LUCC DATA REQUIREMENTS WORKSHOP

Survey of needs, gaps and priorities on data for land-use/land-cover change research

Organised by IGBP/IHDP-LUCC and IGBP-DIS

Barcelona, Spain
11-14 November 1997

LUCC Report Series No. 3

LUCC DATA REQUIREMENTS WORKSHOP

Survey of needs, gaps and priorities on data for land-use/land-cover change research

Organised by IGBP/IHDP-LUCC and IGBP-DIS

Barcelona, Spain
11-14 November 1997

Edited by: Xavier Baulies and Gerard Szejwach

Edition based on texts supplied by Josep Ignasi Augé, Xavier Baulies, Helen Briassoulis, Jeremy Cain, Günther Fischer, Helena Freitas, Lisa Graumlich, Holger Hoff, Chris Justice, John Kineman, Eric Lambin, Martine Michou, Frank Oldfield, Vanda Perdigao, Ichtiaque Rasool, David Skole, Gerard Szejwach, Billie Turner II and Stefan Weiers, as well as from the individual contributions and presentations to the Workshop.

Sponsored by:

ENRICH	(European Network for Research in Global Change), European Commission
NASA	(National Aeronautics and Space Administration), US
START	(Global Change System for Analysis Research and Training)
ICC	(Institut Cartogràfic de Catalunya), Catalonia - Spain
CICYT	(Comisión Interministerial de Ciencia y Tecnología), Spain
IGBP-DIS	(Data and Information System)
LUCC	(Land Use and Land Cover Change)

LUCC Report Series No. 3

ENRICH

Generalitat de Catalunya
Institut Cartogràfic de Catalunya

Comisión
de Ciencia y Tecnología

LUCC DATA REQUIREMENTS WORKSHOP

SURVEY OF NEEDS, GAPS AND PRIORITIES ON DATA FOR LAND-USE/LAND-COVER CHANGE RESEARCH

Barcelona, 11 – 14 November 1997

Organised by IGBP/IHDP-LUCC and IGBP-DIS

LUCC Report Series No. 3

LUCC Report Series Editor: International Project Office

LAND USE AND COVER CHANGE

GLOBAL IGBP CHANGE

IHDP

Generalitat de Catalunya
Institut Cartogràfic de Catalunya

Biblioteca de Catalunya. Dades CIP:

LUCC Data Requirements Workshop *(1997 : Barcelona)*
LUCC Data Requirements Workshop : survey of needs, gaps and priorities on data for land-use/land-cover change research. – (LUCC report series ; 3)
Referències bibliogràfiques
I. Baulies, Xavier, ed. II. Szejwach, Gerard, ed. III. Institut Cartogràfic de Catalunya IV. Land Use and Cover Change (Projecte) V. International Geosphere-Biosphere Programme. Data and Information System VI. Títol VII. Col·lecció: LUCC report series ; 3
1. Sòls – Aspectes ambientals – Investigació – Congressos 2. Sòl, Ús del – Investigació – Congressos 3. Canvi mediambiental global – Congressos
504.05 (061.3)

LUCC Data Requirements Workshop

Survey of needs, gaps and priorities on data for land-use/land-cover change research

Published by:

LUCC International Project Office
Institut Cartogràfic de Catalunya
Parc de Montjuïc – 08038 Barcelona – Catalonia – Spain
Tel.: 34-93 425 29 00 – Fax: 34-93 426 74 42
http://www.icc.es/lucc

ISSN: 1138-7424
Dipòsit Legal: B. 52 200-1998

CONTENT

1. INTRODUCTION

This report is the result of the scientific contributions of the LUCC Data Requirements Workshop organised by IGBP/IHDP-LUCC (Land Use and Land Cover Change) and IGBP-DIS (Data and Information System) in November 1997. About seventy scientists attended the international workshop in Barcelona which was sponsored by ENRICH, NASA, START, CICYT, IGBP-DIS and ICC-LUCC.

This meeting was the first one of four workshops planned within the DAPLARCH programme (Data Plan for Land Use and Land Cover Change Research) adopted by the LUCC and DIS Projects. DAPLARCH goals are to define the land-cover and land-use data needs of the international community engaged in LUCC and global change studies and to convey these needs to the appropriate data-oriented organisations and agencies.

One of the major challenges of the LUCC Project is the creation of a research framework integrating both social and natural sciences. To formalise this multidisciplinary approach a specific effort on data is essential. The formulation and test of complex hypotheses on land-use/land-cover change has to be underpinned by suitable data. These are meant to constitute an empirical component able to anchor the LUCC emerging science into reality.

In this context the LUCC Data Requirements Workshop was built on a theoretical approach as an attempt to outline the 'ideal' nature of land-use/land-cover change data to better address the LUCC's five overarching questions (IGBP/IHDP-LUCC Science Plan), namely:

- How has land cover been changed by human use over the last 300 years?
- What are the major human causes of land use change in different geographical and historical contexts?
- How will changes in land use affect land cover in the next 50-100 years?
- How do immediate human and biophysical dynamics affect the sustainability of specific types of land uses?
- How might changes in climate and global biogeochemistry affect both land use and land cover, and vice versa?

The workshop had three main objectives: articulation of specific data needs for research, identification of major common data needs and priorities, and monitoring system needs.

2. EXECUTIVE SUMMARY

Researchers of land-use/land-cover change convened at the workshop to assess the nature and significance of land-use/land-cover change data needs, as well as to advance on a first statement of ranking of priorities for the streamlining or adaptation of existing data sets or the creation of new ones. The workshop was structured in alternative Plenary and Break-Out Sessions to allow insights, discussions and community consensus.

The general discussion on data requirements was built on the exercise of the 'translation' of LUCC science objectives into data needs, the known problem of fit between data and science. Scientists were asked to identify major situations where the progress in land-use/land-cover change research is inhibited because of the lack or unsuitability of data, and to articulate those impediments in terms of comprehensive and/or observable variables. In spite of the difficulties of this 'theoretical translating exercise' the general response was positive and the discussion very productive.

List of main conclusions

1. LUCC research is oriented towards process/causality analysis. The research task of explaining causality makes it difficult, however, to define the data requirements in advance.

2. The description of land-use/land-cover change processes involves a wide range of types of observations.

3. It is necessary to develop observation approaches able to make the human-environment linkage more direct.

4. The reconstruction of the history of land-use/land-cover change constitutes knowledge crucial for better analysing the current changes and predicting the future ones.

5. The largest gap in land-use/land-cover change characterisation is not the extent, pace and direction of land-cover change, but the functional understanding and adequate parameterization of land-use dynamics.

6. The main constraints for land-use related data are based on a lack of agreement in definition and nomenclatures, consistency in existing socio-economic data, and the need to further investigate on scaling issues.

7. The problems with land-use data may be tackled by means of a framework for conceptual modelling and data assessment.

8. Spaceborne remote sensors keep providing fundamental support for the observation of land-use/land-cover dynamics.

9. There is an immediate demand for a variety of data sets over few geographical areas rather than few data sets over large areas.

10. There is a priority for regional and local data sets.
11. There is no common priority spatial resolutions, but agreement on using multiscale approaches.
12. Scientific approaches to land-use/land-cover change have major demands for temporal and spatial consistency.
13. Global observation initiatives are particularly important for integrative modelling and global integrative assessment.
14. Baseline data sets provide coherency and comparability between LUCC situations.
15. LUCC has a strong requirement for monitoring of a number of parameters within a wide range of spatio-temporal scales.
16. The use of historical imagery data will likely become indispensable to better understanding the recent past land-use/land-cover change dynamics.
17. LUCC needs to develop a co-ordinated data strategy in order to access and produce the various relevant data sets.
18. The efficiency of this data strategy will be dependent on the success in reaching the various land-use/land-cover change data research needs.

Priority information for land-use/land-cover change studies

Ranking of priority data sets was also a task given to the working groups which was dealt with some difficulties, probably because of the involvement of a wide range of data types. In spite of it, the principal types of required data for land-use/land-cover change research were identified in the workshop.

A general criterion for selection of priority data sets is that they should contain measurable information in a first request for process understanding and secondly for the assessment of land-use/land-cover change in the context of global environmental change.

The information required by the scientific community involves on the one hand data from different domains to describe components of a land-use/land-cover change system, namely *general baseline data*, and on the other hand data to infer the mechanisms of action of the main driving forces of change, namely *information on factors of change*.

General baseline data

1. Land-use/land-cover change
- Geo-projections of land-cover/land-use information (baselines: dynamics of urban, industrial, dry land and irrigated agriculture, semi-natural and forestry/non forestry natural areas)
- Geo-projections of legally protected areas
- Historical geo-projections from historical data

2. Environmental
- Climate (precipitation, temperature, radiation, relative humidity, etc.)
- Topographical data (altitudes, slopes and orientations)
- Soils (soil organic carbon, fertility, texture, etc.)
- Nutrient transport
- Land/resources degradation
- Water/resources degradation and pollution (ground and surface water)
- Atmospheric pollution

3. Economic
- Multisectorial production structure (whole economy, not only land based sectors; at district level)

- Input use (technology, agro-chemical inputs, labour, machinery, irrigation; at district level)
- Prices, subsidies and taxes (at province or national level)
- Infrastructure (energy, transport and communication). Two aspects: physical location and rate of use.

4. Societal
- Population census and spatial patterns (at district level)
- Income distribution (at district level)
- Migrations (between countries and between provinces)
- Institutional aspects (land tenure, water rights, access to communal land, etc.)
- Health (distribution of actual/potential ratio of disease)

Information on factors driving land-use and land-cover changes, acting at local to global levels
- Population growth, change in population structure and migration
- Demands for energy, products and amenities (consumption patterns, tourism)
- Life styles and rural-urban interactions
- Extreme events and variability in biophysical conditions
- Macro-economic drivers
- National policy measures and directives
- External drivers ('globalisation', trade regimes, international agreements)

The way forward

1. *Pilot effort.* A conceptual model incorporating many types of parameters currently used in the analysis of land-use/land-cover change situations needs to be developed. Such a model should be oriented to assess measurement needs and selection of variables for specific LUCC studies.
2. *An efficient Data Information System for addressing IGBP/IHDP-LUCC requirements and co-ordination of data efforts.* There is a need for a specific effort in terms of data and information exchange/access for both the biophysical and socio-economical aspects. IGBP-DIS provides some support as far as the biophysical aspects are concerned. This support needs to be increased as foreseen within the IGBP synthesis. The issue of a similar effort concerning socio-economic data should be addressed as well.
3. *Implementation of data activities.* An acquisition strategy will be discussed during DAPLARCH#2 (Data Gathering and Compilation Workshop). The workshop should concentrate on the definition of critical parameters, the processes encompassed by those parameters, and the methods to obtain those critical parameters, as well as the associated measurement needs. The list of priority information raised in DAPLARCH#1 should provide the framework for the exercise. Account should also be taken of existing efforts including global products and data sets.
4. *Special attention to 'hot spots'.* Some specific locations are very typical of major ongoing or anticipated changes. These "hot spot" regions should be given special attention, and a strategy for data gathering should be developed encompassing consistent socio-economic data and covering multiple periods.
5. *Further investigation on indicators.* In addition to the classical data gathering aspect, the DAPLARCH#2 workshop may address the related issue of "indicators" as expressions of trends, particularly useful for assessment purposes.
6. *Proxy parameters.* A particular effort is required to obtain critical parameters not directly measurable at the required spatio-temporal scale.

3. COMMENTED CONCLUSIONS OF THE WORKSHOP

a) **The nature of land-use/land-cover change data**

1. *LUCC research is oriented towards process/causality analysis.* Therefore, LUCC research has to deal with the identification, qualitative description and parameterisation of factors which drive changes in land use, as well as the integration of their consequences and feedbacks.
   The research task of explaining causality makes it very difficult to define data requirements in advance, probably because it implicitly constitutes a part of what is sought.
2. *The description of land-use/land-cover change processes involves a wide range of types of observations.* The assessment of current concepts, ideas, opinions and perceptions of the nature of land-use/land-cover change data, reveals that no single type of data exists which can sufficiently describe the implicated processes.
   Very little data can be considered as automatically usable for LUCC research and the observations, even the simplest ones, involve rather complex approaches.
3. *The need to synthesise human factors and the environment.* The LUCC project has been designed to improve understanding of the human and biophysical forces that shape land-use/land-cover change. Thus linking human behaviour and social structures to biophysical attributes of the land is a fundamental aspect of LUCC research. This link has to be conceived in terms of spatial interrelations the development of which are critically conditioned by scaling and spatialisation methodologies and tools.
   To date this linkage has been largely indirect. It is necessary to develop observation approaches able to make the human-environment linkage more direct. For example, when the population structure and its dynamics are incorporated within a given pixel co-registered with other variables the analysis capacity is increased.
4. *The need for historical perspective.* The historical reconstruction of land-use/land-cover change over a temporal scale of 300 years is of high priority as it has been addressed in the scientific overarching questions of the LUCC project (see introduction). Understanding the mechanisms which operated in the past to determine the main land-use/land-cover changes is a crucial input to analysing the current changes and predicting future ones. These changes occurred at different time periods, paces, and degrees of magnitude with divers biophysical implications.

b) **Data constraints and solutions**

5. *The largest gap in land-use/land-cover change characterisation* is not the extent, pace and direction of land-cover changes, which can be approached by means of remote sensing, but *the functional understanding and adequate parameterisation of land-use dynamics* (e.g. selec-

tion of variables able to characterise interrelations and interdependencies of the elements of a land-use system, like land-use purposes, land-use interventions and their human and biophysical driving forces).

Land-use attributes are complex in kind and the boundaries of types of data quite diffuse. These difficulties are also evident when addressing the following question: to what extent it is possible to infer land use from land cover?

A primary and general attempt for this functional parameterisation of land use should be based on the selection of variables whose values can be quantifiable. This quantification could be tackled through either direct observation (remote sensing, field measurements and interview), proxy or modelling.

6. *Some identified constraints for land-use related data* are:
   - The lack of agreement on definition and nomenclatures.
   - The uneven availability of socio-economic data (different sources, levels of accessibility, levels of completeness, etc.).
   - The lack of temporal consistency of existing statistical socio-economic data.
   - The availability of spatially disaggregated socio-economic data.
   - The need to further investigate scaling issues, both temporal and spatial.
7. *Some identified solutions for land-use related data:*

   The problem of land-use data can be tackled, in a viable way, by means of a framework for conceptual modelling and data assessment in different LUCC situations. Two approaches are to be explored and developed:

   a) An approach oriented to distinguish observable components of a land-use/land-cover change system, based on pattern and/or process analysis, which is mainly dependent on observation capabilities *(systematic approach)*. This approach is critically conditioned and limited by the availability and quality of the different types of concerned data describing those components.

   (Example 1: From-pattern-to-process analysis describing the underlying processes of forest fragmentation. Characterisation based on direct observations of patterns of land-cover dynamics, e.g. from remote sensing, and the analysis of the underlying social processes associated with other biophysical and socio-economic variables).

   (Example 2: Analysis of land-use intensification processes in agriculture based on the selection of relevant measurable and spatially disaggregated variables like production system, input use, land structure, labour, capital, water resources, etc.). This approach is looking at the system to distinguish the relevant components. Clustering of these components can be used to compare processes.

   b) Understanding the interrelations and interdependencies (functionality) of land-use/land-cover change needs to deal with aspects with 'abstract pathways of functioning' and which are therefore difficult to observe. This involves gradual or step-like processes which operate in complex sequences (e.g. pathways from purposes of use leading to types of interventions and to land-use intensification). As the pathways cannot be observed as such, this approach builds on the qualitative analysis of the correlations between these 'abstract aspects' and their 'immediate tangible consequences'. Ranking of these interactions provides the basis for the classification of those 'abstract aspects' *(hierarchical approach)*.

   (Example 1: Different land-use interventions lead to three decreasing levels of environmental impact when interacting with the following processes: changes in water management, soil management, or pest management. This type of ranking can be used to compare land-use interventions. In this case the consequences of changes in water management have a wider impact than the others).

(Example 2: Four hierarchical interactions identified by CLAUDE can be used to determine pathways of land use change. Different land-use changes may imply changes in one or several of the following aspects: in spatial distribution -e.g. land cover-, in function and environmental character -e.g. soil characteristics-, in performance -e.g. potential yield, productivity, etc.-, and in management -e.g. land treatment, cultivation, ownership, etc. In this case, the analysis of the implications that different land-use changes have when affecting one or more of the four aspects, can be used to distinguish land-use/land-cover change pathways. Note that the interactions between land-use changes and the four aspects are hierarchical: changes in management and performance are very likely occurring where there are changes in land cover, but not necessarily vice versa).

(Example 3: Different land-use changes imply different degrees of reversibility, e.g. 'mining versus harvesting').

(Example 4: Different land-use changes imply different degrees of predictability, e.g. 'ability to define indicators of sustainability').

Both systematic and hierarchical approaches should be compatible and allow different LUCC situations to be compared. The hierarchical approach is more function/objective oriented. However, to implement it, the inclusion of systematic oriented procedures is necessary.

8. *Spaceborne remote sensors keep providing fundamental support for the observation of land-use/land-cover dynamics*, not only on a global scale but also at regional and local ones. Nowadays RS observations constitute a unique tool for estimations of land-cover dynamics, often used in an operational way. Nevertheless, there is still a need of further research on remote sensing and image processing, beyond land-cover mapping, related to the characterisation of land biophysical features.

   For land-use/land-cover change modelling there is a clear need for geo-projections of biophysical responses to land use change (e.g. changes in productivity, soil moisture, evapo-transpiration, LAI, etc.). These responses from terrestrial ecosystems, agriculture and terrestrial water/climate act as feed-backs in the land-use/land-cover system.

   Within the earth system context, the interpretation and evaluation of the effects of land use and climate change on land surface properties are also crucial issues for the assessment of the impact of processes occurring at the land surface interface.

   Pilot studies based on airborne sensors can also lead to a significant progress in remote discrimination of biophysical and biogeochemical properties of land.

c) Data development. Needs and strategies

9. *There is an immediate demand for a variety of data sets over few geographical areas rather than few data sets over large areas.* The causality analysis of processes in areas of either gradual changes or extreme changes ('hot spots') requires a wide range of types of variables.
10. *Priority of regional and local data sets.* It has been recognised that different land-use/land-cover change processes have different observation system needs. This not withstanding, the initial key scale for land use assessment is at the regional level or below. A regional approach for data development is most recommended by the community for its synergistic nature. Such a strategy could combine existing data efforts at national, institutional and research levels. However, for this strategy to be successful, the compatibility and consistency of the different data sets is essential.

    The regional scale is seen as a spatial framework in which the collection of both biophysical and socio-economic data can be optimised.

(An example of a regional data set of total coverage area is the CORINE land cover, which provides an overview of information which allows comparability across point studies and a baseline of information for regional assessment activities).

11. *There is no common priority spatial resolutions, but agreement on using multiscale approaches.* Although common spatial resolutions were not identified in the working groups, there was a consensus for the need to combine data at different scales.
    The four scales mainly considered in land-use/land-cover change studies are:
    - land management scale, farm level,
    - landscape,
    - watershed/district level, and
    - from regional to global levels.

    However there is no firm consensus at present concerning technical details (e.g., in terms of pixels, mapping scales, etc.) for each of these scale levels.
12. *Temporal and spatial consistency.* Regarding the temporal scales and temporal resolution (frequency) there are different requirements depending also on case studies analysis and direct observation/from-pattern-to-process scientific approaches. The case studies approach has a major demand of temporal consistency in terms of the simultaneous conditions from the observing systems. This requirement is argued based on the complexity and diversity of the involved data sets and their necessary integration in a given period of time. The second approach demands a multitemporal series of observations, geographically and methodologically consistent.
13. *Global observation initiatives* are particularly important for integrative modelling and global integrative assessment. It is recognised that during the next decades land-use dynamics will play a major role in driving the changes of the global environment. In this context, global mapping of irrigated and dry land agriculture, semi-natural areas and forest cover, reflecting their dynamics, can contribute to the assessment of the biophysical implications of land-use/land-cover change within the Earth's system.
    (An example of a global data set is the DISCOVER-1 km^2, which can be used, in a consistent way, by different global research programmes as baseline land-cover information for interdisciplinary and synthesis activities).
    (Another example of a global data set is the CRU05 recently developed by the Climate Research Unit of the University of East Anglia. It contains a global monthly time series of climate variables, at 0.5 degree resolution, over the entire century, 1901-1995).
14. *Baseline data sets* (e.g. CORINE, AFRICOVER, DISCOVER, etc.) are meant to provide the necessary coherency to allow comparability between LUCC situations. There is a general acknowledgement of the potential value of future updated versions to determine rates, amount and direction of main changes as well as for the evaluation of their impacts.
15. *Monitoring.* LUCC has a strong requirement to monitor a number of parameters for a wide range of spatio-temporal scales. This can be implemented through the establishment of a systematic network for land use monitoring. The joint GCOS and GTOS Terrestrial Observation Panel for Climate (TOPC) expressed a similar need. TOPC developed an observation network strategy called GHOST (Global Hierarchical Observing Strategy) comprising 5 tiers, ranging from a small number of highly instrumented stations collecting measurements at high temporal resolution, to a large number of locations where very simple data are collected less frequently. Such a strategy, which was felt the only one affordable, is only effective when used in conjunction with models and remote sensing measurements. It appears that the strategy adopted by TOPC could be adapted to satisfy many of the LUCC measurement needs, especially for biophysical data.

16. The use of *historical imagery data* (e.g. historical aerial photography from 60-70 years ago and satellite imagery from 20 years ago) will likely become indispensable to better understanding the recent past land-use/land-cover change dynamics. This process can also lead to a vitalisation of existing archives and therefore contribute to their maintenance.
17. *Need of a co-ordination strategy of production efforts of land-use/land-cover change data.* LUCC needs to develop a data strategy in order to access and produce the various relevant data sets. Measurements are collected in various ways and through a variety of processes ranging from individual scientists making field observations in the context of a specific scientific study, to large projects involving the government or international agencies/institutions. In addition to this heterogeneity of sources many of these data efforts are made at the four scales indicated in point #11.
    There is a need to integrate existing data efforts (multi-source, multi-scale, and multi-method) to better cope with critical measurements and missing data sets, and therefore develop strategies for their acquisition.
    Critical for the efficiency of this co-ordination strategy is the degree of success in resolving the issues described below.

d) Data research needs

18. The co-ordination strategy outlined above should encompass, as a minimum, the following aspects:
    - identification of data sources, data and product access procedures,
    - development of a consensus on definitions and nomenclatures,
    - development of typologies and methodologies,
    - approach to methodological research on data adaptation and integration of existing data,
    - definition of methodologies and harmonisation procedures for spatialisation of point information,
    - development and improved availability of spatial statistical methods,
    - translating tools for interoperability between nomenclatures,
    - approach to scaling issues,
    - approach to data validation, and
    - development of metadata.

4. SOME IMPORTANT DEFINITIONS

Land-use and land-cover concepts as have been adopted by the LUCC-IGBP-IHDP project (quoted from the LUCC Implementation Plan, in review)

Land-use/land-cover change studies within the context of global change need a clear definition of four fundamental aspects: land cover, land-cover change, and land use, land-use change.

Land cover refers to the physical characteristic of earth's surface, captured in the distribution of vegetation, water, desert, ice, and other physical features of the land, including those created solely by human activities such as mine exposures and settlement.

Land use is the intended employment of and management strategy placed on land cover type by human agents, or land managers. Forest, a land cover, may be used for selective logging, for resource harvesting, such as rubber tapping, or for recreation and tourism. Shifts in intent and/or management constitute land-use changes.

Land-cover and land-use changes may be grouped into two broad categories: *conversion* or *modification*. Conversion refers to changes from one cover or use type to another. For instance, the conversion of forests to pasture is an important land-use/land-cover conversion in the tropics, while abandonment of once permanently cultivated land and the regeneration of forests is taking place in parts of the mid-latitudes. In contrast, modification involves maintenance of the broad cover or use type in the face of changes in its attributes. Thus a forest may be retained while significant alterations take place in its structure or function (e.g., involving biomass, productivity, or phenology). Likewise, slash-and-burn agriculture, a use, may undergo significant changes in the frequency of cropping, and use capital and labour inputs while retaining the rotation, cutting, and burning that constitute such uses.

Land-cover conversion operates through many pathways, the constellations of which form specific processes. For instance, deforestation leads to many types of land cover, but one common conversion process entails cutting, burning, and even planting of grass to create a pasture. In turn, site abandonment may lead in succession to a secondary forest. These pathways and processes, such as deforestation, desertification, wetland drainage, or agricultural intensification mediate the conversion or modification of land cover. Thus they can be envisioned as forcing functions, which have direction (forest to pasture or pasture to forest), magnitude (amount of change), and pace (rates of change). In turn, these pathways are typically triggered by changes in the use of the land, specific operating strategies (e.g., labour, capital, crops) which are linked to changes in the purpose of land management (e.g., for subsistence, market, occupation, or recreation). Thus changes in the controlling land agents or the context in which they operate affect land use and, ultimately, land cover.

It is important to recognise that many land-use/land-cover change pathways exist and are differentiated globally and over time. The study of LUCC focuses much of its effort and emphasis on understanding the specific conditions and controls - both biophysical and social - which determine these pathways.

5. RESPONSE TO A LUCC DATA REQUIREMENTS QUESTIONNAIRE
A pre-meeting activity for survey of needs, gaps and priorities

Ichtiaque Rasool

The LUCC Project Office sent out a questionnaire to scientists involved in LUCC related activities asking them questions which are paraphrased below:
- What research, in the domain of LUCC, are you doing?
- What data do you need for your research?
- Are there any "data gaps" which are impeding your research? If yes, are these gaps due to data being non-existent or just not available to you?
- What are the limitations of the existing data which you perceive? Are they not compatible with your requirements or are they difficult to obtain.
- Finally, what are your highest priority data needs for LUCC research?

The questionnaire was sent out to about 300 scientists. Although only 26 responses were received, they did provide useful insights into several common problems the LUCC research community is facing in the area of data accessibility. The responses received were mostly from Europe.

The responding LUCC scientists can be divided into three groups the largest one being made up of those who are working on local and regional Land Use. Several respondees are involved in continental scale pan-European efforts and a few who are assembling data to analyse the land cover change over the last 200 years by studying pollen and spores, lake level, etc.

There was also an offer to share data with the LUCC community from another IGBP core project viz GCTE (the push for Synthesis in IGBP seems to be working!).

Local and regional research

Data requirements of this group can be summarized as below:
- spatially disagregated socio-economic data,
- high-resolution soils data bases,
- topography at very high spatial resolution (~10 m) for the regions of study,
- "biodiversity" related data bases,
- temporal cadastral data,
- high resolution satellite imagery (10-30 m),
- "accurate" thematic maps.

This community of scientists had strikingly similar reasons why they were enable to acquire and assemble these data:

- data they needed were spread across MANY different agencies, ministries and institutions,
- space-imagery was much too costly,
- in some cases data was not accessible to non-government researchers,
- too many GIS(s) in use,
- lack of meta-data,
- often no documentation of quality check on data,
- time series of data with too many gaps,
- a common problem in a number institutions of the developing world where the infrastructure to use space-imagery for LUCC research is slow in coming.

Pan-European efforts

Here we got a mix of responses most of them on:

- incompatibility of data formats and information system across the national boundaries (one response identified similar incompatibilities even within the boundary of one country!),
- non-availability of SYSTEMATIC land-use statistics,
- large abundance of land classification systems,
- one response from a person involved in a major E.U. activity (TERI) on European scale, identified major gap in information on abandoned arable land e.g. why abandoned, the nature of soil and data on policy change leading to abandonment.

Respondees from the PALEO community were concerned that although they now have improved methodologies to perform an analysis of 200-year history of land-use in a number of regions, consistent data on certain parameters is not being gathered. For example the science of palynology, Pb-210 dating, lake and reservoir sediment analysis can collectively be applied to document change in environment and in land-use over the last several centuries. It is not happening.

Conclusions

Many of the issues raised in these responses to the questionnaire have been with us since man started mapping the land on a large scale. The sources of data are as heterogeneous as the land itself and the issues obviously get more complex when we cross the national boundaries. So the problems will not go away anytime soon. However we can surely begin to tackle some of the more "doable" ones by joining the efforts of LUCC and DIS. It seems to me that we are ready to do the following:

- provide, via internet and www, listings of all data-holders of LUCC-type data to LUCC researchers,
- through the efforts of DIS and the good intentions of the Space Agencies, the cost of high-resolution satellite images for IGBP researchers has been reduced considerably. LUCC researchers should start to benefit from this offer now!
- in some regious (e.g. Europe) we can already start organizing workshops to determine how to reduce incompatibilities in data formats, GISs, data quality control methodologies, etc. Later such efforts can be extended to other geographical contexts where similar problems exist.

Finally, an after-thought. We all receive questionnaires about data, etc. but how many of us do really answer. In my experience, you only answer when you are really hurting. So should I conclude that only 10% of LUCC researchers are really "hurting" for data and that 90% of the recipients of the questionnaire have NO data problems? On the other hand it could be that some of those who did not answer were either lazy or too busy running around from one meeting to the other. Something else to think about.

6. REPORTS ON BREAK-OUT SESSIONS I. SCIENCE DATA NEEDS, GAPS AND PRIORITIES

A first round of working sessions focused on the survey of general data needs, gaps and priorities for integrated LUCC modelling (Chapter 6.1) and regional research (Chapters 6.2, 6.3 and 6.4). The modelling report raises a complete range of issues and data sets and the regional reports describe different data requirements according to the specific socio-economic and biophysical realities as well as priority research fields.

6.1 INTEGRATED MODELS

Günther Fischer and Chris Justice

Introductory discussion
The working group divided its discussion of data requirements into four areas:
1) science/policy drivers,
2) model types for studying land use and cover change,
3) data requirements, and
4) model validation.

Given the limited time for discussion the group focused on making generic observations concerning the data needs for integrated modeling. It was clearly recognized that assembly of LUCC data has to evolve from regional activities and that a more detailed elaboration would need to rely on regional data requirements working groups to discuss region specific science and policy drivers. At the end of the breakout session it was therefore clear that the working group could establish only a preliminary identification of data needs and that further development of specifications and strategies for the data compilation will need to be developed by the regional LUCC modeling communities.

The group discussed examples of the kinds of science and policy questions which LUCC integrated modeling activities need to address, examples of various processes of land use and cover change, and the kinds of socioeconomic and biophysical linkages that need to be considered in LUCC modeling activities.

Integrated LUCC studies are aimed at addressing issues of societal relevance such as:
– spatially balanced socioeconomic development,
– food security and sustainability of food production,
– land degradation processes and maintenance of land productivity,
– freshwater resource management,
– efficiency of resource and space use,
– urbanization/infrastructure development,
– adaptation/mitigation of global climate change,
– global change impacts on land,
– policy impacts on land.

The integrated models often need to incorporate a range of factors that result in land-use and land-cover change, such as:

– domestic and external demand for crop, livestock, and fisheries products,
– demand for other land-based products and amenities,
– population dynamics and lifestyle changes,
– rural-urban interactions,
– macro-economic drivers,
– national policy measures,
– external drivers (‘globalization’, trade regimes, international agreements).

Integrated LUCC studies should take a broad look at different aspects of resource use (land, water, biological resources) including sustainability, economic efficiency, equity among regions and generations, robustness/resilience. Integration involves two kinds of activities: embedding of process understanding from fine-scale studies in the coarser scale regional analysis, and formal linking of multiple processes. Integration is not targeted to a single scale but should be achieved at least at three levels: the land management level, the level of watershed or eco-zone, and the regional/national/global levels.

Models and integrative approaches can be characterized from various angles. The following approaches to integration were identified:
– Integrated Assessment Models (e.g., EMF models) combining a number of relevant relationships within an economic model. In this approach, the details of representing biophysical processes and geographical heterogeneity are usually severely simplified.
– Integrated simulation models interfacing a number of critical processes (e.g., the IMAGE2 model), applying a bottom-up approach with a fair amount of spatial detail.
– Integrating frameworks assembling a hierarchy of models with the aim of translating and embedding fine-scale information and process understanding for use in the coarser scale regional assessment models (e.g., IIASA-LUC modeling approach).

Four broad groups of models were distinguished when categorizing according to methodological criteria: models based on systems of differential equations, process models following the systems dynamics approach, statistical and econometric models, and various kinds of optimization models.

Data needs

Having discussed model types and approaches the group moved on to identifying the primary data needs for integrated modeling. Data needs for integrated LUCC analysis are demanding, including data sets from four domains:
– Land use and land cover
– Environmental:
  • climate
  • topographic data
  • soils
  • land degradation
  • water resources
  • pollution
– Economic:
  • production structure
  • input use
  • prices, subsidies, taxes
  • commodity accounts
  • infrastructure

– Societal:
  - population census
  - demographic change
  - labor force
  - health
  - institutions

It was recognized that in particular the compilation of economic and societal data sets will require specific regional efforts to access the available data and to resolve problems of spatial coverage and temporal consistency, as well as to reduce institutional obstacles. The group stressed that the data requirements for integrated modeling are multi-scale ranging from regional to local. The following discussion focussed on the regional scale data sets:

Climate data

There was general agreement amongst the group that climate data are critical for integrated modeling. A distinction was made between the general availability of data from historical and more recent times. The requirements for these two data types are the same, however availability dictates what can be done.

– Historical data. It was noted that an initiative is underway by the University of East Anglia to develop a 1900-1990's half-degree, monthly climate data set. If completed and made available this initiative would help meet the community modeling needs for historic data.
– Last 10-15 years and future. It was recognized that there is a need to make available daily meteorological data but that decadal data (and statistics such as number of rain-days, etc.) could be used if daily data were unavailable.

Primary climate data needs were identified as:
– precipitation
– temperature (min./max.)

Secondary data needs were identified as:
– relative humidity (or vapor pressure deficit)
– % sunshine (or sunshine duration)
– wind speed/direction

It was agreed that daily meteorological station data should be compiled to provide regional data sets, and these should be made available on CD for easy access (e.g. a demonstration product of daily station data has been produced from the NOAA Southern Africa Climate Data base). The science community is concerned that the trend towards commercialization of climate data will severely limit the access to these data for the science community.

At the regional scale there is a need for continuous spatial fields of climate data. Various techniques exist for developing spatial fields from point climate data. The more sophisticated techniques incorporate digital elevation data in the extrapolation. It was suggested that such modeling tools should be applied to the basic climate data (i.e., reference spatial fields of climate data be generated) as well as the tools be provided with the data for custom application.

Soils data

Soils data sets suitable for integrated modeling need to be developed for the various LUCC regions. The group recognized the impending availability of the IGBP DIS Global Soil (5 minute) product. This will provide improvements over the existing data availability. However, it was recommended that an inventory of data availability for each of the LUCC regions should be undertaken to identify critical data gaps. This would include a compilation of national pedon data and soil maps. An evaluation of the FAO-UNESCO Soil Map of the World should also be undertaken to establish its limitations for 'regional' use. It was suggested that in some cases advocacy might be needed for new primary data collection to fill critical gaps in regional data availability although the lead time to a product is probably prohibitive. An alternative method may be to infer soil characteristics from using topographic, geologic and vegetation inputs. It was stressed that adequate information on soil characteristics and dynamics is largely unavailable.

Digital elevation data

The group felt that the 1 km GLOBE Digital Terrain data is currently adequate for regional integrated modeling needs, with an understanding that new improved satellite derived data sets are planned prior to 2001. It was recommended that efforts should be made for encouraging the data providers to give priority to areas where the current 1km is weak, e.g., areas without DTED coverage and for LUCC regional focus areas with terrain complexity or where subtle terrain differences may greatly influence land-use patterns, such as in flood plains.

Land cover and land cover change data

The group recognized that the IGBP 1 km Global Land Cover Product could be used for integrated assessment modeling. However, there is a need for validation at regional level and to improve both agricultural and urban classes by using multiyear data, high resolution data or data from other sensing systems such as the DMSP. It may also be possible to augment the IGBP 1 km land cover stratification with statistical data reported by administrative unit. This could provide such information as, for instance, average yields within a reporting area. The group felt that in addition to land cover classes that it was important to promote the creation of continuous fields of remotely sensed variables, such as % tree or grass cover to enhance the availability of information on quality aspects of land cover. In some cases, in particular for national to local scale studies, recent national land cover maps can provide improved spatial resolution over the IGBP 1 km product.

Integration of actual land cover changes in the models requires the availability of regional scale data. It was recognized that high resolution satellite time series data provide an important source of data for spatial land cover changes occurring over the last 20 years. It was recommended that a spatially explicit data base derived from the twenty year, high resolution satellite record be developed for each of the LUCC regions such as provided by NASA and INPE for the Amazon Basin. It was recognized that complete high resolution coverage would be needed every 3-5 years for LUCC regions, with higher frequency for areas of rapid change.

To push the land cover data record back beyond the twenty-year satellite record, it is possible to use historical aerial photography from the 1930's to 1960's. The group noted that the archives for historical aerial photography are generally poorly maintained and in some cases there is a danger of valuable sources of information on land cover and land use being lost. The group also noted the considerable amount of effort that would be needed to secure and preserve these archives.

The modeling group recognized the emerging initiative from LUCC and IGBP DIS on developing a global database of 200 year land cover.

Socioeconomic data

The group discussed the current status of the primary types of socioeconomic data sets needed for integrated modeling:

– Population/demography:
  - spatial distribution (GIS-based)
  - consolidated administrative units (5-10 yr census)
  - definitions harmonized between countries or states
  - age/sex/migration
  - status/employment/income (e.g., rural, urban; share in agriculture, forestry, etc.)
  - health

The requirements for demographic data include a spatially explicit (GIS based) data set for the LUCC regions. This would most likely consist of population by (third level) administrative unit taken from 5-10 year census data. It was recognized that the practice of frequent administrative changes in the past needs to be addressed in the construction of socioeconomic data sets.

– Prices:
  - farm-gate and retail prices of commodities
  - prices of inputs
  - land prices
  - cost of labor, machinery, energy, etc.

– Farm structure and practices (management):
  - size of farms/households
  - household income
  - subsistence and marketed production
  - cost of production
  - operational sequences/timing/rotations in land management
  - use level and kind of inputs, labor, machinery, energy
  - livestock
  - use of water
  - genetic information
  - pests & diseases
  - fire management

– Production (spatially disaggregated):
  - yields and production
  - number of crops per year
  - areas sown/harvested
  - areas cultivated

– Infrastructure:
  - time/distance to markets
  - trafficability (seasonality)
  - roads and rail systems
  - rivers
  - cost of transport

N.B. In general the socioeconomic data should be geo-referenced but in some cases may need to be generalized. However wherever spatial data sets are generated from point data, the input point-based survey data should also be provided.

In addition, building economic models for LUCC requires complete financial and physical commodity accounts (supply/utilization accounts including production, final consumption, intermediate demand, feed consumption, trade, etc.) and I/O tables at sub-national level.

Validation data needs

It was recommended that a LUCC validation network be considered. The requirements for such a network would be to generate and maintain a data base of point and survey data to provide:

- a reality check of integrated model output and model behavior,
- the basis for an independent inter-model comparison,
- a basis for evaluating uncertainty,
- a basis for validating spatial extrapolation from point data,
- a means to calibrate and validate scaling-up methods.

The model validation activity could provide a means by which regional LUCC scientists working at the local level could become involved in the regional integrated modeling. The suggested approach was to develop a series of validation case studies for smaller areas within the LUCC regions.

Data availability

The availability of suitable and comprehensive data is currently a major constraint for LUCC integrated modeling. A concerted initiative to compile the basic data sets for each of the LUCC regions is highly desirable.

Two types of data compilations can be envisioned:

- There is an immediate need to facilitate access to existing regional general 'background' data for LUCC modeling. The LUCC Miombo CD provides an example of a 'background' data compilation, which is a compendium of existing spatial and point data and meta-data sets needed for LUCC studies in the Central/Southern Africa Region.
- As the international science community moves towards model inter-comparison and regional assessments there is a need to develop 'community consensus' or 'standard' data sets. It is envisioned that these will be specific 'data bundles' providing consensus data sets, generated specifically for the purpose of regional integrated modeling. Such data sets would be a LUCC equivalent of the ISLSCP CD which was generated for global SVAT model application. It was suggested that a pilot data initiative be developed to generate a regional sample data bundle for LUCC modeling. Such bundles may in future also include simplified versions of models to enable the community to reproduce integrated assessment results.

6.2 REGIONAL: ASIA

Lisa Graumlich

The charge to this breakout group was to define science data needs, gaps and priorities for LUCC studies in Asia. The group members' strength is in South Asia (with exception of Larry Crissman whose research encompasses demography and settlement patterns in China). The comments below thus reflect issues most relevant to South Asian studies. We recognize that the science plans for the IIASA-LUC project in Eurasia and the LUTEA project (TEACOM) should provide further insights into data requirements for the continent of Asia. This report addresses three questions:

– What are the most important LUCC research questions in a South Asian context?
– How might data requirements for diverse science programs be organized into a common framework?
– What are those variables that are critical to research on LUCC in South Asia that have not been identified or emphasized in previous workshop presentations and discussions?

LUCC research in South Asia

South Asia is characterized by dramatically different ecosystems:
– coastal zones where urbanization and increased coastal aquaculture have altered water resources, sediment transport, and mangrove forest cover,
– the intensely cultivated Indo Gangetic Plains which serves as the breadbasket of India,
– the mountains of the Western Ghats and the Himalaya where forest loss is accompanied by declines in critical fuel, fodder, and timber resources as well as declines in diversity of species and landscapes.

Each of these three broad classes of land use/cover systems are characterized by different critical research questions. The coastal zone of India, Bangladesh and Pakistan supports a population of over 170 million people as well as being home to 16 different parks and biosphere reserves. In the coastal zones, key LUCC changes are driven increasingly by urbanization and growing national and global markets for fish and seafood grown in aquaculture systems. A land cover consequence of these factors is the loss of mangrove forests with consequent changes in coastal sediment erosion and deposition and hydrologic regimes. The extent and timing of the loss of mangrove forests has been extensively documented by R. Krishnamoorthy and his colleagues using remotely sensed data. A key limitation to understanding the dynamics of change in the coastal systems is the availability of spatially referenced socio-economic data for the coastal zone and adjacent watersheds (see Krishnamoorthy's abstract).

The Indo Gangetic Plains are well endowed with deep soils and climatic conditions favorable for growing two or more crops per year. As such, the Indo Gangetic Plains are critical to the food security of the region. For example, rice and wheat grown in the Indo Gangetic Plains contribute approximately 70% of the caloric input for the countries of Bangladesh, India, Nepal and Pakistan (I. P. Abrol's abstract). The agricultural productivity of this region has steadily increased over the last several decades with improvements in irrigation, and increasing use of fertilizers, pesticides, and high yielding crop varieties. Recent evidence suggests that agricultural yields are no longer being sustained and that, in some of the most intensely cultivated zones, yields have started to decline due to salinization, ground water depletion and loss of soil fertility. The Indo Gangetic Plain is relatively rich in data documenting agricultural inputs and outputs, and thus the most pressing data-related requirements is enhanced capabilities in modeling processes at micro to regional scales (Y. Abrol, personal communication) in order to optimize land use.

In contrast to the largely agricultural lowlands of South Asia, the highlands regions, including the Himalaya and Western Ghat Mountains, contain a diversity of land uses/covers including tropical evergreen forests, temperate deciduous forests, subalpine coniferous forests, shifting cultivation, terraced field systems, plantations and pastureland. The diversity of land uses/covers parallel a remarkable level of biodiversity: the Western Ghats and East Himalaya are classified as two of the 80 most important concentrations of biodiversity in the world. The most important changes in the mountains of South Asia are changes in forest cover, including conversion as well as modification of structure and species composition. The most critical data requirements for mountain regions center on documenting the spatial and temporal patterns of forest cover change and developing relevant socioeconomic data on drivers at household to regional scales.

A framework for organizing data requirements

Given the diversity of LUCC dynamics in South Asia, it is inappropriate to identify a limited number of priority data sets that would serve the needs of regional researchers. Rather, we identified a common framework for organizing data streams that is relevant to conceptualizing LUCC in South Asia. The factors listed in the framework diagram are exemplary rather than exhaustive.

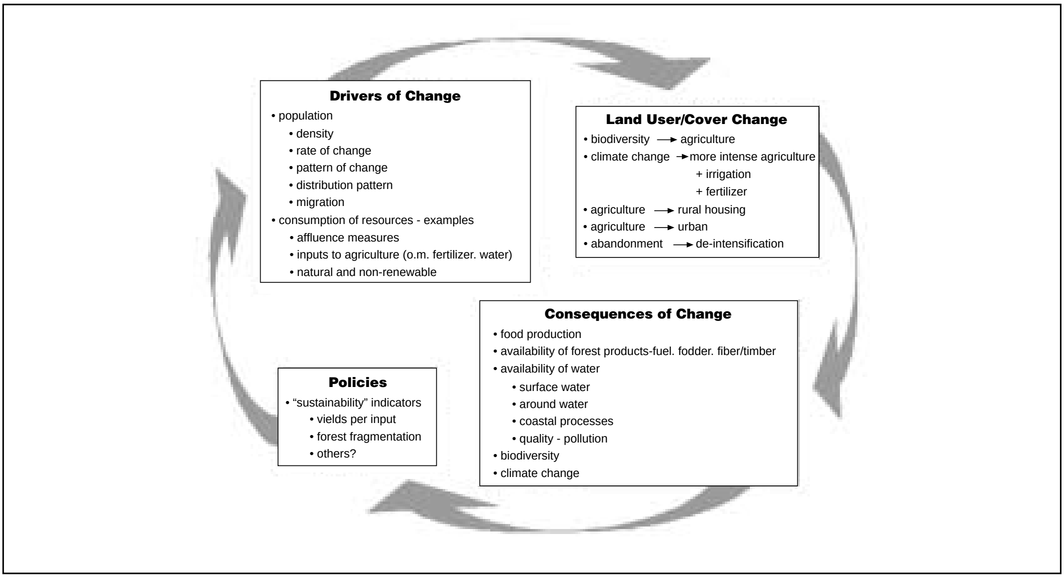
The diagram shows the cyclical connection between the Drivers of Change, which affect the Land Use/Cover Change, which affect the Consequences of Change, which affect the Policies, which in turn affect the Drivers of Change, and so on.

LUCC data needs in context of South Asia

The breakout group recognized that various presentations as well as other breakout groups were making good progress in identifying general data needs of the community. We focused on identifying variables important to understanding LUCC in South Asia that were not emphasized in previous discussion. These variables include:

Variables/Indicators not previously emphasized. Important in Asia.

- Drivers:
  - population dynamics
  - energy consumption/transport tech and infrastructure
  - organic vs. inorganic inputs into agriculture
  - female literacy
  - tourism
  - commercialization of agriculture
  - percent of energy needs met from forest or agriculture products
- Changes in LUCC:
  - historical and contemporary agriculture data - published statistics (disaggregated, low level administrative districts)



Components for the identification of priority datasets in South Asia.

- paleoecological data (tree rings, pollen, historical, etc.)
  - changes in forest structure and species composition (e.g., forest degradation)
  - rates and patterns of abandonment of marginal agricultural land and conversion to woody and/or exotic species
  - rates and pattern of fallow land
- Consequences of change:
  - biodiversity - molecule to landscape
  - change in species numbers and distribution
  - fragmentation

6.3 REGIONAL: LATIN AMERICA AND AFRICA

Jeremy Cain

The group began by identifying LUCC themes which were of particular importance in the work of each of the group members

General themes

- Causes, patterns and rates of land use and cover change
- Drivers of land use and cover change
- Impacts of land use and cover change

Regionally specific themes

- Miombo
  - Landscape fragmentation effects on biodiversity
- Kalahari
  - Biomass burning
  - Rainfall as a driver
- Central America
  - Mangrove function (both bio-physical and socio-economic)
  - Expansion of agricultural frontier in response to global markets
  - Mountain watershed function (as hydropower is important on the region)
  - Conservation of biodiversity
  - Land use fragmentation as important as deforestation
- East Africa
  - Soil erosion
  - Population density and movement
  - Fire
  - Urbanisation
  - Pollution (land, air and water)
- LBA - Brazil
  - Deforestation
  - Land abandonment
  - Secondary growth
  - Impact of politics on land use

Having identified themes, the group proceeded to identify the data which were required to investigate and understand these themes. These data were split into biophysical and socio-economic groups. As all group members were biophysical scientists, it should be expected that this bias is reflected in the tables below.

Biophysical data and variables

Data	Data access	Issues
Active fires	Good	
Burnt areas	Good	
Meteorological data	Needs improvement	Need daily data; Restricted access to data; Higher spatial resolutions required.
Soil types and attributes	Needs improvement	Higher spatial resolution required; Improved quality control; Need transfer functions.
Land cover attributes	Good	
Land use	Needs improvement	Consistency of legend required; Improved accuracy; Higher spatial resolution.
Surface hydrology	Needs improvement	Consistency of measurement required; Restricted access to data.
Topography	Good	
Soil erosion rates (wind and water)	Poor	Use a land quality indicator as a short term proxy while investing in new and accurate measurement techniques for the future.
Biodiversity	Poor	Standardisation required; Data must be spatially explicit (both horizontally and vertically).
Trace gas emissions	Needs improvement	Soil, plant and livestock emission rates needed; Measurements from all plant functional types.

Socio-economic data

As a general comment, the group considered that for socio-economic data, smaller scale data is of greater relative importance when compared to biophysical data.

Data	Spatial scale			
Food and energy consumption	Household	District	National	Global
Income and savings	Household			
Social cohesion	Household			
Farming techniques	Household			
Attitudes to risk	Household		National	

Data	Spatial scale			
Attitudes to the environment	Household	District	National	
Employment opportunities		District	National	
Literacy and education	Household	District	National	
Gender rules	Household			
Resource access and use	Household	District		
Prices (inputs and outputs)		District	National	Global
Markets		District	National	Global
Fertility rates	Household	District	National	
Migration	Household	District	National	
Land tenure and ownership	Household			
Communication		District	National	
Technology	Household	District	National	Global
Urbanisation		District	National	
Trade	Household	District	National	Global
Population indicators	Household	District	National	Global
Health	Household	District	National	
Pests and diseases		District	National	Global

Data access:

- *Global* data are reasonably available.
- *National* data are available with doubtful accuracy and in difficult formats.
- *District* and *Household* data require case by case surveys. This will require a huge investment.

Issues: Some variables are qualitative and highly dynamic. This constitutes a *Major Bottleneck* to LUCC research.

Issues of interest

Throughout the course of the discussions, a number of related issues of interest came up. These are noted below:

1. *Research is needed to investigate how LUCC processes scale* from household to district to national to global scales. In addition we need to understand how the consideration of different time scales effects our data collection activities and modelling efforts. This should be done so that we know at what resolution data is required for various research applications (e.g. modelling studies).
2. *Data rescue.* Much data, particularly in southern Africa is in danger of being lost - it is often only held as a hard copy. This is especially true of aerial photographs. This effort will require significant funding.
3. *Data should be collected in conjunction with estimates of uncertainty.* No measurement technique is perfect and values representing large areas are only averages over that area (the same is true temporally). An understanding of the uncertainties in these data is essential to support realistic modelling and decision making.
4. *Spatial sampling methods need to be designed to account for heterogeneity.* This is another scale issue (as are 1 and 3 above). To do this we need to understand how the spatial and temporal variation in the data in which we are interested effects our research objectives. **Basic research needs to be done to guide and underpin data collection.**

5. *Prioritising and ranking research and data requirements does not make sense* - we are interested in the interactions and processes. Therefore, **we need all data for a few regions NOT some data for all regions** (such as a global map of agricultural zones - this is not needed). Such holistic data sets will help guide the basic research referred to in 4, above.
6. We need to think about how data can be converted into *information for use by policy makers*. What do policy makers want and need? This consideration must guide our research and data collection programmes.
7. Data collection is a continuous process - *monitoring is essential.* Again, research is required to identify the best ways of doing this. Specifically, we need to find the best ways of selecting key indicators and standardising measurement of these indicators. Assessing the spatial and temporal frequencies at which these indicators should be measured.

6.4 REGIONAL: EUROPE

Stefan Weiers

Objectives

The task of the break out session was to define baseline data requirements for LUCC research done in Europe on various scales, to identify data gaps according to the research experience of the participants and to derive agreed suggestions for a strategy in order to improve the data quality, availability and exchange.

Part 1. Open discussion

After mutual introduction of the participants the group was invited to give individual statements on major data problems. Already the introduction revealed a high heterogeneity of research fields and individual interests among the participants leading to some initial problems of differing definition backgrounds but also assuring a certain degree of representativeness (not in statistical terms).

Although the participants were fully aware of the interdependency between research objectives and data production/availability it was agreed to follow a pragmatic approach allocating more attention to specification of data needs rather than a (re)definition of principal research objectives. Apart from the specific demands of the individual disciplines some common problems were identified: Total area coverage data for Europe (like CORINE land cover) are of increasing importance as there are commonly available and providing a good overview baseline information. But they cannot comply with all demands of regional variations and specific disciplinary approaches. They are also exposed to increasing budgetary pressure and thus justification through application in regional and national political/administrative decision making. The need of a complementary concept for area coverage data production and a supporting sampling methodology using highly specific data was stressed.

Land use and land cover data are either used for predictive modelling or spatialization of certain parameters. Future activities should be aware of the usefulness for both approaches. The importance of 'historical' scientific map data that can be georeferenced was emphasized in order to document changes.

Fundamental differences in availability, scale, handling etc. of biophysical and socio economic data were outlined as the first are normally related to natural and the later to administrative units. A need for the coordination between field data gathering and archiving and map data production was stressed. Most of the participants had been faced with major problems of data availability in terms of standards, ownership, quality and scale. Data exchange is often inhibited by very individual standards as it is practised in research projects. The role of European agencies like EUROSTAT in standardization efforts was appreciated.

Many research activities in LUCC are related to the individual farm household level and thus disaggreagation techniques of socio economic data are required. There is strong need to investigate the impact of Europe wide political decisions especially in agricultural policy on the local farm level, that is actually the driving force for biophysical changes in rural landscapes. Equivalent driving forces are to be identified for change processes in (sub)urban landscapes. In the biophysical sector the need to derive model parameters from existing biophysical maps was stressed (e.g. hydrological properties from soils or vegetation features).

For further progress it was agreed to establish a list of thematic data layers on 3 major scales.

Part 2 a. Priority list of major data sets

The participants were requested to specify their major thematic data sets required for their research work. Three principal scale categories were defined:

a) local - ranging from the individual farm level to the size of an individual township, county or tributary catchment area, approximately 1:5.000 to 1:100.000.

b) regional - ranging from a region/province/federal state or major catchment area to a nationwide scope, approximately 1:100.000 to 1:2.000.000.

c) European - encompassing at least 2 entire countries or a major physical geographic unit like the Mediterranean.

The participants were invited to give a statement on the actual use of the thematic data on the defined scale categories. Multiple numerations were admitted.

The results are presented below:

Rank	Topic/Theme	Total	Local	Regional	European
1	land cover[1]	11	6	10	2
2	topography	10	9	8	1
3	climate	10	6	9	1
4	management practices	9	8	7	2
5	soils	8	7	5	2
6	vegetation/biodiversity	7	6	5	1
7	hydrology	6	6	3	1
8	performance/production	6	6	6	3
9	economic activity	5	*	*	*
10	attitudes/perception	4	3	4	1
11	demography/population	4	3	2	1
12	legal status/planning	4	2	2	2
13	geology	3	3	1	0

1. Land use was not listed explicitly, as it was considered as an integrated category comprising layers 1, 4, 6 etc.
* not specified

Part 2 b. Synthesis discussion

The following deficiencies concerning data availability and management were stated:

"Hard gaps" are related to specific data layers as listed above:

- A remarkable lack of soil data including reprensentative profile data and derived physico-chemical parameters was stated by nearly all participants.
- Access to hydrological (field) data was seen as a major impediment for research in the biophysical sector.
- Disaggregated data on land management practices are needed for many regional studies.
- For all stated categories long term time serieses are to be compiled.

"Soft gaps" were defined as deficiencies concerning data management, integration and harmonisation:

- An agreed framework for the integration of data from different sources, scales and thematic areas is still missing.
- Techniques for the disaggregation of data e.g. from statistical sources based on administrative units are still to be developed.
- There is still methodological work required to develop and test parameters and indicators as proxies for the state of the environment.
- Concepts for the harmonisation (not standardisation) of data should be elaborated.
- Numerous restrictions of data release in terms of legal impediments, ownership rights, pricing policy and others are still to be overcome.
- There are no common and agreed standards and methods of quality assurance and approval of LUCC related data sets.
- In spite of many emerging meta information systems there are still deficiencies concerning problem and user orientation in this sector.

General conclusions and recommendations

- Since most of the relevant research is carried out on the local and regional level a strategy for the European continent should follow a bottom up approach.
- More attention should be paid on the complementarity of work on the local and European scale (bidirectional approach).
- Data policy should focus on the improvement of data access and release.
- Deficiencies are more seen in data availability/access rather than existence.
- More efforts should be invested in the elaboration of data integration concepts.
- An appropriate balance between total area coverage data production and a sampling strategy based on detailed local investigations has to be found.
- The discussion process between the communities in the biophysical and the socio economic sector should be enforced in order to clarify still existing definition problems.

7. REPORTS ON BREAK-OUT SESSIONS II. EMERGING CROSS-CUTTING THEMES

The second round working sessions dealt with some important emerging cross-cutting themes relevant to LUCC and vice versa: biodiversity, indicators, sustainability and historical land use. The reports outline research challenges and data needs to develop integrated studies of these key themes in relation with land-use/land-cover changes (Chapters 7.1, 7.2, 7.3 and 7.4).

7.1 BIODIVERSITY

Helena Freitas

Biodiversity includes the variety of species of plants, animals and other organisms and also the genes they contain and the communities and ecosystems of which they form part. Patterns of biodiversity form a nested hierarchy, with genotypic variability being the basis upon which diversity at the population, species, assemblage and ecosystem levels is built. Biodiversity can be considered to include not only the compositional aspects at each hierarchical level, but also structural and functional aspects.

Conservation and use

Fragmentation, grazing, forestry, and nutrient deposition are decreasing the biological diversity of many of the earth's remaining natural and semi-natural ecosystems. Of great concern is the rate at which this biodiversity loss is occurring all over the world, in particular in regions where the richest biota are located (e.g. tropical forests). In these regions biodiversity is an important economical resource, and species often have different cultural and symbolic meanings, thus becoming also sociologically relevant.

Biodiversity studies should be strongly encouraged, in particular in those regions of the world where biota are extremely rich and the lack of knowledge is immense.

Ecosystem stability and functioning

Decreasing diversity may lead to decreased ecological stability and functioning. Ecosystem functioning refers to the capacity of an ecosystem to carry out the primary ecosystem processes of capturing, storing and transferring energy, carbon dioxide, nutrients and water.

It will not be feasible to develop models for every ecosystem of the globe nor represent every species within these ecosystems. It is currently admitted that the essential dynamics of ecosystems can be captured by grouping species into a limited number of functional types.

Studies on the effects of diversity loss on ecosystems productivity, stability and functioning are needed and should be supported worldwide, in different ecosystems and considering global environmental changes.

Fragmentation and invasability

Topographic diversity and multiple land-use patterns are leading to habitat patchiness and change of vegetation structure and composition, causing species extinction and loss of natural habitats, favouring the increase of invasive species. The switch of native species to exotic species, frequently invasives, is being seriously enhanced by landscape fragmentation due to demographic pressure, road construction, fire and nutrient deposition.

The effects of landscape fragmentation on natural habitats and native species loss should be assessed and monitored all over the world.

A general survey of exotic species number and distribution as well as the augment of invasive species and their impact on natural and agro-ecosystems is essential and should also be supported.

7.2 INDICATORS

Helen Briassoulis

General problem context and related considerations

Indicators of land use and cover change (LUCCI) are needed to serve as expressions of trends in the state of the environment and land use and, hence, contribute to assessments of environmental change at various spatial scales. Such indicators will be based on monitoring and measurement of selected variables or indices related to land use and environmental change. Data requirements for assessing LUCCIs, then, follow by considering the scheme below:

DATA → MONITORING → INDICATORS (LUCCI) → ASSESSMENTS

LUCCIs may be distinguished according to the functions they are expected to serve into: *a)* indicators of the spatial and temporal characteristics of LUCC - where and when land use change occurs and *b)* indicators of the quality of land use change.

A broad approach to the development of LUCCIs is provided by World Bank's PSR (Pressure - State - Response) approach. This has been employed to the development of Land Quality Indicators (LQI).The working group indicated that a fourth item is introduced, namely, Impact (i.e. measures of *change* in land use and environmental conditions). Hence, the modified approach PSIR - Pressure - State - Impact - Response. In this respect, it is considered useful to take into account the LQI and similar programs in developing LUCCIs.

To serve the purposes of broad (e.g. cross-country) comparisons as well as of finer regional or local scale assessments and decision/policy making, the basic structure of a system of LUCCIs should comprise: *a)* core indicators - operating at global (up to national perhaps) scales, *b)* regional or ecosystem response indicators - related to particular types of regional environmental systems, *c)* local or issue-based indicators - reflecting particular land use and environmental change concerns.

The development of operational LUCCIs should be guided by the intended use of the indicators (e.g. the particular context and user/decision maker questions) as well as on the available methods and techniques to be employed to this purpose. Therefore, the determination of the required data sets should follow the determination and clarification of the above issues. It is considered premature to define explicitly the required data sets before identifying the desirable forms and types of LUCCIs and the related estimation/assessment methods and techniques.

Required R&D efforts

The principal research directions which draw from the above considerations are:

a) Basic research in LUCC on developing land use and cover change indicators by integrating currently measured variables. Existing LUCC regional and other projects (such as IMPEL) can be used in this connection.

b) Evaluation of the content and policy-relevance of key LUCC and LQ indicators (what they are telling us).
c) Development of an approach/method for validation of response indicators.
d) Application/use of spatio-temporal techniques to assist in the development/design of LUCCIs.

Indicative types of data

Categories of required data for LUCCI assessment relate to the main drivers of LUCC - demographic, socio-economic, environmental. Examples of variables representative of such sets of drivers are provided below distinguished into pressure and state indicators. Most of them draw on S. S. Sundarvel's contribution to the LUCC Data Requirements Workshop "Indicators and Data Requirements in LUCC Research: Status in India" (11-14 Nov. 1997, Barcelona).

– Pressure indicators:
  - Average annual population and population change (transient and permanent residents)
  - Percentage of urban population
  - Per capita land availability
  - Per capita arable land by category (cultivators, agricultural workers)
  - Per capita livestock population
  - Percentage of population under the poverty level
  - Tenure system
  - Size of agricultural holdings (min., max., avg.)
  - Per capita availability of credit
  - Per capita production and consumption of forest products
  - Family labour in agriculture
  - Food security - per capita calorific content of production and rate of change

– State indicators:
  - Slope (less than 5%)
  - Loss of topsoil (less than 5000 t/sq. km/yr)
  - Nutrient loss
  - Salinization (salt content less than 0.6%, pH: 6-8)
  - Acidification (pH not less than 6)
  - Waterlogging (depth of water table greater than 100 cm)
  - Land use conversion rate (deforestation, agricultural expansion, carrying capacity changes)
  - Biodiversity (no. of threatened species, species and genetic diversity, rarity, bioindicators)
  - Yield per hectare
  - Food consumption
  - Energy consumption
  - Accessibility/distance

7.3 SUSTAINABILITY

Vanda Perdigão and Jeremy Cain

Due to the reduced time available and the heterogeneity of the group, the discussion was kept general, focusing on the different aspects to be considered when defining data requirements for sustainability.

To be able to assess the data required to understand the sustainability of land use change it is necessary to define what we mean by the term. Many definitions have been presented and were discussed, although none were considered to be acceptable by all group members. The FAO definition was used as a basis for discussion. It originally consisted of five pillars: *i)* Productivity, *ii)* Security, *iii)* Viability, *iv)* Environmental protection and *v)* Acceptability. *vi)* Land use resilience and *vii)* Social equity have been recently added to the previously accepted five criteria or pillars of sustainable land management. Not all the group were able to agree on exactly what each of these terms meant, although it was felt by some that land use resilience was one of the most applicable indicator for LUCC science.

Sustainability is related to land management. Sustainable land management concerns all kind of land use, from all economic sectors. It should enhance the economic performance of land while maintaining the quality and environmental functions of the natural resources, also preserving the cultural aspect of landscapes. To have a sustainable land management, the contribution of actors from three levels is necessary: the direct unit of management (farmer or equivalent for other uses than agriculture), the regional and/or national planning and the policy development. The data required to decide about sustainable land management should meet the different needs of those three types of actors.

Specific data requirements are related to each of the various dimensions of sustainability, from local to regional and global. The group pointed out that, to pass from one scale to another is not only a question of detail or generalization. Significant factors at one scale can be irrelevant at a different scale.

The group agreed that, basically, the data requirements for sustainability are the same identified for a scientific approach to understand the land use and land cover changes. But the emphasis is placed on the requirements to answer the following questions:

- what can determine the resilience of a land use within specific physico-socio-economic conditions?
- what the quantification is for the levels of intensity and the limit to be considered sustainable at a certain period?
- what land use diversity means for each specific physico-socio-economic conditions?

Land use intensity, land use diversity and land cover are land quality indicators for sustainable land management. Other indicators such as land degradation need data on land cover.

Discussion revealed that sustainability meant different things in different regions. For example, in India, sustainability must mean economic growth. Issues which affected growth included:

- agro-ecosystem biodiversity,
- loss in soil fertility,
- increase in pests and diseases, and
- water induced land degradation.

This was causing food crop production to diminish while the population remained roughly static. This is clearly unsustainable.

It was suggested, however, that in the UK, sustainability might be more dependent on aesthetic judgements. If a land development scheme is proposed and the local people whom it will affect object to it then the scheme will be unsustainable as it will lack local support. In more affluent regions, such as the UK, these objections may well arise because aesthetic sensibilities have been offended. The group, therefore, provisionally suggested that sustainability may be highly subjective and that measuring it will require socio-economic data gathered at the community level.

To attain a sustainable land management is fundamental to understand the dynamics of land use and land cover changes, being the first step to assess those changes for relevant time periods. Data on land cover is available, the assessment of its changes have being done for certain zones (e.g. coastal zones-"LACOAST" European Project) and dates. A systematic inventory and characterization of land uses in Europe, its spatial and temporal distribution is still missing. Data to establish a topology and characterization of land use intensity and diversity at a certain moment and its driving forces are needed. Data that can relate the time dimension to each land use and its land cover, linked to a sustainable situation is very important.

Relevant socio-economic data to be used in the assessment of the impact of National as well as Regional policies on land use and land cover changes is needed. Most of this data exist, what is necessary is to translate it into the necessary information to be matched with the biophysical information.

It was also pointed out that prior to list the data requirements, conceptual models should still be agreed upon and worked out to integrate bio-physical, socio-cultural and economic information. The data requirements will be then easily defined. The use of contingent valuation as method of assessing how people value their environment was suggested as a way of quantifying sustainability.

7.4 HISTORICAL LAND USE

Frank Oldfield

The importance of studying long term records of land-use/land-cover change was acknowledged by the group. One major goal would be to document, by all available means, the history of land use and land cover change over the last 200 years. This is in accordance with the views expressed more widely at the IGBP Congress in 1996. The spatial cover would ideally be global, though regional disparities in data were recognised as a significant limitation for some parts of the world.

In order to achieve this initial goal, it will be necessary to generate a common commitment between interested groups in LUCC and PAGES, which, in turn, implies developing the initiative in ways that can generate mutual benefits to both communities.

As a first step, it was proposed to hold a small workshop (10-12 people) with, as its proposed title "Historical Dynamics of Land Use, AD 1800 to 1997".

The main aims of this would be to:

- define and start to establish a collaborative community willing and able to carry the initiative forward,
- identify and build on existing data sets,
- define and promote rationales for the initiative that would attract broad support and participation,
- establish guidelines for regional and methodological contributions and for harmonising these to create a global data set,
- resolve issues of spatial scale and temporal resolution,
- create classification schemes directly linked to LUCC activities and priorities, and

– address, as required, the question of data calibration with respect to fully documented land use/land cover categories at the present day and in the recent past.

The likely participants in such an initiative are quite diverse, as are the types of data they use and the insights they can provide. They include, for example, pollen analysts, historical geographers, environmental historians, dendro-ecologists and landscape ecologists. Harmonising the interests, skills and data output of such a disparate group is a non-trivial task.

The most practical product of the initiative would be a spatially referenced data base from which a series of time-slice maps, for example, could be generated at any stage and refined as the project progressed.

It was suggested that DIS, LUCC, PAGES, GAIM and GCTE were all potential participants from within IGBP and that the IGU Land Use/Land Cover Commission were possible partners from outside the IGBP.

The group also discussed less fully the need for longer term perspectives, especially in ecosystems like forests, where successional/competitive processes took place over longer periods of time. In such cases, biophysical feedbacks, species composition and ecosystem structure and function may change on relatively long time scales and a perspective from 200 to 1.000 years was considered desirable. Other issues like the importance of studies documenting non-reversible human impact on fragile ecosystems in the past, the need to include a well articulated historical dimension in regional case studies of special significance to LUCC and the value of exploring the impact of natural climate variability on land use and land cover were not fully discussed, but the impression gained from the meeting as a whole, was that they should form the basis for an ongoing interaction between interested groups in both PAGES and LUCC.

8. REPORTS ON BREAK-OUT SESSIONS III. MEETING THE COMMUNITY DATA NEEDS

The third round of the discussion aimed at identifying community data needs and monitoring needs. Two groups centered the discussion on common data needs when addressing the two main types of pattern/process analysis found in current studies: *1)* conversions of land cover and *2)* intensification of land use (Chapters 8.1 and 8.2). Finally a third group developed general recommendations for monitoring of land-use/land-cover change (Chapter 8.3).

8.1 LAND COVER DYNAMICS

Lisa Graumlich

The charge to this group in Breakout Session III was to define critical variables for regional studies where change in land cover dominates as a process. In the list that follows, very general recommendations for global data sets are followed by data sets more appropriate for local regionally focused studies.

Population
- Scales
  - state - country
  - district/province
- Frequency
  - ideal is 2 years
  - realistic is 10 years
- Amount, national growth rate, migration, age/sex structure

Land Management - amount and pace of change
- Cultivation
  - cereal/roots
  - fiber
  - shrub/tree
  - % market/subsistence
  - irrigated
  - paddy
  - inputs (organic, inorganic)
- Livestock
  - pasture-improved
  - fire regimes - grassland
  - % for market
  - livestock density
- Forest
  - logging, clearcut vs. selective
  - timber regime - commercial - replanting
  - forest use/biomass

– Preserves and parks
– Settlements, "paved"

Institutions of land/resource access
Land - private ownership, rent, usufruct, communal, state, non-governmental organization, private/state.
Water - private, state, communal.
Forest - state, non-governmental organization, communal.

Economy
Market price (commodity)
Measure of "functionality" market
% of informal or black market
Subsidies
Proximity/access to roads - distance to and density of
Proximity/access to markets - distance to local/regional and density of
Response to local, regional, national, international signals
% household income off-farm
State sponsored action to/on land
% of income from forest products including ecotourism

Soils
Fertility (C:N ratio)
Bulk density

Pilot projects - finer scale sampling

Land cover Landsat TM, 5 year, baseline
Shifting cultivation and/or multiple cropping systems - multiple scenes per year
TM data, 5 year intervals

Pilot projects - interannual and intraannual variability in shifting cultivation

Fragmentation - landscape structure
Number and patterns of exotic/invasive species
Topology of landscape, size, matrix, shape, degree of isolation
Temporal and spatial of species
Landscape structure - derived from cover data

Pilot projects - include species number and distribution

Climate
Daily minimum and maximum temperatures
Daily precipitation

Pilot projects - tools to estimate climate at fine scales, slope, aspect, elevation, etc.

8.2 LAND USE AND COVER INTENSIFICATION

Günther Fischer

Introductory discussion

The main purpose of the afternoon breakout group II was to follow up on the deliberations of the earlier breakout groups and to use the very limited time available (about 1 hour) to discuss in more concrete terms the data requirements for describing and modeling land use/cover intensification processes. These have been taking place in all geographic regions as a result of human activity and intervention.

The group started from the observation that land use/cover intensification processes were difficult to capture due to their subtle and gradual nature. The IGBP-IHDP LUCC Science Plan distinguishes two types of land use/cover changes: land use/cover conversions, i.e. very distinct changes in land use from one broad category to another (e.g., from farmland to urban use), and land use/cover modifications denoting changes within a broad land use category (e.g., from natural pastures to improved/sown pastures). The group concluded that the discussion should follow these distinctions though most of the debate concentrated on the aspects of land use/cover modifications.

Intensification across major land use categories

Intensification processes resulting in land use/cover conversion were seen as less difficult to detect and monitor. As a logical prerequisite for capturing land use/cover intensification across major categories the group recommended to apply a classification scheme that uses intensity of use as one of its organizing principles. For example, the following broad classes reflect intensity of use: urban/industrial use, mining/extraction, agriculture, forestry, hunting and gathering, unused. Group members pointed out that several (and much more sophisticated) such classification schemes had been proposed in the past.

Intensification within major land use categories

The group fully agreed that the more difficult (for detection and modeling) kinds of intensification processes were taking place *within* the broad land use/cover categories. Given the very limited time available for discussion the group decided to elaborate examples of indicators that would be necessary or helpful in capturing such intensification processes. Illustrations were developed for five sectors: agriculture, forestry, tourism, urban, industrial. Though the group did not try (due to time limitations) to define for each indicator the most appropriate data source it was obvious that different kinds of data (survey information, statistics by administrative units, and maps) would have to be combined and checked for compatibility and consistency.

It must be stressed that the collection of proposed data items and indicators following below is considered neither exhaustive nor prioritized. However, since most group members had ample experience with data availability and accessibility in their home countries the discussion tried to focus on data items and indicators that were believed to be potentially available or derivable from existing data rather than producing a 'dream' list of attributes.

Example 1: Intensification in agriculture

Both intensification and extensification of agricultural practices is taking place in different parts of Europe and North America. Production increments in South and East Asia have been (and will be) largely achieved through expansion of irrigation and intensification of production inputs. For a good description of such intensification processes data needs range over several domains: population, land, outputs, inputs, and land capitalization:

- Population
  - Population density
  - % of agricultural in total labor force
  - % of part-time farmers
  - % of regional income derived from agriculture
  - Age of farm household/agricultural population
  - Gender and education of farm managers
- Land
  - % natural and semi-natural areas in region
  - % cultivated land in total land
  - % of fallow land in total cultivated land
  - % of irrigated in total cultivated land
  - % of mechanized cultivated land in total cultivated land
  - % of set-aside crop land in total cultivated land
  - % of abandoned agricultural land
  - Multi-cropping index
  - Livestock density
  - % of animals permanently kept in stables
  - Settlement patterns
  - Sediment loss (erosion indicators)
- Outputs
  - Crop yields
  - Total crop production
  - Crop distribution and rotation
  - Livestock yields
  - Livestock production
  - Livestock types
  - Gross value of output per unit of agricultural land
  - % of marketed output
- Inputs
  - Total value of inputs per unit of land/animal
  - Fertilizer use (chemical, organic)
  - Use of agro-chemicals
  - Use of irrigation water
  - Feed use (%concentrates, primary products, residues and by-products)
  - Machinery use
  - Energy use
  - Use of plastic sheets (% of cultivated area covered)
  - Tillage methods
  - Efficiency of nutrient application
- Capitalization
  - Farm structure (size, fragmentation)
  - Machinery (size, power, replacement interval)
  - Irrigation infrastructure/equipment

The group concluded that in particular the availability of spatially disaggregated data on production, input use, and factor use (labor, capital, water) is severely limiting current analyses. The need was pointed out for balanced development and joint availability of geographic, statistical and survey data based on harmonized sampling strategies and consistent data collection frequencies.

Example 2: Intensification in forestry

The discussions on forestry followed the previous example on agriculture and aimed at producing a comparable list of indicators.

- Population
  - % of forestry in total labor force
  - % of income derived from forestry
- Land
  - % forestry area (i.e., designated, including both forested and unforested)
  - % forested area
  - % cover density
  - Indicators of forest fragmentation
  - % protected forest and degree of protection
  - % of irrigated forest
  - % of degraded/abandoned forest
- Outputs
  - Yields of forest products
  - Forest stock
  - Total wood production
  - Gross value of output per unit of land
  - % of commercial harvesting
- Management
  - % of native tree cover
  - % of fast-growing trees
  - Fertilizer/other inputs use
  - Irrigation water use
  - Machinery use
  - Energy use
  - Harvesting methods (clear-cutting, selective, etc.)
  - Harvesting frequency
- Capitalization
  - Machinery (size, power, replacement interval)
  - Forest road density

Example 3: Urban intensification indicators

Extent of land built/developed per year
Number of building permits per year
Value of new construction per year
Area of land annexed to cities per year
Population density
Rural/urban migrants
Other migrants
Car ownership, cars per person

Example 4: Industrial intensification indicators
Volume of industrial output
Value of industrial output
% of industry in total labor force
% of industry in regional value added
Capital investment in industry
Energy and resource use by industry
% of export in total industrial output

Example 5: Intensification of tourism
Number of visitors per month
Number of nights spent per year
Number of tourists per unit area
% of tourism in total labor force
% of tourism in regional income
Number of hotel beds per unit area
Ratio of tourists/inhabitants
% of natural (wilderness) areas

8.3 MONITORING

Holger Hoff

Constraints in monitoring of LUCC

As a general monitoring constraint, spatial and temporal resolution of measurements and observations are limited. A global coverage at resolutions required to capture the LUCC relevant processes and patterns will not be achieved. Often a trade-off has to be made between temporal and spatial resolution, e.g. high temporal resolution in LUCC monitoring is only feasible for a limited spatial coverage or for a coarse network.

Some general recommendations for LUCC monitoring and monitoring of LUCC relevant parameters

The following recommendations can help to overcome to the above stated constraints.

WHAT to measure:
- Aggregated parameters that are robust, e.g. against short term fluctuations or variations in external conditions, aggregate parameters can also integrate over time, hence need less frequent measurements - R&D needed.
- Proxy parameters, which are easier to measure or available with better coverage or resolution - R&D needed.
- Parameters that serve for validation of remote sensing information; that way better integration of remote sensing and field measurements can be achieved, e.g. to extrapolate field measurements in time and space or to establish the spatial context for measurement sites.
- Instead of only designing new measurement networks, utilize and exploit better the existing data sets, in particular where long term time series are available.

WHERE to measure:

- Concentrate on hot spots of changes or expected changes.
- Set up monitoring sites for representative areas, e.g. in the case of land-atmosphere exchanges following the concept of plant functional types, with monitoring sites covering all relevant types - R&D needed.
- Measure along transsects/gradients (e.g. IGBP transsects), i.e. gradients of biophysical properties for boundary conditions of land use, or gradients of land use intensity.

HOW to measure:

- Use a two tier strategy, based on:
  high resolution networks for operational monitoring, and
  more sparsely spaced sites for research and further development of methods
- Multivariate measurements at a given site, covering a range of parameters (direct measurement of LUCC parameters as well as supporting measurements to describe the environment/context of the site).
- Multipurpose measurements, using site's infrastructure and measurements to answer a range of science questions, serving different disciplines.

9. CONTRIBUTIONS AND PRESENTATIONS (Index in alphabetical order)

In alphabetical order of participants to the workshop:

- "Indo-Gangetic Plains - Sustaining Productivity". Inder Pal Abrol.
- "LUCC Data Requirements for Regional Initiatives in the Hindu Kush-Himalaya". Lisa J. Graumlich and Sharad Adhikary.
- "Data Requirements for Assessing Patterns and Causes of Biodiversity Loss". Kamaljit Bawa and Shaily Menon.
- "Data Needs for Integrated, Intertemporal Analysis of Land Use Change at the Local Level: Notes on Definitional, Methodological and Practical Issues". Helen Briassoulis.
- "Belief Networks: A Tool for Experimental Design". Jeremy D. Cain, C. H. Batchelor and D. K. Waughray.
- "GTOS (Global Terrestrial Observing System); Objectives, Functions and Structure". Antonio Cendrero.
- "EU-TERI-project ECOMONT: Research on ecological effects of land-use/cover changes in European mountain landscapes". Alexander Cernusca and Ulrike Tappeiner.
- "Evaluation of Land Cover Modification and Vegetation Distribution in Arid Areas by means of Remote Sensing and GIS Techniques". Claudio Conese and Andrea Di Vecchia.
- "The LUCC Data Requirement for Socio-economic and Demographic GIS Datasets". Lawrence W. Crissman.
- "MicroLEIS Project: Exploring the Agro-ecological Limits of Sustainability". Diego de la Rosa.
- "Progress Towards a 1 km Global Inventory of Human Settlements". Christopher Elvidge.
- "Urbanisation and Vegetation: Measuring Landscape Patterns by Remote Sensing Techniques". Enrico Feoli, Cristina Milesi and Alfredo Altobelli.
- "LUCC Data Needs for Integrated Assessment Models of Climate Change". Hans-Martin Füssel and Ferenc L. Toth.
- "Modelling Environmental Phenomena Related to Agricultural Land Use: Experiences from Two Research Projects on the Watershed of the Lagoon of Venice". Carlo Giupponi.
- "Large Scale Biosphere Atmosphere Experiment in Amazonia (LBA) - Data Requirements and Data Management". Holger Hoff.
- "CLAUDE presentation: Recommendations from the Users Meeting on Land Use and Land Cover Monitoring in Europe. Wageningen, the Netherlands, 22-23 May 1997". Margret Ihle and David Briggs.
- "Database of the Long Term Land Use Changes Research in the Czech Republic". Leos Jeleček.
- "Land Cover Changes in Coastal Zones. Area of Catalonia". Maria del Mar Joaniquet.

- "Operational Systems for Continuous Identification and Monitoring. World Data Center". John Kineman.
- "Data vs. "Science?" General Comments on Epistemology in DAPLARCH-I". John Kineman.
- "Data Constraints in Land Use and Land Cover Change Research: Coasts and Islands of India". R. Krishnamoorthy.
- "Simulations of land-cover changes in Africa: Remote sensing and socio-economic data". Eric Lambin and Benoît Mertens.
- "How can recent lake sediment be used in connection with remote sensing techniques to understand processes of environmental changes in the recent past?". Suzanne A. G. Leroy.
- "Socio-Economic Information for a Comprehensive Analysis of Land Use Changes". Nelson Lourenço, Teresa Pinto Correia, Maria do Rosário Jorge and Carlos Russo Machado.
- "LUCC Data Validation and Requirement of Russia". Elena V. Milanova, E. Y. Lioubimtseva and P. A. Tcherkashin.
- "Linking PAGES and LUCC - Some Preliminary Ideas". Frank Oldfield.
- "Land Use and Land Cover Changes and Agricultural Policies: Problems in the Selection of Suitable Indicators". Begoña Peco.
- "Assessing Land Cover Changes for Sustainable Land Management". Vanda Perdigão.
- "Data Requirements for Farm and Regional Scale Agricultural Land Use Modelling: Experiences from the IMPEL Project". Mark Rounsevell.
- "Changing Land Use Impacts in Mediterranean Coastal Ranges". Maria Sala.
- "Land-Cover Monitoring by a Change Analyser". Francesca Serra, Roman Arbiol and Vicenç Palà.
- "Survey of Needs, Gaps, and Priorities on Data for Land Use and Land Cover Changes Research in Nepal Himalaya". C. K. Sharma.
- "Definitive Driving Forces of Land Use Change in Tokyo Metropolitan Area (TMA)". Yo Shimizu and Yohei Sato.
- "The European Environment Agency and its European Environmental Information and Observation Network (EIONET)". Chris Steenmans.

INDO-GANGETIC PLAINS - SUSTAINING PRODUCTIVITY

Inder Pal Abrol
Facilitation Unit, Rice-Wheat Consortium for the Indo-Gangetic Plains, ICRISAT, New Delhi, India

South Asia's Indo-Gangetic Plains spread over the region's four countries, Pakistan, India, Nepal and Bangladesh is agriculturally the most important region of the subcontinent. The Indian portion of the plains extends from the border with Pakistan in the north-west to the state of West Bengal in the east and includes the states of Punjab, Haryana, Uttar-Pradesh, Bihar, and West Bengal. The plains cover an area of about 65 million ha, almost one-fifth of the country's geographical area and extend over a length of nearly 2,000 km all along the foot hills of the Himalayan mountains with a width ranging from 150 to 300 km, being narrow in the extreme east in West Bengal.

Geologically the whole region is made up of alluvium brought down by the Himalayan rivers. The alluvial plains constitute one of the richest and most potential groundwater resources. The salinity of the groundwaters increase in the south-west direction with the decrease in rainfall 150 hytes.

The plains extending east west through the valleys of Indus and Ganges system undergo a gradual transition in the level of land, climatic features, natural vegetation, cropping pattern etc. Between the arid Rajasthan plains in the west and the per humid lower Ganges Plains in the east lie the semi arid Punjab Plains, the sub humid upper Ganges Plans and the humid middle Ganges plains each merging into the other imperceptibly.

Climate and cropping

The region has a high degree of climatic variability - average annual rainfall ranges from less than 400 mm in Haryana in the west to more than 1,600 mm in the Bengal plains in the east. An analysis of the water balance suggests that no assured rainfed cropping is feasible in the west but that non-paddy rainfed cropping is possible in the central and rainfed paddy in the eastern region with inherent risks due to rainfall uncertainties. Traditionally cropping in the region has been millets in the arid, wheat and gram in the semi-arid but irrigated, wheat and rice in the sub-humid but irrigated upper Ganges plains, rice and wheat or barley in the middle Ganges plains and rice-jute in the lower Ganges plains.

Indo-Gangetic Plains current land use

Agriculture involving annual/multiple cropping is the major land use in the region (table 1). The region as a whole constitutes nearly 21% of the country's area but accounts for 26 percent of the net cropped area and 31 percent of the gross cropped area implying higher intensity of land use through multiple cropping. A consequence of intensified cropping is that the region

Table 1. Indo-Gangetic Plains - Current Land Use (1994-95).

State	Reporting area (,000 ha)	Net cropped %	Cropping intensity	Not available for cultivation %	Pasture/grazing land area under the grasses %	Fallow land %	Forest %
Punjab	5,033	82.2	183	9.6	0.7	1.7	5.6
Haryana	4,376	79.4	169	9.3	1.6	5.9	3.9
Uttar Pradesh	29,797	57.9	149	11.8	6.3	6.7	17.3
Bihar	17,330	41.3	130	18.3	4.5	18.8	17.0
W Bengal	8,846	60.3	160	20.5	1.8	5.0	12.3
Total		57.15	158	14.35	4.46	9.27	14.7
All India	305,005	46.7	130	22.74	9.85	25.72	14.1

currently (1995-96) accounts for 37.2% of the area under foodgrains but contributes nearly 51.5% of the production. In comparison the area under forests is only 14 percent and most forests in the region are in a highly degraded state. Within the region there are significant variations in current land use as a result of changes induced by past research and development efforts. In the north western state of Punjab nearly 82% of the land area is cropped and of this 83% is cropped more than once annually. In the eastern region, in comparison, the intensity of cropping and crop yields have remained low. The region accounts for 49% of the population. The density of population is high, 507 in comparison to an all India population density of 267. The density of population increases from north-west to east; from 400 in the state of Punjab to 767 in the West Bengal. Average size of operational holding decreases from 3.61 ha in Punjab to less than one in the eastern states.

Past Changes. In the past three decades rapid changes in agriculture and related activities have taken place in the region. These changes were largely promoted by the Green Revolution technologies of mid 60s - the principal components of these technologies were the availability and spread of high yield crop cultivars, rice and wheat in particular; expansion of irrigated area, increased use of inputs including fertilizers and plant protection chemicals and the associated infrastructural changes necessary for adoption of improved technologies. This technological breakthrough today allows an exceedingly large number of people to be fed from a relatively small area. Two cereals, rice and wheat grown in an intensive double cropping system contributes the bulk of regions' food supply. Widespread adoption of technologies and resulting expansion in cropped area led to marked increases in rice and wheat production. The adoption of new technologies was quite variable across the region - adoption was faster and the gains higher in the region which were relatively better endowed. In the lesser endowed areas, in the eastern sector, there was a lag in adoption of technologies and the gains were much smaller compared to the north-west. The question that needs better explanation is - why have the yield enhancing technologies widely adopted in the west, but not in the east? In part this could be ascribed to the inherently lower potential due to climatic features. Differential farm size may play a role since a small subsistence farmer has little capacity to invest in high yield technologies. Other important factors related to the relevance of technologies themselves, rural infrastructural development, marketing conditions, financial incentives. Whatever the specific reasons a better understanding of the reasons leading to insecurity involved in the agricultural condition would permit evolving improved strategies in the future.

For the region as a whole, average rice and wheat yields rose at about 2% per annum between 1960 and 1990. There is increasing evidence to suggest, however that such growth rates are no longer being sustained. Sustainability concerns are being contributed by several factors. Most importantly these are:

- Declining Soil Quality. In the intensive cropping system nutrient inputs have rarely matched nutrient depletions causing increasing imbalances and reduced efficiencies. With reduced recycling of organics the soils are increasingly becoming prone to physical deterioration due to repeated soil working by way of pudding and cultivations.
- Water related Degradation Processes. Declining water table in some of the intensively cultivated areas is causing increased pumping costs, and an increase in the risk of spreading salinity and sodicity problem. In some regions of West Bengal serious arsenic toxicity problem in the groundwater have emerged due to excessive depletion of groundwater. Inefficiencies in water use at the farm and system level fuelled by inappropriate pricing and policy environment are further leading to resource degradation.
- Continuous adoption of cereals based cropping system has greatly increased the incidence of pests including weeds. The problem has attained serious dimensions in many areas - thus there is evidence that the grassy weed Phlaris minor commonly found in wheat fields has developed resistance to the commonly used weedicides - rendering its control very difficult.
- Environmental concerns arising from greenhouse gas emissions, e.g. methane from paddy fields, CO_2 emissions/pollution from burning of crop residues, contamination of water bodies by chemicals etc.

It is apparent that the future poses huge challenges - our land resources are shrinking - how do we use these optimally to meet the increasing demands, and emerging internal and external environments.

One thing is certain; large and increasing population need food and that we have to find measures to ensure food security of the region. This will have to be done largely through intensification which implies increased production per unit area since the horizontal expansion is almost complete in the region. However, we will need to do this as a manner which is environmentally less degrading. This would require certain compromises and we will need to decide where we can and where we cannot compromise. In addition to the human population, the region has nearly 33% of the cattle and 42% of buffaloes. Due to increasing incomes and effluence the dietary habits are leading to greater consumption of animal based proteins. Similarly world trade related agreements offer new opportunities to compete and benefit from the world markets. All these factors will determine future options of land use in the region. The growth of major cities in this region has been phenomenal. In the states of Delhi alone between 1971 and 1994, 23,800 ha of prime agricultural lands were diverted for non-agricultural purposes. These changes prompted shifts to non-foodgrain crops like vegetables, fruits etc. which though reduced the area under foodgrains, resulted in substantial income increases. Such changes will likely intensify in the future.

Similarly the need to maintain rural availability of fuelwood and industrial support for high value low risk short-term tree farming has promoted a shift towards agroforestry systems. In future such changes towards multi-species ecosystems are inevitable. These options lead to high biodiversity and provide options for diversified resource use.

The future land use changes are of concern as these have an immediate impact as the sustainable livelihood of a large section of the population. They also have inturn substantial impact on the driving forces of global change - carbon sequestration/greenhouse has emissions, hydrologic balances, land degradation, biodiversity including soil flora/farmer etc. Methodologies and tools for better understanding of the nature and magnitude of imminent changes can provide us a basis for decision that could influence such changes.

LUCC DATA REQUIREMENTS FOR REGIONAL INITIATIVES IN THE HINDU KUSH - HIMALAYA

Lisa J. Graumlich
Biosphere 2 Center, Arizona USA
Sharad Adhikary
Himalayan Climate Center, Kathmandu, Nepal

LUCC data requirements for regional initiatives in the Hindu Kush - Himalaya (HKH) were identified at a workshop in Kathmandu, Nepal in April 1997. The workshop provided a forum where researchers from Asia and around the world could synthesize current knowledge and plan further interdisciplinary investigations into the nature and consequences of land-use/land-cover changes in the HKH.

Why LUCC studies in the Hindu Kush - Himalaya?

The HKH is one of the most diverse regions on earth in terms of biophysical and human measures. Short north to south transects of little more than 120 km traverse tropical monsoon rainforest at 300 m to permanent snow and ice in excess of 8,000 m in the east, or semi-arid steppe at 700 m to permanent snow and ice above 7,000 m in the Northwest. Superimposed on this extreme physical diversity is a historical, cultural, ethnic, religious, and land-use mosaic that presents a formidable and complex challenge for understanding land-use/cover dynamics and their implications for global change sustainable livelihoods and development.

The region as a whole provides the life-support base for about 400 million people. Economic pressures on the resources of the mountains add yet further pressures on the life-support base of the HKH. Given the continued rapid population growth, which accelerates the already critical pressures on natural resources, the region has long been characterized as on the brink of a super-crisis.

Critical Research Issues in the HKH

A prominent integrating theme in the workshop discussions was the characterization of the HKH region as a high energy environment with many 'fragile' ecosystems. This fragility is a manifestation of the tight and sensitive coupling between human activities and the state of the land cover. Workshop participants sought to refine these notions by identifying those land-use/cover changes that are most critical for basic as well as more applied research. Breakout groups identified the following as critical changes for the HKH: changes in forest cover, including conversion as well as modification of structure and species composition; and changes in land use, including intensification as well as disintensification of agriculture.

These changes were, in turn, linked to key regional trajectories such as: changes in forest use leading to declining forest resources and ecosystem degradation; abandonment of marginal agricultural lands leading to conversion to woody species and invasions of exotic species; intensification of agricultural leading to increased output with varying ecosystem impacts; decreased fallow area in the absence of other inputs leading to degraded cropped lands; and increased socioeconomic and biophysical links between highland and lowland areas leading to complexity in the identification of causal linkages and policy options.

Both human and biophysical factors were identified as key forces driving the observed changes. Workshop participants identified economic restructuring, population growth, infrastructure of access, resource institutions and entitlements, urbanization, stakeholder conflicts, and cultural values as critical human drivers. Water resources, soil fertility, biological invasions, climatic variability, and the general nature of mountains as high energy environments were identified as important exogenous biophysical drivers and/or feedbacks to land use.

Next steps

Given that the HKH is one of the most diverse regions on Earth in terms of biophysical and human measures, how might we proceed with an integrated study of critical land-use/cover issues? Participants agreed that a transect approach should be developed that simultaneously accounts for broad gradients in biophysical variables as well as socioeconomic variables. Participants stressed that the results from any coordinated regional activity include outputs in a form broadly accessible to user groups and decision makers.

DATA REQUIREMENTS FOR ASSESSING PATTERNS AND CAUSES OF BIODIVERSITY LOSS

Kamaljit Bawa
Department of Biology, University of Massachusetts, Boston, USA
Shaily Menon
Department of Biology, Grand Valley State University

Most studies of land-use and land-cover change involve documentation of changes in natural habitats. The loss of natural habitats, in essence, is a proxy for the loss of biodiversity, certainly at the level of ecosystems and communities. Thus, biodiversity loss, especially at the ecosystem and community levels, can be easily assessed while studying land-use and land-cover change. We examine data requirements for *a)* documentation of biodiversity loss at various levels, and *b)* identification of the factors responsible for biodiversity loss. The data requirements are discussed in the context of our work on the patterns, causes, and consequences of land-use and land-cover change in the Western Ghats and Arunachal Pradesh, two biodiversity hotspot regions in the Indian subcontinent.

Levels of loss

Biodiversity loss occurs at the level of **ecosystems**, **species populations**, and **genes**. Moreover, land-use change influences the evolutionary and ecological processes that generate and maintain diversity. Land quality indicators can provide useful information about the possible effects of habitat and landscape alteration on ecological and evolutionary processes. Such indicators include the size, shape and number of habitat fragments, the degree of isolation of the fragments, and the landscape matrix within which fragments are embedded.

Ecosystems

The amount and rate of forest cover loss are often the most common statistics indicating the depletion of biodiversity in studies of land-use and land-cover change. Data on changes in other types of ecosystems, such as deserts, grasslands, and wetlands, are usually not available, but are essential to document biodiversity loss at the landscape level. Further, maps and remote sensing imagery used to document land-use change usually do not have high enough resolution to enable discrimination of individual forest or vegetation types. Yet, this level of discrimination is critical to the study of biodiversity loss because different vegetation types differ with respect to species richness. Thus, a full characterization of forest or vegetation types is essential for assessing the magnitude of loss in biodiversity at the landscape and ecosystem level. Moreover, ecosystems include a diverse array of habitats but it is difficult, at present, to estimate the rate at which habitat diversity is being lost in various types of ecosystems. The availability of high resolution imagery coupled with ground work is required to map the major ecosystems and vegetation types and, in turn, to estimate their loss.

Different parts of the earth contain unique biotas. Thus, the existing biodiversity can be grouped into various bioclimatic and biogeographical zones. Maps of biogeographical zones superimposed on maps showing changes in land cover, including changes in forest and other habitats, can provide information about the loss of biodiversity and the level of landscapes or biogeographical and ecoregions. For example, we have examined the distribution of different forest types within various biogeographic zones in the Western Ghats, India (figure 1a). Similarly, one can map the distribution of protected areas within each biogeographic zone (figure 1b). Useful information about distribution of vegetation types and the representativeness of the protected area network can be derived from such maps.

Species

The number of species lost is often the most widely used measure of biodiversity depletion. However, extirpations of species in a given habitat cannon be determined without thorough ground surveys. Even with ground surveys mapping the distribution of thousands of species will not be an easy task. Thus, data on the distribution of endemic species, economically important species, keystone species, indicator (of overall biodiversity levels) species, and exotics should be accorded high priority for estimating biodiversity loss. Such maps form the basis of gap analysis exercises in which areas of high conservation value in a region are highlighted along with gaps in their protection. Variation in the distribution of endemic plant species in the Agastyamalai region of the Western Ghats, India is shown in figure 2. On the basis of maps of floristic species richness, floristic endemic zones (figure 2), faunal endemic zones, and unique ecosystems, we have developed a conservation value index of the region (Ramesh, Menon, and Bawa 1997).

Populations

Much of the biodiversity loss is occurring at the population level. Assuming that population extinction is a linear function of habitat loss, Hughes, Daily, and Ehrlich (1997) have estimated that approximately 1,800 populations per hour (16 million annually) are being destroyed in tropical forests alone.

In order to assess the rate at which populations are being lost, information is required concerning the distributional range of the species, parts of the range in which the species is threatened, and the geographical scale over which populations are differentiated. Data on population genetic structure are often difficult to obtain, but for major groups there is sufficient information from selected species, which can be generalized to other taxa with similar life forms and life histories. Data requirements for estimating the loss of diversity at the population level then, in essence, are the same as those for species, i.e. maps of species distribution, which would provide a starting point for assessing population diversity. The next requirement would be genetic data about the scale at which populations are genetically structured, at least for selected endemic, threatened, keystone, and economically important species.

Fragmentation

Two types of changes in habitat are responsible for loss of biodiversity: habitat shrinkage and fragmentation. Land-use changes result not only in outright habitat loss but also alter landscape dynamics by increasing the number of habitat patches, reducing the average patch size, and changing the distribution and arrangement of fragments. Landscape-level data can provide such statistics as size, shape, and number of patches, the matrix of the habitat in which patches are embedded, and the connectivity among patches. All three parameters can reveal the extent to which ecological and evolutionary forces that generate and maintain diversity may be influenced by land-use and land-cover change.

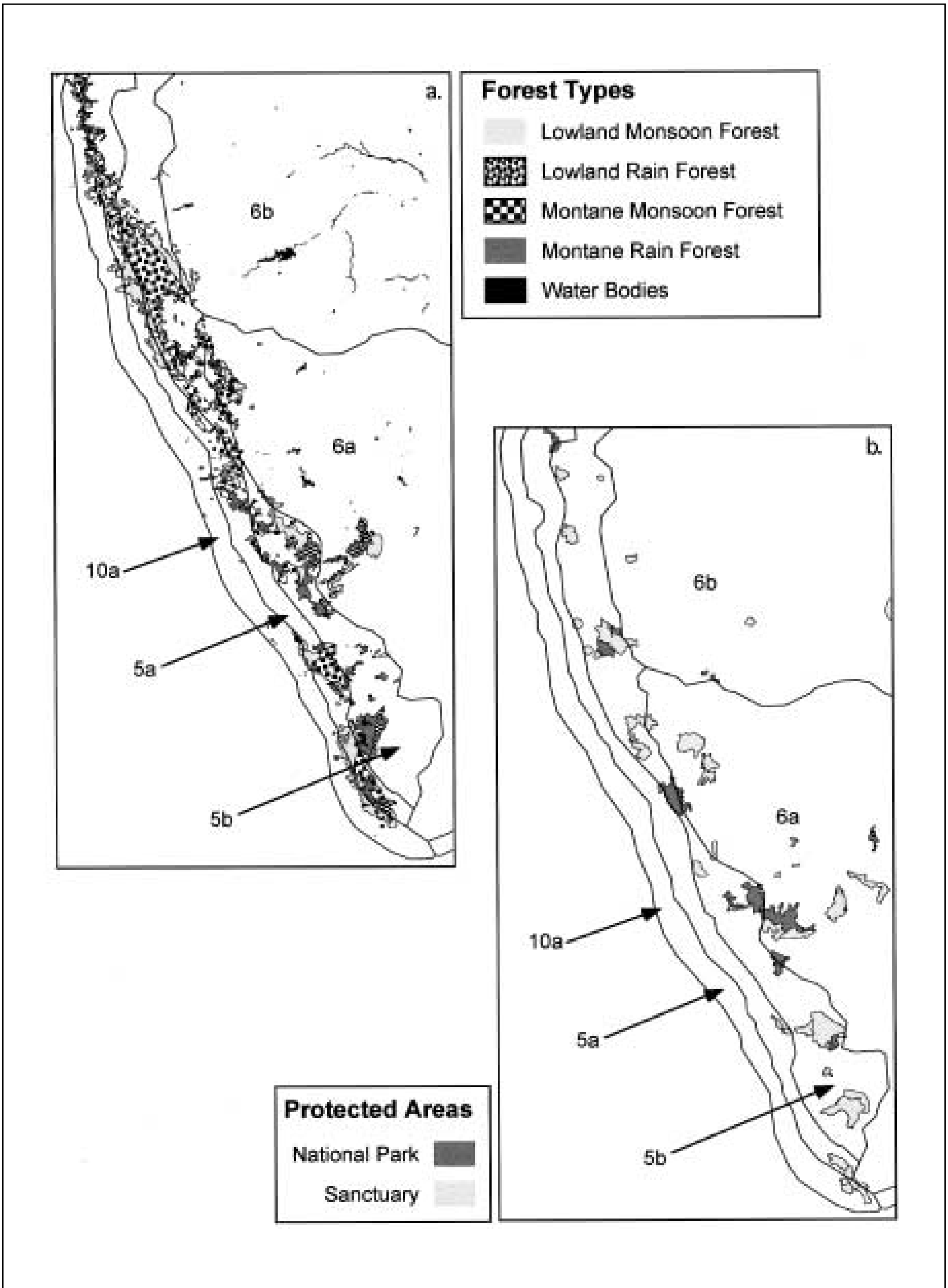


Figure 1. Distribution of forest types *(a)* and protected areas *(b)* within biogeographic zones in the Western Ghats, India. Biogeographic zones obtained from Rodgers and Panwar (1988) and protected areas from a WCMC-IUCN database on CD-ROM. Key for biogeographic zones: 10a - The west coast, 5a - Malabar coast, 5b - Western Ghats mountain, 6a - Deccan Plateau South, 6b - Central Plateau.

Causes of biodiversity loss

Data are needed not only for the assessment of biodiversity loss but also for identification of factors underlying depletion of biodiversity so that mitigation strategies to combat losses can be developed.

The overall causes of biodiversity loss are often the same as those responsible for land-use and land-cover change. As in the case of land-cover change, the causes can be distinguished into proximate and ultimate factors. The proximate factors, operating at the local scale, often include such variables as population (growth, density, and immigration) land use (settled agriculture, shifting agriculture, plantations, cattle ranching, etc.), biophysical factors (soils, slope,

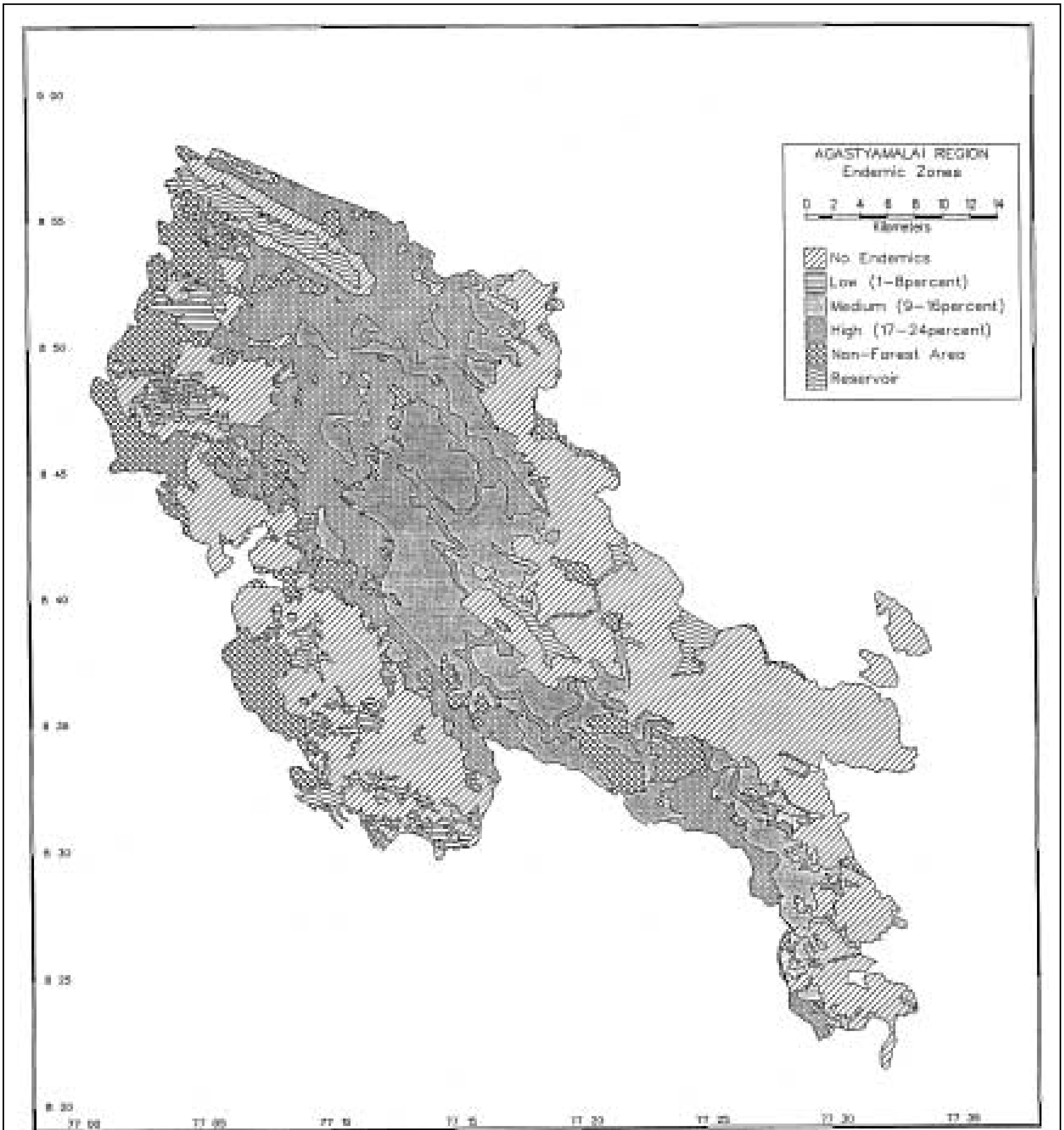


Figure 2. Zones of floristic endemic species occurrence in the Agastyamalai region of the Western Ghats, India. (Reproduced with permission from Ramesh, Menon, and Bawa 1997).

elevation), trade in forest products, and access to markets. At the local level, household variables, such as family size, education, income, female literacy, and land tenure, also play an important role in biodiversity and environmental degradation. Moreover, the amount of reliance on the extraction of non-timber forest products and the levels of extraction and hunting will determine the long-term sustainability of such practices both for the local biodiversity as well as the local human population.

Ultimate factors that often operate at national, regional or global levels include conservation policies, macroeconomic policies, subsidies, tax breaks and trade. The number of factors involved is so large and our understanding of causal mechanisms is so poor that it is difficult to determine the relative importance of various factors. Thus, data are required for a range of variables at various scales (macro and microlevel studies) in order to gain a better understanding of the root causes of biodiversity loss.

Approaches

The approaches used in obtaining information about the patterns and causes of biodiversity loss are often similar to those used in the study of land-cover and land-use change and the two can easily be linked. These approaches range from the derivation of information through data obtained from space (remotely sensed imagery) to on-the-ground surveys and data gathering. In fact, in many cases the two go hand-in-hand as it is often essential to do ground work in order to classify or verify information obtained through remote sensing sources.

Aerial photographs and satellite data have found widespread application in the study of land-cover and land-use change. The techniques and approaches developed in these studies can be extended to issues of examining biodiversity loss and developing strategies to counter threats to biodiversity. Remotely sensed data offers the major advantage of covering large geographical areas (spatial coverage) over several time periods (temporal coverage). Obtaining field data on biodiversity from such large areas repeatedly over several time periods would be a near-impossible task for all practical purposes. In fact, large areas of the planet have not been surveyed even once for biodiversity related information due to a combination of factors including the amount of time and taxonomic expertise required for ground surveys coupled with lack of funding for such basic biodiversity monitoring activities.

Given the ongoing crisis of species extinctions, it becomes even more critical to develop approaches and methodologies for the rapid assessment of and monitoring of biodiversity-rich areas, areas of high conservation value, ecologically sensitive areas, and areas most vulnerable to biodiversity loss through anthropogenic factors. There is a need for the availability of high resolution satellite data that might allow one to determine species composition and species richness, as well as hydrological and land-quality indicators, because ultimately one is also interested in ecological and economic consequences of biodiversity loss.

An example of how local measurements of species diversity can be extrapolated to regional scales using remote sensing technologies is provided by work we are doing together with J. Rose and with the help of intensive ground data collected by local scientists working in the Biligiri Rangaswamy Temple Sanctuary in India. This methodology is under development and takes advantage of the well- known relationships between species diversity, environmental variables, and their detection by satellite imagery. Variables such as net primary productivity and evapotranspiration can be detected by remotely sensed imagery through indices and can serve as proxies for biodiversity estimation. In this study net primary productivity was assessed through a set of indices derived from AVHRR imagery and evapotranspiration from was estimated using thermal imagery. Field data were used to calibrate the relationships. The output was a map depicting a range of values for species diversity (figure 3). The general trend is for

Figure 3. Species richness zones delineated with indices from remotely sensed imagery (AVHRR) and field data. Species diversity increases from light shades to dark.

species richness to be lower outside the sanctuary boundary (shown in heavy black line) and to increase as one moves away from the periphery to the center of the sanctuary. Furthermore, as one might expect, species diversity level is correlated with vegetation type.

Remotely sensed imagery can also be used in habitat quality assessment. The example in figure 4 illustrates such applications and also illustrates the importance of image resolution in extracting such information. The top image derived from AVHRR data (1.1 km resolution) pertains to a portion of the Western Ghats, India, and covers a large geographic area but is limited in the amount of information related to habitat quality that it can yield. The inset image (bottom) is derived from Landsat Thematic Mapper data (30 m resolution) and shows the Biligiri Rangaswamy Temple Sanctuary. Here, forested landscapes can be distinguished from agricultural and cash-crop plantations. Tree plantations, on the other hand, have reflectances not too dissimilar from natural forests and the two are often indistinguishable even at this resolution. Thus, imagery at even higher resolution (10 m or better) is required to extract detailed data related to habitat type and quality.

Patterns of deforestation and land-use change can be predicted with the use of spatially explicit and dynamic landscape modeling. Data requirements for such modeling exercises include maps of land-cover and land-use change from two time periods and maps of one or more drivers of change such as elevation, aspect, slope, precipitation, soil types, transportation networks, waterways, biogeographic zones, and protected areas. Our group is involved in modeling future patterns of deforestation in the Western Ghats and in Arunachal Pradesh, based on projected population growth, current patterns of change, and a set of drivers of land-use change.

As mentioned earlier, ground surveys are often integral parts of biodiversity monitoring through satellite imagery. Field work is necessary for information about habitat types before images are classified and for post- classification accuracy assessments. Furthermore, field data on variables such as species identification, species diversity, productivity, and biomass would be necessary to calibrate various relationships with environmental variables and the reflectances detected by satellite imagery.

Field work would also be required to collect socioeconomic data at the village and household levels in order to tease apart factors underlying biodiversity loss. At national or regional levels, secondary data on social and economic variables can be correlated with loss of biodiversity. Integrating socio-economic data with ecological data at various spatial scales would be a challenging task.

Concluding remarks

The data requirements for documenting biodiversity loss and for identifying factors underlying this loss are diverse. High resolution imagery, archival maps, and ground surveys are often needed to estimate losses at the level of ecosystems, species and populations. Imagery or aerial photographs are useful for detecting changes at the level of landscapes, ecoregions, ecosystems, and habitats, while ground surveys are essential for estimating losses at the level of species and populations. Maps indicating the distribution of biogeographical zones; vulnerable habitats; and endemic, threatened, keystone, indicator, and economically useful species are critical for documenting patterns and trends of biodiversity loss. Land quality indicators must be assessed, including information about the size, shape and number of habitat fragments, the degree of isolation of the fragments, and the landscape matrix within which fragments are embedded. In order to identify causes of biodiversity loss and to develop mitigation strategies, data are required for a number of socioeconomic variables. At the local level, biodiversity loss can be correlated with a number of household variables, such as family size, education, income, female literacy, and land tenure. Losses at the landscape, ecosystem, or species-population level need

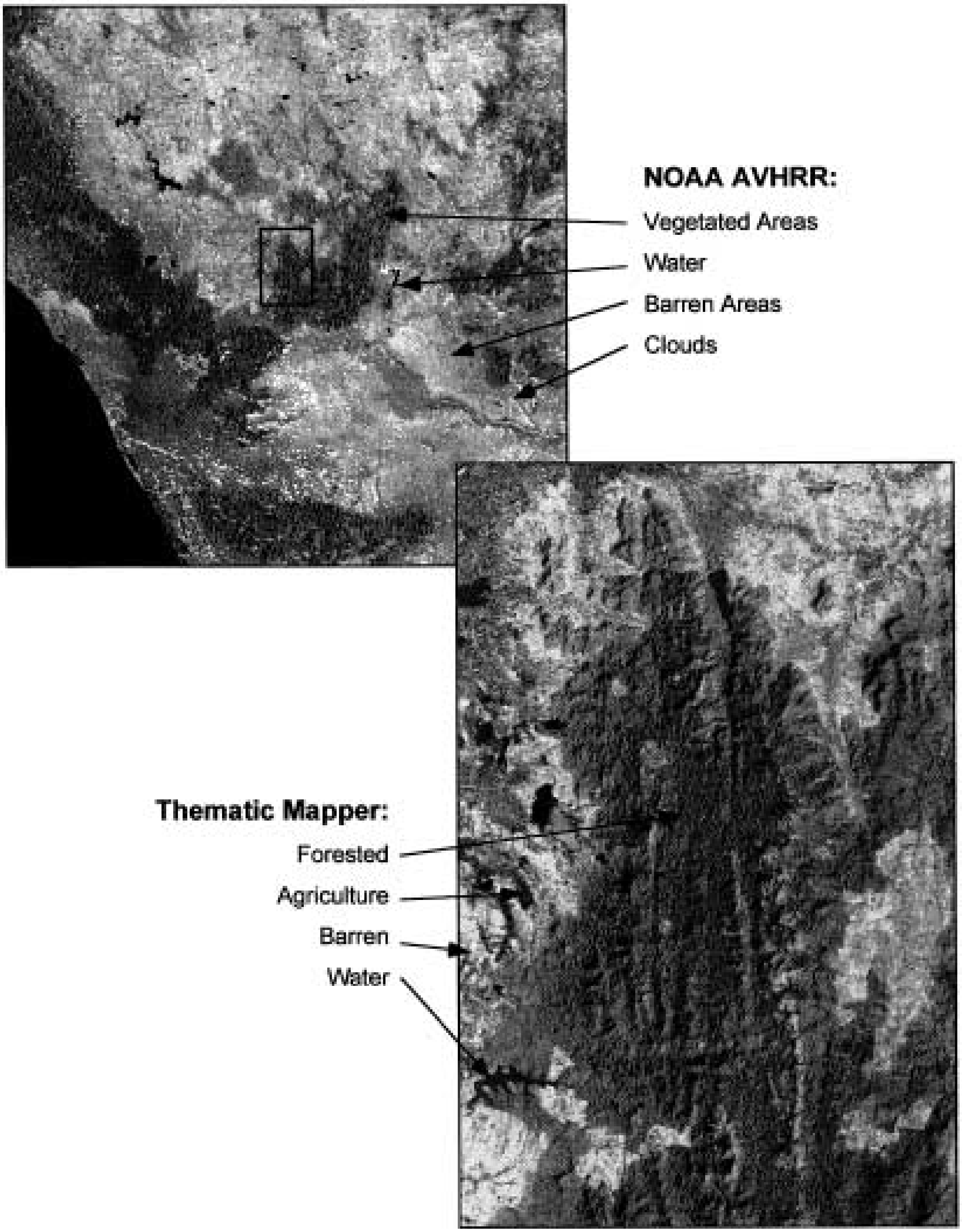


Figure 4. Potential of different types of satellite imagery in providing information about habitat quality.

to be correlated with land use, population parameters, access to markets and commodity prices. At the national or global level, biodiversity loss needs to be examined in relation to policies concerning subsidies, tax breaks, trade, and conservation.

References

HUGHES, J. B., G. C. DAILY AND P. R. EHRLICH. 1997. "Population diversity: Its extent and extinction". *Science* 278 (5338): 689-691.

RAMESH, B. R., S. MENON AND K. S. BAWA. 1997. "A vegetation based approach to biodiversity gap analysis in the Agastyamalai region, Western Ghats, India". *Ambio* XXVI (8): 529-536.

RODGERS, W. A. AND H. S. PANWAR. 1988. *Planning a Wildlife Protected Area Network in India.* Volume I- The Report. Wildlife Institute of India, Dehra Dun.

DATA NEEDS FOR INTEGRATED, INTERTEMPORAL ANALYSIS OF LAND USE CHANGE AT THE LOCAL LEVEL: NOTES ON DEFINITIONAL, METHODOLOGICAL AND PRACTICAL ISSUES

Helen Briassoulis
Department of Geography, University of the Aegean, Lesvos, Greece

1. Introduction

The paper attempts to structure the issue of data needs for integrated, intertemporal analysis of land use change with special emphasis on the local level. More specifically, it aims: *(a)* to identify the main issues related to the data needs; *(b)* to evaluate the suitability and reliability of available or new data on the basis of selected criteria and *(c)* to suggest framework guidelines for addressing the data needs identified.

Data needs are influenced, on the one hand, by the uses and users of the analytical results and, on the other, by the nature of the entities being analyzed and the particular mode of analysis. In the present case, the ultimate users are policy and decision makers who need a scientifically rigorous and reliable basis for making sustainable land use decisions. The object of the present inquiry is the integrated, intertemporal analysis of land use change. The particular focus is on the local level as: *(a)* the ultimate agents of land use change are the owners of land or, those with the power to influence land use decisions and *(b)* policies are implemented at the level of concrete users and owners of land who operate at the local level while being influenced by both local and supralocal factors.

The integrated analysis of land use change is guided by the conceptual schema of figure 1 which depicts the main groups of determinants of land use and its change as well as their linkages. The determinants are distinguished into local (shaded boxes) and supralocal (white boxes). Based on this schema, the (ideal) data needed to conduct an integrated, intertemporal analysis of land use change can be identified. Table 1 presents selected variables (and commonly used operational expressions) related to each module as well as to the linkages between modules. At the local level, additional variables may be necessary or different operational measures may be more appropriate to record local particularities. The land use types and conditions as well as several societal variables, similarly, may need finer measures than those used at higher levels. In general, local level analysis of land use change is demanding in information which is more detailed and qualitative and, at present, not systematically recorded, classified and analyzed.

2. Data evaluation

The main dimensions of the required data which are considered here are: spatial and temporal systems of reference, definitions and data collection issues. Substantive (compatibility, consistency, reliability of data) and practical (availability, ease and cost of data collection/finding as well as transferability of data among scales) evaluation criteria are employed. These represent desirable properties of the data dimensions to ensure their fitness for policy relevant integrated analysis of land use change. The evaluation may be carried out either by variable or by criterion and refers to data needed both for single or multi-region analyses. The evaluation criteria and the data dimensions, although interrelated, are treated separately for the purposes

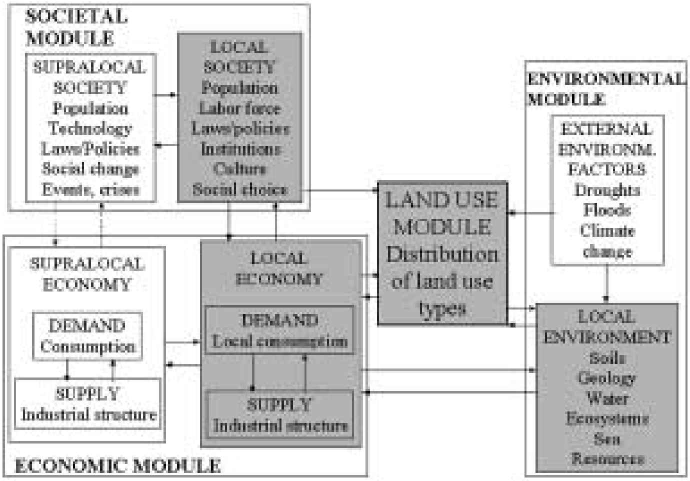


Figure 1. The integrated modeling schema.

of this analysis. The following evaluation examines selected issues by major criterion. A full flung evaluation is beyond the purpose of this paper. It is a task which must be undertaken on a systematic basis both nationally and internationally.

2.1 Compatibility

– *Spatial dimension.* The systems of spatial reference used for economic, land use, environmental, etc. data collection are rarely compatible in terms of level of spatial resolution, coverage and spatial definition. The spatial units usually follow administrative boundaries which, although appropriate for policy implementation, may not be meaningful for all types of data (e.g. the environmental). Data are available for larger scales mostly. Analysis for entities at lower spatial scales is rendered impossible. Spatial systems of reference change over time for the same entity studied. Longitudinal data for a given variable may indicate great differences over time which may be simply due to changes in the spatial system of reference. Overall, for a given spatial unit, full and spatially compatible data sets to operationalize meaningfully all the modules of an integrated model of land use change rarely exist. In the best case, adequate longitudinal data referring to the same spatial system of reference exist only for certain variables in one or more modules. When comparing different jurisdictions or when the study area includes more than one jurisdictions employing different spatial systems of reference, the issue of compatibility is even more serious.
– *Temporal dimension*. Similar problems relate to the temporal systems of reference used. Disciplinary and scientific, in addition to practical reasons, may dictate the unit of temporal aggregation, the spacing and number of observations, etc. Like spatial systems, temporal systems of reference change over time and if the transition from one system to the other is not planned and indicated, data from different systems may be incompatible. Serious problems arise when aggregating or disaggregating such data.

  Data for all variables of interest do not always refer to the same dates due to lack of systematic planning and coordination between data collection agencies. Reliable policy impact analysis especially requires that data on variables reflecting both the policy stimulus and the characteristics of the impacted entities are collected for the same time periods (and/or dates)

Table 1. Categories of land use determinants and indicative operational expressions.

Determinants	Operational expressions
A. ENVIRONMENTAL DETERMINANTS	
Climate	Temperature, precipitation; evapotranspiration
Geological composition	Areal distribution of rock types
Soil composition and conditions	Areal distribution of soil types and of soil degradation classes
Topography	Areal distribution of slope types
Vegetation structure	Distribution of main vegetation types
Ecosystem structure	Areal distribution of ecosystem types
	Biodiversity index; ecosystem productivity
	Stability/resilience indices
Water resources	Annual Yield; rate of annual extraction
	Exploitation ratio (Use/Yield)
B. ECONOMIC DETERMINANTS	
Economic structure/	Product by industrial sector; rate of change
Industrial composition	Employment by industrial sector; rate of change
	Investments by industrial sector; rate of change
	Value added by industrial sector; rate of change
Exports/imports	Exports by sector; Imports by sector; rates of change
Consumption structure	Ratio of local to total consumption by sector
C. SOCIETAL DETERMINANTS	
Population	Magnitude of population; rate of change
Population age/sex structure	Population age/sex distribution; rate of change by age/sex
Labor force	Econom. active population; total and by sector; rate of change
Distribution of professions	Percentage distribution of main classes of professions
Income distribution	Income distribution by main economic sector
Quality of life	QOL indicators; rate of change
Literacy	Literacy rate
Policies	Taxation; incentives; policy spending
D. TECHNOLOGICAL DETERMINANTS	
Mechanization	Capital investments in equipment by sector
Technological progress	Index of technological progress (?)
E. POLITICAL DETERMINANTS	
Political regime	Different types of political regimes
Conventions	Different type of conventions
Wars, unrest, crises	(no direct measure)
F. INSTITUTIONAL DETERMINANTS	
Institutional structure	Types of institutions and personnel by institution
Institutional change	Rate of change of employees by type of institution
G. ECONOMY-ENVIRONMENT	
Use of environmental resources	Water demand per unit output; total and by sector
	Energy demand per unit input; total and by sector
	Pollution load per unit output; total and by sector
	Per capita pollution
Productivity of resources	Output per unit volume of water; total and by sector
H. ECONOMY-SOCIETY	
Social welfare	Per capita output; per capita environm. protection expenditures
Labor productivity	Output per employee
I. ECONOMY-LAND USE	
Land productivity	Output by sector per unit area; total and by land use type
Land use intensity	Investments per unit area
	Population density

and with the same frequency. This is rarely done intentionally and it is even less probable that data with these desirable characteristics exist. In the case of different jurisdictions or study areas composed of segments of different jurisdictions the above problems are compounded. In addition, the greater the length of the time period analyzed, the greater the difficulty of ensuring the temporal compatibility of the data used. Frequently, however, problems arise due to lack of *spatiotemporal* compatibility especially at the local level.

– *Definitions*. The compatibility of the definitions of land use types - or, generally, the land use classification systems used - are critical aspects of the validity and reliability of the whole analytical effort. Definitions of various land use types differ among jurisdictions especially when particularly detailed land use types are considered, a very common situation at the local level. This may happen also in the case of the same region but at different time periods. Two problems arise, at least. Firstly, when analyzing land use change alone, figures representing the area occupied by different land use types refer to different entities and, hence, measurement errors instead of land use change are analyzed! Secondly, in integrated modeling, data on land use types are related to economic, social and other data. If definitions change arbitrarily and not systematically, the analysis may be meaningless in the best case.

  In another respect, the percentage of a certain characteristic which must be present in order to assign an area to a particular land use type is usually undefined and this may lead to seriously diverging figures. This point is especially critical when *delineating* these areas on maps.

  Frequently, definitions are aggregate and it is impossible to disaggregate the respective data for particular entities. Definitions - both conceptual and operational - change over time. This creates problems in the compatibility of data collected as, nominally, they may refer to the same variable but they are measured differently. The problems are aggravated when the data sources do not provide the explicit definitions or when they do not indicate that a change in definition has been introduced or, finally, when combining data from different sources.

– *Data collection issues.* Data collection procedures and rules differ from one agency to the other as well as from one country to the other unless some of them are standardized internationally (e.g. population censuses). Similarly, they change over time with changes in technology, organization, etc. and they affect the quality of available data. Modern data collection procedures ensure better data quality (systems of recording, training of personnel, data cleaning) but in intertemporal analysis, past data are important also. For integrated analysis, the variety of data which must be collected necessarily implies differences in procedures used by the corresponding data collection agencies which may introduce incompatibility. Data for the same variable for the same dates may differ from agency to agency. Misreporting - intentional and unintentional - is common which creates problems both in the analysis of a single variable as well as in its use in an integrated model used for policy analysis.

2.2 Consistency

– *Spatial dimension*. When data for various variables of an integrated model do not refer to the same spatial system, their analysis lacks consistency. Changes in spatial systems of reference over time may force the analyst to make assumptions to disaggregate available data. In this case, both the variable under consideration as well as its relation to other variables are treated inconsistently.

– *Temporal dimension*. If data are not (or, have not been) collected for the same dates, the assumption may be made that the data from close dates can approximate the real values which may or may not be true. As with the compatibility criterion, it is better to treat spatial and temporal consistency together as the two are not easily separable.

- *Definitions*. Problems arise with aggregate definitions when the analysis requires disaggregate data, a very common demand at the local level. Inconsistencies are introduced also when the time period analyzed is long and different categories appear or disappear within larger ones. Consistency problems should be expected also when indexes are used for economic, environmental, social, etc. conditions. Changes in the composition or calculation of the index generate inconsistent data sets.
- *Data collection issues*. Changes in organizational, technological and other conditions generate inconsistencies in data collection without rules for the transition from one collection system to the other.

2.3 Reliability

- *Spatial dimension*. Data are frequently collected without an explicit spatial system of reference - i.e. they are aspatial data. The problem is serious at the local level when the boundaries of the area to which data refer are fuzzy producing, thus, spatially unreliable data. When using such data for integrated analysis, there may be no guarantee that the analysis concerns the study area of interest.
- *Temporal dimension*. Unreliable longitudinal data are produced when compatibility and consistency problems exist as discussed previously.
- *Definitions*. Frequently, concepts and/or variables used are not defined explicitly. Hence, it is not always certain whether available data refer to the same entity. The problem is encountered frequently when historical data are combined with more recent data and particularly at the local level where details count more than and obscure general patterns.
- *Data collection issues*. Lack of systematic data collection procedures affect significantly the *precision* of measurements taken. Incorrect and imprecise collection and recording of field observations, intentional or unintentional omission or concealing of true data, untrained personnel, etc. generate unreliable data. Especially, historical data should be scrutinized closely for their plausibility. The lower the spatial level, the fuzzier and less reliable the available information becomes. Ex ante and ex post policy impact analyses are impossible without reliable socioeconomic and environmental data.

2.4 Availability

- *Spatial dimension.* Frequently, data do not exist at the desirable level of spatial resolution or for the whole study area. Moreover, georeferenced longitudinal data are missing with the exception of recent time periods. This is a particularly acute problem in local level analysis of land use change.
- *Temporal dimension*. Lack of desirable spatiotemporal data may be due to: *(a)* lack of agency coordination responsible for the different categories of data; *(b)* lack of users of data (no demand - no need to collect data!); *(c)* lack of organizational continuity in the data collecting agencies; *(d)* lack of funds; *(e)* lack of feedback from users of data; *(f)* lack of systematic data collection procedures and rules; *(g)* lack of integrated planning in general.
- *Definitions*. Coarse, aggregate data may exist even at lower levels but the analysis may require disaggregate data. Definitionally aggregate data are risky when comparing different jurisdictions as what a given category includes in one area is not necessarily the same in the other. In general, data are available at higher spatial scales and for aggregate definitions of the concepts involved.
- *Data collection issues.* Frequently, quantitative data do not exist for all variables of interest in an integrated model. However, qualitative data of various types do exist which may be valuable not only in terms of missing data but also in interpreting quantitative data or disaggregating aggregate data.

2.5 Ease of collection/retrieval

- *Spatial dimension*. Data on most common variables are easier to find at higher than at lower levels. This is not only a matter of data availability but also of agency preparedness and management.
- *Temporal dimension*. Longitudinal data for long time periods or at frequent time intervals are usually less easy to find and retrieve. The further back into the past data are needed, the harder it is to find them especially from a single source. Land use type data are collected from past records, historical records, past maps, aerial photographs and satellite data. Problems of compatibility, consistency and reliability arise naturally and the time needed to collect and clean these data is considerable.
- *Definitions*. The easiest data to find are those concerning aggregate categories of variables and at aggregate spatiotemporal levels. Specialized surveys to gather detailed information or to obtain existing but less accessible detailed information may be difficult to conduct in many circumstances.
- *Data collection issues*. Data collected systematically (censuses or regular surveys) are usually easier to find. Data from specialized surveys and studies may not be accessible to non-specialized publics. The organizational system of data collection agencies influences also the ease of data collection.

2.6 Cost of collection/retrieval

- *Spatial dimension*. Coarser level data, in general, are less costly to obtain as they are published and stored in libraries or other organizations. Spatially refined data may be more costly to obtain.
- *Temporal dimension.* The more longitudinal data one needs, the higher the cost of obtaining them especially when these are not easily accessible. Moreover, the cost of retrieving past information of the desired quality may become prohibitive especially in local level studies.
- *Definitions*. Aggregate land use, economic, demographic, social and other data are available at no or little cost. Others - e.g. detailed climatic records, detailed vegetation maps - may imply high costs both in terms of money and time.
- *Data collection issues*. Public agencies usually provide data free of charge while private or semi-public agencies may impose fees for the data provided (e.g. the cost of satellite images). Also, data regularly collected and with standardized techniques are less costly than it is the case otherwise.

2.7 Transferability

- *Spatial dimension*. Transferring data among spatial scales is particularly serious from coarse to fine spatial levels. Data disaggregation rules used differ according to the type of variable (economic, environmental, social, policy) as well as from one country to the other. Disaggregate data may not be congruent to each other and, hence, the consistency criterion is violated.
- *Temporal dimension*. The same applies to the temporal disaggegation of coarse data. Simplifying assumptions may be necessary to make which, however, will threaten the consistency of the data sets. A special problem with temporal data in integrated modeling is that the endpoints of the data collection periods do not coincide and, hence, disaggregation is more problematic. Moreover, it is not certain that the data available can be disaggregated to approximate the state of the system during particular periods of interest.
- *Definitions*. Things are more serious when definitions are aggregate or have changed. The disaggregate data may not correspond to the definition of the variable(s) involved.
- *Data collection issues.* The transferability of data among spatial and temporal scales as well as categories of the variables used is seriously affected by the different data collection pro-

cedures employed. Personal and idiosyncratic factors may intervene also to modify the output of the most standardized procedure and make the transfer of data a task requiring great caution.

3. Framework guidelines to address the main types of data needs

Four main issues of data needs emerge along the four principal data dimensions - spatial system of reference, temporal system of reference, definitions, and data collection issues. The ensuing discussion suggests framework guidelines for both existing and new data with particular attention to the specific needs of the local level.

- *Spatial system of reference*. The spatial systems of reference used for data collection should be made compatible by procedures which ensure good approximations of the disparate systems by a common, new system. The spatial aggregation rules should be clear and transparent. The new system should utilize the GIS technology and should incorporate aggregation algorithms for easy transfer of data among spatial scales. The use of GISs will make possible finer levels of spatial aggregation and will secure a reasonable degree of easy and not expensive data retrieval. The standardization of the spatial systems of reference used should ideally apply to all countries and to all disciplines.
- *Temporal system of reference*. The temporal frames of reference used by different disciplines should be made compatible so that different variables can be analyzed simultaneously. A common denominator for the different temporal scales employed by the various disciplines should be found as well as temporal aggregation rules. Common dates of data collection should be established so that data collection does not seriously jeopardize the temporal order of the real events. The standardization of the temporal systems of reference used ideally should apply to all countries and to all disciplines. Ideally, the standardization of the temporal systems of reference should be done, in conjunction with the standardization of the spatial systems of reference to secure spatiotemporal compatibility and consistency.
- *Definitions*. Standardization of the conceptual and operational definitions of all variables used in integrated analysis is an absolute necessity. Internationally, several efforts at standardization have already been made. However, it refers to coarse spatial and temporal scales while it is less common at the local level due to the greatest variability of local characteristics. The development of generally applicable land use classification systems at various levels of spatiotemporal aggregation and harmonized between countries is a first priority research topic. In general, development and adoption of common classification systems will secure explicit, operational, consistent, and unambiguous definitions which will facilitate the integrated analysis of land use change. For past data, conversion and "translation" rules need to be elaborated on a case-by-case basis.
- *Data collection procedures*. Several aspects of data collection demand standardization such as the spatial and temporal systems of reference, operational definitions at each level of detail, corresponding formats of data collection, methods of data collection (census, survey), techniques for data cleaning, coding, recording, and updating, technological infrastructure (computers, GIS), dates of data collection, training of the personnel. This task should be carried out in relation to the development of classification systems suggested before.

  The treatment of qualitative data collection especially for past time periods and at the local level is of particular importance as regards: *(a)* the georeferencing of the existing historic information; *(b)* the spatial and temporal aspects of historic data; *(c)* the operational definitions corresponding to the data collected; *(d)* the harmonization of historic and qualitative information with quantitative information for the same variable(s) of interest.

Finally, the management of the variety of data needed for the integrated analysis of land use change assumes an organizational apparatus with a lattice structure (both horizontal and vertical) which is responsible for all aspects (organizational, financial, legal) of this task. Hence, it is proposed to create a unified, integrated system of data management for the analysis of land use change. This system will operate at all spatial levels - from the international to the local - its competencies becoming stronger and more explicit at the lower levels.

BELIEF NETWORKS: A TOOL FOR EXPERIMENTAL DESIGN

Jeremy D. Cain, C. H. Batchelor and D. K. Waughray
Institute of Hydrology, Wallingford, UK

Five principles for data collection

Experience of modelling integrated environmental systems at the small catchment scale has suggested that an effective data collection strategy should follow five main principles:

1. Stakeholders should be involved in the identification of key variables. Effective research is demand, not capacity, driven. What is important to the scientific modeller may not be of such importance to the stakeholder. Models should ultimately be designed to support stakeholder needs and they can only do this if they directly address issues which stakeholders consider to be important.
2. At small scales, data requirements are highly system dependent. Small catchment scale environmental systems are highly individual. Indeed, each stakeholder's perception of the same system may be different. This highlights the need to design data collection specifically for each system being modelled. Generic programmes of data collection will be useful but not sufficient. It is only once the key variables of the system and their interactions have been identified that the data requirements become clear.
3. Uncertainty in data should be considered and quantified. Our often imperfect understanding of process function, together with the inexact nature of measurement, makes precise specification of the causal links between system variables a difficult task. The uncertainty inherent in environmental data should be acknowledged, quantified and incorporated into land use models. In this way, model predictions will be no more accurate than the data which produced them and policy decisions based upon them will be better able to account for the possible risk of failure.
4. Economic data collection should not be focused just on specifying a profit function. It should include all environmental values that quantify the full cost or benefit to society of a change in environmental quality as well as all variables that affect people's decision making. Environmental costs and benefits consist of more than sums of money spent or gained and decisions affecting land use are made for a wide variety of reasons other than profit maximisation. Even though such decisions and their consequences may not have a direct or immediate financial impact, they can still be characterised in economic terms. For example, it may be important to collect data quantifying stakeholders' concern for issues such as inter-generational equity and biodiversity. If these data are excluded in favour of a profit maximisation model then an incomplete description of the system will be obtained and any decisions based on such models will be flawed.

5. Important indicators should be defined in a generic and flexible way. If a model is designed to bring about an improvement in the environment then there must be a means of assessing whether this has been achieved. As discussed above, success will not just be a matter of increased income, but will depend on less readily defined factors such as sustainability, biodiversity and quality of life. It is helpful to define indicators capable of quantifying these factors so that they can be applied to a wide range of systems.

Belief networks for systems analysis and experimental design

Belief networks provide a useful modelling framework within which integrated data collection programmes can be designed and multi-disciplinary modelling carried out. They offer a method of quantifying relationships between variables even if the relationships involve uncertainty, unpredictability or imprecision. Links between variables can be established using field data or, if more appropriate, expert opinion.

The advantages of belief and decision networks are numerous. Firstly, the graphical nature of the approach facilitates formal discussion of the system structure with people from a wide variety of backgrounds and so encourages interdisciplinary data analysis and stakeholder participation. Secondly, the ability to specify the relationships between variables in uncertain terms is ideal for true integrated modelling where the relationship between physical and socio-economic dynamics may not be well understood. Moreover it enables expert knowledge to be incorporated into the model on the same basis as more objectively derived data. Such features allow the creation of a model which may contain mathematical relationships as well as subjective elements corresponding to the experience of the people who are, in many cases, an integral part of the system being modelled. A further advantage lies in the formal identification of the system variables and interactions. In doing this, data collection programs can be designed to provide comprehensive and well-balanced datasets.

Conclusion: Specific data collection for complex modelling

If data collection programmes are truly to serve the needs the land use modellers and, in turn, users of models, then it is important that these needs are defined precisely. Generic strategies designed to meet the requirements of the majority will fail to provide the specific detail necessary to account for the complexity inherent in environmental systems. Land use models should not seek to avoid this complexity but must find effective ways of incorporating it into analysis. Belief networks show great promise in enabling the achievement of such a goal.

GTOS (GLOBAL TERRESTRIAL OBSERVING SYSTEM); OBJECTIVES, FUNCTIONS AND STRUCTURE

Antonio Cendrero
Global Terrestrial Observation System (GTOS) Steering Committee
Departamento de Ciencias de la Tierra y Física de la Materia Condensada, Facultad de Ciencias, Universidad de Cantabria, Santander, Spain

The Global Terrestrial Observing System (GTOS) was established in 1995, with the completion of a Scientific an Technical Planning Group Report, which was followed in 1996 by the formation and first meeting of a Steering Committee. The mission of GTOS is "to provide policy makers, resource managers and researchers with access to the data they need to detect, quantify, locate, understand and warn of changes (especially reductions) in the capacity of terrestrial ecosystems to support sustainable development". In brief, to provide the basis for more informed decisions about the management of environmental change.

GTOS is sponsored by the Food and Agriculture Organization of the United Nations (FAO), the International Council of Scientific Unions (ICSU), the United Nations Environmental Programme (UNEP), the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the World Meteorological Organization (WMO).

In order to achieve GTOS objectives, we must understand the nature, causes, extent and rate of changes as well as determine their consequences for human well being. This requires the coupling of long-term observations at various spatial and temporal scales with process studies and models.

GTOS focuses on five issues of global concern:
1. changes in land quality
2. availability of freshwater resources
3. loss of biodiversity
4. climate change
5. pollution and toxicity

It works under the following guiding principles:
a) user-driven system
b) phased approach
c) reliance upon existing systems
d) equal access for all participants
e) facilitator for collection, distribution and archiving of data and information
f) pro-active in assisting nations to obtain resources for upgrading existing systems and, where necessary, establishing new ones

According to its aims, GTOS promotes: the integrated analysis of bio-physical and socio-economic data; interaction between monitoring networks, research programmes and policy makers; data exchange and application; quality assurance and protocols to harmonize measurements; and also provides guidance in data analysis.

It is also pertinent to point out that GTOS is not meant to be a research programme nor a source of primary data; neither it is a source of funding, although it may assist others in seeking funds for scientific work consistent with its objectives.

The GTOS structure includes the following components:

- Sponsors group. It assures that the needs and requirements of the sponsoring organizations are me; the co-sponsors make annual financial contributions to the programme.
- Steering Committee. Responsible for the overall technical management of GTOS; it advises the co-sponsors on conceptual and design matters, reviews and assesses progress and identifies opportunities for collaboration.
- Panels and working groups. Specialized technical groups to liaise with other organizations or to deal with specific topics.
- Executive Secretariat. Assists and supports the former.

GTOS users and providers of data include: governments, scientific programmes, UN organizations, international agreements, the other global observing systems (GCOS for climate and GOOS for oceans), NGOs and the private sector. GTOS has already carried out first round of contacts and will further undertake consultations with potential associates and users groups, to identify their requirements and determine to what extent it will be able to meet those requirements. Discussions with the Convention Secretariats have produced a report on their data needs. A joint GCOS-GTOS Terrestrial Observation Panel for Climate has produced a Version 2.0 of a plan for climate-related observations, including a list of variables. This plan is based on the Global Hierarchical Observation Strategy (GHOST) which includes five tiers, ranging from detailed “in situ” observations and measurements in a few selected areas to complete satellite coverage.

In cooperation with GCOS, a meeting of experts on ecological networks was held in June 1997. A strategy for forming a Global Terrestrial Observation Network (GT-Net) was defined and a demonstration project on Terrestrial Ecosystem Productivity was designed to be carried out in cooperation between GTOS, GCOS and the networks.

Other potential users and partners of GTOS include programmes such as CGIAR and IGBP in general or LUCC in particular. The cooperation with LUCC could be especially fruitful in areas such as the preparation of a list of variables for “in situ” and space measurements for land, freshwater and biodiversity. Another line of collaboration could be the establishment of the global network of monitoring and research sites. It would be especially helpful if this network could develop common approaches to data collection to assure the comparability of data, and sampling and modelling techniques to “upscale” the data.

It is to be hoped that this initial contact between LUCC and GTOS will lead to extensive and fruitful collaboration in the near future.

EU-TERI-PROJECT ECOMONT: RESEARCH ON ECOLOGICAL EFFECTS OF LAND-USE/COVER CHANGES IN EUROPEAN MOUNTAIN LANDSCAPES

Alexander Cernusca
Institut für Botanik, Universität Innsbruck, Sternwartestraße 15, A-6020 Innsbruck, Austria
Ulrike Tappeiner
Europäische Akademie Bozen, Weggensteinstraße 12a, I-39100 Bozen, Italy

1. Introduction

Since thousands of years the Alps have been inhabited and cultivated by man. In European mountain regions long-lasting agricultural practice has shaped a highly complex cultural landscape; a landscape that is characterised by great diversity, fulfilling a number of important functions, such as agricultural production, keeping an ecological balance, as well as social and protective functions. This cultural landscape is tightly connected with traditional rural structures. The changing economic conditions, however, have caused an increasing intensification of land-use in valleys and on plateaus, whereas steep slopes and unfavourably situated areas are increasingly being abandoned. This development has caused a large number of serious problems: in many Alpine regions agriculture is bound up with the cultural identity and the social life of its inhabitants, and is the essential "driving force" to maintain the artificial ecological balance in this Alpine cultural landscape. Hence structural changes in the management of mountain areas threaten the traditional cultural landscape and lead to far-reaching ecological, social, cultural and economical changes. In order to stop this process the principle of sustainable development of Alpine management must be more strongly emphasised in the future. In accordance with the UN-summit of Rio in 1992 all three aspects referring to this term are of vital importance (figure 1) in order to achieve a sustainable development in ecology but also in social and economical fields (cf. TAPPEINER and JÖRN 1997). The scheme shown in figure 1 could also hold for a possible co-operation between TERI and a European LUCC. TERI is providing research on the effects of land-use changes on diversity, ecological complexity and ecosystem functioning at the level of composite landscapes and regions, whereas LUCC could provide research on the socio-economic driving forces affecting land-use changes in different parts of Europe.

In contrast to peasants living in the foothills of the Alps peasants in mountain regions must secure their income by *(1)* high quality products with regional marketing, and *(2)* support of agricultural achievements other than production. Due to the lack of scientifically based criteria and indicators in politics, which would allow an objective judgement of the ecological importance of agriculture, assistance in view of a sustainable management in mountain areas is not possible. The necessity of such indicators can be seen in the fact that the Commission in Brussels is working out a paper on suitable indicators for sustainability. For the European Intergovernmental Conference for sustainable development of Mountain Regions these indicators are also a matter of vital importance as they have stated in their meeting in October 1996. Indicators for the assessment of the ecological function of mountain landscapes must consider *(1)* the high sensitivity of nature and ecology in Alpine areas, *(2)* the European dimension and *(3)* the great regional differences.

As a contribution to the Terrestrial Ecosystem Research Initiative (TERI, EU-RTD-Framework IV) ECOMONT (http://Info.uibk.ac.at/ECOMONT) aims at investigating the ecological effects of agriculture and forestry induced land-use changes in the mountains. Within this project the effects of a reduction of land-use and abandonment, but also of an intensification and reforestation of hay meadows and pastures above and below the timber line are being investigated.

2. Research sites

In order to consider the effects of land-use changes on processes in terrestrial mountain ecosystems at a European scale six composite landscapes are investigated in the subalpine belt of different European mountain regions (see figure 2). Three landscapes are situated along a South/North-transect across the Eastern Alps (from the Italian to the Austrian Alps, geologically dominated by limestone or silicate), and a fourth site, geologically dominated by 'Flysch', is located in the Swiss Alps. In order to consider adequately the different background conditions of mountain ecosystems in Europe, investigations in the Spanish Pyrenees and the Scottish Highlands are also included.

3. Work packages and contributing partner teams

In each ECOMONT study site comparative, multidisciplinary integrated ecosystem studies are conducted on differently managed and abandoned ecosystems (meadows, pastures, abandoned areas, dwarf shrub communities and forests). Table 1 shows the 12 research topics (work packages) of ECOMONT and the contributing partner teams. ECOMONT attempts to integrate two different basic approaches: a landscape ecological approach, including investigations of vegetation dynamics, soil properties and agricultural ecology along different successional stages from intensively managed to abandoned ecosystems (work packages n° 1, n° 2, n° 10, n° 11); secondly, integrated ecosystem studies including comparative investigations of dif-

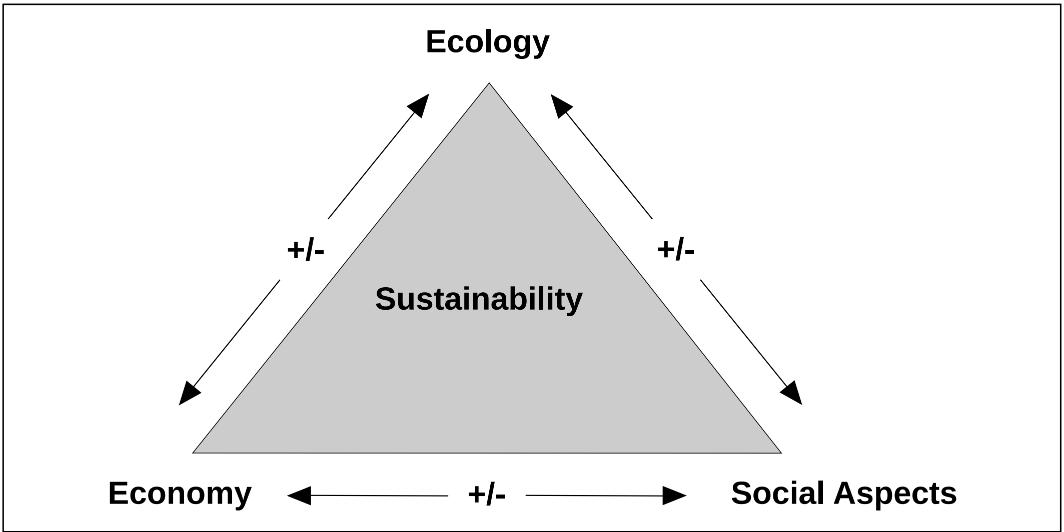


Figure 1. The three aspects of sustainability (cf. Tappeiner and Jörn 1997).

ferent successional stages within the composite experimental sites. Integrated ecosystem research aims at examining in detail how changes in the canopy structure are connected with species composition and performance, and to understand the influence of land-use changes on soil organic matter (SOM) status and turnover, on biogeochemical cycles and hydrological processes at the ecosystem level, and on the exchange processes between the ecosystems and the lower layers of the atmosphere. Following a bottom up approach (Cernusca *et al*. 1998) the gas exchange (CO_2, H_2O, and related trace gases) of single plants, functional plant groups, ecosystems and composite landscapes (work packages n° 6, n° 7, n° 8) is investigated (Bahn and Cernusca 1998, Bahn *et al.* 1998, Graber *et al.* 1998, Tappeiner *et al.* 1998a, Tappeiner and Cernusca 1998a). A hierarchy of process based models (work package n° 12) is used to link gas exchange processes at the different scales (Royer *et al*. 1998, Tappeiner and Cernusca 1998b, Tappeiner *et al.* 1998b, Tenhunen 1998, Wohlfahrt *et al.* 1998).

4. First results

First results of ECOMONT show that changes in land use are connected with long-lasting changes in the structure, functioning and dynamics of the involved terrestrial mountain ecosystems. Above all changes in species composition and performance, as well as in species competition and interaction are occurring. Land-use has a decisive influence on the number of species in differently managed alpine grassland-ecosystems. The number of plant species is highest on lightly-managed meadows. The species number declines with intensification, but also with abandonment (Cernusca *et al.* 1996, Tasser *et al.* 1998). Abandonment leads to an accumulation of necromass on the soil surface, and soil organic matter increases (Bitterlich *et al.* 1998). Changes in the uppermost layer of the soil profiles may occur within decades, whereas changes in deeper soil layers might need even more than thousands of years. In spite of common principles of changes of vegetation, soils and related processes with altered land-use, geology, climate, exposition, slope inclination and land-use history may play an important role in determining species composition and specific patterns and processes on a community, ecosystem and landscape level in different European terrestrial mountain ecosystems (Tappeiner *et al.* 1998b).

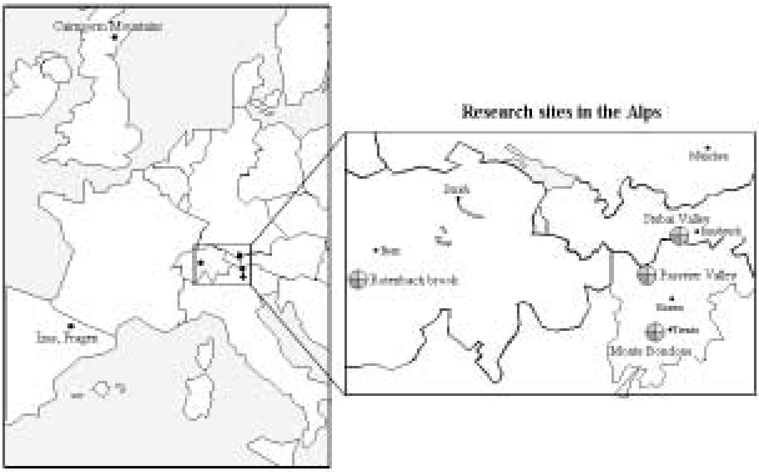


Figure 2. ECOMONT research sites in the Alps, the Pyrenees and the Scottish Highlands.

Table 1. ECOMONT research topics and contributing partner teams.

Work packages of ECOMONT
1. Spatial distribution of vegetation and soil in the composite experimental sites
2. Physical and chemical soil properties, SOM status and turnover
3. Canopy structure, primary production
4. Water relations of ecosystems and catchment areas
5. Microclimate, energy budget of ecosystems
6. Gas exchange of single plants and ecosystems
7. Gas exchange between the composite experimental sites and the atmosphere
8. Population and plant biological studies
9. Potential risks through land-use changes
10. Geographical Information System (GIS)
11. Remote sensing
12. Modelling activities integrating from the plant level to the ecosystem and landscape level
Contributing partner teams
Institut für Botanik, Universität Innsbruck (A) (coordinator)
Institute of Terrestrial Ecology (ITE), Banchory, Kincardineshire, Scotland (GB)
Institut für Terrestrische Ökosystemforschung (BITÖK), Universität Bayreuth (D)
Europäische Akademie Bozen (EAB), Bozen (I)
Centro di Ecologia, Monte Bondone (CEA), Trento (I)
Instituto Pirenaico de Ecologia (IPE), Jaca (E)
Paul-Scherrer-Institut (PSI), Villigen-PSI (CH)
Forschungsanstalt für Agrarökologie und Landbau (IUL), Bern-Liebefeld (CH)
Geo-Partner, Zürich (CH)

Closely connected with changes in the plant cover are also changes in the canopy structure (Tappeiner *et al.* 1998a) and changes in ecosystem processes, as for example in the in the energy regime and the gas exchange processes of ecosystems. Reduced management and abandonment leads to a reduction of evapotranspiration (LE), and to a corresponding increase of the sensible heat fluxes to the atmosphere (H). Abandonment leads to an increasing accumulation of dead plant material within the canopy, and as a consequence a larger part of the absorbed radiation energy is converted into sensible heat (Tappeiner and Cernusca 1998a).

The observed reduction of canopy photosynthesis in the abandoned areas is partly the consequence of the mentioned accumulation of attached dead plant material, absorbing light without any contribution to canopy photosynthesis. Another very important explanation for the observed decrease of the canopy photosynthesis after abandonment could be provided by detailed ecophysiological investigations. As measurements of Bahn *et al.* (1998) have shown the photosynthetic capacity of species decreases with decreasing management. The reason for this is twofold: Firstly, on the abandoned area a number of species get established that display a lower photosynthetic capacity per se, such as shrubs and dwarf shrubs. Secondly, decreasing land-use reduces the nitrogen availability for plants, which frequently results in lower leaf nitrogen concentrations causing lower photosynthetic capacities on abandoned areas as compared to the intensively managed areas.

5. Some bullet-points in context with the LUCC data requirement workshop

Based on first results of the EU-TERI-project ECOMONT the following bullet points to the aims and tasks of our LUCC Data Requirement Workshop can be provided:

- In context with decision-making processes it is necessary to develop scenarios, which should integrate socio-economic models.
- Land-use history plays a decisive role for the actual spatial distribution of plant cover and has to be included in land-use research.
- Mountain ecosystems show a specific high diversity and spatial complexity. This has to be taken into account in land-use/cover research.
- From the point of view of European ecosystem research (e.g. Framework IV) the methodology of LUCC fits well the European needs but the applied scales in time and space are not suitable for the European dimensions:
  1. In context with the expected land-cover/land-use changes answers are needed in Europe for the next 10 to 30 years and not for hundreds of years.
  2. In context with the high spatial fragmentation of European regions and landscapes an appropriate smaller spatial scale has to be used in Europe. This scale has further to be reduced for mountain areas.
- Land-use has a decisive influence on diversity and ecological complexity (species, ecosystems, landscapes, regions). Changes in diversity and ecological complexity are closely connected with ecological functioning. In order to develop scenarios on sustainable development integrated research initiatives are urgently needed. Contributing projects should provide both, research on diversity/ecological complexity and ecological functioning. They should also link scales from the species to the landscape and regional level (as many as possible).
- Since political decisions are made at a regional level, the European ecosystem research has to focus on the processes within composite landscapes and regions. New process oriented concepts and methods have to be developed linking research at the level of single species and biocenosis with the level of ecosystems and landscapes.

6. References

BAHN, M. AND CERNUSCA, A. (1998): "Effects of land-use changes on plants - a functional approach". In: *ECOMONT: Ecological effects of Land-use changes in Mountain Areas of Europe.* (ed. by A. Cernusca and U. Tappeiner). Blackwell Wiss.-Ver., Berlin, Wien, in press.

BAHN, M., WOHLFAHRT, G., HAUBNER, E., HORAK, I, MICHAELER, W., ROTTMAR, K., TAPPEINER, U. AND CERNUSCA, A. (1998): "CO_2 assimilation and leaf nitrogen contents of 26 grassland species in differently managed mountain ecosystems in the Eastern Alps". In: *ECOMONT: Ecological effects of Land-use changes in Mountain Areas of Europe.* (ed. by A. Cernusca and U. Tappeiner). Blackwell Wiss.-Ver., Berlin, Wien, in press.

BITTERLICH, W., SARTORI, G. AND CERNUSCA, A. (1998): "Impact of land-use on soils along an Eastern Alpine transect". In: *ECOMONT: Ecological effects of Land-use changes in Mountain Areas of Europe.* (ed. by A. Cernusca and U. Tappeiner). Blackwell Wiss.-Ver., Berlin, Wien, in press.

CERNUSCA, A., TAPPEINER, U., BAHN, M., BAYFIELD, N., CHEMINI, C., FILLAT, F., GRABER, W., ROSSET, M., SIEGWOLF, R. AND TENHUNEN, J. (1996): "ECOMONT - Ecological Effects of Land Use Changes on European Terrestrial Mountain Ecosystems". In: *Pirineos* 147-148: 145-172.

CERNUSCA, A., BAHN, M., CHEMINI, C., GRABER, W., SIEGWOLF, R., TAPPEINER, U. AND TENHUNEN, J. (1998): "ECOMONT: A combined approach of field measurements and process-based modelling for assessing effects of land-use changes in mountain landscapes". In: *Ecol. Modelling*, in review.

GRABER, W. K., SIEGWOLF, R. T. W. AND FURGER, M. (1998): "Land-use changes in the Alps and its effect on CO_2 and water vapour exchange between a composite landscape and the atmosphere". In: *ECO-*

MONT: Ecological effects of Land-use changes in Mountain Areas of Europe. (ed. by A. Cernusca and U. Tappeiner). Blackwell Wiss.-Ver., Berlin, Wien, in press.

ROYER, S., CERNUSCA, A., ROYER, A. AND TAPPEINER, U. (1998): "A multi species canopy model for analysing gas exchange processes in grassland ecosystems". In: *ECOMONT: Ecological effects of Land-use changes in Mountain Areas of Europe.* (ed. by A. Cernusca and U. Tappeiner). Blackwell Wiss.-Ver., Berlin, Wien, in press.

TAPPEINER U. AND JÖRIN R. (1997): "Pour une gestion durable de l'espace par l'agriculture et la sylviculture". In: *Revue de Géographie Alpine.* Supplement au n° 4/1996, pp. 101-107.

TAPPEINER, U. AND CERNUSCA, A. (1998a): "Land-use changes in the Alps and their effects on exchange processes (CO2, H2O) in grassland ecosystems". In*: Headwater Control IV: Hydrology, Water Resources and Ecology in Headwaters.* (ed. by K. Kovar, R. Craig, J. Peters and U. Tappeiner), in press.

TAPPEINER, U. AND CERNUSCA, A. (1998): "Model simulation of spatial distribution of photosynthesis in structurally differing plant communities in the Central Caucasus". In: *Ecol. Modelling*, in review.

TAPPEINER, U., SAPINSKY, S. AND CERNUSCA, A. (1998a): "Effects of land-use on canopy structure and microclimate of grassland ecosystems in the Alps". In: *ECOMONT: Ecological effects of Land-use changes in Mountain Areas of Europe.* (ed. by A. Cernusca and U. Tappeiner). Blackwell Wiss.-Ver., Berlin, Wien, in press.

TAPPEINER, U., TASSER, E. AND TAPPEINER, G. (1998b): "Modelling human and naturally triggered changes in the landscape: First experiences with a GIS based model applied to an Alpine area". In: *Ecol. Modelling*, in review.

TASSER, E., PROCK, S. AND MULSER, J. (1998): "Effects of land-use changes on the plant cover in the Eastern Alps". In: *ECOMONT: Ecological effects of Land-use changes in Mountain Areas of Europe.* (ed. by A. Cernusca and U. Tappeiner). Blackwell Wiss.-Ver., Berlin, Wien, in press.

TENHUNEN, J. D. (1998): "Model hierarchies for relating vegetation structure, ecosystem physiology, and plant community distribution to landscape water use". In: *ECOMONT: Ecological effects of Land-use changes in Mountain Areas of Europe.* (ed. by A. Cernusca and U. Tappeiner). Blackwell Wiss.-Ver., Berlin, Wien, in press.

WOHLFAHRT, G., BAHN, M., HORAK, I., TAPPEINER, U. AND CERNUSCA, A. (1998): *A nitrogen sensitive model of carbon.*

EVALUATION OF LAND COVER MODIFICATION AND VEGETATION DISTRIBUTION IN ARID AREAS BY MEANS OF REMOTE SENSING AND GIS TECHNIQUES

Claudio Conese and Andrea Di Vecchia
IATA-CNR, CeSIA - Accademia dei Georgofili, Firenze, Italy

In this work the results achieved by a project (PEICRE) against desertification and land degradation in Niger will be showed. Remote sensing techniques and GIS have been used to evaluate the land modification and food production improvement produced by a previous FAO project called Projet Integree Keita (PIK), developed in a test site in Niger. The area of interest is about 3.500 kmq wide and it is located around the Keita village. In this country the climatic conditions are really hard, because of a very low rainfall level per year and the heavy soil erosion process interesting such an area. The PIK project started in 1984 thanks to a Niger/Italy/FAO agreement and it has been interrupted two years ago to observe the effects it produced on the area of interest. During these ten years a lot of field works have been developed to improve the potential agricultural productivity of the region, in order to reduce both desertification and erosion processes.

With the PEICRE project, developed in 1995 and 1996, CeSIA has been charged of evaluating if the PIK project produced the desired effects. However CeSIA has to evaluate any modification of the territory shown since 1984 up to 1995. The methodologies applied to achieve such goals are based mainly on multitemporal processing and analysis of remote sensed data and also on developing a specific Geographic Information System devoted to manage both remote sensed processed data and auxiliary information. The developed processing chain has been applied to images acquired by different satellite systems, the Landsat TM, MSS and the multispectral SPOT HRV. The used images have been acquired in three different dates within the PIK duration to establish the vegetation coverage (both agricultural and natural) evolution.

The processed images have been integrated in the customised GIS and linked to the other socio-economic, meteorological and topographic information, provided by the Nigerin administrations and FAO archives and acquired, as well, from French cartographic production concerning the studied area. Aerial photographs have been also used, together with field observations, to verify the reliability of the developed classification algorithms. To improve and to make easier the photointerpretation, a data fusion process between satellite data and aerial photographs has been studied producing encouraging results.

Finally the operative methodology, which was developed and implemented thanks to the PEICRE project, will be presented referring to the several practical encountered problems, as well: from the heavy soil influence on the measured reflectance, up to the large extension of the test area and the similarity of the typologies to extract.

THE LUCC DATA REQUIREMENT FOR SOCIO-ECONOMIC AND DEMOGRAPHIC GIS DATASETS

Lawrence W. Crissman
Griffith University, Nathan, Australia

The LUCC data requirements workshop appeared, to me, to concentrate mainly on either of two things: one was the need for more and better satellite imagery and/or more access to existing remote sensing resources; and the other was on drawing up lists of all the various kinds of information, of whatever nature from whatever sources, that could possibly impact on LUCC and which would, therefore, be nice to have if someone would fund or otherwise organise their accumulation. Attention was also paid to the need to integrate the relevant work of social scientists, who were felt to perhaps have the key to understanding the human dimensions of LUCC.

As a bona fide social scientist (anthropologist first, and now geographer *manqué*), I am not so sure about the generality of the last point, but I am firmly convinced of the need for LUCC to incorporate certain kinds of data relating to demographic and socio-economic variables in order to address the 'human dimensions' of the ways land is being or has been used. I also believe that I know how that can be done, at least in the first instance, in a manner that will be basically compatible with the data sets derived from remote sensing that are now dominant in existing LUCC research agendas. The key need is to incorporate available sources of relevant data on humans - their numbers, characteristics, and activities - into Geographical Information System databases at national or even continental levels, which could eventually aggregate into world coverages.

The quantity as well as the quality of existing data sources vary greatly from one country to another, of course, but there are enough commonalities in basic census materials, for instance, to produce a GIS-based 'World Demographic Database' with a fine enough discrimination to allow pixelization onto a 1 km grid that would be compatible with other datasets at that resolution. If suitably structured to differentiate between urban and rural populations and to represent other information on settlement patterns, those kinds of data would provide the empirical basis for local, regional, and even national demographic models that would in turn allow the generation of more complex models for such things as surplus or deficit of demand for various commodities produced from the land, clearly one of the major 'driving forces' of land use changes.

The manner in which such existing demographic and socio-economic data (including agricultural statistics and import/export levels, etc.) can be readily incorporated into small scale (nominally at least 1:1 m) GIS databases is well known - all that is necessary are the local-level administrative boundaries for the units for which such statistical data are routinely published, along with the point locations of cities, towns, and rural settlements, particularly in regions of relatively sparse rural population densities where average figures are often more or less meaningless.

Although such boundary information is generally available, at least on paper maps, there are many incompatibilities. Nonetheless, the Worldwide Map Consortium (WMC) is compiling a complete set of such administrative and settlement data that will be of great relevance to LUCC research. However, the WMC is a commercial initiative that must not only recover all its costs but also make a profit, so in the absence of funding that would allow the 'global change research community' to access those data at nominal or even low cost, they will have to be purchased by individual researchers. Further information on the WDC will eventually be available from the Internet (probably http://www.worldmaps.com).

MICROLEIS PROJECT: EXPLORING THE AGRO-ECOLOGICAL LIMITS OF SUSTAINABILITY

Diego de la Rosa
Instituto de Recursos Naturales y Agrobiología de Sevilla, CSIC, Spain

The Microcomputer-based Land Data transfer and Evaluation Information System, MicroLEIS 4.1, is a sophisticated interactive software with comprehensive documentation for modelling and planning the sustainable use and management of rural resources, with special reference to Mediterranean regions. It provides an orderly arrangement of land survey data (for more than 5,000 variables) through spatial databases and computerised land evaluation (quality/vulnerability assessment) models with the following major characteristics: information and knowledge engineering, using a variety of database, and empirical and simulation modelling techniques; scaling-up of process knowledge from the micro-scale to the landscape-scale (regional, national and continental scales); evaluating-units used: place (climate), soil (site+soil), land (climate+site+soil) and field (climate+site+soil+management); using monthly meteorological data and standard information as recorded in routine land surveys; information extracted from point observations to be interpolated to areas; integrated approximation, combining biophysical data with agricultural management experience, although socio-economic attributes are not considered; incorporation of the sustainability concept in land evaluation, considering land capability, suitability and productivity, and soil erosion and contamination as sustainability indicators; and prediction of global change impacts by creating hypothetical scenarios.

This software, selecting the English or Spanish presentation, runs under MS-DOS and is keyboard menu-driven. It has a user-friendly front-end which allows the models to be operated in interactive or batch modes. Data output is produced in format readily accepted by GIS packages. The programs include "on-line" explanation. The accompanying documentation give a clear and detailed description of the modules and uses examples to explain how to get the most out of MicroLEIS.

The application of this system can facilitate the production of unified research datasets of soil factors, climate variables, crop characteristics and management practices, with emphasis placed on the point observations of representative soil survey profiles, and the typical agricultural land use systems in representative sites. Thus, existing land survey information can be made much more useful for agro-ecological modelling and planning developments; with the aim of a new precision agriculture. MicroLEIS is in a continuous process of development, as an "open" system which can be easily modified in the future.

PROGRESS TOWARDS A 1 KM GLOBAL INVENTORY OF HUMAN SETTLEMENTS

Christopher Elvidge
NOAA National Geophysical Data Center, Boulder, Colorado, USA

Much of global change research is dedicated to discerning and documenting the impacts of human activities on natural systems. Human population numbers have expanded from ~750 million in the mid-1700's to 5.8 billion in 1997 and are expected to double in the next 45 years.

Human activities which are known to be cumulatively altering the global environment include greenhouse gas emissions from fossil fuel consumption, air and water pollution, and land cover/land use change. Far from being evenly distributed across the land surface, to a great extent human activities with environmental consequences are concentrated in the vicinity of human population centers.

NGDC is near completion of a global inventory of human settlements, derived from night-time data from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS). The DMSP-OLS has a unique capability to observe faint sources of visible - near infrared emissions present at the Earth's surface, including cities, towns, villages, gas flares, and fires. NGDC receives global coverages of DMSP-OLS data in near real time and has developed algorithms for producing georeferenced fire and human settlements products.

The first global human settlement product has been assembled at 1 km resolution using a time series of DMSP-OLS observations spanning the 1994-95 time period. Data applications which are being explored include the spatial apportionment of human populations, fossil fuel trace gas emissions, urbanization impacts on food production, and urban heat island effects on meteorological records.

URBANISATION AND VEGETATION: MEASURING LANDSCAPE PATTERNS BY REMOTE SENSING TECHNIQUES

Cristina Milesi and Alfredo Altobelli
Centre for Theoretical and Applied Ecology, Gorizia, Italy
Enrico Feoli
Department of Biology, University of Trieste, Trieste, Italy

The urbanisation process depends on historical and socio-economic factors that defined and continue to define the urbanisation pattern of a given territory. Urbanisation is a diffusive process that is conditioned by geomorphological features and by ways of communication (roads, railways, rivers, lakes, seas). Urbanisation occupies land and thus fragments vegetation. Vegetation is to be considered as an indicator of the environmental state. In different degrees, depending on artificial or natural status, vegetation produces oxygen, retains CO_2, protects the soil, regulates the water cycle and therefor the climate, and hosts biodiversity. In this work remote sensing is considered as a source of data for detecting landscape patterns. The spatial distribution of vegetation intensity, measured as a distribution of different amounts of green biomass by means of NDVI (Normalized Difference Vegetation Index), is analysed by different mathematical techniques (semivariograms, fractals, chaos analysis, clustering, etc.) to make correlations with other ancillary data (urbanisation index, industries distribution, land use and socio-economic data). Landscape is analysed both along transects defined according to different criteria, and by different kinds of operational geographic units (OGU) defined by grids or by tessellation techniques at different scales and by administrative boundaries. Effects of fragmentation caused by urbanisation are well detected by vegetation biomass and diversity patterns.

The integration of remote sensing data with historical data, concerning urbanisation process and socio-economic development, including the changes in agricultural practices, by GIS may give the possibility to model different scenarios based on operational geographic units defined by objective and subjective criteria.

LUCC DATA NEEDS FOR INTEGRATED ASSESSMENT MODELS OF CLIMATE CHANGE

Hans-Martin Füssel and Ferenc L. Toth
Potsdam Institute for Climate Impact Research, Dept. Integrated Systems Analysis, Germany

Land-use and land-cover change (LUCC) and global climate change (GCC) are among the most important examples of global environmental change. Many LUCC processes like deforestation, afforestation, soil disturbances and changing agricultural practices contribute to GCC by emitting/absorbing greenhouse gases (GHG) or changing surface albedo. Tropical deforestation alone accounts for about 25% of global anthropogenic CO_2 emissions (cf. figure 1), and the share of LUCC processes for other GHGs is even higher. Also, impacts of GCC drive LUCC by processes like inundation due to sea-level rise, changing biomes, and thawing permafrost soils while mitigation measures include afforestation and the use of biomass energy. Moreover, LUCC and GCC have a number of demographic, socio-economic, political and cultural driving forces in common.

This situation calls for the integration of LUCC processes into Integrated Assessment Models of Climate Change (IAM-CC). There have already been some efforts in this direction, aiming, i.a., at the establishment of more realistic scenarios for non-industrial GHG emissions, and at assessing the relevance of feedback loops between LUCC processes on the one hand and GCC impacts and/or mitigation measures on the other.

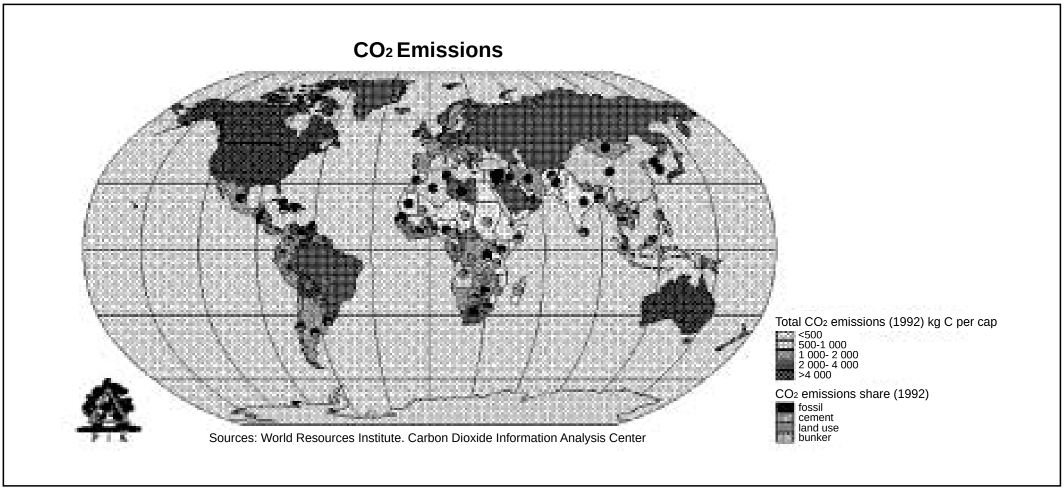


Figure 1

Although the coupling between LUCC models and other modules of IAMs-CC is still in a very early stage, some important insights into the interaction of GCC and LUCC have already been gained. An improved representation of LUCC processes in IAMs-CC certainly requires a refined set of LUC categories, and more precisely elaborated land allocation rules. Yet these efforts are often severely restricted by the lack of adequate data even on the current extent of LUCC. The most recent IPCC report still states a range of 0.6-2.6 Gt C for the global CO_2 emissions from tropical deforestation, and the uncertainty is even higher for data on a national level and for non-CO_2 GHGs.

It is important to improve our knowledge on this subject, both for obvious scientific reasons and for political and legal reasons, in particular with respect to GHG emission reductions and the enhancement of sinks as requested by the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). Fortunately, the increasing availability of remote sensing data from satellite systems like the Advanced Very High Resolution Radiometer (AVHRR) as well as progress in the field of computerized Geographical Information Systems (GIS) and data storage systems provide the opportunity to improve this situation considerably in the next few years. Many international programs, like LUCC, IGBP, GEMS, WISE, and SOTER already address this issue.

From the viewpoint of an IA modeller, the most important aspects concerning LUCC data as input to IAMs-CC are as follows. LUC classifications and databases need to be related to sinks and fluxes of GHGs and possibly to surface albedo. Datasets must have global coverage, and they should be globally comparable, consistent and of uniform quality, to the highest degree achievable. For high-level, functional data (e.g. based on net primary productivity) the spatial resolution can be rather coarse (about 100 km grid size) whereas for physiognomic data (e.g. land-cover classes) a much finer resolution is required. The provision of nationally aggregated parameters would be very helpful for meeting data demands related to the implementation of the UNFCCC. The Intergovernmental Panel on Climate Change (IPCC) suggests an update frequency of 3-5 years for data on non-industrial GHG emissions.

From the considerations above, the following specific needs for LUC data can be derived: a globally standardized, hierarchically classified, geo-referenced database depicting land use and land cover, which is updated at regular intervals; soil carbon and biomass carbon inventories that are compatible with the LUC classifications; a database for typical one-time GHG emissions connected with major LUCC processes (as an intermediate step); and a database on GHG fluxes for different categories and intensities of agricultural land use.

MODELLING ENVIRONMENTAL PHENOMENA RELATED TO AGRICULTURAL LAND USE: EXPERIENCES FROM TWO RESEARCH PROJECTS ON THE WATERSHED OF THE LAGOON OF VENICE

Carlo Giupponi
Dipartimento di Agronomia Ambientale e Produzioni Vegetali, Università di Padova, Italy

In recent years the Faculty of Agriculture of the University of Padova has been involved in two main research projects on agricultural land use in the area of the Watershed of the Lagoon of Venice, located in northern Italy: the RAISA and the IMPEL projects.

The RAISA Project Researches carried out from 1990 to 1996 in the Advanced Research Project for Innovation of Agricultural Techniques (RAISA) of the National Research Council of Italy are briefly presented. Within the project a model that produces and evaluates alternative farming systems, defined in terms of land use (in farm crop allocations and regional statistics of crop hectarages) and cultivation practices was developed. The economic and environmental viewpoints were considered within different hypotheses of agricultural policy and farmer's decision-making process.

The methodology for the environmental impact assessment of farming systems with changing land uses in the context of a geographical information system (GIS) is described into more details. The GIS supported spatial data management in particular for:

a. the definition of simulation environments;
b. the integration between physical and statistical geographical information;
c. the cartographic representation of results and the comparison of alternative scenarios.

The IMPEL Project

The contribution of the Italian group to the IMPEL project (Integrated Model to Predict European Land use) funded by the European Commission (DGXII) is also briefly presented. The project, which is currently in progress, aims to evaluate the impact of climate change on agricultural land use and its management at the farm and regional scales, including an assessment of potential adaptation strategies to climate change. A modularised model to estimate farmer decisions about land use that integrates biophysical representations of soils and crops with socio-economic considerations is being developed by researchers involved in the project.

In the IMPEL project geographical data are managed in a GIS context to undertake regional or national scale applications by aggregating from farms using georeferenced data sets of the physical environment (e.g. soils, climate, topography) and the socio-economic environment (e.g. prices, farm sizes, etc.).

Data requirements and management in the two Projects: During the last 7 years two research projects have studied mainly the same environmental variables in the same area. Nevertheless the significant differences of the aims of the two researches and the time lag between them made necessary considerable efforts in the re-organisation of the spatial database and new acquisition of data. Two detailed lists of data requirements of the two projects are presented and some practical problems encountered are discussed; in particular:

- the management of data deriving from various sources (different projections, coordinates, imprecise digitising, etc.),
- the effects of format conversions (e.g. raster/vector),
- the effects of various scales and resolutions,
- the needs of data maintenance.

LARGE SCALE BIOSPHERE ATMOSPHERE EXPERIMENT IN AMAZONIA (LBA) - DATA REQUIREMENTS AND DATA MANAGEMENT

Holger Hoff
BAHC - CPO Project Officer, Potsdam, Germany

Amazonia is a region, where large land use changes, mostly from forest to pasture and agricultural land have taken place. LBA is an integrated experiment to create new knowledge on the current climatological, ecological, biogeochemical and hydrological functioning of Amazonia as a regional entity. Effects of changes in land use and climate will be assessed and results will be translated into a policy relevant form.

Integration in LBA will be achieved across the different science themes and will reflect also in data management. Field sites, measurements and local and regional data will serve for different science themes. Integrated modeling will bridge across the major disciplinary modeling approaches in LBA. Integrated LBA data management is aiming at a uniform standardized database, incorporating physical and socio-economic data. GIS will serve as a major tool for integration on the data level.

LBA and LUCC. The LUCC component of LBA is closely linked with the other science themes. Research will focus on interrelations between LUCC and

– the physical climate
– nutrient cycles
– responses of river flow and constituent transport
– carbon budgets and emissions of greenhouse gases

as well as socio-economic causes of LUCC and predictive LUCC models.

LUCC data in LBA. The most relevant LUCC data in LBA are rates, spatial patterns and mechanisms of forest conversion. In addition to these aspects selective logging, agricultural land use and land abandonment also will be monitored closely. Major sources of these data will be remote sensing images, government statistics, survey data, case studies, and others.

LBA Data and Information System. A consistent and integrated data and information system (DIS) for LBA is currently designed and will be set up before the actual data flow begins. The LBA-DIS will provide uniform access to all data as well as standardized data formats and documentation. Due to the amount of data and the variety of types of data it is expected that a distributed data node design, across South America, North America, and Europe will be most effective for LBA.

Existing Amazon data relevant to LBA, from previous experiments and other sources are currently compiled on CD-ROM and on the LBA homepage (http://yabae.cptec.inpe.br/lba/). LBA key scientists were surveyed to rank data sets according to their LBA relevance.

LUCC related data to be provided for LBA are:
- Landsat Pathfinder, deforestation, vegetation
- AVHRR, NDVI vegetation
- Meteosat, deforestation, vegetation
- ISLSCP Initiative I, vegetation
- PRODES forest / non-forest areas, deforestation
- FLOODAMA, Amazon floodplains
- IBGE census
- RADAM, vegetation
- Woods Hole, vegetation
- Mathews, vegetation
- Skole & Tucker, deforestation
- Fearnside, biomass burning

and others

CLAUDE PRESENTATION: RECOMMENDATIONS FROM THE USERS MEETING ON LAND USE AND LAND COVER MONITORING IN EUROPE. Wageningen, the Netherlands, 22-23 May 1997

Margret Ihle and David Briggs
Coordinating Land Use/Land Cover Analysis and Data in Europe (CLAUDE) Project

1. Introduction

Background and aims of CLAUDE

The overall objective of the concerted action project "CLAUDE" (**C**oordinating **La**nd **U**se and Cover **D**ata and Analyses in **E**urope) is to develop an internally consistent Europe-wide plan for land use and land cover monitoring and research and to link with other international programmes on this issue.

CLAUDE aims to

- assess methods of monitoring land use/cover changes in Europe with emphasis on *change* and *monitoring* rather than on static data,
- investigate and improve the comparability and integration of land use data,
- improve coordination between different EU partners in land use research activities,
- improve linkages between EU and international land use efforts, and
- prepare guidelines for an EU-wide land use/cover programme.

2. Wageningen meeting

Types of land-use information

The type of land-use information which were discussed at the meeting included:

- Land-use information at the national level driven by EU policy
- Land-use information at the national level where EU policy is a response to land-use change
- Information on land-use change driven by external factors affecting all EU countries

Issues which were addressed during the meeting

- What are the drivers for Land-use Change?
- What types of Land-use Change are there?
- What are the data needs?
- What specific issues need attention?

Conclusions on the main issues

Regarding the drivers of land-use change the importance of information on the interconnections between policies which affect land use was stressed. The activity or reactivity of those policies should be understood as well as the differences in scale between levels of occurrence of land-use change and the level of policy development.

On the types of land-use change the need for information includes data on changes in spatial distribution, in function and character, performance and management. On each of those 'information levels' the need for data increases.

The integration of data and different concepts needs special attention.

3. The future course of CLAUDE

Meeting in January, 8-13, 1998. Zell-am-See, Austria

The remaining activity of the CLAUDE project will focus on the design of a land-use and land cover project (for Western Europe). It could and should provide a component of the international LUCC project.

DATABASE OF THE LONG TERM LAND USE CHANGES RESEARCH IN THE CZECH REPUBLIC

Leos Jelečcek
Department of Social Geography and Regional Development, Charles University, Prague

The paper deals with the basic features of the database used in the unique research project on the land use changes in Czechia in the periods 1845-1948-1990(95) which is being carried out at the Department. of Social Geography and Regional Development, Faculty of Science, Charles University, Prague. Since 1995 the project is sponsored by Grant Agency of the Czech Republic.

The database is based on archival data concerning approx. 13,000 cadastral units (1845 and 1948 data) which were taken from the Central Land Survey and Cadaster Archive. More recent land use data (1990, 1995) were taken from the Database Center of Czech Land Survey in Prague. All data originate from detailed ongoing cadastral mapping of the Czech territory started in the 1st half of the 19th century.

The following alterations of the original dataset have been made:

1) Simplification of the comparable 48 land categories from archival files (1845, 1948) and of 12 land categories from the computer database files (1990) into 8 land categories (arable land, permanent cultures, meadows, pastures, forest areas, water areas, built-up areas and other areas). This structure has been grouped into three more general categories (agricultural land, permanent grassland and remaining areas only).

2) For the sake of historical comparison in time and space, some 10,000 comparable basic territorial units covering the whole territory of Czechia were created. Both datasets have been edited in spreadsheet and transformed into GIS digital map of cadastral units. This altered database allows to carry out land use studies covering both large and rather small areas, to trace land use trends over certain period of time, to compare the land use structure with other socio-economic and natural data, and to use the results in a number of environmental analyses. Since the cadastral mapping has been carried out using the same methods on the whole western part of former Habsburg monarchy (Cis-Leithania) and the following mapping is probably based on it, a similar dataset could be presumably collected also for the area of contemporary Austria, Slovenia, and on the territory of former Galicia (i.e. south-eastern Poland and north-western Ukraine).

Further on, supporting cartographic datasets in this research are described. These originate from cadastral mapping and from detailed field mapping of the recent land-use structure in Czechia (1:2,880 - 1:25,000).

Finally, selected examples of GIS outputs of the database analysis covering the whole territory of the Czechia (tables, colored cartograms etc.) are presented. Major human impacts and related consequences on the land use structure in Czechia over the period 1845-1948-1990 are characterized.

LAND COVER CHANGES IN COASTAL ZONES. AREA OF CATALONIA

Maria del Mar Joaniquet
Institut Cartogràfic de Catalunya (ICC), Barcelona, Spain

Definition and context

The aim of this study is to estimate quantitative changes of land cover and/or land use in European coastal zones over a period of about 15 years. This project is carried out by the Joint Research Centre (JRC) of Ispra (Italy). Under the coordination of the Instituto Geográfico Nacional (IGN), the area of Catalonia has been assigned to the Institut Cartogràfic de Catalunya (ICC).

Methodology

The inventory of land cover changes is based on visual image comparison between digital satellite imagery, supported by consultation of the CORINE Land Cover (CLC) data base created during 1987 over coastal zones. A monitoring of changes between 1975 (Landsat MSS) and 1987 (TM) doing a retrospective updating of a strip of 10 km along the coastline has been made. The legend which is used in this territory is organised in levels. It is based on the Spanish legend of 64 classes (forth and fifth level), of which 44 correspond to the European legend (third level). Ancillary data like aerial photography has been consulted: The ICC provides the Catalonian flight on a scale of 1:20,000 and 1:18,000 covering the whole buffer area. The zone which was studied includes 12 sheets on a scale of 1:100,000 of the *Mapa Topográfico Nacional* (National Topographic Map). The minimum area interpreted was an area of 25 ha, and in the case of artificial surfaces, areas of less than 25 ha were interpreted and retrospectively updated.

After this interpretation phase, the information has been integrated in a GIS, obtaining a difference map between both inventories. This map summarizes the land cover changes at CLC first level nomenclature (five categories).

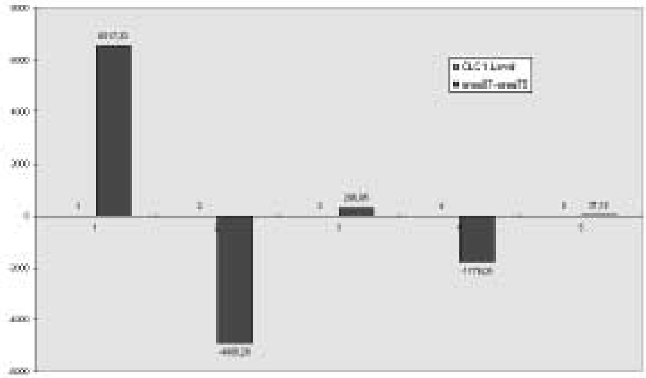
Global analysis of results

The evolution of the land cover in Catalonian coastal areas between 1975 and 1987 at first level of the CLC nomenclature, is as follows:

1. *Artificial surfaces.* Extension of discontinuous urban fabric (+ 5,726 ha) and industrial sites (+ 1,160 ha) mainly in agricultural and natural areas. Also extension of continuous urban fabric, harbours, camping sites and leisure parks, mineral extraction and the prolongation of the highway.
2. *Agricultural land.* Some areas of arable land decrease supplanted by bushy vegetation (there were non-productive areas) and extension of artificial surfaces. In the south of Catalonia agricultural land (rice fields) have increased replacing coastal wetland.

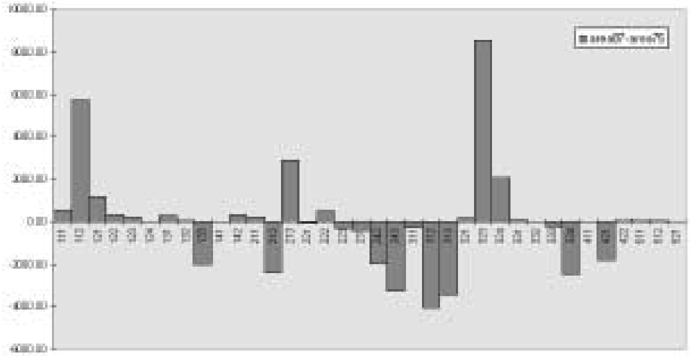
3. *Forest and semi-natural classes*. Forest have shrunk in zones where residential areas, mineral extraction, new crops and deforestation have increased. But in several areas shrub increased after forest fire regeneration or abandoned crops.
4. *Wetlands.* Coastal wetland decrease (- 1,801 ha). In the Costa Brava (Girona) changed into camping sites, and in the Delta de l'Ebre (Tarragona) mainly changed into rice fields.
5. *Water bodies.* Harbour extensions in the cities of Barcelona and Tarragona, and new marines along the coast. Modification of stream courses by human activities.

LAND CHANGES BETWEEN 1975 AND 1987 (ha)
(Catalonian coastline +10 km buffer)



The next histogram shows the evolution of the land cover in Catalonian coastal areas between 1975 and 1987 at third level of the CLC nomenclature, considering the difference between the two dates in hectares:

LAND CHANGES BETWEEN 1975 AND 1987 (ha)
(Catalonian coastline +10 km buffer)



Legend CLC 3rd level

1.1.1 Continuous urban fabric
1.1.2 Discontinuous urban fabric
1.2.1 Industrial or commercial units
1.2.2 Road and rail networks and associated land
1.2.3 Port areas
1.2.4 Airports
1.3.1 Mineral extraction sites
1.3.2 Dump sites
1.3.3 Construction sites
1.4.1 Green urban areas
1.4.2 Sport and leisure facilities
2.1.1 Non-irrigated arable land
2.1.2 Permanently irrigated land
2.1.3 Rice fields
2.2.1 Vineyards
2.2.2 Fruit trees and berry
2.2.3 Olive groves
2.3.1 Pastures
2.4.2 Complex cultivation patterns
2.4.3 Land principally occupied by agriculture, with significant areas of natural vegetation
3.1.1 Broad-leaved forest
3.1.2 Coniferous forest
3.1.3 Mixed forest
3.2.1 Natural grasslands
3.2.3 Bushy sclerophyllous vegetation
3.2.4 Transitional woodland-scrub
3.3.1 Beaches, dunes and sands
3.3.2 Bare rocks
3.3.3 Sparsely vegetated areas
3.3.4 Burnt areas
3.3.5 Glaciers and perpetual snowfields
4.1.1 Inland marshes
4.2.1 Salt marshes
4.2.2 Salines
5.1.1 Stream courses
5.1.2 Water bodies

Main land cover changes between 1975 and 1987

- Residential areas extension in the north and central coast, and new constructions in the south coast
- Industrial sites and harbour extension, mainly around cities of Barcelona and Tarragona
- Rice field extension reducing coastal wetlands (south of Catalonia)
- Fruit trees increasing their surface taken over arable land and mosaic items
- Abandoned crops in difficult areas increasing scrub
- Burnt areas decreasing during this period
- Increasing bushy vegetation after forest fire regeneration
- Decreasing forest trees after deforestation (mainly human activities)

Observed trends

Based on the obtained results, a tendency of evolution of land cover can be estimated for the next years. These changes were due mainly to human activities, as they will continue to be in the future. Artificial surfaces will increase, but not so much as the 70's (during this period of time, investment in tourist complexes was very important along the coast). Some people from big cities like Barcelona move to live outside in residential areas, and this tendency will continue during the next years. Also second residences will increase. Area of arable land will change depending on the EC policy for subsidy, and non productive areas will be abandoned. Forest and semi-natural areas will decrease because of deforestation (forest fire and human activity). Coastal wetlands will remain more or less stable, because currently they are protected areas (natural parks).

OPERATIONAL SYSTEMS FOR CONTINUOUS IDENTIFICATION AND MONITORING. WORLD DATA CENTER

John Kineman
World Data Center - A. NOAA National Geophysical Data Center, USA

Overhead 1: Global map of the World Data Centre system

There are (at quick count) 11 or more WDC's worldwide which are organized by discipline, and like the IGBP, are also part of ICSU. The World Data Center system is not an institutional structure as such, but rather an international agreement among existing data centers, such as national data centers.

Overhead 2: History of the WDC system

- The WDC system has a history dating back to the IGY in 1957-1959
- Since inauguration of the IGBP in 1986 the WDC's have been evolving to meet new and more interdisciplinary needs

Overhead 3: Major guiding principles and other characteristics of the WDC system

This shows some of the guiding principles and other characteristics of the World Data Center system:

- 11+ WDC's (disciplinary) - which are evolving
- Data accessible by any scientist
- Goal of free or minimum cost for data
- International coordination by ICSU
- Long-term operation/archive
- Everything from data rescue to distribution
- International agreement -> relies on national, etc. data centers

Overhead 4: Services offered through the World Data Centers

- Collecting data using international exchange agreement
- Documenting the data
- Referring users to data not held in the WDC
- Initiating data rescue operations
- Publishing data sets on CD-ROMs and floppy diskettes
- Providing on-line directory services
- Assisting less developed countries with data management
- Providing facilities for scientist access to data

Overhead 5: Bilateral flow of services between core projects and WDCs

Priorities:	IGBP/IHDP	→	WDC	→	Data Centers
Methods:	IGBP/IHDP	↔	WDC	↔	Data Centers
Preparation/archive/distribution:	IGBP/IHDP	←	WDC	←	Data Centers

Overhead 6: A proposed plan for how WDC's can work to support LUCC

– WDC priorities must be driven by research priorities (e.g., LUCC)
– WDC priorities influence data center programmes:
  1. Need continuing collaboration:
    Core project (LUCC / DAPLARCH)
    IGBP-DIS
  2. Need meeting report to match with availability of data and resources
– WDC Response to DAPLARCH-I for DAPLARCH-II
– Specification of needs via DAPLARCH:
  • DAPLARCH-I: conceptualization of needs
  • DAPLARCH-II: strategy for production
  • DAPLARCH-III: dataset specifications
  • DAPLARCH-IV: operational systems

That completes what I want to say about the WDC system. Now I will briefly mention a small experimental project in data integration called the "Global Ecosystems Database." You may have seen material for GED Disc-B in the display area.

Overhead 7: Example WDC-A project: Global ecosystems database (Disc-B)

– This project began in 1990 in collaboration with the US EPA to build a spatially integrated set of global change research data in Geographic Information System format to meet the program needs of the EPA Global Change Research Program in Corvallis, Oregon. This latest CD completes these original requirements and extends the database to include several new datasets that have been contributed recently.
– What is its relevance to LUCC?:
  • Addresses need for integration methods and comparability between datasets
  • Addresses need for better documentation and publishing methods
  • Datasets? Most are too coarse to meet LUCC needs, but some examples of higher resolution regional data (10 km) on the CD
– Two futures for this kind of work:
  • Dataset publishing activity - based on contributions and distribution needs
  • Specific integration projects to support analysis, research, and modeling needs

Overhead 8: Table of dataset contents from GED-B

– The CD contains 14 datasets grouped into 3 spatially compatible databases
– Datasets range from regional (10 km) coverage to global (10 min to .5 degree) coverage

Overhead 9: Title page from documentation: Fedorova, Volkova, and Varlyguin World Vegetation Cover

– This, along with the associated Bazilevich Net Primary Productivity data, is the newest dataset published on the CD

Overhead 10: Title page from documentation: EPA (Corvallis) climate database and 2xCO_2 predictions: Marks regional water balance model and dailey et al. PRISM model precipitation

- This is a higher resolution (10 km) integrated regional database
- It is also innovative in that it represents outputs from models under a specific (CO_2 doubling) scenario

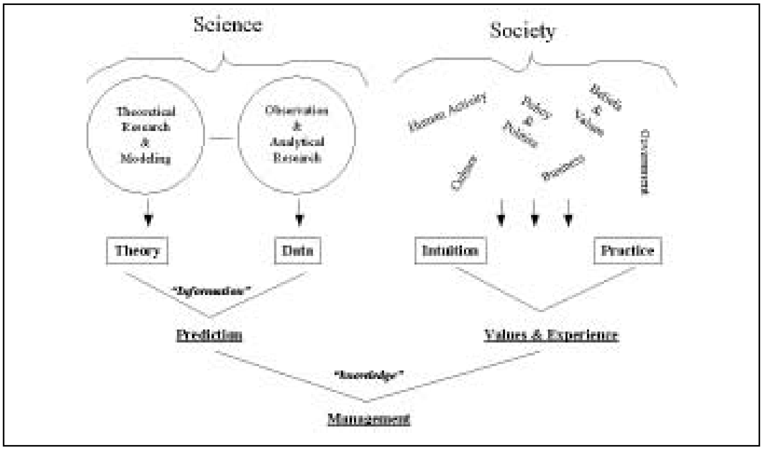
Overhead 11: Metadata template

- Rigorous documentation and link to system metadata
- Continuing development to achieve full FGDC compatibility
- Possible template for IGBP/IHDP research datasets? Discussed (at this meeting) with IGBP-DIS

Conclusion

That completes the formal part of my presentation. Now, with your indulgence, I would like to take perhaps unfair advantage of the placement of this talk at the end of the program and offer a personal observation. Sometimes I masquerade as an amateur philosopher, and last night I was thinking about several comments made during the plenary and working sessions regarding the philosophy of LUCC science.

Overhead 12



Several objections were raised on the second day to the implied split between "science" and "data." This diagram shows "theoretical research and modeling" (which improves theory) and "observation and analytical research (which improves data) as both being part of "science" and complementary in nature. It also depicts information as resulting from the combination of these two. This seems particularly relevant in LUCC, for which the stated approach is to be inductive (reasoning from observation/analysis to process description, to general theory, and then to model development and testing), thus placing considerable emphasis on observation and analytical methods.

A statement was made in breakout session III that: "Science alone cannot provide all the answers." If we talk about "knowledge," then, I think we have to step partially outside of science. So here, I have shown a loosely organized (compared to science) set of societal activities (in business, farming, politics, religion, etc.) that comprise our combined human experiences. It is then the combination of this experience and values with objective scientific information and reasoning that may give us something we can call "knowledge," and which can hopefully lead to sound management.

DATA VS. "SCIENCE?" GENERAL COMMENTS ON EPISTEMOLOGY IN DAPLARCH-I

John Kineman
World Data Center - A. NOAA National Geophysical Data Center, USA

I would like to offer the following philosophical issues for consideration by participants of DAPLARCH - I who are interested in the details of LUCC epistemology:

Introduction

In the opening session "science" was describe in contrast with "data." On the second day some participants voiced strong objection to this distinction. This relationship between "data" and "science" needs to be better described. I attempted to provide a simple schematic of the most basic relationship in the last slide of my WDC presentation. My write-up of that is repeated below (from my Trip Report), followed by further discussion.

Several objections were raised on the second day to the implied split between "science" and "data." This diagram shows "theoretical research and modeling" (which improves theory) and "observation and analytical research" (which improves data) as both being part of "science" and complementary in nature. It also depicts information as resulting from the combination of these two. This seems particularly relevant in LUCC, for which the stated approach is to be inductive (reasoning from observation/analysis to process description, to general theory, and then to model development and testing), thus placing considerable emphasis on observation and analytical methods.

A statement was made in breakout session III that: "Science alone cannot provide all the answers." If we talk about "knowledge," then, I think we have to step partially outside of science. So here, I have shown a loosely organized (compared to science) set of societal activities (in business, farming, politics, religion, etc.) that comprise our combined human experiences. It is then the combination of this experience and values with objective scientific information and reasoning that may give us something we can call "knowledge," and which can hopefully lead to sound management.

Discussion

IGBP/IHDP LUCC use of the word "science" should clearly distinguish analytically based (inductive) and theoretically based (deductive) approaches in science. I would distinguish "observation and analysis" from "theoretical research and modelling." Models can't do it all, and many of the more analytically oriented participants objected to the idea (in the plenary sessions) that "science" was described only in terms of modeling. The inductive approach relies heavily on observation and analysis to precede and nourish model development, whether to reveal processes or to infer general principles. Once modeling takes over, data becomes a subservient statistical task involving more precise sampling to test a prediction; but this is a very different exercise from what is needed for inductive analysis in LUCC. My strong impression from the meeting discussions LUCC documents is that the modeling paradigm is not a viable starting point because the basic inductive work has not been done yet.

The phrase "theoretical research" may be a better choice to refer to deductive methods of experimental science (hypothesis testing). In this sense "research" would refer to theory, processes, and dynamic mathematical models; and it would be distinguished from data analysis and descriptive models (non constructed on dynamic components). In making this distinction, we need also to recognize that the two are related and complementary aspects which together make up "science."

In practice one moves back and forth between inductive ("analytical") and deductive ("theoretical") approaches, and their boundaries can become blurred, as in the special cases discussed below. There may also be a shift in emphasis from inductive to deductive methods as a discipline matures ("revolutions" excepted). Many of the IGBP disciplines refer to a considerable body of prior work, including much of the disciplines foundational inductive work. In other words, for these disciplines, theories have already been developed from inductive reasoning and the greatest advances are now thought to be associated more with refining and testing predictive models. This, of course, can change with new questions.

In the case of LUCC it is recognized (first LUCC science report) that models are lacking and many basic processes are unknown. LUCC science is thus at the beginning inductive phases now, and needs to build its observations and analysis to reveal processes, generalize from those processes, then propose theories, and finally build and test models. In reality these phases will not be so sequential, but the basic principle remains nevertheless. Data collection and analysis are thus critically important to LUCC at this inductive stage.

I also want to call into question the statement (from the workshop) that *"A model without data has no predictive value, but data without a model leads to confusion."* A model (which I shall take to mean a dynamic or theoretical model rather than a representational scheme, as in a "data model") without data lacks more than predictive value, it has no reference system and thus no relevance to nature at all. On the other hand, statistically valid and well analyzed data, even without a corresponding model (theory-neutral) remain useful because they are a representation of reality against which one can develop (and to some degree, test) hypotheses - now, or in the future. There is no better way to settle a theoretical argument than by introducing a discriminating fact, but that does not mean, in turn, that the fact has no value outside the argument. The fact can be reused, just as a predictive theory can be reapplied under different circumstances.

Darwin's voyage on the Beagle is, of course, the classic story of induction, though it is debated exactly when the theory was actually born. Nevertheless, had the theory not emerged, the data would still be useful today. In fact, one could argue from history that more confusion and conflicting ideologies have arisen from irrelevant theories (include models) than from arbitrary data.

The above quote also reveals a well-know modern bias toward predictive dynamic theory development and modelling over retrospective analysis and more descriptive approaches. This is appropriate for some disciplines but not all. It presumes, for one thing, that an adequate foundation has been established (from inductive methods) for theoretical development. In new and interdisciplinary fields such as we are encountering in LUCC, we must remember that the observation and analysis stage is essential and very definitely a part of science, and that it can even, at times, stand alone. In contrast, no theory or model of nature can stand without data.

What are the implications of misclassifying these terms? Later in the same presentation the statement was made, in the context of discussing the importance of data, that money for data should not be *"taken away from the science."* Here the danger becomes clear. If "Science" equates with theoretical research and model development, then data and analysis (and perhaps the entire inductive process) are not science and must therefore be supported from some other resource. Through repeated hard experience, those involved with data have learned that theoretical research out-competes data analysis for science funding. Yet the history of science contains notable examples where paradigm changing facts were discovered through methodical (and often unsupported) data analysis. Where does one go for funding such painstaking work without an interesting, and some would say, popular theory?

But this is not the whole story either, because tremendous funds are being spent on raw data collection (e.g., satellite programs), and this does seriously compete with research funding. Sometimes these programs can be self-perpetuating rather than being strictly dictated by scientific priorities. Perhaps the problem can be summarized as follows: Far too often, in the modern rush for rapid progress, new (and expensive) models are substituted for sound theory and new (and expensive) data are substituted for careful analysis. To what extent can we afford to be fooled by the glitter on either side?

Special cases

I can think of two special cases where induction and deduction are not so clearly divided. The first one is the case of sampling to test an hypothesis (or model). The second is the case of "empirical" or "instrumental" models.

Sampling

This is a case where analytical methods (more commonly associated with induction) are employed to assist in testing deduction (hypothesis testing, model testing, etc.). Data that are specifically referenced (i.e., sampled) according to a theory, model, or specific hypothesis are presumed to be superior to general observations and analysis when one is involved in testing (hypothetico-deductive phase). But this is only true in the sense that they are more efficient and statistically independent from the data from which the original inferences were made. The lasting value of data collected according to a specific sampling design depends greatly on the quality of the science dictating that design, and generally has less "reusability." Data sampled specifically for testing purposes may have little value for general induction (to learn other things). By design, these kinds of data incorporate theoretical biases and eliminate information that is not directly relevant to the idea being tested. Here too, because of this strong dependency, many examples exist where data sampling has been seriously biased by an ill-conceived theory (like the drunk looking for his keys under the lamp post, because that's where the light is). The distinction I am describing here is what motivates the participants in the workshop to distinguish specific validation requirements from the need for datasets of general design. Those of general design tend to be more reusable.

"Observing" with a model?

In one of the breakout groups the statement was made: *"Models may be thought of like observing instruments: first use them to understand the processes, then use them for prediction."* This probably refers to the use of empirical models in the first instance, then predictive models in the second, and perhaps implies that one can evolve into the other. However, this runs into epistemological problems in terms of the relationship between observation and modeling discussed above. First, we must accept that most scientist mean dynamic, theory-based, or mathematical models when they use the word "model" and these are clearly distinguishable from non-dynamic, observation-based, data models (such as Geographic Information Systems and their analytical derivations). Models in this sense, which are theoretical constructs, cannot "observe" anything that has not been built into the model; however, they can produce testable predictions based on their simulation of processes or system behavior.

The strange case in this regard is the "Empirical" or "instrumental" model. Such models are designed as arbitrary constructs and are not claimed to be founded on basic laws. In the extreme case, they are built solely to mimic (not explain) observations; and thus they are relatively theory-neutral. The classic example here is Ptolemy's model of the solar system constructed on the idea of perfect circles (which was useful and predictive to a certain level of precision). In that sense they might be said to represent the observations of one system, but in reality they are still built on theoretical elements which are arbitrarily adjusted to fit observations, not unlike a "best-fit" regression. Because they are not based on fundamental laws (which are unknown), they are not necessarily transferable to another system (unless one is lucky), although the tendency is to try, then re-adjust the parameters of the "fit." If such a model seems to fit several circumstances and systems, the tendency is to at least suggest that some basic laws have been accidentally discovered.

The point is, however, that such instrumental models are still built on simplifying constructs which would be considered "theoretical" except that one doesn't necessarily claim that the theoretical constructs have any universal meaning. This is not analogous to an "observation;" it is a system-dependent model with disposable theoretical constructs. Also, to the extent that it is strictly empirical (or instrumental), it is correspondingly unpredictive outside of the system it was constructed from (and quite likely of even future states of the system it was constructed from), because it doesn't claim to capture the nature of basic principles. Its applicability to other systems and to prediction rests entirely on the assumption that the processes considered are the same in each case. Thus the only way instrumental models can be analogous to observing systems is in the fact that neither attempts explanation. Such extremes are not the goal of modeling and are nevertheless still distinctly different from observational systems in that they are constructed with theoretical constructs, not data. A GIS-based, static, or "data" model, or other form of comprehensive data analysis, on the other hand, can be thought of as an observing system; like any lab instrument that produces a representation of the thing it is observing and remains constructed primarily on the data. But this is very different from even the most instrumental empirical models.

Conclusion

I suspect that some of the other participants can do a better job of describing these issues than I have, but I find that not many practising scientists have the time or tolerance for digging into the epistemological subtleties and jargon of all this. The bottom line is I think we need to carefully distinguish the observation/analysis and "data modeling" or "static modeling" approach from all forms of modeling where the method is to construct the model on top of time-dependent functions, processes, transition rules, basic laws, etc., which underlay system dynamics (whether these are considered realistic or instrumental/empirical constructs). The static or data model/analysis approach that is largely aided by GIS technology is on the analytical/inductive side of the paradigm and can be representative of observations and even dynamics in the sense of representing observed changes as "time-slices" of data layers or other more sophisticated statistical and mathematical derivations that remain fully dependent on the data. These methods are in much need of improvement and wider use, and require "science" funding. The following is a quick summary of such needs mentioned in the workshop.

Analytical/inductive methods

A number of discussions during the workshop on methods needed for integration, analysis, and comparability of datasets replicated prior methodology discussions that may have reached farther among geographers and other spatial analysts. This apparent duplication may be attributable to a general lack of understanding of the links between the GIS analytical field and these modeling and monitoring needs. An initial connection should be made using compelling analytical examples showing current methods for:

1. Scale integration (re-gridding, etc.)
2. Scale linkage (information that can move between scales)
3. Geographic and inter-dataset registration (not so challenging, but commonly overlooked)
4. Statistical techniques
5. Algorithmic corrections (during and post acquisition)

Many additional issues of linking spatial analysis (e.g., “GIS”) and modeling need to be addressed in their own right. To this end, there is a series of “GIS and Modeling” conferences, now entering the fourth in the series (which is being organized at the University of Colorado and NGDC), which are designed to deal directly with this interface. The next conference is being planned for the Spring of 1999 in Banf.

DATA CONSTRAINTS IN LAND USE AND LAND COVER CHANGE RESEARCH: COASTS AND ISLANDS OF INDIA

R. Krishnamoorthy
Senior Scientific Officer, M.S. Swaminathan Research Foundation, Chennai, India

India has a coastline of about 7,500 km length and nearly 170 million population live in the 100 km coastal belt. Three biosphere reserves, three national parks and thirteen wild life sanctuaries are located on and off the coast. The coastal zone and its resources are more important for nation's economy and also for the livelihood of the people. Due to population pressure along the coastal zone and also the impact of global change in coastal zone evidenced with degradation of coastal resources and coastal pollution. Various research being conducted under the title of integrated coastal zone management to address the coastal zone problems. However it is important to analyse the root cause for coastal ecosystems degradation and other environmental degradations. So far much attempt was not given to understand and analyse the land use and land cover changes in the adjacent watershed along the coastal zone, changes in irrigation practices, modelling the transport and terrestrial materials and freshwater to coastal ecosystems, and other related biophysical factors. After the advent of remote sensing technology, considerable amount of spatial information for the India's coast were generated. The main lacking in effective usage of coastal zone data is primarily due to non-availability of supportive socio-economic data and other field data. This paper discusses about the requirement of socio-economic data and importance of land use and land cover analysis of adjacent watershed along the coastal zone with present LUCC data constraints in particular reference to coasts and islands.

SIMULATIONS OF LAND-COVER CHANGES IN AFRICA: REMOTE SENSING AND SOCIO-ECONOMIC DATA

Eric Lambin and Benoît Mertens
Department of Geography, Université catholique de Louvain, Belgium

Data requirements depend on the specific research question to be addressed. The four main questions related to land-cover change analysis are:

(i) In which locations are land-cover changes likely to occur - *where?*
(ii) At what rate will land-cover changes progress in the future - *when?*
(iii) Which environmental and cultural variables contribute the most to an explanation of land-cover changes - *why?*
(iv) What are the likely impacts of land-cover changes.

Two case studies on the modelling of deforestation in southern Cameroon and on the impact of biomass burning in the Central African Republic are used for illustration.

First, we demonstrate that predicting areas at risk of being affected by deforestation can easily be achieved using a single, easily measurable spatial variable: the distance of any forest area from the nearest forest/non-forest edge. Developing complex multivariate models does not improve spatial projections of deforestation.

Second, we demonstrate that modelling land-cover change trajectories over more than two observation years leads to a better prediction of the probabilities of land-cover change than the modelling of simple land-cover conversions over just two periods of time. Therefore, collecting long time series of land cover data is necessary for improving temporal projections of land-cover changes, as there are generic trajectories of changes which are predictable.

Third, we illustrate the classic «modifiable area unit problem» in the explanation of deforestation. The spatial entities used to calibrate a spatially-explicit land rent model of deforestation have a significant impact on the model performance. The variables needed as an input to this model are typically collected at the level of administrative units. These units do not match in size (scaling problem) and shape (aggregation problem) to the spatial units which are homogeneous in terms of deforestation processes. The interpretation of the spatial pattern of forest-nonforest interfaces as detected by remote sensing allows to identify regions affected by different deforestation processes.

Finally, we illustrate that, depending on the specific impact of biomass burning which is investigated, data on the distribution of either active fires or burnt areas are needed. These two indicators have fundamentally different spatial and temporal sampling characteristics. To estimate atmospheric emissions which originate from fires, accurate estimates of the total area burnt are important. By contrast, to investigate the impact of biomass burning on land cover, the timing of active fires is the crucial information.

HOW CAN RECENT LAKE SEDIMENT BE USED IN CONNECTION WITH REMOTE SENSING TECHNIQUES TO UNDERSTAND PROCESSES OF ENVIRONMENTAL CHANGES IN THE RECENT PAST?

Suzanne A. G. Leroy
Centre for Palaeoecology, School of Geosciences, Queen's University, Belfast, N. Ireland

Lake sediment serves as an natural archive repository for environmental changes occurring in its drainage basin and outside of it. If a sediment core is taken from the middle of a lake (figure 1), the data that will be retrieved give information on what is happening regionally (from a few hundreds of m to several km), whereas sediment cores taken from the shallower parts of the lake will tell us more about what is happening in its immediate vicinity (note thickness of arrow in figure 1). The sedimentary record from the middle of the lake will be more detailed, more continuous and more expanded; whereas locations near the shores suffer from possible hiatus of sedimentation if there is a change in the water level, and from a coarser and bioturbated sediment (figure 2).

Lacustrine sediment is formed by a mixture of allochthonous elements brought to the lake by rivers, by run-off and by air and of autochthonous elements produced within the lake water itself (figure 2). If there is a lack of oxygen in the bottom waters (anoxia), the absence of bottom fauna will allow for the preservation of annual lamination (figure 2).

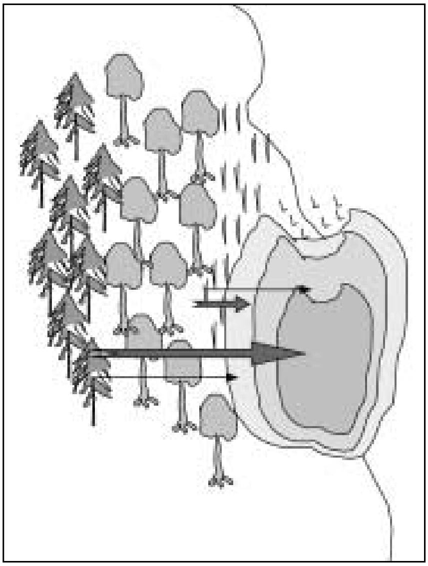


Figure 1

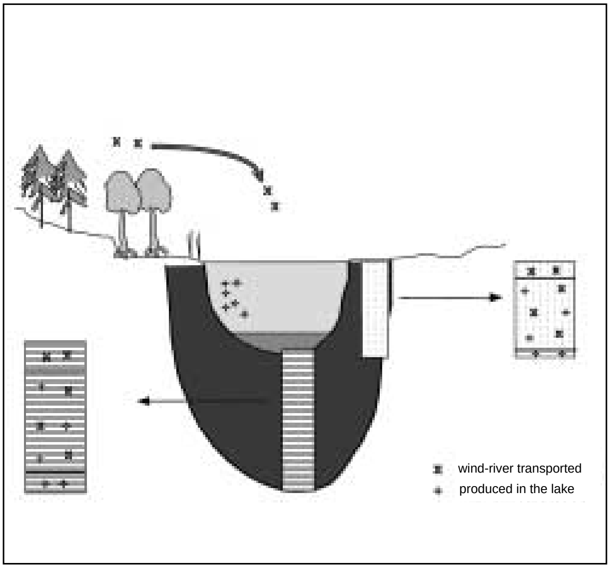


Figure 2

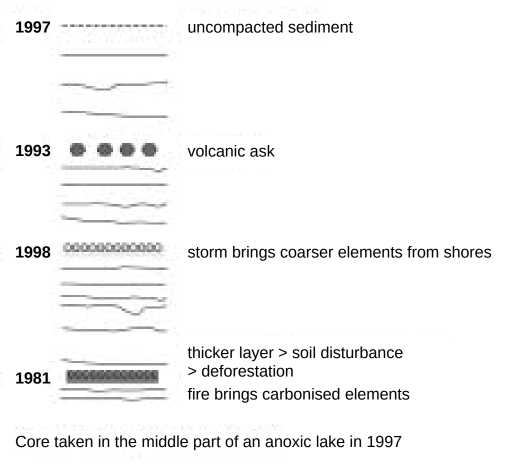


Figure 3

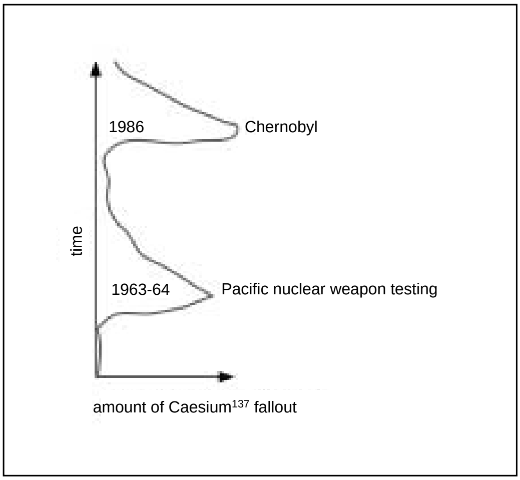


Figure 4

In the case of annually formed laminites, by counting the layers from top downwards, it is possible to attribute an absolute age to the sequence (figure 3). Undisturbed laminites will also record specific events. If a fire occurs, carbonised particles will be brought to the lake by water and by air. Then the resulting disturbance in soil and vegetation cover will cause run-off and a thicker annual layer will be formed. A storm may cause a seiche (regular movement of the water) which will bring shallow (and often coarser), sediment to the lake centre. A volcanic explosion may be marked by a distinct layer of volcanic material. If the sediment is disturbed by bioturbation (no annual layers) are visible, it becomes necessary to use radiometric methods to date the sediment. For periods as recent as the last 100 years, the Lead 210 (Pb 210) method, a radionucleide with a half life of 22 years, can be used to give an absolute age to the sediment. The amount of Caesium 137 (Cs 137, half life of 30 years) produced the fallout of nuclear explosions may also serve as an indirect dating tool (figure 4). The Pacific nuclear weapon testing forms a clear peak in 1963-1964, whereas the more recent Chernobyl accident forms a second one in 1986.

SOCIO-ECONOMIC INFORMATION FOR A COMPREHENSIVE ANALYSIS OF LAND USE CHANGES

Nelson Lourenço
Universidade Nova de Lisboa, Portugal
Teresa Pinto Correia, Maria do Rosário Jorge and Carlos Russo Machado
Universidade Atlântica, Portugal

Understand the meanings and motives underneath the processes of land use/land cover changes is an important issue to the knowledge of these processes of change. In this way the scientific basis of this work is the belief that integrating physical and socio-economic approaches in the study of land resources and land use systems represents a conceptually correct means of addressing the unifying issue of economic and environmental sustainability.

Thus, we are departing with the farmer and his farm as our Unit of Analysis. This departing point assumes that the farmer induces the land use changes but he also reflects the changes made by other agents that intervene, directly or indirectly, in the land use.

So if we want to study these processes of change in an European context we must consider and analyse the impact of external driving forces such as the Common Agricultural Policy or Environmental Measures, which consists in a large group of political measures and regulations of the different interventions in rural areas.

However we must also consider the possible consequences resulting from the global environmental changes. The desertification processes, aridity processes, the increase of flooded areas or the changes in the productivity of soils are some environmental processes of change that must be in account regarding its possible consequences on the productions systems dynamics.

We think that this kind of approach must be made at two different level of analysis. In a Regional Level we must identify, by the use of remote sensing techniques and statistical information, the changes, and its trends, present in the region studied. In a Local Level we must understand, using local case studies, the dynamics of the processes of change.

Therefore the construction of indicators of land use change is an important step in this kind of approach which aims to achieve an integrated comprehension about the land use changes effects.

What kind of information is needed to the construction of indicators of land use change? The land use changes studies must be a contextualised analysis centred in the individual (the farmer) inside the context where he acts. Thus the analysis must be made at a Regional Level and at a Local Level.

At Regional Level we want to know some information related to:

Changes in population

The knowledge about the dynamics of resident population structure, active population, agricultural family population, farmer's age and pluriactivity allow us to understand, for example the changes in the regional and local markets, the changes in the labour available in articulation with others activities, etc.

Changes in agrarian structure

The analysis of the dynamics in the number of farms, concentration/dispersion of agricultural area used, and of type of use: forest, crops, pasture and fallow area and cattle production stand for the identification of the changes in the dominant regional production systems.

Changes in the territory uses

Other territory uses like touristic or other rural services, urban or industrial can compete to or complement the agricultural use of the land. Moreover the identification and analysis of ecological and environmental problems are often related to this different territory uses.

Agricultural policies assessment, impacts, planning and regulation

The analysis of this issues permit the identification of the main legal constraints influencing the ordnance of the region. The regulations on the agrarian structure, the differences in land taxation, the political priorities defined to the region induces distinct trends of change.

Therefore, the collection for different periods and the treatment of this information allow us the identification of the main characteristics, problems and development of the region. However we must always consider the interrelation with a global (national and international) frame and the importance of the different local contexts (local lobbies, municipal intervention).

Nevertheless the regional frame doesn't allow the total comprehension about the different processes of change. The dynamics of change are, therefore, studied at two levels of analysis: identification and understanding of the more global factors of change at regional level, and the integration in the analysis, at local level, of the complex web of social relations that structure the social systems (attitudes, expectations and representations of the future) permitting the comprehensive analysis of the social dynamics.

Thus we must analyse some information at Local Level (Farmer Level) which let us identify and apprehend in what way the farmers intervene in the land. So we must collect information related to:

The farmer

His age, level of instruction, dominant activity and his articulation with the agricultural policies. These characteristics are important because they influence the processes of decision making by the farmer, his capacity of articulation with the market, introduction of innovations (technological and organisational).

Farmer's expectations

The farmer succession expectations and his opinions about the future are a very important question about the future dynamics of the farm unit and allow us a perspective of evolution. In the same way the knowledge of the succession and heritage systems, related to the land tenure systems, is very important to the comprehension about the transmission of properties.

The farm

The dimension/dispersion of the farm, the main land uses: forest, crops, pasture and fallow area and the cattle production in different periods show us the farm structure and the production system allowing the definition of trends of change.

Organisation of the production factors

The information related to the evolution of the Investments, Labour force in the farm, Level of mechanisation and chemical products permit the identification of the intensity of the use of the land and contribute to the definition of trends of change.

These different types of information should provide, after a statistical treatment, an analysis about which ones are the most associated to the changes in land use. At the same time they should be at service of the integrated methodology and help us to understand, at different levels of analysis, the meanings and the motives of the land use changes.

This approach allows therefore the complexity of the interactions defined by the social systems/natural systems to be incorporated in the analysis and allow us to know where and why land use/land cover changes occurs and to understand, from a regional and local perspective, its impacts on economic and environmental sustainability.

LUCC DATA VALIDATION AND REQUIREMENT OF RUSSIA

Elena V. Milanova, E. Y. Lioubimtseva and P. A. Tcherkashin
Moscow State University, Russia

There are currently in existence various small and broad scale vegetation, landscapes and land use maps for Russia, compiled over past decades using field survey, aerial and satellite imagery and other sources of information. However, many of existing maps leave much to be desired in terms of resolution of data, the accuracy of information given, and their compatibility. Most of these maps have no digital versions. Different data on LUCC (local and regional maps, satellite imagery, detailed ground-truth field observations in key areas) as well as data gaps, needs and priorities were found and analyzed in the frame of research project on "Land cover/land use mapping and monitoring of Russia" which is currently underway at the Faculty of Geography of Moscow State University within the VEGETATION International Preparatory Programme in order to determine their applicability for LUCC study and modelling. Analysis of long-term (100 years) land cover changes, their historical, natural and social factors was done. Retrospective analysis is used to study land use for time against last 20 years (before remote sensing data became available).

There is a strong need for development effective methods for integrating national and regional datasets on land use and environment of Russia, and linking them to adequate frames of territorial sampling. Integrated land cover/land use mapping and classification, and especially broad-scale mapping on the macroregional and continental level, inevitably faces a problem of handling and manipulating huge sets of spatially distributed data. The latter are being constantly refined in terms of new geographical, ecological and environmental insights and the increased access to new data sources (e.g. remote sensing data). Many practical and methodological problems of land cover/land use mapping can be effectively solved by using GIS.

Nowadays remotely sensed data becomes more and more available. The most significant effort is the global 1-km AVHRR data archive available for distribution by EROS Data Center and the European Space Agency under the guidance of IGBP. We found that the most sufficient source of NOAA-AVHRR NDVI images for continental scale feasibility study of LUCC in Russia was Global Ecosystem Database (GED) by EPA Global Climate Research Program, NOAA/NGDC Global Change Database Program. Two principle sources of satellite imagery were used for data simulation on regional level over Central Russia: AVHRR images of 1 km resolution and photographic high and medium resolution images from Russian satellite Resource -F1.

One of the most serious problems is combination of AVHRR 1 km resolution data with high resolution data from Russian satellites (Resource) and data scaling. To resolve this problem a major advantage is using VEGETATION SPOT data because of possibility of their direct combination with high resolution data of HRVIR instrument, carried on the same platform and allowing direct combination of high and low resolution views of the same target. Also composition of different spectral channels of VEGETATION (including BLUE one) is better adapted to characterisation of vegetation cover and its dynamics, would considerably improve atmospheric correction of data.

LUCC study of such a vast area as Russia is to help in better understanding the ways and mechanisms of global land cover evolution and dynamics and to contribute to international programmes on global and macroregional environmental change.

LINKING PAGES AND LUCC - SOME PRELIMINARY IDEAS

Frank Oldfield
PAGES IPO, Bern, Switzerland

Linking the different methodological approaches of PAGES and LUCC will require a serious and sustained effort, but it is an essential one if there is seen to be some advantage in trying to test, from empirical evidence, the extent to which the time-series models inferred from spatial patterns/relations and brief period of observation are compatible with actual historical data. Particularly important are those environments where the differences in some of the components of the contemporary mosaic reflect very different modes of ecosystem function (water and nutrient regimes, NPP, role of soil organic matter, etc.). Under these conditions, significant changes in the relative proportions of the different elements in the mosaic may indicate major non-linear shifts between contrasted quasi steady state systems of self regulation. Gaining some sense of recent temporal trends may shed light on these types of ecosystem shift, some of which certainly occurred millennia ago, at the time of first significant human impact, others of which are in progress today. Reconstructing the recent history of ecosystem change (the last 200 to 500 years for example) can also provide an historical context and a dynamic, hence more realistic base-line for future observations.

Success will depend, in part, on finding a common categorisation of ecosystems that satisfies LUCC classification schemes and is achievable from palaeo-data. It will also be essential to calibrate reconstructions that have been made on the basis of, for example pollen analysis, against known land use/land cover variations in both space and time. Spatial calibration may be possible by using the contemporary pollen spectra lodged in data bases such as the European Pollen Data Base (EPD) and relating them to contemporary LUCC classification schemes. Preliminary exploration of this possibility with the manager of the EPD is encouraging.

Temporal calibration in chosen localities is also essential and requires a careful comparison between pollen records and the documentary/cartographic history of land use change in the area surrounding the source of the reconstruction. Such studies are beginning, for example in the University of Southampton, UK, and there is ample scope for broadening them in many areas where adequate documentary evidence is available for the last few centuries.

The kind of sites suitable for reconstructing recent land use/land cover history from proxy palaeodata include growing peat bogs, hydromorphic soils and lake or even reservoir sediments provided they are still accumulating reasonably undisturbed, so that the record they contain can be used to bring the history of the site and surrounding area through to the present day. Where sediments are used, this can include reconstructions of soil erosion/degradation and of mineral fluxes within the system. Some sites with a record of land-use change contain annually laminated (varved) sediments and hence a detailed chronology, but in most cases dating control for the last few decades will come from short-lived radio-isotopes like 137Cs and 210Pb. On longer time-scales a range of dating methods can be used to constrain each other.

A key question is the spatial scale on which a joint PAGES-LUCC effort may be undertaken. Clearly from an IGBP standpoint, there is a major advantage in approaching as closely as possible to a global coverage. Research projects linking remote sensing and present-day experimentation and observation to palaeo-reconstruction do actually exist (in the Southern High Plains of the USA for example) and these may help to pioneer the type of approach required. An essential first step will be to identify key individuals from the two Project Elements and provide them with an opportunity to specify research priorities (hence data requirements) as soon as possible.

LAND USE AND LAND COVER CHANGES AND AGRICULTURAL POLICIES: PROBLEMS IN THE SELECTION OF SUITABLE INDICATORS

Begoña Peco
Departamento de Ecología, Universidad Autónoma de Madrid, Spain

Considerable attention has been paid in the last decade to the use of agri-environmental indicators to evaluate the state and environmental quality of farming systems and the consequences of agricultural policies. The majority of contributions, however, have been at a theoretical level (OECD, 1997; Brower & Crabtree, in press). Attempts to apply proposed agri-environmental indicators to real specific situations have brought to light serious conceptual, methodological barriers (Peco *et al.* in press, Oñate *et al.* 1997).

Several land use and land management indicators were proposed as a tool for analyzing the effects of the CAP Agri-environmental Regulation 2078 in different European agro-systems. These indicators (driving forces or pressure indicators, OECD, 1997) were chosen due to the serious difficulties in estimating state indicators, which moreover posed problems for the definition of causalities because of their lack of unequivocal nexus with the agri-environmental policies' effects we wished to evaluate.

One of the problems detected has been the impossibility to work with a single European system of indicators. Although certain indicators are common to different agro-systems in national and international comparisons, a large proportion of them are exclusive to certain systems. This leads to the conclusion that the system of indicators should be regionalised.

The availability or the mere existence of suitable data in official statistics has arisen as a limiting factor in the selection of agri-environmental indicators. This problem has two dimensions: scale and definition. For the first dimension, the spatial scale of the aggregate data must be significant for the process to be analysed. Many of the levels of aggregation at which official statistics are available are highly heterogeneous internally from a social and environmental perspective. The appropriate scale depends on the spatial continuity of the agrosystem and the homogeneity of the process of change it is undergoing (intensification, extensification, abandonment). The second dimension is linked to how suitable the available statistics are to the type of data required. Few statistics for indicators are relevant from an environmental perspective because the variables they cover are aimed at measuring farm production and are focused on a socio-economic analysis of the zone and not an environmental analysis of the agro-system.

The consideration of both dimensions implies the need to measure certain indicators at a local and/or farm level, and that official agricultural statistics should cover additional, more environment-related parameters if they are to be used to establish agri-environmental indicators.

References

BROUWER F. AND CRABTREE R. (ed.): *Agriculture and environment in Europe: The role of indicators in agricultural policy development.* Cab International. Wallinford.

OECD. 1997: *Environmental indicators for agriculture*. OECD. Paris.

OÑATE J. J., ANDERSEN E., PRIMDAHL J., PECO B., MALO J. E. AND SUAREZ, F. 1997. "Crypto- and fenosystemic values of agricultural landscapes: the role of indicators as valuing tools for conservation". *International Conference on transformation of agricultural landscapes*. Roskilde, Denmark.

PECO B., MALO J. E., OÑATE J. J., SUAREZ F. AND SUMPSI J. M. (in press). "Agri-environmental indicators for extensive land-use systems in Spain". In: BROUWER F. & CRABTREE R. (ed.): *Agriculture and environment in Europe: The role of indicators in agricultural policy development*. Cab International. Wallinford.

ASSESSING LAND COVER CHANGES FOR SUSTAINABLE LAND MANAGEMENT

Vanda Perdigão
Space Applications Institute, Joint Research Centre, European Commission

Different land utilisation types compete to use the same natural resources. Natural resources can potentially be used in a sustainable way if appropriate land management, regional planning and policy development act in a purposeful way, according to the principles and concepts of sustainable development. It requires due consideration of specific local environmental, socio-cultural and economic conditions.

For Sustainable Land Management (SLM), the integration of technologies, policies and activities in all sectors, agriculture in particular, is needed in such a way as to enhance economic performance while maintaining the quality and environmental functions of the natural resources.

Through the process to identify and to define the basic principles of SLM, the concepts of land use resilience and social equity have been added to the previously accepted five criteria or pillars of SLM (productivity, security, protection, economic viability and acceptability).

International agreement has been achieved so far on the five sets of land quality indicators for SLM, which can be developed in the short term. Land use intensity, land use diversity and land cover are three of them (nutrient balance and yield trends are the others). Other indicators such as land degradation need land cover data as one of the inputs to be matched with other information.

On the other hand, sustainability in any real system is also time dependent. Though change may be slow and difficult to detect, changes will and do occur. Issues concerning the detection and characterisation of spatial-temporal patterns that may affect a sustainable solution are still relevant.

In this frame, and knowing that in Europe an harmonised land cover database is available, a priority need is to assess the changes on land cover, which immediately define a set of data requirements: changes from the past and recent changes, to be able then to identify trends and to forecast scenarios. For the same scale of application, it is not always easy to identify those changes or, once identified, a sharp boundary to delineate them is not found. Difficulties can occur in each of the three components of a land cover mapping unit: thematic, spatial and temporal. To way to solve them has practical consequences in terms of homogeneity of results and assessment of changes and on the cost of the assessment activity.

Once quantified (and spatialised), changes needs to be interpreted in a socio-cultural and economic context.

Other important issue to take into account when defining the data requirements is the scale and its effects.

DATA REQUIREMENTS FOR FARM AND REGIONAL SCALE AGRICULTURAL LAND USE MODELLING: EXPERIENCES FROM THE IMPEL PROJECT

Mark Rounsevell
Soil Survey and Land Research Centre, Cranfield University, Silsoe, UK

The IMPEL project (Integrated Model to Predict European Land use) is being funded by the European Commission (DGXII) under the Climate and Environment Programme of Framework IV, and includes eleven partners from throughout Europe. The project aims to evaluate the impact of climate change on agricultural land use and its management at the farm and regional scales, including an assessment of potential adaptation strategies to climate change. In order to achieve this aim, the project is developing a modularised model to estimate farmer decisions about land use that integrates biophysical representations of soils and crops with socio-economic considerations. The guiding principles in the development of IMPEL are *(a)* to describe land use processes mechanistically and dynamically, *(b)* to address the basic spatial unit of land use decision making, *i.e.* the farm, and *(c)* to undertake regional or national scale applications by aggregating from farms using georeferenced datasets of the physical environment (e.g. soils, climate, topography) and the socio-economic environment (e.g. prices, farm sizes, etc.).

Given the multidisciplinary nature of IMPEL its data requirements are widespread. At the farm scale, the model requires observed, experimental data for the calibration and validation of the soil and crop models, as well as data for model application (e.g. soil particle size distribution, bulk density, organic carbon content; daily weather data). The farm management model requires a number of input variables relating to crop husbandry (e.g. yields, prices, costs, timing of operations, timeliness penalties, rotational penalties), operations (workrate and workable hours) and machinery and labour (costs and replacement intervals). Most of these data are specific to a region for a given moment in time. However, crop yields, prices and costs will change in response to drivers such as climate and/or policy change.

Extrapolation from farms to wider regions (e.g. countries, Europe-wide) requires the same basic datasets as for the farm scale application, but these data also need to be georeferenced. It is also necessary to make judgements on how best to apply the model within a region. With the assistance of a GIS, there appear to be three basic ways in which this can be done: *(a)* for actual farms of known (irregular) boundaries and sizes, *(b)* for generic (model) farms with regular boundaries and sizes, or *(c)* for representative farms. The approach that is adopted will depend primarily on the quality and availability of data. Application to actual farms is theoretically the best option, but is very demanding of data and computer processing time. Such an approach is probably more suited to small, well documented regions. Application to generic farms provides better scope for extrapolation to larger geographic areas. However, such an approach requires assumptions to be made about the characteristics of the generic farm or farms within a region, which is another potential source of model error. The use of representative farms is a good way of applying the model to regions with limited data availability, although care needs to be taken in defining the representative farms, and to ensure that they are still representative following the effects of climate and/or policy change.

CHANGING LAND USE IMPACTS IN MEDITERRANEAN COASTAL RANGES

Maria Sala
Grup de Recerca Ambiental Mediterrània, Departament de Geografia Física, Universitat de Barcelona

Land use in the northern part of the Catalan Coastal Ranges is changing rapidly induced by socioeconomic factors because of: *a)* the expansion of touristic and urban land uses, *b)* the recession of the agriculture and forestry activities. These changes lead to a critical situation. On one side the touristic urban expansion is the base of the economic income. On the other side public opinion is more aware of the necessity of preserving the natural and cultural heritage. To take the correct decisions in this dilemma (economic development/environmental conservation) it is necessary to generate the scientific information that allows to design a global plan for the utilization of this and similar environments on Mediterranean coastal belt avoiding these areas to become irreversibly degraded.

A research design based on the study of surface hydrology and erosion of representative land use units at a small catchment level and at a plot level has been undertaken, to obtain data about the differences between the impact of rural and urban land use on woodland areas.

Anticipated risks of degradation and erosion in urbanized woodland areas have been confirmed from the occurrence of two forest fires in the surrounding Urbanization. The impact of both urban and rural land use is affecting water quality, in the first case due to waste disposal and in the second case due to fertilizers. Flooding in the lowland areas of the urbanized catchments, although it has not occurred during the study period, is another common degradation impact that is not usually considered by developers.

LAND-COVER MONITORING BY A CHANGE ANALYSER

Francesca Serra, Roman Arbiol and Vicenç Palà
Institut Cartogràfic de Catalunya, Barcelona, Spain

Background

A current concern is the monitoring of land-cover that may be carried out by analysing the changes between the last remote sensing data and results from previous studies. The detected changes may be caused either by real territory evolution or by classification errors. At this moment, the Institut Cartogràfic de Catalunya has three previous land-use studies at 1:250,000 scale as products of classification of satellite images acquired in 82, 87 and 92. In addition, Land-cover data base generators should also take under consideration collateral information from other sources different from satellite imagery such as agriculture studies, the CORINE study, topographic layouts, and climatic data.

Nowadays, many tools may contribute to a land-cover data base development. First, geographic information systems might provide the supporting collateral data. Second, expert systems can handle the heuristic rules which represent the relationship between land cover and its supporting data. Finally, remote sensing gives the most recent information on the territory.

System description

The change analyser can help in different project phases such as supervised classification and the revision of the final product quality. In the classification stage, the analyser can reinsure a candidate label obtained by training. During the quality revision task, it would be very helpful for the operator to be guided by supporting data ordered by their revision severity degree.

Another important characteristic of the system is its global application since the logic of the system and its methodology can be extended to any geographic areas. For instance, if the system is used in a tropical country, the only requirement is to provide some experts on local land cover who would have to fill an easy-structured table of rules for the regional version of the system.

Methodology

1. Knowledge and data acquisition for the land-cover change analyser:
   1.1 Comparison among previous studies to help the analysis of the rule-based system
   1.2 Definition of the object-oriented structure of the land cover
   1.3 Adjustment of the rules of change to the object-oriented data structure
2. Development of the current land-cover data base:
   2.1 Remote-sensing processing for the satellite imagery to obtain a classified image

   2.2 Supervised classification assisted by the land-cover change analyser
   2.3 Quality revision of the final product using supporting data which have been ordered by severity degree
3. Feedback of the system behaviour from the local experts

Case Study: Vic, Catalonia

To test the system, the Vic area, located in Catalonia, Spain, was chosen. The knowledge and data acquisition for the analyser were mainly provided by Joaniquet, M., Tardà, A. and Viñas, O. -the thematic experts at the remote-sensing department- and statistics obtained from comparison of the previous studies. The change types defined are event, gradient, and error. The severity degree is based on the area of the polygon and its morphology.

SURVEY OF NEEDS, GAPS, AND PRIORITIES ON DATA FOR LAND USE AND LAND COVER CHANGES RESEARCH IN NEPAL HIMALAYA

C. K. Sharma
Chairman of the Himalayan Climate Centre, Nepal

The Himalayan Kingdom of Nepal is an agriculture based mountainous country with limited usable land resources. Two third of the country is mountainous and one third area is of plain. The plain has to support the entire food need of the 22 million people (1997). In the past 300 years, the land cover had changed considerably in the middle belt of Nepal where people started mining activity during the period of industrial revolution in the western countries. Most of forest was utilized for smelting of iron and copper as Nepal does not have coal deposit. Later on mining activities were stopped due to lack of commercial size of minerals as well as supply of charcoal. With the result midland was practically reduced from forest resources and whatever is available at present it is from the natural growth.

Energy use data of Nepal shows that it is still dependent of 93% of her energy resources on biomass (forest, agriculture waste). The forest resources are heavily pressurized and covers only 36% of the total area of the country with a very thin crown cover. After the advent of democracy in 1950, the population of Nepal has been steadily growing at a rate of above 2% and to feed the growing population the forest area is being encroached. The arable total agricultural land has increased from 1,626,000 to 2,392,000 hectares at the expenses of forest, whereas between 1961 and 1991 the population was 9 and 18 million respectively.

As there is not much scope for the further encroachment in the forest the people have started to use irrigation, fertilizer and better seed to increase the intensity and productivity of the land to meet the growing food demand. It is estimated that within next 30 years the population will be double to 40 millions. Nepal has to utilize land resources data for careful land use planning in order to precisely meet her demand of fuel wood, food and fiber and at the same time control the population. For this, data on bio-physical and socio economic systems of Nepal become very important for land resources use. Availability of data from the satellite imageries and ground truthing are important in the field of:

agriculture land
forest cover
snow cover
hydrometeorological data

and also socio economic data of:

land holding per capita income, well being of people
population growth

Experience shows that data collection and utilization of processed data for planning purpose there is a time gap of 7 years and by this way the country can not plan. Furthermore, at present most of planning is done on the basis of 1977 data. Within last 20 years there was a considerable change. It is important that Nepal should institute a "Land Resource Department" which is responsible for properly collection and processing of the data on the land use and also monitoring of the land cover changes. It should also monitors the proper use of land resources as per capability of the resource in a land limited country for ecologically sound and sustainable development of the resources.

DEFINITIVE DRIVING FORCES OF LAND USE CHANGE IN TOKYO METROPOLITAN AREA (TMA)

Yo Shimizu
Doctoral Program in Policy and Planning Sciences, Univ. of Tsukuba, Ibaraki, Japan
Yohei Sato
Graduate School of Agricultural and Life Sciences, Univ. of Tokyo, Japan

The present population of Tokyo Metropolitan Area (TMA) is 40.4 million which is about one third of the total population of Japan, and is increasing due to rural-urban migration. Land uses have been changed with changes of socio-economic conditions. At present, there are various land use problems that urban-rural mixed areas have yielded due to urban land use extension in the urban fringe area. This is, because of arable and forest lands in less-favorable areas are abandoned due to the ageing and the difficulty of farm management. In order to understand the structure of land use changes, we first need to find out driving forces of land use changes and determinants of it.

National Land Agency has adopted the digital national land information system since 1974. This system includes land use/cover data and topographic data etc. We used this land use data (1976 and 1989), and classified land use types into 4 categories for statistical analyses. These categories are arable, urban, forest, other land uses. We obtained each land use ratio in the every administrative area (513 municipalities).

Socio-economic activities that use or change land attributes are considered as the proximate sources of land use change. Land use changes are constrained by biogeophysical factors. In our study, we used physiographic and socio-economic data for the statistical analyses. Since there are limitations of land use data (13 years) and the study is designed within the scope of micro scale analyses, climate is, therefore, taken homogeneous in the area. The data are organized by administrative units. In order to find out physiographic factors and socio-economic driving forces, we used the single correlation analysis and the canonical correlation analysis.

Findings of the analyses are described as follows:

In physiographic factors, arable and urban lands are found on gentle slope, low altitude. Forest lands are found on steep slope, high altitude, mountainous area. Arable and urban land use types have the same physiographic conditions, these land uses, accordingly, compete for the location. In extension of urban land use, actually, increase of urban land between 1976 and 1989 roughly corresponds to that of decrease of arable land. Forest land, however, have the different physiographic conditions, forest lands on steep slope, high altitude, mountainous area are, relatively, less converted into other uses. Land use change, therefore, are constrained by slope, altitude, topography conditions.

In socio-economic driving forces, Arable lands have strong relation to the number of farm households and agricultural employees, because the farm households and agricultural employees sustain and manage arable lands. Decrease of them directly influenced the conversion of arable lands into other uses.

Urban lands have strong direct relation to population density, secondary and tertiary industries, and inverse relation to farm households. Increase of population causes building housing directly, making growth of secondary and tertiary industries, and thereby increasing urban land uses consequently.

Forest lands have direct relation to forestry households and distance from Tokyo. Forestry households directly influenced forest lands. Areas of higher forest land ratio are in the extreme outward peripheral lands in TMA and far from Tokyo. In areas which are close to Tokyo and are on gentle slope and low altitude, arable and urban land ratios are high, forests are in flat lands and, therefore, are converted into other uses.

This research concludes that the above driving forces and determinants represent the correct analyses and is appropriate applied to isolate the factors of land use changes in TMA.

THE EUROPEAN ENVIRONMENT AGENCY AND ITS EUROPEAN ENVIRONMENTAL INFORMATION AND OBSERVATION NETWORK (EIONET)

Chris Steenmans
European Environment Agency

The European Environment Agency and the related European Environmental Information and Observation Network (EIONET) were conceived to provide information - to screen, evaluate, validate, and process data and information pertinent to the environment to transform this into efficient information principally for the European Union Institutions and the Member States, and also for the general public at large. The use of existing data and information, and the improvement of existing capacities in Member States and other European institutions to produce reliable and efficient data and information is, without doubt, the main goal of the European Environment Agency. Improved information about, as well as analyses and assessment of the environment results in improved surveillance of adequacy and efficiency of EU environmental legislation.

It is, however, important to stress that the Agency deals with European environmental information - more particularly - on the basis of the information which exists and which will be developed under the national systems in the years to come.

The European Environment Agency itself is a small, compact organisation situated in the centre of Copenhagen. Today, approximately 80 persons are working on its premises. The total budget for 1996 was 14.5 MECU. The budget for 1997 is 16.7 MECU.

Despite the small size of the Agency, its full capacity includes the activities of the EIONET - the European Environment Information and Observation Network. EIONET consists now of 18 National Focal Points (NFPs), 9 European Topic Centres (ETCs) and over 500 Main Component Elements (MCEs). This comes to a grand total of over 600 EIONET elements. The European Topic Centres (ETCs) are funded from the EEA budget, and the Agency furthermore purchases expertise from all over Europe for projects.

The ETC on Land Cover (ETC/LC) is led by the Environmental Satellite Data Centre (MDC) and works as a consortium of 16 different organisations all over Europe. Together with Centro Nacional de Informaçao Geográfica (CNIG) in Portugal and the European Commission's Joint Research Centre/Space Applications Institute (JRC/SAI) in Italy, a Steering Committee has been formed. The strategy for the ETC/LC is to provide users of land cover data, in a European perspective, with accurate data that corresponds to needs in a wide range of applications such as environmental monitoring, biodiversity measurements, nature resource inventories, mapping of areas sensitive to erosion, coastal zone monitoring, flooding, forest fires, toxicity, desertification, acidification, eutrophication and human infrastructure and environmental impact assessments.

The organisation of the EEA is project-oriented to execute the projects as defined in the Work Programme. The Management Board of the EEA is composed of one member from each of the 15 Member States of the EU, one member from Iceland, Liechtenstein and Norway respectively (members of the Agency since 1995), two members from the European Commission and two members designated by the European Parliament. The Scientific Committee is the advisory body on scientific matters for the Management Board and also advises the Executive Director on staff appointments.

The Work Programme is the main management tool of the Agency - it allows full transparency of the work of the Agency and the EIONET, thereby allowing Member States to participate fully in the work. This transparency also allows the users of the products and services delivered to make full use of the deliverables, and express their requests for the following years. The Information Strategy provides a framework of goals, priorities and ways of working that links together the work programmes (Annual and Multi-Annual) with the staff & partner organisations involved in the activities and products of the EEA.

In addition to the formal relationship and exchange of information with the EU Institutions and Member States, a dialogue with other potential users, European industrial federations, trade-unions and non-governmental organisations (NGOs), has begun. This is an ongoing process, feeding into the development of criteria for priority setting.

The Work Programme covers to some extent the whole range of topics laid down in the Agency's founding Regulation. It is the basis to ensure links between projects and a fully integrated response to the requirements of the Regulation. The approach is to define projects as building blocks to serve the development and production of environmental information which is a synthesis of available information, and information which is comparable, problem oriented and policy relevant.

As a result, products and services will be relying on the mutually reinforcing results of projects across the spectrum of the Agency's activities. The integrated framework developed for the Multi Annual Work Programme (MAWP) constitutes - inter alia - the basis for developing capacities for environmental forecasting techniques, so that adequate preventive measures can be taken in good time. The Multi Annual Work Programme (1994-1999) has 93 projects divided into 10 programme areas. This Multi Annual Work Programme is executed through Annual Work Programmes, adopted each year.

The European Environment Agency has had its World Wide Web service available on the Internet. The EEA home page can be found at: http://www.eea.dk/.

10. APPENDIXES

10.1 LIST OF PARTICIPANTS

Abrol, Inder Pal. Rice-Wheat Consortium for the Indo-Gangetic Plains; ICRISAT, 23, Golf Links; New Delhi 110003; India.
Tel.: 91 11 4644971; fax: 91 11 4619865; email: abrol@giasdl01.vsnl.net.in

Abrol, Yash P. Division of Plant Physiology; Indian Agricultural Research Institute; New Delhi 110 012; India.
Tel.: 91 11 6962147 , 6858804; fax: 91 11 6960947; email: yash@bic-iari.ren.nic.in

Adhikary, Sharad. Himalayan Climate Center; PO Box 191; Kathmandu; Nepal.
Tel.: 977 1 415741; fax: 977 1 415866; email: hcc@himac.mos.com.np

Arbiol, Roman. Institut Cartogràfic de Catalunya; Parc de Montjuïc; E-08038 Barcelona; Spain.
Tel.: 34 93 425 29 00; fax: 34 93 426 74 42; email: arbiol@icc.es

Armesto, Xosé Anton. Dep. Geografia Física i Anàlisi Geogràfica Regional; Facultat de Geografia i Història; Universitat de Barcelona; Baldiri Reixac s/n; 08028 Barcelona; Spain.
Tel.: 34 93 348 02 01

Augé, Josep Ignasi. LUCC IPO; Institut Cartogràfic de Catalunya; Parc de Montjuïc; E-08038 Barcelona; Spain.
Tel.: 34 93 425 29 00; fax: 34 93 426 74 42; email: iauge@icc.es - lucc@icc.es

Baulies, Xavier. LUCC IPO; Institut Cartogràfic de Catalunya; Parc de Montjuïc; E-08038 Barcelona; Spain.
Tel.: 34 93 425 29 00; fax: 34 93 426 74 42; email: xavierb@icc.es - lucc@icc.es

Bawa, Kamaljit S. Department of Biology; University of Massachusetts; 100 Morrissey Blvd.; Boston, MA 02125; USA.
Tel.: 1 617 287 6657; fax: 1 617 287 6650; email: bawa@umbsky.cc.umb.edu

Bernia, Sara. Departament de Geografia Física i Regional; Facultat de Geografia i Història; Universitat de Barcelona; Baldiri Reixac s/n; 08028 Barcelona; Spain.
Tel.: 34 93 442 66 57

Bielsa, Isabel. Dept. Physical Planning & Rural Dev.; Wageningen Agric. Univ.; Gral. Foukesweg 13; 6703 BJ Wageningen; The Netherlands.
Tel.: 31 317 483995; fax: 31 317 482166; email: isabel.bielsa@plano.rpv.wau.nl

Briassoulis, Helen. Dept. Human Geography; Univ. of the Aegean; Karantoni 17; Mytilene; Lesvos 81100; Greece.
Tel.: 0030 251 29579; fax: office: 0030-251-23783; email: e.briassouli@aegean.gr

Briggs, David. Nene College; Boughton Green Road; NN2 7AH Northampton; UK.
Tel.: 44 1604 735500; fax: 44 1604 791114; email: david.briggs@nene.ac.uk

Cain, Jeremy. Institute of Hydrology; Crowmarsh Gifford, Oxon., OX10 0JX; UK.
Tel.: 44 1491 838800; fax: 44 1491 692424; email: jdca@ioh.ac.uk

Capella, Hugo. Dept. Geografia Física i Anàlisi Geogràfica Regional; Facultat de Geografia i Història; Universitat de Barcelona; Baldiri Reixac s/n; 08028 Barcelona; Spain.
Tel.: 34 93 457 49 84

Cendrero, Antonio. DCITIMAC; Facultad de Ciencias; Universidad de Cantabria; Av. de Los Castros, s/n; 39005 Santander; Spain.
Tel.: 34 42 201503; fax: 34 42 201402; email: cendrera@ccaix3.unican.es

Cernusca, Alexander. Univ. Innsbruck; Institute for Botany; Sternwartestrasse 15; A-6020 Innsbruck; Austria.
Tel.: 43 512 5075922; fax: 43 512 288591; email: Alexander.Cernusca@uibk.ac.at

Choudhury, A. M. Bangladesh Space Research and Remote Sensing; Agargaon Sher-e-Bangla Nagar; G.PO Box 529; Dhaka; Bangladesh.
Tel.: 880 2 327335; fax: 880 2 813080; email: drsds@bas.bdmail.net
Conese, Claudio. IATA - CNR; Via Caproni 8; I-50145 Florence; Italy.
Tel.: 39 55 301422; fax: 39 55 308910; email: conese@sunserver.iata.fi.cnr.it
Crissman, Lawrence. Australian Centre of the Asian Spatial Inf. & Analysis Network; Griffith Univ.; Nathan, QLD 4111; Australia.
Tel: 61 7 38755137; fax: 61 7 38757956; email: crissman@asian.gu.edu.au
de la Rosa, Diego. Instituto de Recursos Naturales; CSIC; P.O. Box 1052; E-41080 Sevilla; Spain.
Tel.: 34 5 4624711; fax: 34 5 4624002; email: diego@irnase.csic.es
Desanker, Paul V. Department of Environmental Sciences; University of Virginia; Clark Hall; Charlottesville, VA 22903; USA.
Tel.: 1 804 9243382; fax: 1 804 9822137; email: desanker@virginia.edu
Duguy, Beatriz. Fundació CEAM; Parque Tecnológico; calle 4 , sector Oeste; 46980 Paterna (València); Spain.
Tel.: 34 3 402 14 62; fax: 34 3 411 28 42; email: bduguy@porthos.bio.ub.es
Elvidge, Chris. Solar-Terrestrial Physics Div.; NOAA National Geophysical Data Center; 3100 Marine Street; Boulder, CO 80303; USA.
Tel.: 1 303 4976121; fax: 1 303 4976513; email: cde@ngdc.noaa.gov
Feoli, Enrico. Department of Biology; University of Trieste; via L. Giorgeri, 10; I-34100 Trieste; Italy.
Tel.: 39 40 6763879; fax: 39 40 568855; email: feoli@univ.trieste.it
Fischer, Günther. IIASA; Schlossplatz 1; A-2361 Laxenburg; Austria.
Tel.: 43 2236 807 292; fax: 43 2236 71313; email: fisher@iiasa.ac.at
Freitas, Helena. Departamento de Botanica; Universidade de Coimbra; 3000 Coimbra; Portugal.
Tel.: 351 39 22897; fax: 351 39 20780; email: hfreitas@cygnus.ci.uc.pt
Füssel, Hans-Martin. Potsdam Institute for Climate Impact Research (PIK); P.O.Box 601203; D-14412 Potsdam; Germany.
Tel.: 49 331 288 2537; fax: 49 331 288 2527; email: fuessel@pik-potsdam.de
Gambiza, James. Department of Biological Sciences, University of Zimbabwe; PO Box MP 167, Mount Pleasant; Zimbabwe.
Tel.: 263 4 63255; fax: 263 4 63575; email: gambiza@biosci.uz.zw
Gautam, Naresh Chandra. National Remote Sensing Agency; Department of Space, Government of India; Balanagar; Hyderabad-500037; India.
Tel.: 91 40 278962; fax: 91-40-278962
Giupponi, Carlo. Dipartimento di Agronomia; Università di Padova; 16, via Romea; I-35020 Legnaro (PD); Italy.
Tel.: 39 49 8272837; fax: 39 49 8272839; email: giupponi@agripolis.unipd.
Granados, Montserrat. Dept. de Geografia Física i Regional; Universitat de Barcelona; Baldiri Reixac s/n; 08028 Barcelona; Spain.
Tel.: 34 93 440 92 00; fax: 34 93 449 85 10; email: sala@trivium.gh.ub.es
Graumlich, Lisa. Earth Learning Center; Biosphere 2 Center; 32540 S. Biosphere Road; PO Box 689; Oracle, AZ 85623; USA.
Tel.: 1 520 8965016; fax: 1 520 8966429; email: lgraumlich@bio2.edu
Haxeltine, Alex. Department of Physical Geography; Lund University; Solvegatan 13, 223 62 Lund; Sweden.
Tel.: 46 46 222 4039; fax: 46 46 14 3859; email: alexh@flab.natgeo.lu.se
Hoff, Holger. BAHC IPO; Potsdam Institute for Climate Impact Research; PO Box 601203; 14412 Potsdam; Germany.
Tel.: 49 331 288 2543; fax: 49 331 288 2547; email: bahc@pik-potsdam.de
Iglesias, Ana. Fundacion Premio Arce; Escuela Técnica Superior de Ingenieros Agrónomos; Ciudad Universitaria; 28040 Madrid; Spain.
Tel.: 34 1 3365832 fax: 34 1 5434879; email: apicazo@lander.es

Ihle, Margreet. Jackson Environment Institute; 5 Gower Street; London WC1E 6HA; UK.
Tel.: 44 171 8135206; fax: 44 171 8135283; email: margaret.ihle@ucl.ac.uk

Jeleček, Leos. Charles Univ.; Dept. Social Geography & Regional Dev.; Albertov 6; 12843 Prague 2; Czech Republic.
Tel.: 420 2 21953310; fax: 420 2 21945418; email: jelecek@prfdec.natur.cuni.cz

Joaniquet, Mar. Institut Cartogràfic de Catalunya; Parc de Montjuïc s/n; E-08038 Barcelona; Spain.
Tel.: 34 93 425 29 00; fax: 34 93 426 74 42; email: marj@icc.es

Justice, Chris. University of Virginia; Dept. Environmental Sciences; Clark Hall; Charlottesville VA 22903; USA.
Tel.: 1 804 924 3197; fax: 1 804 963 2679; email: justice@kratmos.gsfc.nasa.gov

Kineman, John. NOAA/NESDIS; National Geophysical Data Center & World Data Centers; 325 Broadway, Code E/GCx1; Boulder, CO 80303; US.
Fax: 1 303 497 6513; email: dclark@ngdc.noaa.gov

Krishnamoorthy, Ramasamy. M.S. Swaminathan Research Foundation; 3rd Cross Street; Chennai 600 113; India.
Tel.: 91 44 2351229; fax: 91 44 2351319; email: mdsaa51@giasmd01.vsnl.net.in

Lambin, Eric. Department of Geography; Universite catholique de Louvain; place Louis Pasteur, 3; B-1348 Louvain-la-Neuve; Belgium.
Tel.: 32 10 474477; fax: 32 10 472877; email: lambin@geog.ucl.ac.be

Leroy, Suzanne A. G. Centre for Palaeoecology; School of Geosciences; Queen's University; Belfast; N. Ireland.
Tel.: 44 1232 273 978 and 335 143; fax: 44 1232 321 280; e-mail: s.leroy@qub.ac.uk

López de Silanes, Ignacio. Instituto Geográfico Nacional; Dept. of Remote Sensing; General Ibáñez de Íbero 3; 28003 Madrid; Spain.
Tel.: 34 91 597 95 68; fax: 34 91 597 97 70; email: tel.edeteccion@igntel.org

Lourenço, Nelson. Universidade Nova de Lisboa; Avenida de Ceuta, 1 - 14º; P-1300 Lisboa; Portugal.
Tel.: 351 1 3626336; fax: 351 1 3626341; email: nelson@mail.eunet.pt

Majoral, Roser. Dep. Geografia Física i Anàlisi Geogràfica Regional; Univ. Barcelona; Baldiri Reixac s/n; 08028 Barcelona; Spain.
Tel.: 34 93 440 92 00; fax: 34 93 449 85 10; email: majoral@trivium.gh.ub.es

Malingreau, Jean-Paul. Joint Research Centre; European Commission; 200 rue de la Loi; SDME 10/85; 1049 Brussels; Belgium.
Tel.: 32 2 2969433; fax: 32 2 2950146; email: jean-paul.malingreau@jrc.cec.be

Mathy, Pierre. European Commission; DG XII, ENRICH; 200 Rue de la Loi; B-1049 Brussels; Belgium.
Tel.: 32 2 2958160; fax: 32-2-2963024; email: pierre.mathy@dg12.cec.be

Michou, Martine. IGBP-DIS Office; 42 Avenue G. Coriolis; 31057 Toulouse Cedex; France.
Tel.: 33 5 61 078582; fax: 33 5 61 078589; email: martine.michou@igbp.cnrm.meteo.fr

Milanova, Elena V. Dept. World Physical Geography & Geoecology; Moscow State Univ.; 119899 Moscow; Vorobievy Gory; Russia.
Tel.: 7 095 4319670; fax: 7 095 4319670; email: elena@isc.msk.su

Milesi, Cristina. Department of Biology; University of Trieste; Department of Biology; via L. Giorgeri, 10; 34100 Trieste; Italy.
Tel.: 39 40 6763879; fax: 39 40 568855; email: milesi@sci.area.trieste.it

Miralles, Jordi. Servei d'Acció Territorial de la Diputació de Barcelona; Urgell 187; E-08036 Barcelona.
Tel.: 34 93 402 22 22 ext. 7313; fax: 34 93 402 24 93

Nunes, Caroline. LUCC IPO; Institut Cartogràfic de Catalunya; Parc de Montjuïc; E-08038 Barcelona; Spain.
Tel.: 34 93 425 29 00; fax: 34 93 426 74 42; email: carolinen@icc.es - lucc@icc.es

Oldfield, Frank. PAGES - IPO; Barenplatz 2; CH-3011 Bern; Switzerland.
Tel.: 41 31 312 3133; fax: 41 31 312 3168; email: oldfield@pageigbp.unibe.ch

Palà, Vicenç. Institut Cartogràfic de Catalunya; Parc de Montjuïc; E-08038 Barcelona; Spain.
Tel.: 34 93 425 29 00; fax: 34 93 426 74 42; email: vicencp@icc.es

Perdigão, Vanda. European Commission; Joint Research Centre; Ispra Establishment; I-21020 Ispra; Varese; Italy.
Tel.: 39 332 785052; fax: 39 332 789222; email: vanda.perdigao@jrc.it
Peco, Begoña. Departamento de Ecología; Facultad de Ciencias; Universidad Autónoma de Madrid; Cantoblanco; 28049 Madrid; Spain.
Tel.: 34 1 3978002; fax: 34 1 3978001; email: begonna.peco@uam.es
Pilesjö, Petter. Department of Physical Geography; University of Lund; Solvegatan 13; S-223 62 Lund; Sweden.
Tel.: 46 46 2229654; fax: 46 46 143859; email: petter.pilesjo@natgeo.lu.se
Rasool, Ichtiaque. 52 Boulevard Sébastopol; F-75003 Paris; France.
Tel.: 33 1 48878020; fax: 33 1 48878022; email: 101650.56@compuserve.com
Rounsevell, Mark. Soil Survey and Land Research Centre; Cranfield University; MK45 4DT Silsoe; Bedford; UK.
Tel.: 44 1525 863268; fax: 44 1525 863253; email: m.rounsevell@cranfield.ac.uk
Sala, Maria. Dept. de Geografia Física i Regional; Universitat de Barcelona; Baldiri Reixac s/n; E-08028 Barcelona; Spain.
Tel.: 34 3 4409200; fax: 34 3 4498510; email: sala@trivium.gh.ub.es
Salazar, Josep-Lluís. Project Manager International Programmes; European Environment Agency; Kongens Nytorv-6; DK-1050 Copenhagen; Denmark.
Tel.: 45 33 367100; fax: 45 33 367199
Sánchez-Azofeifa, Arturo. Research Center on Sustainable Dev.; Univ. Costa Rica; PO Box 231-1200 Pavas; San José; Costa Rica.
Tel.: 506 283 9705; fax: 506 296 0047; email: arturos@cariari.ucr.ac.cr
Saurí, David. Departament de Geografia; Universitat Autònoma de Barcelona; E-08193 Bellaterra; Barcelona; Spain.
Tel.: 34 3 5811527; fax: 34 3 5812001; email: ilgesauri@cc.uab.es
Sebastián, Ana. Instituto Geográfico Nacional; Dept. of Remote Sensing; General Ibáñez de Íbero 3; E-28003 Madrid; Spain.
Tel.: 34 1 5979568; fax: 34 1 5979770; email: tel.edeteccion@igntel.org
Serra, Pau. Departament de Geografia Humana; Divisió I; Universitat de Barcelona; Baldiri Reixac s/n; E-08028-Barcelona; Spain.
Fax: 34 3 4498510; email: pauserra@trivium.gh.ub.es
Serra, Francesca. Institut Cartogràfic de Catalunya; Parc de Montjuïc; E-08038 Barcelona; Spain.
Tel.: 34 93 425 29 00; fax: 34 93 426 74 42; email: xserra@icc.es
Sharma, Chandra K. Himalayan Climate Center; Pangea House, Bishalnagar; P.O.Box no.2562; Kathmandu; Nepal.
Fax: 977 1 419069; email: chandra@cks.wlink.com.np
Shimizu, Yoh. Univ. Tsukuba; 3F617 Institute of Policy & Planning Sciences 1-1-1 Tennodai; Tsukuba, Ibaraki; Japan.
Tel.: 81 298 535577; fax: 81 298 535577; email: ymakino@shako.sk.tsukuba.ac.jp
Skole, David. Basic Science & Remote Sensing Init.; Dept. Geography; 407 Nat. Sciences Bldg; Michigan State Univ.; East Lansing, MI 48824-1115; US.
Tel.: 1 517 3554649; fax: 1 517 4321671; email: skole@pilot.msu.edu
Steenmans, Chris. Project Manager Land Cover; European Environment Agency; Kongens Nytorv-6; DK-1050 Copenhagen; Denmark.
Tel.: 45 33 367100; fax: 45 33 367116; email: chris.steenmans@eea.dk
Sundarvel, S. S. School of Ecology & Environmental Sc.; Pondicherry Univ.; R. Venkataraman Nagar; 605014 Pondicherry; India.
Tel.: 91 413 65513; fax: 91 413 65265; email: sunvel@pondiuni.ren.nic.in
Szejwach, Gérard. IGBP-DIS Office; 42 Avenue G. Coriolis; F-31057 Toulouse Cedex; France.
Tel.: 33 5 61 078581; fax: 33 5 61 078589; email: gerard.szejwach@igbp.cnrm.meteo.fr
Totolo, Otlogetswe. University of Botswana; P/Bag 0022; Gaborone; Botswana.
Tel.: 267 355 2523; fax: 267 355 2784; email: totoloo@noka.ub.bw

Turner II, Billie L. George Perkins Marsh Institute /Geography; Clark Univ.; 950 Main St.; Worcester, MA 01610-1477; US.
Tel.: 1 508 7514622; fax: 1 508 7514600; email: bturner@black.clarku.edu
Weiers, Stefan. DLR, German Laboratory for Space; Porz-Wahnheide, Linder Höhe. D-51170 Köln; Germany.
email: stefan.weiers@dlr.de

10.2 ACRONYMS

AVHRR	Advanced Very High Resolution Radiometer
BAHC	Biospheric Aspects of the Hydrological Cycle (IGBP)
BAS	Bangladesh Academy of Sciences
BITÖK	Institut für Terrestrische Ökosystemforschung
CAP	Common Agrarian policy (EC)
CEA	Centro di Ecologia, Monte Bondone
CEAM	Centre d'Estudis Ambientals
CGIAR	Consultative Group for International Agricultural Research
CICERO	Centre for International Climate and Energy Research
CICYT	Comisión Interministerial de Ciencia y Tecnología
CLAUDE	Coordinating Land Use/Land Cover Analysis and Data in Europe
CLC	CORINE Land Cover
CNIG	Centro Nacional de Informaçao Geográfica (Portugal)
CNR	Consiglio Nazionalle delle Ricerche
CORINE	Coordination of Information on the Environment (EU)
CPO	Core Project Office
CSIC	Consejo Superior de Investigaciones Científicas
DAPLARCH	Data Plan Development for Land Use and Land Cover Change Research
DGXII	Directorate General XII: Science, Research and Development
DIS	Data and Information System
DLR	German Aerospace Research Establishment
DMSP	Defense Meteorological Satellite Program (US)
DTED	Digital Terrain Elevation Data
EAB	Europäische Akademie Bozen
EC	European Commission
ECOMONT	Ecological Effects of land use Changes on European Terrestrial Mountain Ecosystems
EEA	European Environment Agency
EIONET	European Environmental Information and Observation Network
ENRICH	European Network for Research in Global Change
ENSO	El Niño - southern oscillation
EPA	Environmental Protection Administration (US)
EPD	European Pollen Database
EROS	Earth Resources Observation System (US)
ERS	European Remote Sensing Satellite
ETC	European Topic Centres (EEA)
EU	European Union
FAO	Food and Agriculture Organisation (UN)
GAIM	Global Analysis, Interpretation and Modelling (IGBP)
GCC	global climate change

GCOS	Global Climate Observing System
GCTE	Global Change and Terrestrial Ecosystems (IGBP)
GED	Global Ecosystem Database
GEMS	Global Environmental Monitoring System (UNEP)
GHG	Greenhouse Gases
GHOST	Global Hierarchical Observation Strategy (GTOS)
GLOBE	Global Land One kilometre Base Elevation
GOOS	Global Ocean Observing System
GTOS	Global Terrestrial Observation System
HKH	Hindu-Kush and Himalaya
HRV	Haute Resolution Visible
HRVIR	Haute Resolution Visible and Infra-Red
IAM	integrated assessment model
IAM-CC	integrated assessment model - climate change
IATA	Instituto per l'Agrometeorologia e l'Analisi Ambientale applicata all'Agricoltura (Italy)
ICC	Institut Cartogràfic de Catalunya
ICRISAT	International Crops Research Institute for the Semi Arid Tropics
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Programme
IGN	Instituto Geográfico Nacional (Spain)
IGU	International Geographical Union
IGY	International Geophysical Year
IHDP	International Human Dimension Program on Global Environmental Change
IIASA	International Institute for Applied Systems Analysis
IMAGE2	Integrated Model to Assess the Greenhouse Effect, 2
IMPEL	Integrated Model to Predict European Land use
INPE	Instituto Nacional de Pesquisas Espaciais (Brazil)
IPCC	Intergovernmental Panel on Climate Change
IPE	Instituto Pirenaico de Ecologia
IPO	International Project Office
IRS	Indian Remote Sensing Satellite
ISLSCP	International Satellite Land Surface Climatology Project
ITE	Institute of Terrestrial Ecology (UK)
IUCN	International Union for the Conservation of Nature
IUL	Forschungsanstalt für Agrarökologie und Landbau
JRC	Joint Research Center (EC DGXII)
LACOAST	Land Cover Changes in Coastal Zones (EU)
LAI	Leaf Area Index
LBA	Large-scale Biosphere-atmosphere experiment in Amazonia
LC	land cover
LQ	land quality
LQI	Land Quality Indicators
LUCC	Land-Use and Land-Cover Change (IGBP/IHDP)
LUCCI	land use and cover change indicators
LUTEA	Land Use in Temperate East Asia
MAWP	Multi Annual Work Programme (EEA)
MCE	Main Component Elements (EEA)
MODIS	Moderate Resolution Imaging Spectrometer
MSS	Multispectral Scanner System (LandSat)
MTPE	Mission To Planet Earth (NASA)
NASA	National Aeronautics and Space Administration (US)

NDVI	normalised difference vegetation index
NESDIS	National Environmental Satellite Data and Information System (US)
NFP	National Focal Point (EEA)
NGDC	National Geophysical Data Center (NOAA, US)
NOAA	National Oceanic and Atmospheric Administration (US)
OECD	Organisation for Economic Co-operation and Development
OGU	operational geographic units
OLS	Operational Linescan System
PAGES	Past Global Changes (IGBP)
PIK	Potsdam Institute of Climate Impact Researches (Germany)
PIK	Projet Integree Keita
PSI	Paul-Scherrer-Institut
PSIR	Pressure - State - Impact - Response
PSR	Pressure - State - Response
RAISA	Advanced Research Project for Innovation of Agricultural Techniques (Italy)
RIVM	National Institute of Public Health and the Environment (NL)
RS	remote sensing
RSD	remote sensing data
RTD	Framework Programme for Research and Technological Development (EU)
SAI	Space Applications Institute (JRC)
SLM	sustainable land management
SOM	soil organic matter
SOTER	World Soils and Terrain Digital Database
SPARRSO	Bangladesh Space Research and Remote Sensing Organisation
SPOT	Satellite Pour l'Observation de la Terre
START	Global Change System for Analysis, Research & Training (IHDP/IGBP/WCRP)
SVAT	Soil-Vegetation Atmosphere Transfer
SYPR	LC and LU change in the Southern Yucatan Peninsular Region
TEACOM	Temperate East Asia regional planning Committee (START)
TERI	Terrestrial Ecosystem Research Initiative (EU)
TM	Thematic Mapper (Landsat)
TMA	Tokyo Metropolitan Area
TOPC	Terrestrial Observation Panel for Climate
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
WCMC	World Conservation Monitoring Centre
WDC	Panel on World Data Centers (ICSU)
WISE	World Inventory of Soil Emission Potentials
WMC	Worldwide Map Consortium
WMO	World Meteorological Organisation