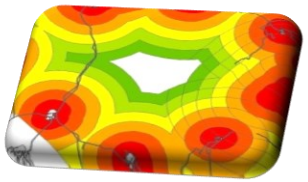
GIS in Natural Resource Management



GIS Applications

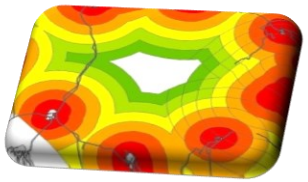
EGS 2401

GIS in Natural Resource Management

Lecture No. 04

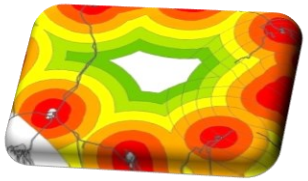
Felix Mutua, Ph. D

Wednesday, October 4, 2023



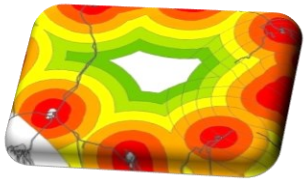
Lecture Plan

Week	Topic		Week	Topic	
1	Overview		8	Networks – I *(concepts, network problems)*	
2	Review of GIS analysis Techniques		9	Networks – II *(building networks, optimization)*	
3	GIS in Agriculture *(concepts, application areas, Crop Suitability Analysis)*		10	Networks – III *(routing, tracking)*	
4	Natural resource Management – I *(concepts, application areas)*		11	Utility Management *(concepts, viewsheds,lineof sight)*	
5	Natural resource Management – II *(Groundwater, forestry)*		12	Health and Disease control *(concepts in epidemiology)*	
6	GIS in Business *(store location, consumer profiling)*		13	Governance *(crime, districting, LIS, census)*	
7	CAT I		14	CAT II	



Outline

- Natural resource Management. What is it?
- Applications of GIS and RS in NRM. What potential ?
- Case studies

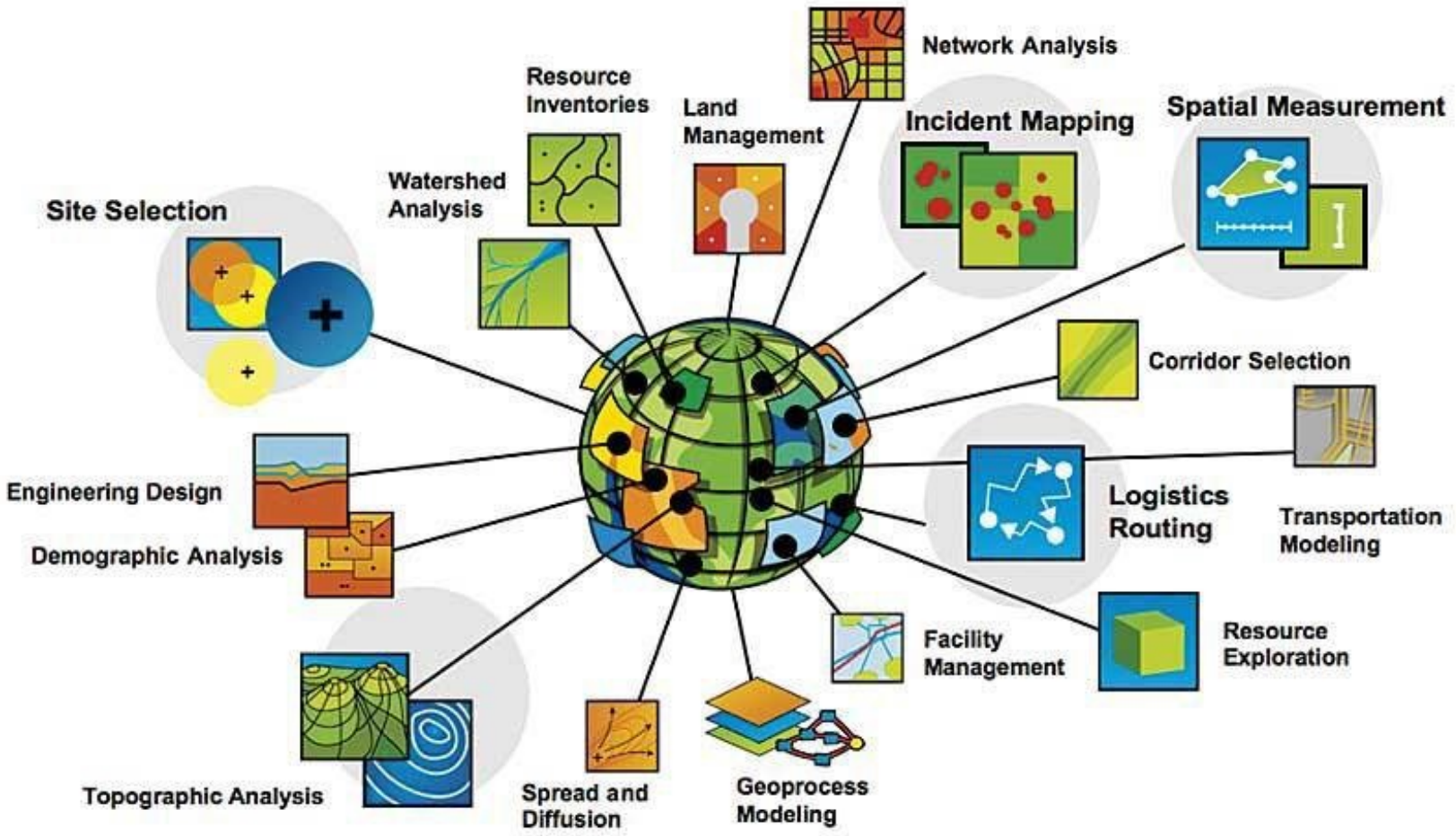


Introduction

- The economic, social and cultural viability of any nation is mainly determined by the land and water resources that it has (Harahsheh, 2001).
- These natural resources are essential to the economy of a nation since they play a critical role in the provision of employment, they are a source of raw materials for various industries, acts as a source of food and income, medicine as well as energy.
- At the present moment, the utilization of the resources present in the world has been overstretched due to the ever rising population of human beings (Swe, 2005).
- It is as a result of this population pressure that forest cover all over the world has declined due to human encroachment.
- This has greatly increased human/wildlife conflicts and encouraged the development of desert like conditions.

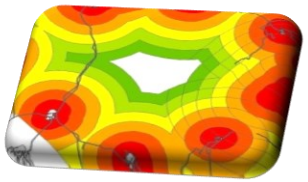
GIS Is Being Applied Around the World

Across Many Disciplines, Professions, and Organizations



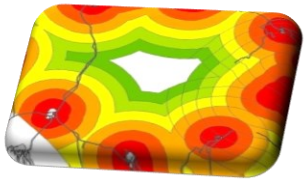
Becoming an Instrument of Evolution

Source ESRI, 2011



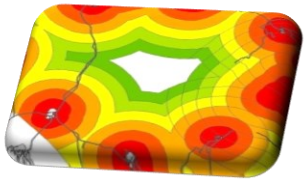
INRM, CBNRM, Biodiv Conservation, CDM

- 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

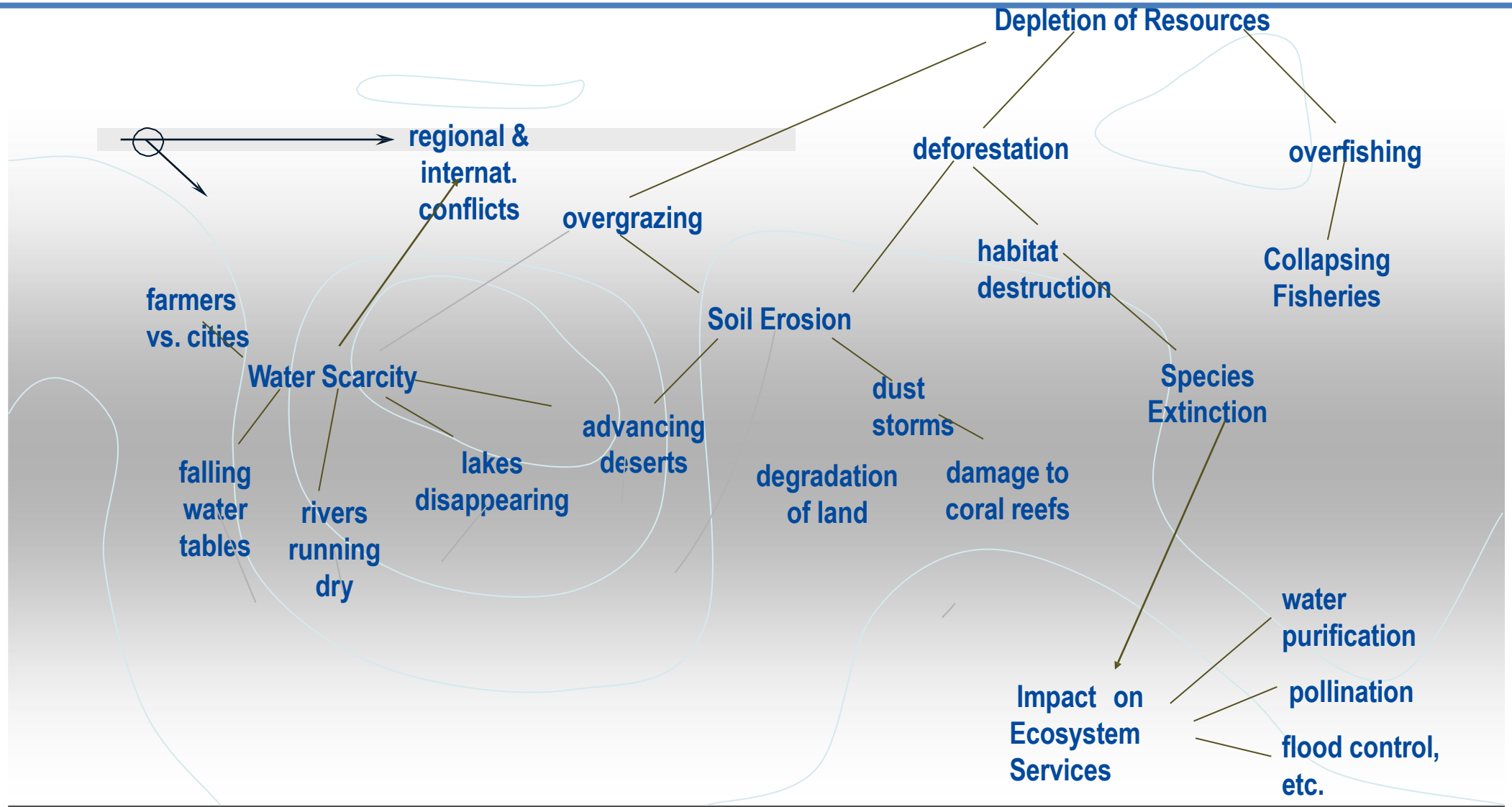


NRM – characterization

- 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 extreme slow cannot be replenished once they get depleted.

Depletion of Natural Resources

Part of complex resource management questions



Ecosystem services

Medicine/pharmaceutics

Traditional knowledge

LAND

Biodiversity

Home

Genetic resources

Energy

Food

Non-timber forest products

Sacred place

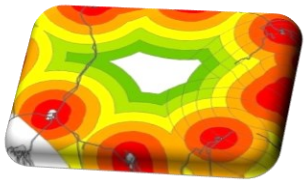
Water; air; landscape

CARBON

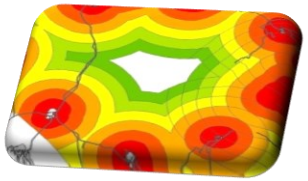
Timber (legal and illegal logging)

Non-renewable resources

Agrobiodiversity



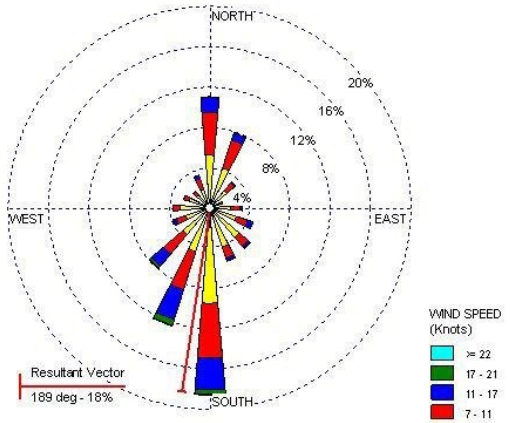
APPLICATIONS OF GIS AND REMOTE SENSING IN NRM

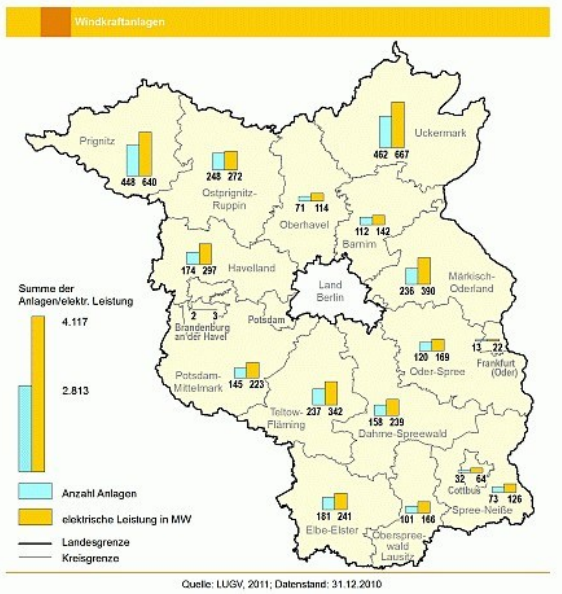


Natural resource inventory

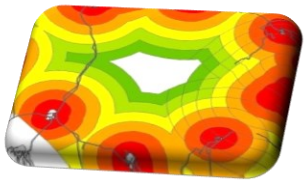
- Natural resource inventory is a statistical survey of the condition of natural resources.
- It provides relevant information about the environmental condition and policy including conservation program that is obtained through GIS in natural resource management.
- The information through maps in GIS provides information about the location and current resources.

Wind energy potential in forest stands





GIS wind energy project concept



Regional Wind energy potential

Restricted area buffer

Constructed wind mills

Realistic Wind potential

land cover

Buffer

Actual potential area for wind mill constructions

Technical construction limits

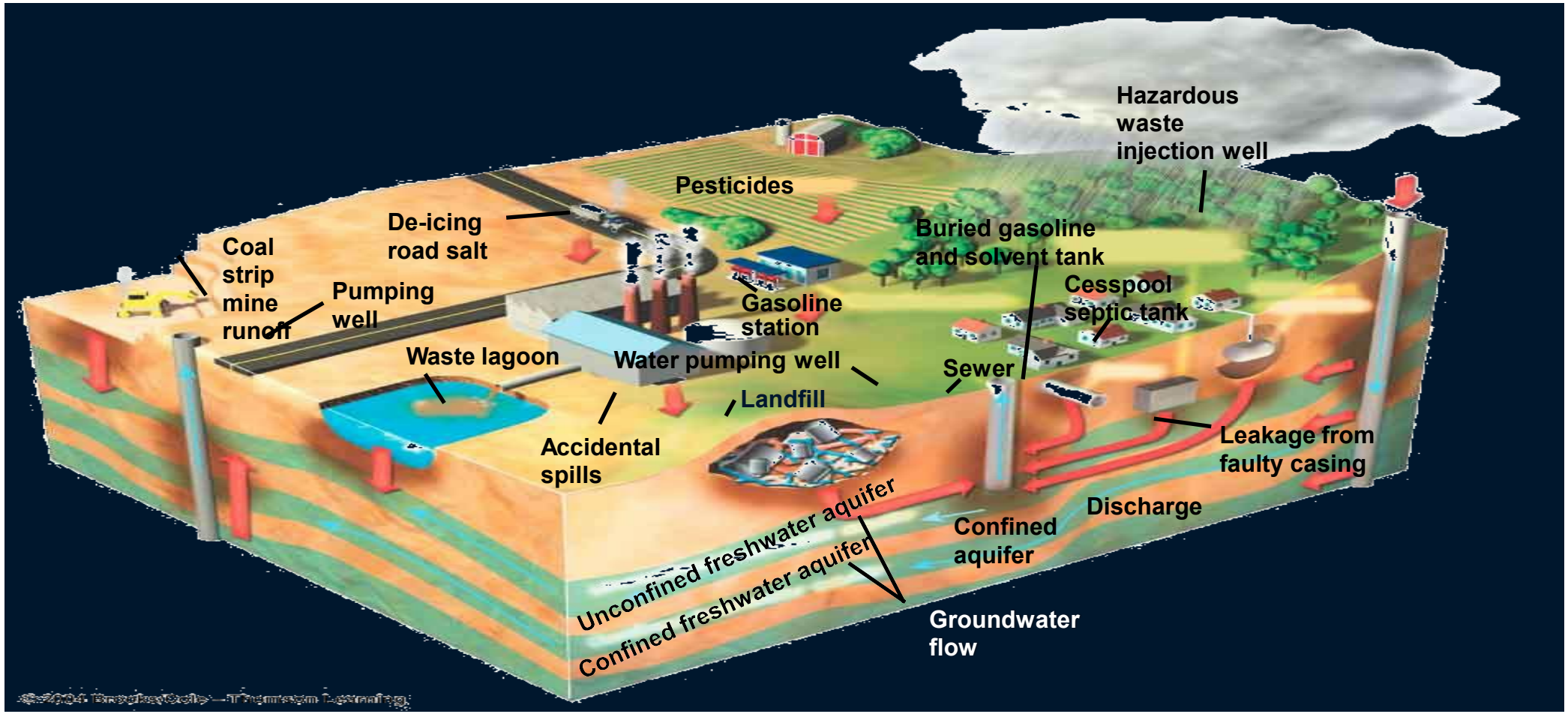
Technical construction limits

Social and political considerations

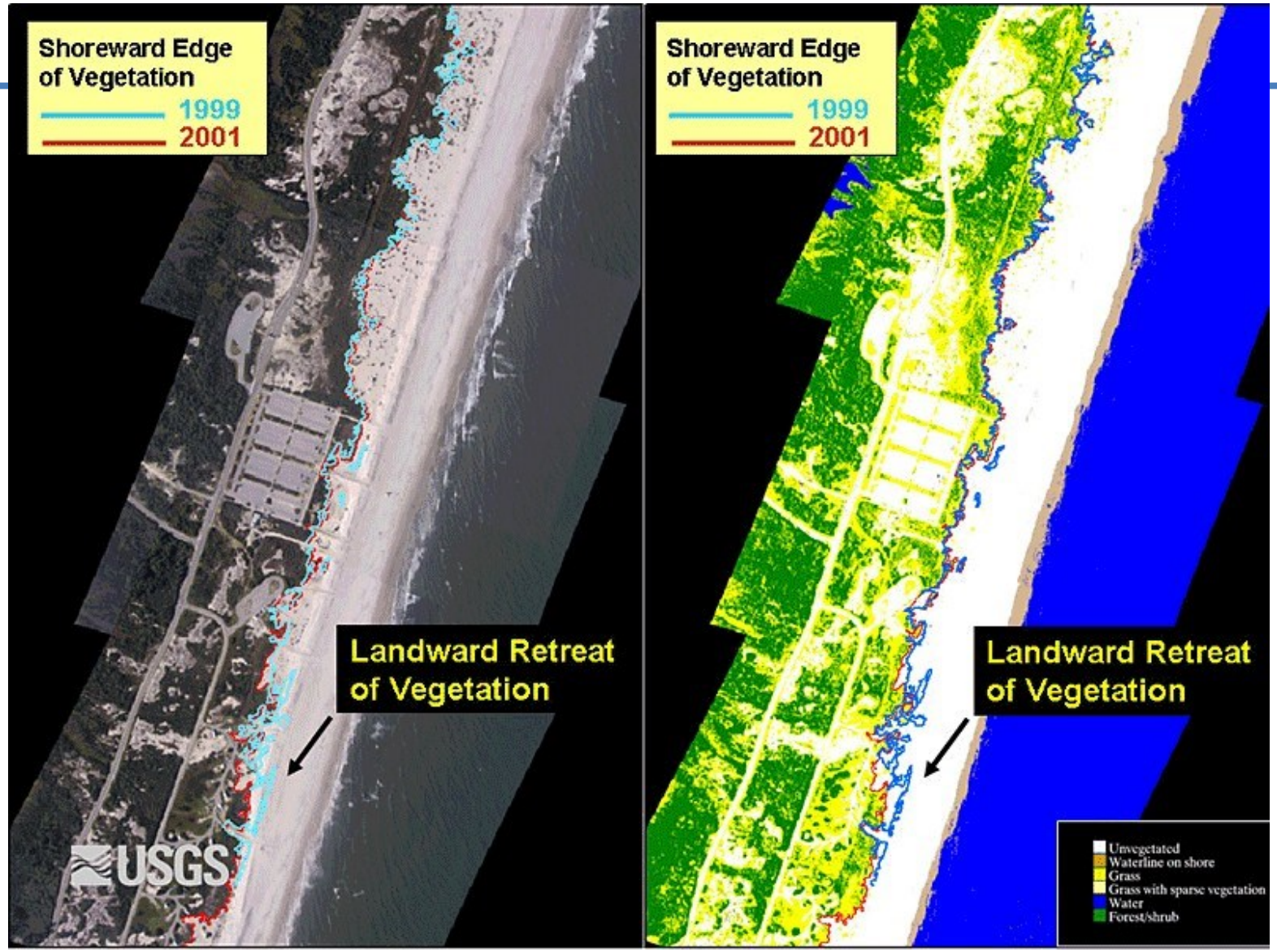
Ecological and nature protection

Realistic potential area for wind mill constructions

Groundwater pollution causes



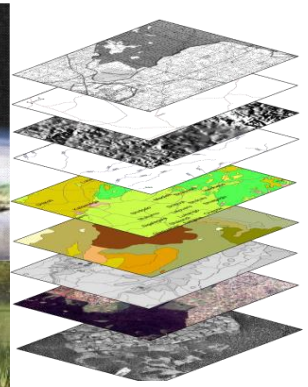
Coastal zone management

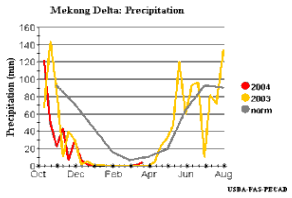


Water related Decision Support system

Input

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

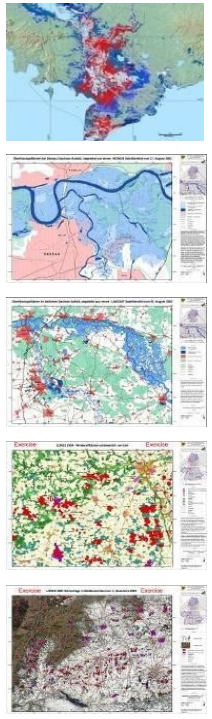




Modelling and analyses

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

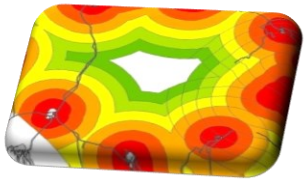
Output / Display



Source: DLR- Wisdom Project Viet Nam 2008

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

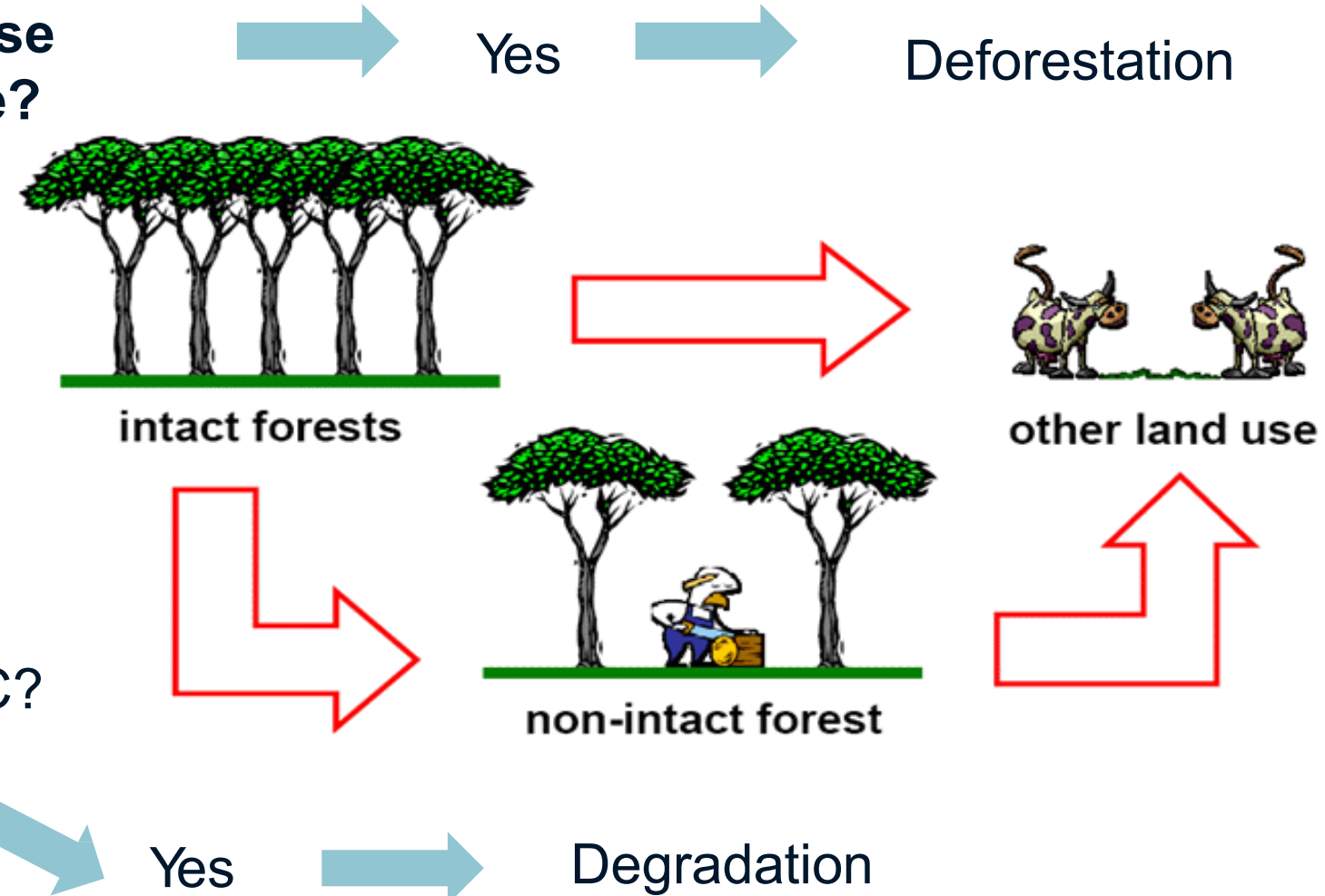
- Flood prevention
- Water management
- Ecosystem protection
- Land cover and urban planning



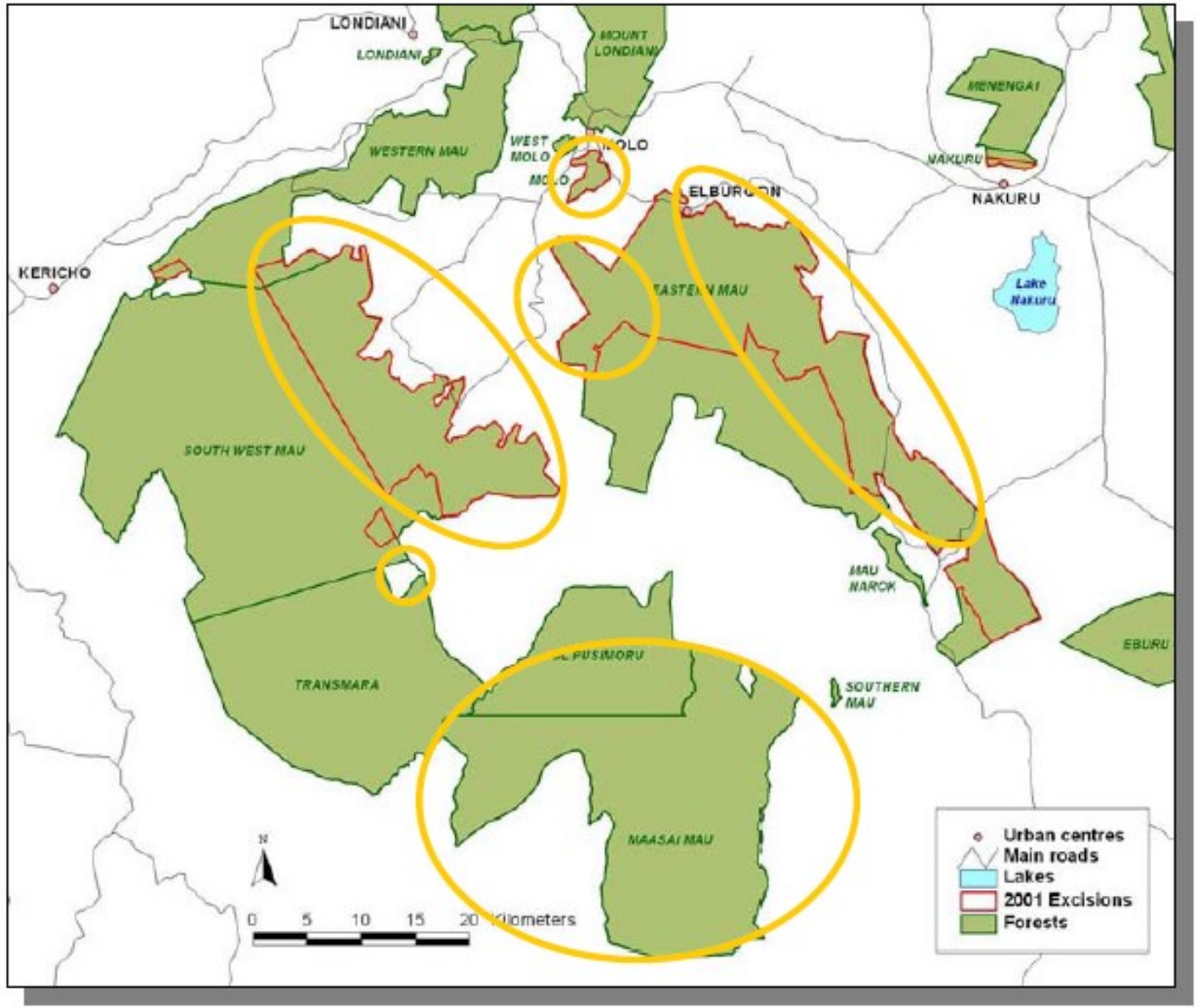
Change detection

- GIS in natural resource management provides information about land area change between time periods.
- The land change documents detected through satellite imagery or aerial photographs.
- It is a useful application in land change, deforestation assessment, urbanization, habitat fragmentation etc.
- The information obtained from GIS in natural resource management help to study the specific area and monitoring can be done in and around the area.
- It is a way of studying the variations taking place in the landscape and managing the environment.

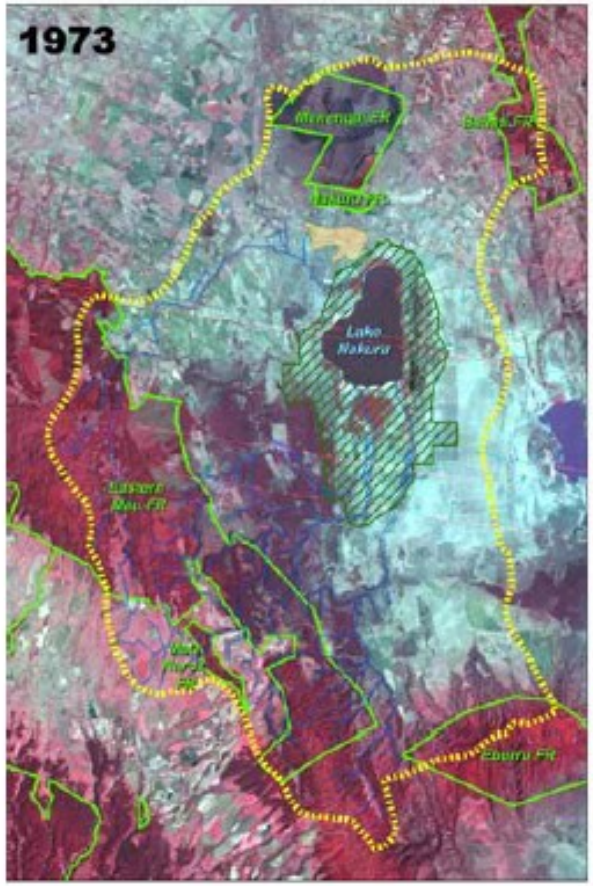
Deforestation and degradation

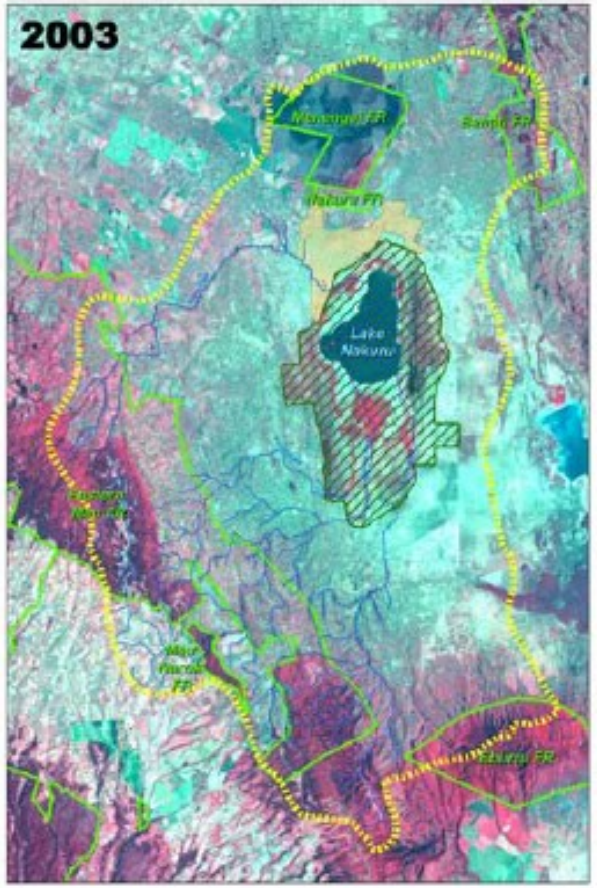


Location of major forest cover losses in the Mau Complex



Eastern Mau Forest: impact of destruction on Lake Nakuru





Loss of dense vegetation cover between 1973 – 2003

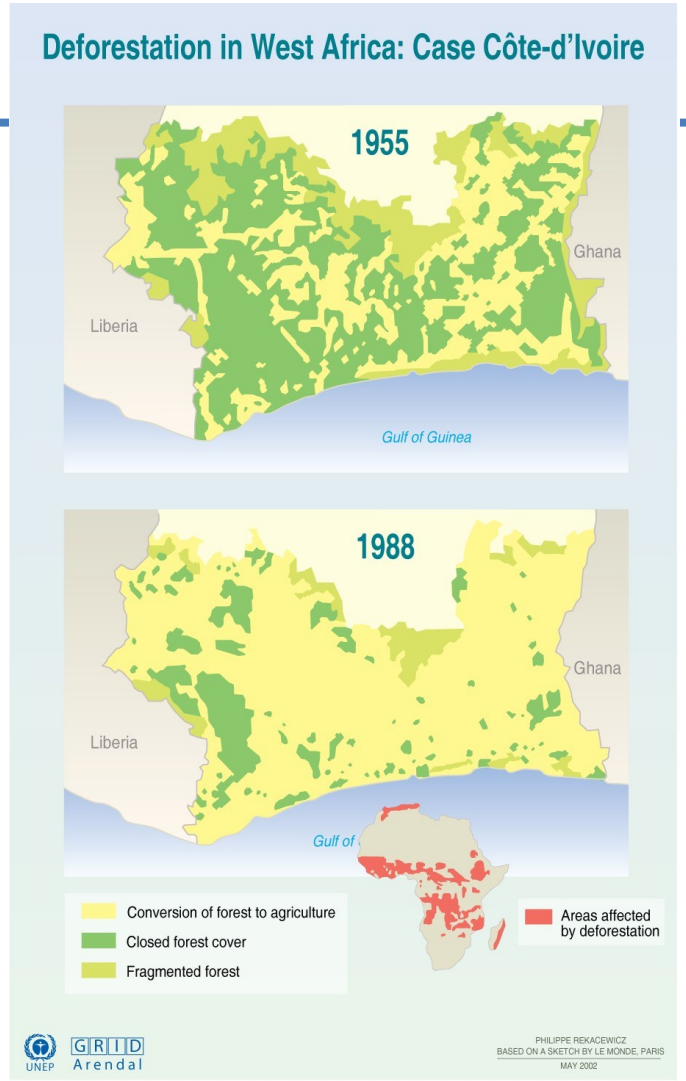
Inside forest reserves:	15,820 hectares
Outside forest reserves:	20,960 hectares
Total:	**36,780 hectares**

representing 49 % of the dense vegetation cover in the catchment of Lake Nakuru

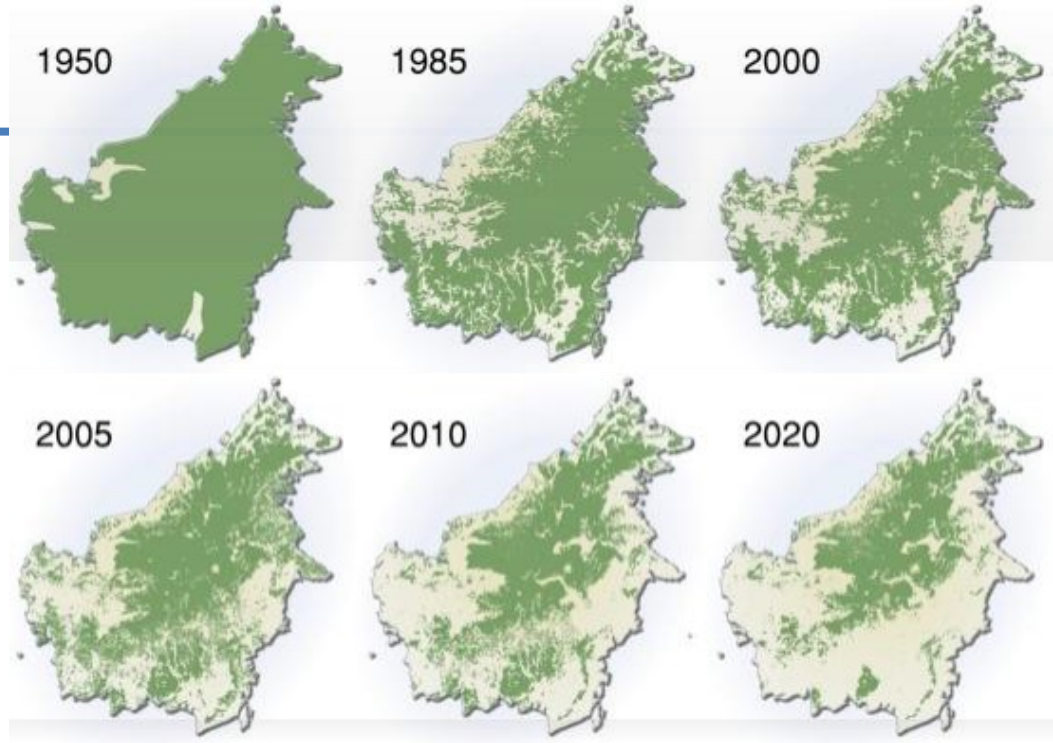
Legend
- Forest Reserves
- Lake Nakuru catchment
- Lake Nakuru National Park

Sources
- Landsat MSS and ETM images. False colour composition
- Forest boundaries: KIFCON project, Forest Department

Regional examples of deforestation: Ivory Coast, Borneo



Sources: Le Monde, Institute of Research for the Development (IRD), 1996 ; Uned Nations Environment Programme (UNEP), International Soil Reference and Information Centre (ISRIC), *World Atlas of Desertification*, 1997.



GIS integration in National park management

Forest Resource Management

Wildlife Management

Ranger Service

National legislative and administrative framework

National Park Management

GIS Service Support

Water Resource Management

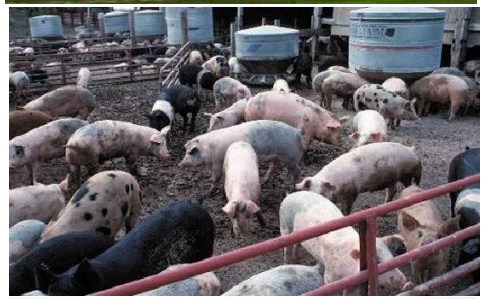
Non Timber Forest Products Management

Environmental Protection Watershed Management

REDD Carbon stock estimation Overview

FOREST CARBON STOCK (AFOLU)

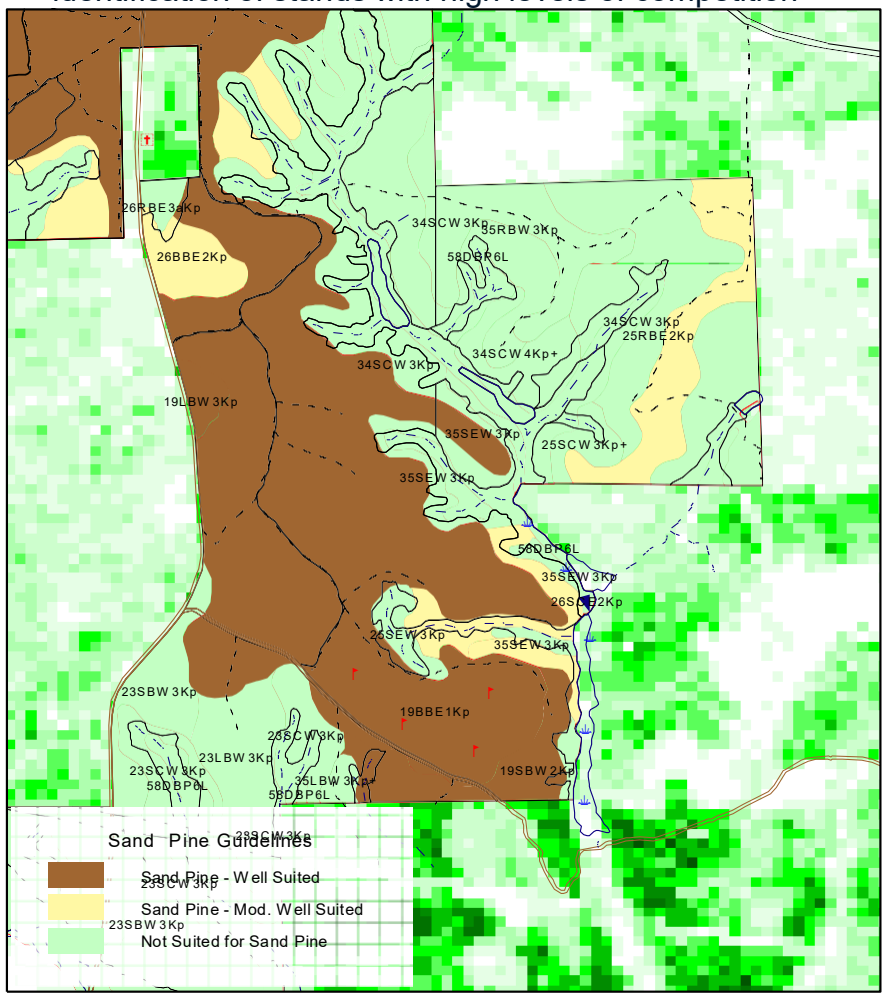
- Forest Area (ha)
  - Affected by:
    - deforestation (REDD)
    - Afforestation / Reforestation (CDM)
- Carbon Density (C/ha)
  - Affected by:
    - degradation (REDD)
    - restoration / rehabilitation (REDD)



Growth efficiency and Biomass estimation

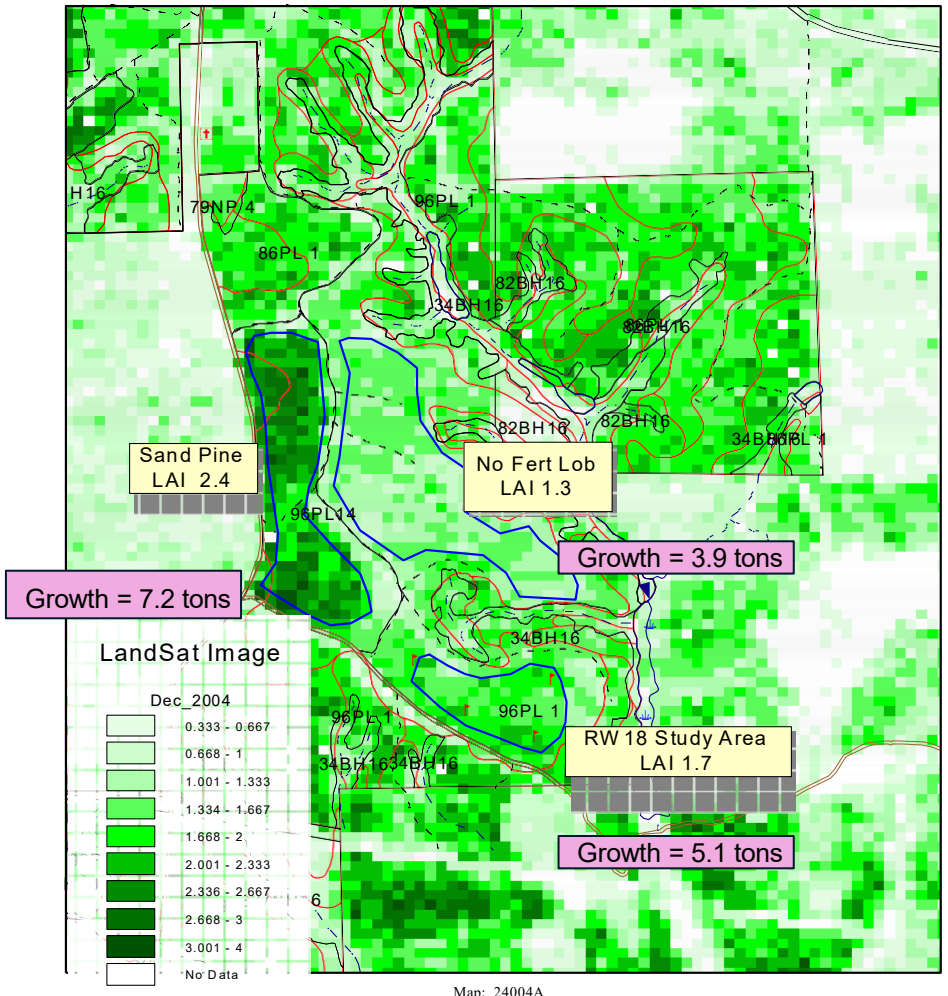
LAI (Leaf Area Index):

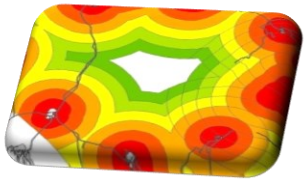
- stand stratification for inventory
- identification of poor-performing stands for early harvest
- identification of stands with high levels of competition



LAI plus GE (Growth Efficiency)

Provides ability to estimate stand-level response to silviculture: (fertilization, release, tillage)





Hazard and risk assessment

- GIS in natural resource management is used in the reduction of a natural hazard such as flood, landslide, soil erosion, forest fires, earthquake, drought etc.
- One cannot totally stop these natural disasters but can minimize these warnings by early planning, preparation, and strategies.
- GIS in natural resource management is being used in analyzing, organizing, managing and monitoring the natural hazards.
- GIS in natural resource management provides spatial data of the disasters that have taken place before or might to occur so that early risk can be prevented. It is indicated through the GIS-based map

EU - Forest fire detection and management

http://effis.jrc.it

Date
Location (lat/lon)
Commune / Province
Perimeter of the burnt
Damage analysis by c
type

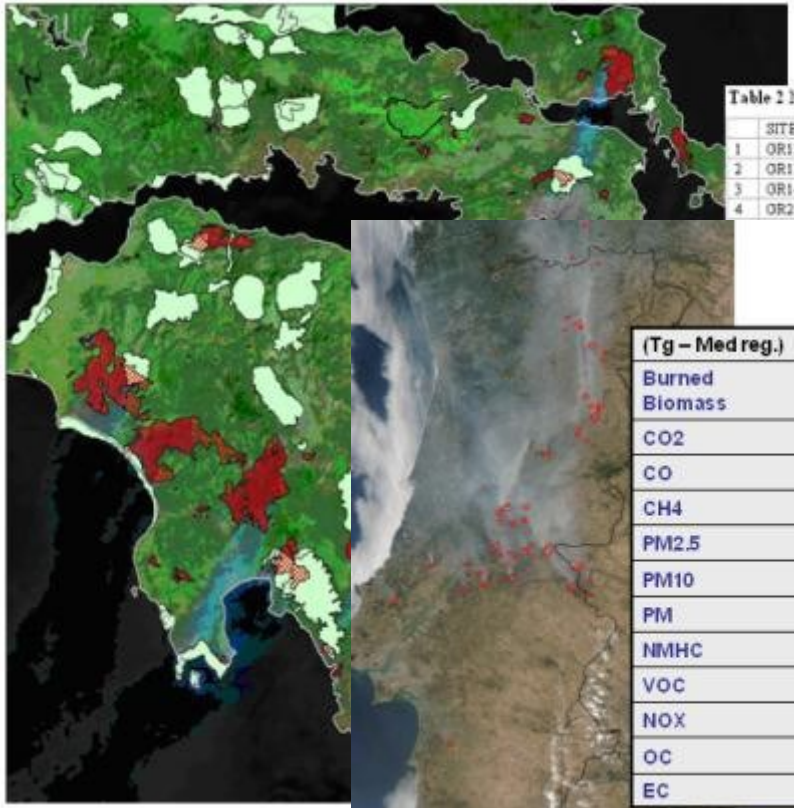


Table 2 Natura2000 sites directly affected by forest fires in Greece

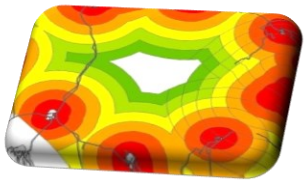
	SITECODE	SITENAME
1	GR1250002	PIERIA ORI
2	GR1340001	ETHNIKOS DRYMOS PREPON
3	GR1430001	OROS PILIO KAI PARKATIA THALASSIA ZONI
4	GR2120009	ORI TSAMANTA, FILIATRON, FARMAKOVOUNI, MEGALI RACHI

(Tg – Med reg.)	2000	2001	2002	2003	2004	2005
Burned Biomass	6.4	4.4	4.1	11.5	5.5	7.8
CO2	10.7	7.3	6.9	19.3	9.1	12.9
CO	0.434	0.287	0.279	0.749	0.363	0.529
CH4	0.023	0.015	0.014	0.039	0.019	0.027
PM2.5	0.043	0.029	0.028	0.075	0.036	0.052
PM10	0.051	0.034	0.033	0.089	0.043	0.062
PM	0.071	0.048	0.046	0.125	0.060	0.087
NMHC	0.019	0.012	0.012	0.032	0.016	0.023
VOC	0.022	0.015	0.014	0.039	0.019	0.027
NOX	0.030	0.020	0.019	0.052	0.025	0.037
OC	0.026	0.017	0.017	0.045	0.022	0.031
EC	0.003	0.002	0.002	0.005	0.003	0.004

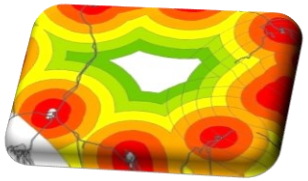
Estimates PT, ES, FR, IT, GR (Tg)

Available Information:

- Current info (activ
- Last week (fire perimeter + damage ana
- All (From the start of the campaign (Jun

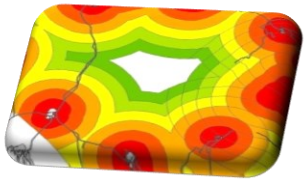


CASE APPLICATIONS



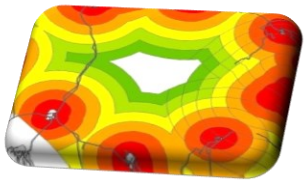
Forestry: introduction

- Remote sensing and GIS are complementary technologies that, when combined, enable improved monitoring, mapping, and management of forest resources (Franklin 2001).
- The information that supports forest management is stored primarily in the form of forest inventory databases within a GIS environment.
- A forest inventory is a survey of the location, composition, and distribution of forest resources. As one of the principal sources of forest management information, these databases support a wide range of management decisions from harvest plans to the development of longterm strategies.



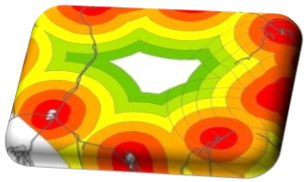
Forestry: introduction

- Applications of remote sensing and GIS to forestry The use of remote sensing by forest managers has steadily increased, promoted in large part by better integration of imagery with GIS technology and databases, as well as implementations of the technology that better suit the information needs of forest managers (Wulder and Franklin 2003).
- The most important forest information obtained from remotely sensed data can be broadly classified in the following categories:
  - detailed forest inventory data (e.g., within-stand attributes)
  - broad area monitoring of forest health and natural disturbances
  - assessment of forest structure in support of sustainable forest management



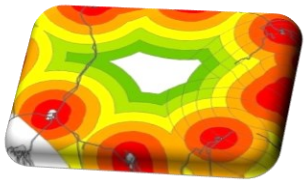
Forestry : Detailed forest inventory data

- Forest inventory databases are based primarily on stand boundaries derived from the manual interpretation of aerial photographs.
- Stand boundaries are vector-based depictions of homogeneous units of forest characteristics.
- These stand polygons are described by a set of attributes that typically includes species composition, stand height, stand age, and crown closure.
- Digital remotely sensed data can be used to update the inventory database with change (e.g., harvest) information for quality control, audit, and bias detection.



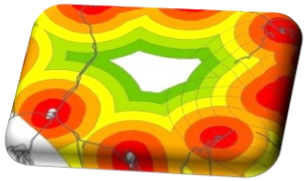
Forestry : Forest health and natural disturbances

- Fire, insects, and disease are among the major natural disturbances that alter forested landscapes.
- Timely update information ensures inventory databases are current enough to support forest management planning and monitoring objectives.
- Integrated remote sensing and GIS analyses that support insect damage monitoring and mitigation include:
  - detecting and mapping insect outbreak and damage areas
  - characterizing patterns of disturbance relative to mapped stand attributes
  - modeling and predicting outbreak patterns through risk and hazard rating systems
  - Providing data to GIS-based pest management decision support systems



Forestry : Fire

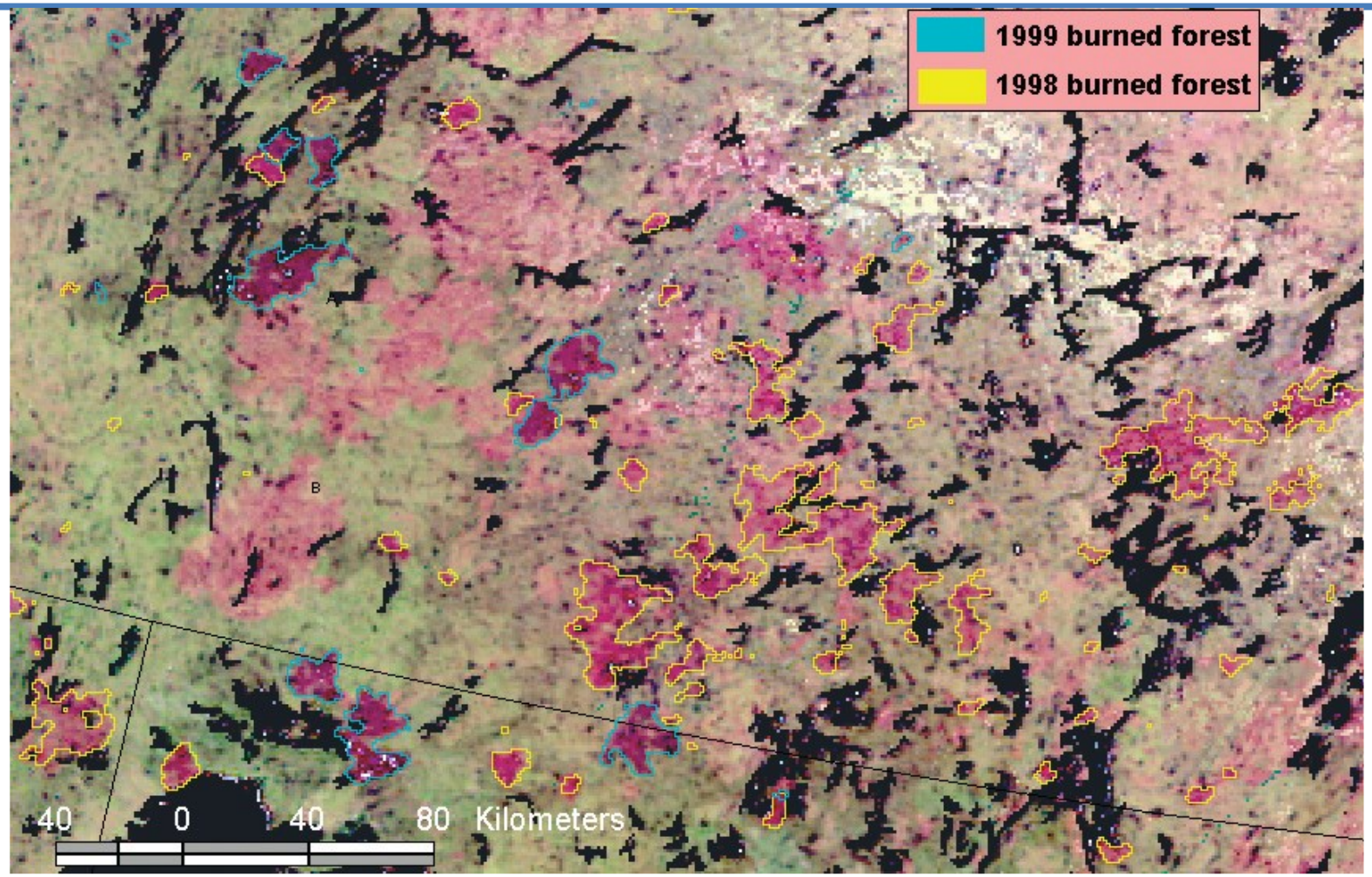
- Fire is an ecological process that governs the composition, distribution, and successional dynamics of vegetation in the landscape (Johnson 1992).
- Knowledge of fire disturbance is necessary to do the following:
  - understand fire impacts on timber and non-timber values
  - defi ne salvage logging opportunities
  - understand the effect of climate change and feedback processes on forest fire occurrence
  - quantify the influence of fire on regional, national, and global carbon budgets (Kasischke and Stocks 2000).



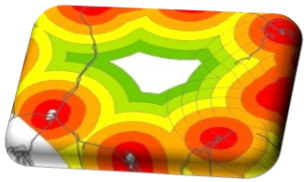
Forestry : Fire

- To address this range of issues, foresters employ a multitude of field, global positioning system (GPS), and remote sensing (airborne and satellite) methods and data sources.
- Integrated remote sensing and GIS fire support systems are used in real-time, near real-time, and post-fire applications.
- For example, infrared and thermal-infrared cameras with integrated GPS/INS (inertial navigation system) technologies can observe fire hot-spots, active fires, and fire perimeters in real-time.
- Data on fire location and size is sent from the aircraft to field-based systems from which precise directions can be given to water-bombers and firefighting crews.
- Near real-time remote sensing and GIS systems are generally based on daily observations from coarse-resolution satellites such as the AVHRR (1 km pixel) and MODIS (250 m to 1 km pixel) satellites.
- Daily hot-spot information identifies the occurrence of fire activity over large areas and helps to target locations to collect more detailed information.
- Postfire applications largely entail mapping the extent of burned areas from aerial photographs or satellite imagery and assessing fire damage to vegetation.

Forestry : Fire

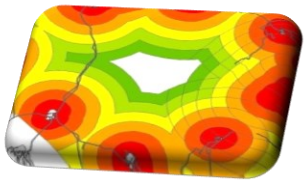


Sample of Canada-wide burn area mapping from Fire M3 depicting an area in the Northwest Territories.



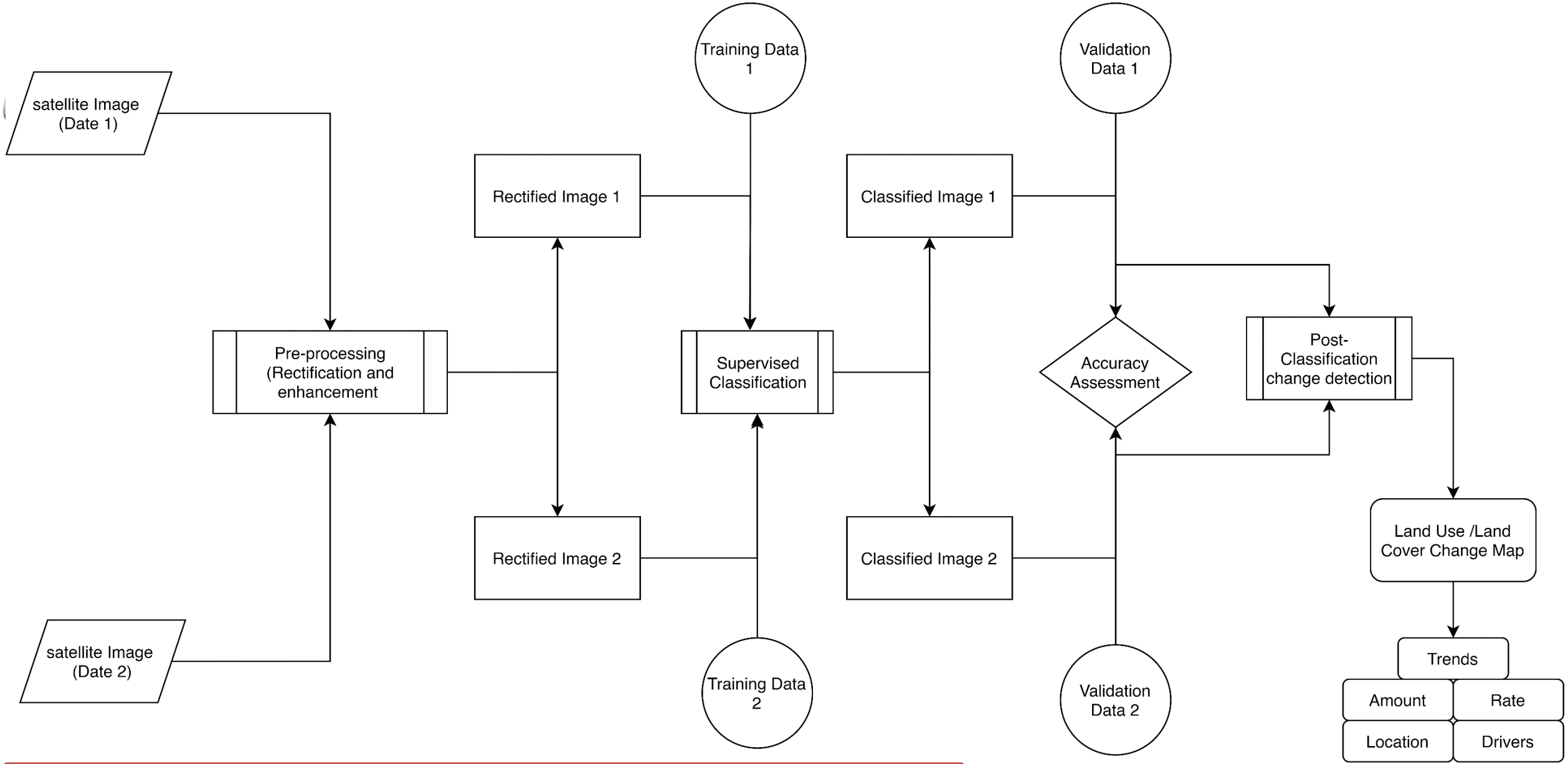
Landscape ecology, habitat, and biodiversity

- Sustainable forest management requires that landscape ecological characteristics related to habitat and biodiversity be included in forest inventory and certification procedures (Vogt et al. 1999).
- The characteristics of interest are (1) spatial patterns within the landscape, (2) specific habitat-related forest conditions, and (3) the ecological processes that link spatial pattern, habitat, and ecosystem functioning.
- Land-cover information is one example of spatial patterns readily obtainable by classifying remotely sensed data.
- Other useful datasets include forest canopy information (e.g., crown closure or leaf area estimates), understory information (Hall et al. 2000), and measures of the distribution and boundaries of landscape units such as forest fragmentation (Debinski et al. 1999).
- Remote sensing can provide repeatable and consistent methods to develop these data layers such that changes over time can be monitored and habitat models can be developed and validated for individual species.

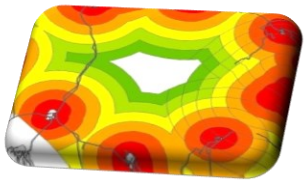


Future directions of remote sensing in forestry

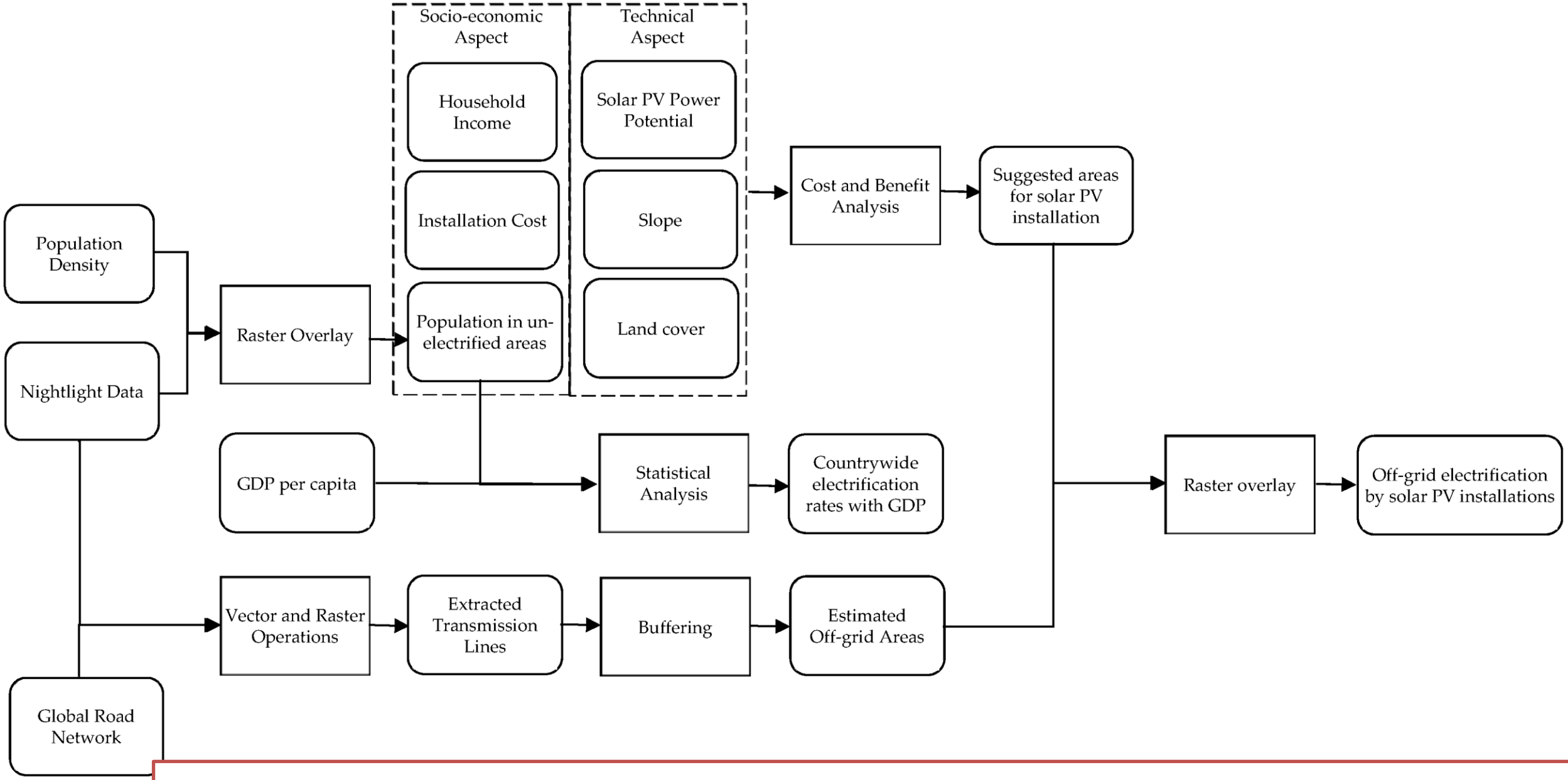
- A key development in remote sensing has been the increased availability of high-spatial- and high-spectral-resolution remotely sensed data from a wide range of sensors and platforms including photographic and digital cameras, video capture, and airborne and spaceborne multispectral sensors.
- Hyperspectral imagery promises to provide improved discrimination of forest cover and physiological attributes.
- Radar applications are being developed that penetrate the forest canopy to reveal characteristics of the forest .
- New technologies such as LIDAR can provide estimates of forest biomass, height, and the vertical distribution of forest structure with unprecedented accuracy
- The use of advanced digital analysis methods and selective use of complementary data have provided more detailed information about forest structure, function, and ecosystem processes than ever before



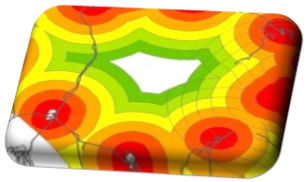
Land use / Land cover detection Workflow



OTHER APPLICATIONS



Supply and Demand Assessment of Solar PV as Off-Grid Option



Solar farms placement using fuzzy-AHP and fuzzy-DS methods

Input data

1) Solar radiation intensity
2) Relative humidity
3) Number of dusty days
4) Number of cloudy days
5) Land use
6) Land elevation
7) Distance to residential area
8) Distance to major road
9) Temperature
10) Distance to PTL
11) Land slope

Input data

Make rules

Fuzzy-AHP method

Membership function

Fuzzy map

Dempster-Shafer theory

Selection the best method

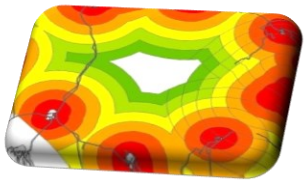
Resample and stack layers

4 × 4 moving windows to select data

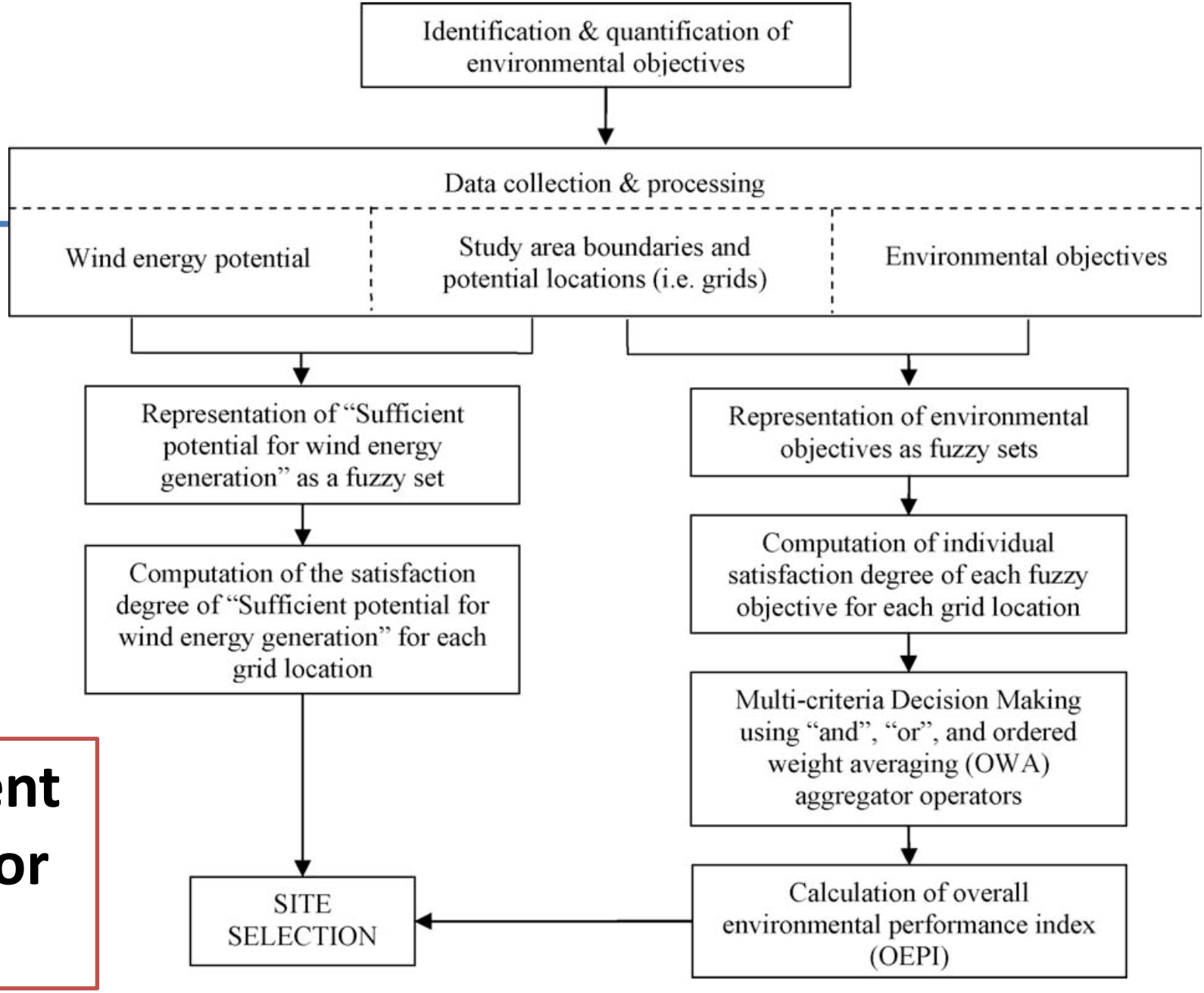
Apply Dempster-Shafer theory

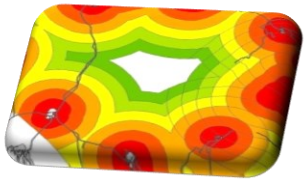
95% certainty
99% certainty
99.5% certainty

Location of Solar Farms



environmental assessment of wind energy systems for spatial planning





Areas to explore for projects

- Forest Fire detection and Management in forestry
- Interanual biomass monitoring and management in a forest
- Watershed management in a selected areas
- 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 Kenya
- 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
- Elephant/large mammal tracking
- And many more