  - Core Data

Source: DLR-Wisdom Project Viet Nam 2008
Water related Decision Support system

Input
Satellite data and products
Socio-economic data
Field data
Statistical data
Other geospatial data

Modelling and analyses

Output / Display

Strategies for a sustainable use of the resources within the Mekong Delta

- Flood scenarios
- Agricultural use
- Urban development
- Socio-economy
- Water / wastewater
- Water use
- Land cover / land use

Source: DLR - Wisdom Project Viet Nam 2008

- Flood prevention
- Water management
- Ecosystem protection
- Land cover and urban planning
Deforestation and degradation

Land use change?

Yes → Deforestation

No → intact forests

Loss of C?

Yes → non-intact forest → Degradation

No → other land use
Regional examples of deforestation: Ivory Coast, Borneo

Deforestation in West Africa: Case Côte-d’Ivoire

1950  |  1985  |  2000

1955  |  1988  |  2005

Conversion of forest to agriculture
Closed forest cover
Fragmented forest

Deforestation in Cambodia from 1976 to 2002

Mapping Forest cover with Satellite Imagery, i.e.:

Cambodia's primary rainforest cover fell dramatically from over 70% in 1970 at the end of the Vietnam/American War to just 3.1% in 2007.

Forest Cover 1976

Legend

- Evergreen forest: 6,887,481
- Deciduous forest: 4,814,512
- Coniferous forest: 7,410
- Inundated: 333,242
- Mangrove forest: 95,776
- Orchards and Plantation: 95,746
- Woodland and shrub: 1,021,955

Total Forest: 13,860,133
Total Non Forest: 4,287,775

Note: To account for the overestimation of deciduous forest and under estimation of non forest, a 15% adjustment must be applied to total forest which should drop from 60,375,000m² of forest.

Forest Cover 2002

Legend

- Evergreen forest: 37,294,506
- Semi-Evergreen: 1,595,200
- Deciduous forest: 4,833,861
- Other forest: 1,094,727

Total Forest: 11,104,284
Total Non Forest: 7,056,268

Note: Original categorisation of data includes: Urban/Industrial, all non forest in 1997 and all other forest in 2002.

Data Sources:
- Forest Cover 1976: Ministry of Environment
- Forest Cover 1997: MoEIC, RCIC
- Forest Cover 2002: MoEIC, RCIC, International and Provincial Boundary: Department of Geography 2002
GIS integration in National park management

National legislative and administrative framework

National Park Management

- Forest Resource Management
- Wildlife Management
- Ranger Service
- Water Resource Management
- Non Timber Forest Products Management
- Environmental Protection

GIS Service Support
Time series analysis and forest fragmentation

- Forest fragmentation at EU level
Typical fragmented Land Cover
Analysis of regional forest fragmentation

Example of Thiessen polygons around forest patch polygons (grey) inside

Example of Thiessen polygons representing value of distance to nearest neighbor analysis
Analysis of regional forest fragmentation

Index of forest conservation value (generalized)

County of Barnim (forest)

Index of forest conservation value. Applied to forests in Barnim. Values ranging from 19 - 74 in Barnim - possible range from 0 (lowest conservation value) to 100 (highest value). Generalized and classified. (Natural Breaks)

Index value:
- Class 1 (10 - 39)
- Class 2 (40 - 45)
- Class 3 (46 - 55)
- Class 4 (51 - 57)
- Class 5 (58 - 74)
- No data (forest)

Map created by Julia Sauermann 02/2012 as part of Master Thesis: "A spatial forest index supporting functional habitat conservation: case study of Barnim County (Brandenburg), Germany using a local forest management database in HNE Eberswalde and SGGW Warsaw."
Mapping Products in the GMES Forest Service Portfolio

**Land Cover**

- Forest Area
- Forest Type
- Tree Species
- Biomass & Carbon

**Land Cover Change**

- Forest Area Change
- Clear Cut
- Forest Type Change
- Tree Species Change
- Biomass & Carbon Change

**Land Cover / Change**

- Land Cover Classification; Land Use; LUCC Change Map

**Forest Area / Forest Type / Change**

- Clear Cut Map; Forest Monitoring Service
- High Precision Forest Cover Change Map
- Stand Type Map for Sub-national Forest GIS
- Forest Fragmentation and Structural Diversity
- Forest Cover Change Map for Cloudy Regions (SAR technology)

**Stem Volume / Biomass / Carbon Statistics / Change**

- Stem Volume, Biomass & Carbon Change Statistics
REDD Carbon stock estimation Overview

FOREST CARBON STOCK (AFOLU)

Forest Area (ha)

Carbon Density (C/ha)

Affected by:
- deforestation (REDD)
- Afforestation / Reforestation (CDM)

Affected by:
- degradation (REDD)
- restoration / rehabilitation (REDD)
Growth efficiency and Biomass estimation

**LAI (Leaf Area Index):**
- stand stratification for inventory
- identification of poor-performing stands for early harvest
- identification of stands with high levels of competition

**LAI plus GE (Growth Efficiency)**
Provides ability to estimate stand-level response to silviculture: (fertilization, release, tillage)

Growth = 7.2 tons
Growth = 3.9 tons
Growth = 5.1 tons

LandSat Image

Sand Pine
LAI 2.4
No Fert Lob
LAI 1.3
RW18 Study Area
LAI 1.7

Sand Pine Guidelines
- Sand Pine - Well Suited
- Sand Pine - Mod. Well Suited
- Not Suited for Sand Pine

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Suitability maps and decision support
EU - Forest fire detection and management

Available Information:
- Current info (active fire, location, main cover type affected)
- Last week (fire perimeter + damage analysis)
- All (From the start of the campaign (June 2008)) (fire perimeter + damage analysis)

http://effis.jrc.it
Forest fire management in Ontario
Suggestion for Student Projects

- Forest Fire detection and Management in Greece
- Interannual biomass monitoring and management in a deciduous forest
- Watershed management in a selected area from Finland
- Buffer zone, stakeholder and resource management of national park areas
- Mapping of deforestation in selected forest environment
- Wind throw analysis in a mountain area of Germany
- Urban forestry management and urban forestry inventory
- Assessing ecosystem services of forest environments
- Forest vulnerability analysis of conservation areas
- Forest calamities of natural infectious diseases
- Red deer tracking and animal based spatial data from Schorfheide
- ...
- And many more
Some further reading

- **Baland, J-M.; Jean-Philippe Platteau,** 1996: *Halting degradation of natural resources: is there a role for rural communities?*
- **Schlager, E, Ostrom, E,** 1992: *Property rights regimes and natural resources,* in Land economics, vol 68, No 3,
- **Leach, M., Mearns, R. and Scoones, I.** 1999: *Environmental Entitlements: Dynamics and Institutions in Community-Based Natural Resource Management*
- **Bryant, R. L.,** (1992). *Political ecology: an emerging research agenda in Third World studies,* Political Geographical Quarterly 11 (1)
Examples of further reading

The context of REDD+ in Cameroon
Drivers, agents and institutions

Guy Patrice Dkamela
Thank you for your kind attention