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IGBP-IHDP/LUCC Focus 3: Regional and Global Models

Lambin, E.F., Baulies, X., Bockstael, N., Fischer, G., Krug, T., Leemans, R., Moran, E.F., Rindfuss, R.R., Sato, Y., Skole, D., Turner II, B.L. & Vogel, C.

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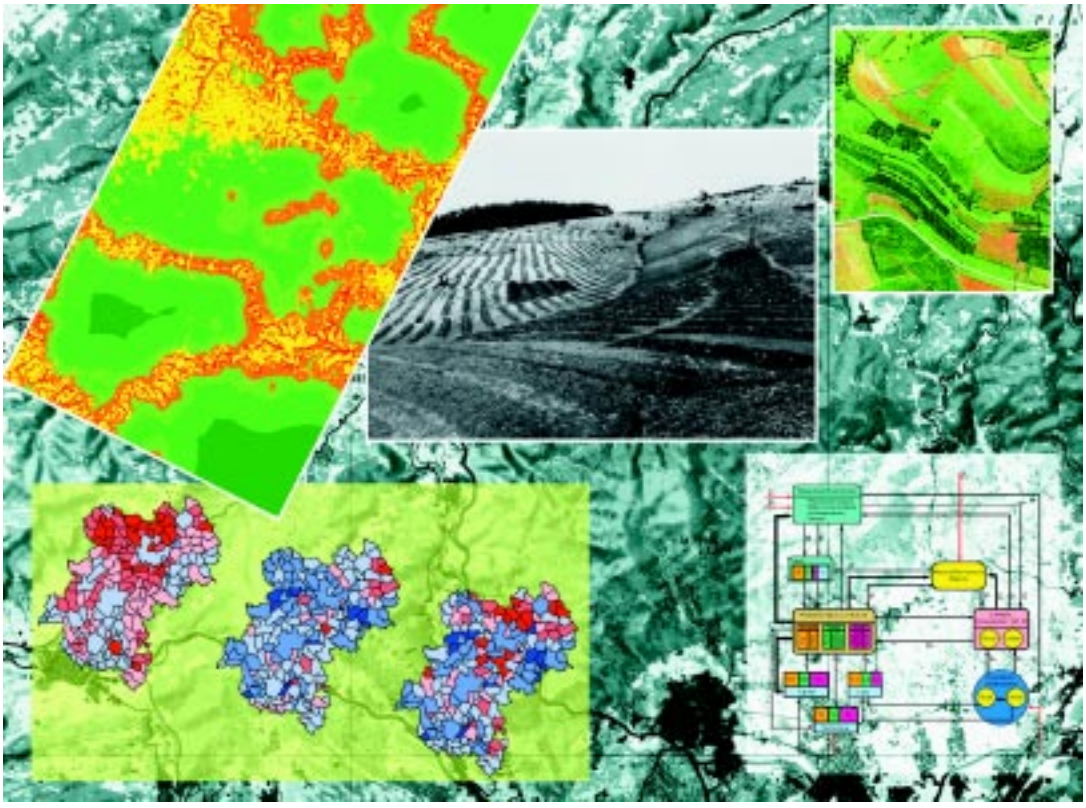

LUCC

Land-Use and Land-Cover Change (LUCC)

Implementation Strategy

IGBP REPORT 48

IHDP REPORT 10

Land-Use and Land-Cover Change (LUCC)

Implementation Strategy

A core project of the

International Geosphere-Biosphere Programme

and the

International Human Dimensions Programme on Global Environmental Change

Prepared by the Scientific Steering Committee and International Project Office of LUCC

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Implementation Strategy

This document describes an IGBP and IHDP Implementation Strategy approved by the Scientific Committees for the International Geosphere-Biosphere Programme (SC-IGBP) and the International Human Dimensions Programme on Global Environmental Change (SC-IHDP)

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Foreword

from the Executive Directors of
the International Geosphere-Biosphere Programme (IGBP) and
the International Human Dimensions Programme on
Global Environmental Change (IHDP)

The Implementation Strategy of the Land-Use and Land-Cover Change (LUCC) project specifies in greater detail the activities and projects that will fulfil the mandate outlined in the LUCC Science/Research Plan published in 1995. The project, a joint initiative of IGBP and IHDP, is addressing important global change questions on the local, regional and global scale. The planned and ongoing activities involve a wide community of natural and social scientists.

In contrast to other IGBP projects and as the first IHDP project, the LUCC Scientific Steering Committee (SSC) has produced an Implementation *Strategy* rather than a Plan. Using this strategy, the SSC will oversee the development and coordination of the planned activities. The Implementation Strategy will provide guidance to the scientific community on priorities for research and stimulate the expansion of the community of researchers working on LUCC topics. The SSC also plans to organize an Open Science Meeting at the end of the year 2000 to provide an opportunity for the community to present its research on land-use and land-cover change.

We thank the LUCC SSC and the LUCC International Project Office for the hard work that they have put into the preparation of this Implementation Strategy, and we wish the LUCC project all success as they move into the implementation phase of this collaborative effort of pathbreaking research.

The new understanding of land-use and land-cover change dynamics following from the work carried out under the LUCC Implementation Strategy will be of crucial importance to the global environmental change research community as well as to decision-makers at the local, regional and global levels.

Will Steffen
Executive Director
IGBP

Jill Jäger
Executive Director
IHDP

Summary

To understand recent changes in the Earth system, the scientific community needs quantitative, spatially-explicit data on how land cover has been changed by human use over the last 300 years and how it will be changed in the next 50-100 years. Such data can be generated through a dual approach: (i) based on direct or indirect observations, for the regions and time slices for which such data exist, and (ii) based on projections by models. To generate scenarios on future modifications of the Earth system, one has to project how changes in land use are likely to affect land cover in the future using integrated land-use change models.

Measurements of past rates and spatial patterns of land-cover changes can be derived from: (i) maps and indirect evidence on past land cover, for the historical period (past 300 years to the present), (ii) palaeorecords for a more distant past, and (iii) remote sensing-based data for the recent past (last 30 years). As none of these measurements can be produced at the global scale with the required level of detail and accuracy, some spatial sampling scheme needs to be put in place. Two approaches are to be pursued: (i) definition of a typology of «land-use situations» and sampling of case studies which are representative of these situations, (ii) identification of critical regions or «□hot spots□» of change (whether these are defined in terms of rates of change or in terms of the vulnerability, ecological value or socio-economic sensitivity of the region affected by land-cover change).

The modelling of land-use change can be performed along two tracks: (i) empirical, diagnostic models based on an extrapolation of the patterns of change observed over the recent past, with a limited representation of the driving forces, and (ii) dynamic integrated models based on an understanding of the processes of land-use change. Diagnostic models integrate landscape variables and proximate causes of change in a data-rich spatial context. However, they can only provide short-range projections (5 to 10 years at most) due to non-stationarity in land-use change processes.

Longer range projections require an understanding of major human causes of land-cover changes in different geographical and historical contexts, as well as an understanding of how changes in climate and global biogeochemistry affect land use and land cover. Such understanding is gained through a collection of case studies of land-use dynamics, which highlight how land-use decisions are made. A generalized understanding of the drivers of land-use change, that can be linked to patterns of change at the regional scale, is gained through comparative analysis of these case studies.

Models of land use at regional to global scales include a representation of economy-environment linkages. They have to cope with such issues as heterogeneity and scales, technological innovations, policy and institutional changes, and rural-urban dynamics. Regional scenarios and assessments can be generated for projecting future land-use changes or for identifying land-use patterns with certain optimality characteristics. These models are used to evaluate the impact of policy or climate change on land use. Creating a new generation of spatially-explicit land-use change models is another major challenge.

In addition, there are crucial human dimension questions related to land-use change that justify research aimed towards a better understanding of processes of land-use change in its own right. These questions are: How do human and biophysical dynamics affect the sustainability of land uses? And how do land uses and land covers affect the vulnerability of land users in the face of change? How do land-cover changes in turn impinge upon and enhance vulnerable and critical regions? Issues of human responses to land-cover changes also need to be considered.

This Implementation Strategy proposes a set of specific activities to be conducted by the scientific community to move forward on this research agenda. It also proposes a strategy, based on scientific networks, to progress collectively and in a coordinated fashion on the LUCC science questions. The underlying objective of this Implementation Strategy is to add value to the many individual projects dealing world-wide with land-use/land-cover change issues. The assumption is that, by creating a set of active scientific networks, the whole will be of greater value than the sum of the parts.

Science objectives and scope of LUCC

"From natural to human, from global to regional"

Introduction

At a global scale, land-use changes are cumulatively transforming land cover at an accelerating pace (Turner et al., 1994; Houghton, 1994). These changes in terrestrial ecosystems are closely linked with the issue of the sustainability of socio-economic development since they affect essential parts of our natural capital such as climate, soils, vegetation, water resources and biodiversity (Mather and Sdasyuk, 1991). Today, there is increased recognition that land-use change is a major driver of global change, through its interaction with climate, ecosystem processes, biogeochemical cycles, biodiversity and - even more importantly - human activities.

LUCC is an interdisciplinary project designed to improve the understanding and projections of the dynamics of land-use and land-cover change. The LUCC community of scientists aims for new integrated and regional models, informed by empirical assessments of the patterns of land use and case studies that explain the processes underpinning such configurations of land-use and land-cover change over varying spatial and temporal scales. The following key themes outline the broader research agenda of LUCC (Figure 1, page 17):

- patterns of land-cover change,
- processes of land-use change,
- human responses to land-use/land-cover change,
- integrated global and regional models,
- development of databases on land surface, biophysical processes and their drivers.

Land-use/land-cover change is central to the interests of the science of global environmental change. It is a significant agent of change which influences, and is affected by, climate change, loss of biodiversity, and the sustainability of human-environment interac-

tions. Land-use/land-cover change is a significant cause, or forcing function, of global change, and the medium through which many human responses to global change will occur. It is clearly an essential component in all considerations of sustainability. LUCC is building a bridge between social and natural sciences. It is a pathfinder project for a «science of sustainability». We refer the reader to the LUCC Science/Research Plan (IGBP/HDP, 1995) for a more thorough description of the role of land-use/land-cover change as a critical issue for global change research, and as «bridging programme» between the natural and social sciences.

The overall objectives of LUCC

The ultimate and broad objective of LUCC is to improve understanding of, and gain new knowledge on regionally based, interactive changes between land uses and covers, especially as manifested in modelling approaches. A more specific goal is the development of improved means for projecting and backcasting land uses and land covers. The leitmotif of the science may be described as "from natural to human, from global to regional," with LUCC science involving an integrative synthesis of the natural and social sciences. Research that is cross-cutting and regional is important because some of the effects accompanying global change will be most significant at the regional level. A region is defined as a continuous portion of the earth's surface, characterized by a rough match between a distinct physical environment and a system or set of systems of human use. The region offers a middle level for land-use/land-cover change studies between the local and global poles. At the regional level we can gain an understanding of the nature of human decisions that alter land-use/cover, and it is usually at this level that policy interventions are both possible and effective. Dealing with the regional approach as an intermediate level between the global and the local requires a good understanding of methodologies for up- and down-scaling. The LUCC research agenda is based to a large extend on the development of comparable research designs in different regions to address a similar set of questions. This research orientation reflects recent shifts within the broader IGBP and IHDP communities toward integrating the natural and social sciences, and focusing on the regional perspective of global environmental change.

To meet these objectives, LUCC has defined several science questions which are central to the project. These have been enumerated in the Science/Research Plan as:

1. How has land cover been changed by human use over the last 300 years[1]?
2. What are the major human causes of land-cover change in different geographical and historical contexts?
3. How will changes in land use affect land cover in the next 50-100 years?
4. How do immediate human and biophysical dynamics affect the sustainability of specific types of land uses?
5. How might changes in climate and global biogeochemistry affect both land use and land cover?
6. How do land uses and land covers affect the vulnerability of land-users in the face of change and how do land-cover changes in turn impinge upon and enhance vulnerable and at-risk or critical regions?

Questions 1, 2, 3, and 5 need to be addressed to generate land-cover change projections and investigate the role of land-use change as a major driver of changes in the Earth system. Questions 4 and 6 deal with crucial human dimensions questions related to land-use change, that justify research on a better understanding of processes of land-use change in its own right.

The intellectual challenge is not only to answer such questions but also to develop cogent and effective methods, mechanisms and partnerships by which these questions can be effectively addressed. Through such a collaborative process, gaps and priorities in global change science will be identified. The LUCC community (Figure 2, page 18) can play a major role in this process through its data collection efforts, its collection of case studies, and its model intercomparisons of various regions. Scientific advances on LUCC questions and the integration of land-use/land-cover issues in the broader global change scientific agenda will be achieved by reinforcing the LUCC components in IGBP or START regional networks (e.g. LBA, Hindu-Kush Himalaya, Miombo, Indo-Gangetic Plains, LUTEA, Sustainable Rangelands, and Southeast Asia).

Measures of success

The measures of success from LUCC science will be many and varied. One of the major benefits and measures of progress will be the establishment and operation of viable scientific networks around specific components of the Science Research Plan. In this way, scientists from both social and natural sciences will be able to gain access to improved local, regional and national data sets. Methodologies will be enhanced and scientific peer reviewed contributions will emerge. These networks are a vital way of gaining entry into global change science, particularly for those scientists from developing countries. A measure of success may thus be the degree to which such scientists have been able to contribute and enhance land-use/land-cover change science from those regions that may well be sensitive land-use/land-cover change areas in the future. Through the networks, other measures of success will include the production and development of integrated and comprehensive models for future assessment of transitions to sustainability, and the identification of criteria for evaluating success (failure) of various land-use/cover and land-use change scenarios. The identification of research gaps and areas where the science is lacking will also be a useful yardstick by which to measure land-use/land-cover change science. In these ways, land-use/land-cover change scientists will be able to offer a science which may be relevant to policy makers but also provide tangible, measurable benefits from the products of the research to a variety of scientists working both on land-use/land-cover change and other related research issues.

[1] 300 years is mentioned here as it corresponds, in most regions of the world, to the start of the period of greatest and most rapid transformations of land cover with measurable impacts on today's landscape configurations. Indeed, in many regions, human use of land resources dates far beyond the last 300 years. These longer time scales of human impact on land cover should be considered whenever it is relevant.

The various approaches of LUCC

The level of integration and synthesis in research on land-use/land-cover change requires a combination of perspectives of understanding: namely the narrative, the agent-based, and the systems approach. The narrative perspective seeks depth of understanding through historical detail and interpretation. It tells the LUCC story, providing an empirical and interpretative baseline by which to assess the validity and accuracy of the other visions. It is especially beneficial in identifying stochastic and random events that significantly affect land-use/land-cover changes but might be missed in approaches employing less expansive time horizons or temporal sampling procedures. Both the agent-based and the systems approaches depend on explicit model development and empirical testing. The former seeks to distil the general nature and rules of land-use decision making by individuals. The forms of the distillation are many, ranging from the rational decision making of neo-classical economics to household, gender, class, and other such formations common to the social sciences at large. Central to this perspective is the significance of human agent's land-use decisions. The systems/structures perspective, in contrast, finds understanding in the organization and institutions (rules) of society that establish opportunities and constraints on decision making (Ostrom 1990). These structures operate interactively at different spatial and temporal scales, linking local conditions to global processes and vice versa (Moran, Ostrom and Randolph, 1998). The systems or structures may manifest themselves in unforeseen and unintended ways. Some institutions are direct drivers of change. Others, such as markets, are intricately linked to individual decisions.

The narrative, agent-based, and systems/structures-perspectives can be and are combined in various ways and need not be constrained to a particular explanatory genre. It is within this cooperative spirit that the LUCC Science Plan and associated research foci have been framed, addressing research questions through interlocking strategies that differentially rely on the three perspectives and take advantage of the full range of LUCC practitioners.

Equally, the LUCC research agenda is building on, and needs to combine, three epistemological traditions: (i) to observe and describe (i.e. *inductive approach*); (ii) to model (i.e. *deductive approach*); and (iii), to integrate (i.e. *dialectic approach*). The richness of land-use/land-cover change research stems from its position at these multiple interfaces between different scientific traditions. Its main challenge is to integrate them to increase our understanding of a major aspect of human-environment interactions.

An outline of the Implementation Strategy of LUCC

An outline of how the Science Plan of LUCC is to be implemented is provided below. This is not a prescriptive listing of how or what should be undertaken, but rather it is a series of key Tasks and Activities which will result in the achievement of the broad objectives outlined above. To meet these objectives and to fulfil the Implementation Strategy, it is envisaged that a number of activities, workshops, and various other forums for results will be required. The strategy as outlined here is also not to be regarded as static or rigid, but is to be viewed as flexible, adapting to feedback, new data inputs, and changing paradigms.

Three interlocking strategies are encapsulated in the three research foci of LUCC (Figure 3, page 19). These are:

Focus 1

Development of case studies to analyze and model the processes of land-use change and land management in a range of generalized global situations;

Focus 2

Development of empirical, diagnostic models of land-cover change through direct observations and measurements of the explanatory factors;

Focus 3

Utilization of analysis from Focus 1 and 2 for the development of integrated and prognostic regional and global models.

Each group of Focus Activities is trying to answer the same science questions formulated above but from a different scientific perspective and at different scales. Each Research Focus also incorporates activities that create the linkage with other perspectives and scales of analysis. The LUCC Implementation Strategy is an attempt to engage different scientific communities (e.g. human ecologists, land economists, remote sensing/geographic information system specialists, land-use/land-cover change modellers, scientists engaged in integrated assessment) to work together. The Focus Activities represent the natural entry point for these communities. Through the set of Activities and Tasks in each Focus, these communities are brought together.

Links between Foci are of particular importance: local to regional scale studies of land-use and land-cover dynamics (Foci 1 and 2) to inform the construction of integrated models (Focus 3); spatially-explicit analyses in Focus 2 to provide a spatial framework to the integrated models (Focus 3); regional-scale land-cover change projections (Focus 3) to provide contextual information to the understanding and projection of fine scale land-use dynamics (Focus 1); validation at the fine scale (Foci 1 and 2) of broad scale projections (Focus 3); and investigation of the scale-dependency of the relationship between driving forces and rates of land-cover changes (Foci 1, 2 and 3). Moreover, there are a number of methodological issues that are cross-cutting the three Foci - e.g. multi-scale approach, integration of spatial and socio-economic heterogeneity, and assembly of appropriate biophysical and socio-economic spatially-explicit databases. As LUCC is exploring new grounds at the interface between social and natural sciences, it requires a number of methodological research and/or workshops.

The priority Tasks - i.e. those which the community is ready to undertake (or are being carried out) - are indicated in the document. Moreover, the Implementation Strategy identifies a few representative LUCC projects which are generating and will continue to generate major results on land-use/land-cover change in a two to three year time frame. This list is in no way exhaustive (more details on these and other LUCC projects can be accessed through the LUCC Web pages: http://www.uni-bonn.de/ihdp/lucc/index.html).

The audience for this document is: (i) the scientific community involved in land-use/land-cover change research, (ii) scientific communities which require land-use/land-cover change projections for their own investigations, (iii) policy-makers dealing with land use-related issues, and (iv), agencies funding scientific research on global change issues.

Figure 1

The broader research themes of LUCC

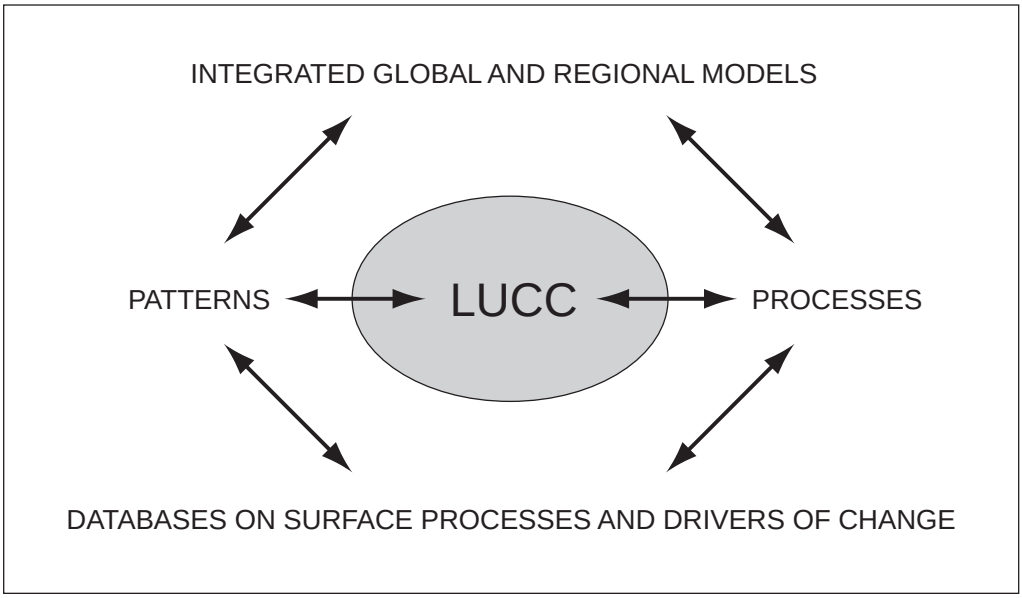


Figure 2

The LUCC community

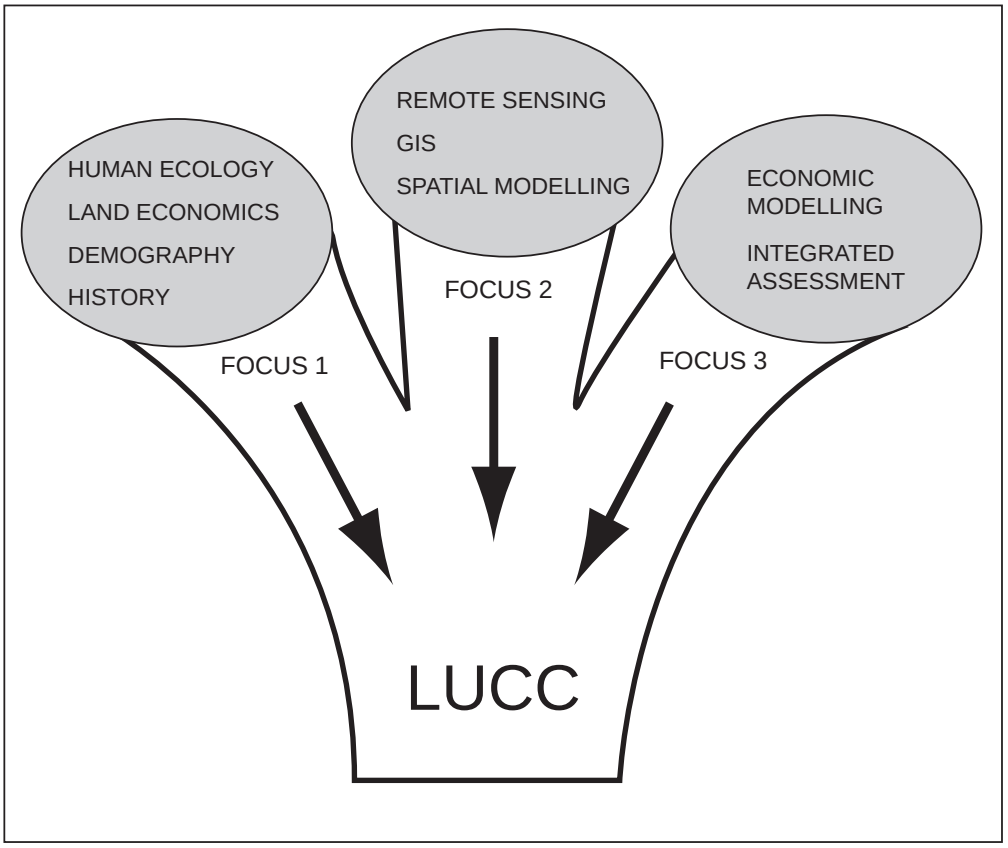
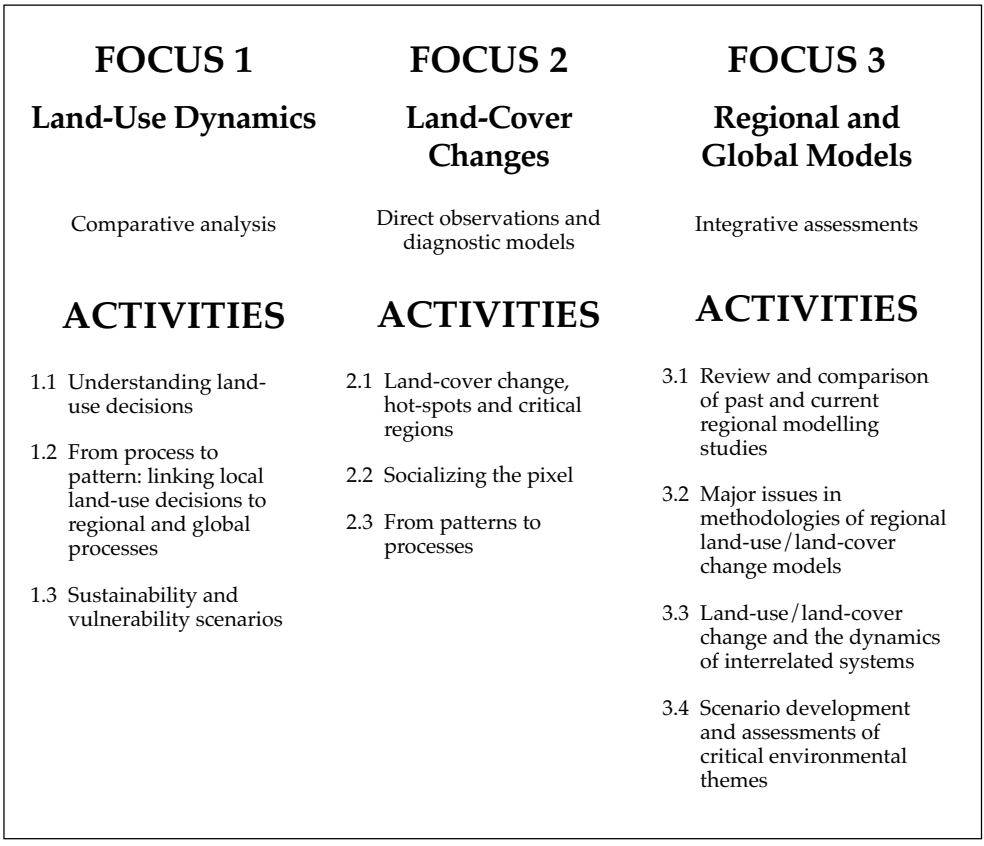


Figure 3

Series of Activities related to the various Focus areas of LUCC



The evolution of "big issues" and LUCC

Global change science and LUCC emerged from concerns about human-induced impacts on the biogeochemical foundation of the biosphere and their implications for climate change. Subsequent to the publication of the LUCC Science Research Plan, refinements in understanding the initial concerns have illuminated new ones, leading to new but complementary "big issues" of global change science. The three "big issues" identified below represent an update in this thinking and the range of themes that draw diverse research communities to engage in an expanding LUCC science. They are provided as examples that give meaning to the specific Activities and Tasks detailed in this Implementation Strategy (Figure 4, page 24).

Transition to a sustainable world

This theme refers to the large number of concerns involved in providing for a future world in a more environmentally benign way than has characterized the recent past. With origins in the Brundtland report and increasingly embedded in global change science agendas, the overarching concern is achieving this provisioning in a warmer, more crowded, and more resource demanding world characterized by unexpected and extreme events. This transition requires an improved understanding of the *trajectories of land-use/land-cover change* that invoke positive or negative human-environment relationships (e.g., desertification and chronic malnutrition on the one hand and forestation and restoration on the other). Better understanding should improve the identification of *critical regions and places,* that is the forecasting of the people, places, and regions that face high probabilities of entering states of crisis. Central to these trajectories are *rural-urban dynamics* in a world of large, sprawling urban areas competing for peri-urban lands, changing production-consumption relationships in their hinterlands. Inherent in this tension between urban and rural land uses is the degradation of aquatic systems, with consequences for urban populations, brought about by nutrient run-off and soil erosion from agriculture and tropospheric pollution, affecting agriculture, and generated by the urban sector. *Sustainability* involves a balance between the environmental, economic and social dimensions of society. Unsustainable systems are those for which growing environmental degradation eventually surpasses society's ability to substitute productive systems or to

intervene to control or mitigate the damage. *Strategic environmental assessment*, with its aim of focusing human impacts on specific places, thereby reducing stressors on others, cannot be effectively undertaken without serious land-use/land-cover change assessment.

Biogeochemical cycles and biodiversity

The significance of land-use/land-cover change for global environmental change, as sources and sinks of biogeochemical elements or biological diversity, is well understood by the research community. It thus is important to considerations of the *use and consumption of environmental resources*. LUCC continues to contribute to the understanding of these diverse research questions through its *regional based studies* and *multiple-scale, integrative models* designed to explain and project land-use/land-cover changes. These studies and models are fundamental to assessments of *inter annual variability*, be it carbon fluxes or climate. LUCC studies also inform baseline assessments from which the degree of *modification and transformation of landscapes* are determined and hold the promise to establish measures of the *human impact on natural landscape.* LUCC examines the behaviour and structures of human populations in regard to how they value biodiversity and environmental change more generally as expressed through their landscape systems. Economic, political, and social considerations loom large in these analyses. LUCC is currently recognized as one of critical gaps in our knowledge of the *terrestrial carbon cycle* which in turn has implications for the rate of greenhouse gas accumulation in the atmosphere and potential climate change. LUCC contributes key knowledge to the processes that result in *landscape transformation*, including fragmentation and degradation. As such, land-use/land-cover change becomes a key driver of changes in biodiversity.

Critical regions and vulnerable places

Environmental change does not affect all places similarly. Differential impacts and abilities to respond create winners and losers in this change. Central to the big issues above is the identification and understanding of dynamics giving rise to *vulnerable people and places* in the face of global change. Whether involving land fragmentation, degradation of agricultural productivity, declines in economic well being, or involuntary human migration, land-use/land-cover change plays an important role. Further work is needed on the identification of *critical land-use/land-cover change regions* and the dynamics giving rise to them. This emphasis examines the *vulnerability and resiliency* of people, infrastructure, production systems or biodiversity rich "hot spots" in the face of trends such as sea-level rise, increased frequency of extreme storm events, and chronic land degradation. LUCC research is also essential in assessing *environmental entitlements* and the role of institutions (rules and regulations) in exacerbating or mollifying human impacts on the environment and the impact of a changing environment on the human condition.

These "big issues" and the themes embedded in them demand a new generation of spatially explicit, integrated land-use/land-cover change models of the kind which the LUCC project promotes. The necessary scientific studies must be developed within the reality of rapidly changing spatial and temporal data derived from technologies of earth

observation. Future LUCC work will be informed by global coverage on a seasonal basis at fine-tuned spatial resolutions, and the results of this work can be expected to challenge existing theories and models of land-use/land-cover change. As this research progresses, people and pixels need to be linked to analyze human agency and social structure in land change. The depth of understanding brought to bear from bottom-up, field-based approaches must be made spatially explicit, including efforts to integrate results with remote sensing information (*pixelizing the social*); remote sensing approaches that potentially increase spatial and temporal dimensions of land-use/land-cover change understanding must be pushed beyond its biophysical dimensions (*socializing the pixel*). The connection between micro-level behaviour of individuals and communities and macro-level structures and patterns is critical but remains poorly understood. Addressing these questions at this scale of analysis raises serious issues about *data confidentiality* that the LUCC community has not yet adequately addressed.

Figure 4

The big issues and some examples of the specific Tasks and Activities

"BIG ISSUES"	FOCUS 1	FOCUS 2	FOCUS 3
Transition to a Sustainable World	Activity 1.1: Understanding land-use decisions Task 1.3.2: Simulation modelling of land-use/land-cover change to identify sustainable future scenarios	Task 2.1.2: Definition of land-cover change indicators	Activity 3.2: Major issues in methodologies of regional land-use/land-cover change models Activity 3.3: Land-use/land-cover change and the dynamics of interrelated systems Activity 3.4: Scenario development and assessments of critical environmental themes
Biogeochemical Cycles and Biodiversity	Activity 1.2: From process to pattern: linking local-land use decisions to regional and global processes Task 1.3.1: Identify key biogeochemical and climate variables associated with changes in land cover over long time periods	Task 2.1.1: Monitoring biophysical and socio-economic variables Activity 2.2: Socializing the pixel	Activity 3.2: Major issues in methodologies of regional land-use/land-cover change models Activity 3.3: Land-use/land-cover change and the dynamics of interrelated systems Task 3.3.2: Water issues in regional land-use/land-cover change
Critical Regions and Vulnerable Places	Task 1.3.3: Simulation models that identify key interactions associated with degradation and vulnerability	Activity 2.1: Land-cover change, hotspots and critical regions Task 2.3.2: Definition of risk zones and potential impacts	Task 3.2.2: Improving the environment-economy linkage Task 3.3.2: Water issues in regional land-use/land-cover change Task 3.3.3: Expanding the global food and fibre production Activity 3.4: Scenario development and assessments of critical environmental themes

Strategy for implementation

Objectives

The LUCC project seeks to prioritize, promote, and catalyze international research on the topic of land-use/land-cover change by developing and articulating an international community consensus on the key questions and requirements for research (Figure 5, page 36). The implementation strategy of the LUCC project pursues two main objectives: (i) to reach a still larger scientific community, and (ii) to generate a wealth of results on the LUCC scientific questions. This implementation strategy is a major medium to facilitate interdisciplinary research work, in particular between the social and natural sciences, and to globalize research on land-use/land-cover change processes by contrasting results obtained in a variety of regions and geographic situations.

(i) To reach a still larger scientific community

LUCC will only make progress if it reaches and engages a large community, representative of a diversity of regions, cultures and scientific backgrounds. As human activity is currently the main driver of land-use/land-cover changes, a LUCC project in a specific geographical setting can only be successful if it involves in a strong way, or is led by, scientists from the region, who are well aware of the complex interactions between driving forces and human actions in the specific region. Involvement of local scientists is also crucial to ensure that results of scientific investigations on processes of land-use/land-cover changes in a region can be translated into meaningful policies. As the regional approach is central to the implementation of LUCC, one expects the LUCC project to engage scientists from all the regions of the world.

Several major disciplines, especially in the social sciences (e.g. anthropology, economics, demography, history, political science and sociology), have not yet come to appreciate that there are major and numerous entry points for their disciplines in the LUCC research agenda. The same is true for research communities working on the interface of environment and development and, to a lesser extent, on the reconstruction of past land cover/land uses on a time scale of 200 to 300 years (e.g. environmental historians and palaeoecologists). A special outreach effort targeting these communities is necessary, since their expertise is essential to progress

on the LUCC science questions. This involves a broadening of the terminology and concepts used to formulate our science questions.

(ii) To generate a wealth of scientific results on LUCC scientific questions

LUCC needs to achieve major scientific advances on its research questions. It also needs to rapidly identify and publicize a few demonstration case studies and success stories which will help LUCC illustrate and promote an integrated approach to the understanding of land-use/land-cover change processes, with a good mix of data on patterns of land-cover change, case studies on land-use dynamics, and integrated models at the regional scale.

One of the major outputs of LUCC - which the broader global change community eagerly seeks (e.g. for the IGBP GAIM efforts toward a synthesis of the IGBP research) - is a database of land-cover change over a period going 300 years back in the past and outlooks extending 50 years into the future. Achieving this in a reasonable time frame requires a strong collaboration among: (i) environmental historians and palaeoecologists for the past 300 to 50 years; (ii) monitoring systems of the land surface for the past 50 years; (iii) empirical, diagnostic models for short-range projections (up to 5 to 10 years at most); and (iv) dynamic integrated models for the future, from now on to 50 years ahead.

Finally, there are major policies that require for their implementation spatially-explicit land-use/land-cover change data and models of land-use change processes. The spatial scope of these policies ranges from the global scale (e.g. to implement the Kyoto protocol) to the local scale (e.g. to promote a sustainable use of resources and sustainable livelihoods), through the regional scale (to design land-use policies, e.g. at the rural-urban interfaces or to control processes of spatial differentiation in a region). The LUCC project needs to generate the knowledge, models and data on land-use/land-cover change processes which are required to inform these policies.

Strategy

To meet these objectives, the LUCC strategy encompasses four groups of actions: (i) development and coordination of scientific networks, (ii) outreach activities, (iii) coordination of research on land-use/land-cover change processes in regional networks, and (iv) integration in LUCC scientific networks of individual projects which are relevant for LUCC through project endorsement.

1. Scientific networks

- Identification of gaps and prioritisation of research

The LUCC Science/Research Plan and this Implementation Strategy identify priority areas for research on land-use/land-cover change processes. This is the result of numerous workshops around the world, which involved a large number of scientists from different regions and disciplinary backgrounds. This setting of priorities can serve as a basis to help individuals seeking research funding, and to suggest new research lines, e.g. for young researchers who have not yet acquired a broad overview of the key and current questions in a discipline.

- Dialogue with funding agencies

LUCC is working with agencies and projects to create new funded LUCC research projects. In particular, LUCC is directly soliciting funding for new projects in priority regions. The goal of LUCC is to quickly generate funded pilot projects with interdisciplinary teams of scientists focused on specific LUCC questions and/or regions. To that end, LUCC will continue its dialogue with the European Commission and its fifth Framework Programme (e.g. LUCC electronic conference held in 1997), the US Global Change Research Program initiatives on LUCC (e.g. NASA), the Japanese LUCC programmes, and other agencies world wide.

- Definition of data requirements for land-use/land-cover change research

LUCC is holding a series of workshops on the definition of data requirements for land-use/land-cover change research. This is funded by EU's ENRICH programme, with contributions from other international agencies and programmes like NASA and START, under the DAPLARCH plan (Data plan for LUCC research), which has workshops on data requirements (1997), compilation and algorithms (1998), implementation and updating (1999), and information systems for dissemination (2000). Other similar workshops are also required, focusing particularly on the social sciences, so that data research needs and gaps in such fields can be identified.

- Coordination of data efforts

LUCC needs to develop a data strategy in order to access and produce needed data sets. For this, it is crucial to develop efficient systems for integrating socio-economic, institutional, and biophysical information, for addressing (data) measurement needs, and for identifying the key variables for LUCC studies and model requirements. Typically, in a given region, data on land use and socio-economic drivers are much less accessible for research than data on land cover. A researcher on land-use/land-cover change processes needs data on a large number of variables for the region of study, rather than data on just a few variables at a global scale.

- Standardization of methodologies and definition of experimental protocols

Conformity of methodologies to attain standard protocols for data collection and analysis is essential to make comparable the results generated by individual studies. This is important because of the need to generalize from a large set of local-scale studies to regionally and globally-valid results, and is of special value for the large number of local-scale projects on land-use dynamics.

- Generation of results on Activities/Tasks identified in this Implementation Strategy

The main task ahead of LUCC is to launch one or several initiatives (e.g. research projects), based on a network of scientists, for each Activity and Task identified in the Implementation Strategy. This is the most crucial aspect of the implementation of international projects such as those from IGBP and IHDP. LUCC expects to identify a sufficient number of Activity leaders and networks, motivated to address initiatives for the benefit of the scientific community as a whole, so that scientific advances can be made on these Activities and Tasks and, therefore, on the LUCC science questions.

- Synthesis and state-of-the-art papers

An important contribution of LUCC to the scientific community will take place through the production of "state-of-the-art" papers, reviewing recent work and major research questions on specific topics which are essential for the progress of the LUCC scientific agenda. Some of the topics which require a review paper are:

- A summary of integrated models of land-use change;
- Concepts, methods and approaches for "socializing the pixel";
- Methods and databases to assess global land-cover changes over the past 300 years and for the next 50 years;
- Methods and models to integrate social and natural sciences for a better understanding of the processes of land-use change;
- Scaling issues, both in human and ecological systems, inherent in research on land-use/land-cover changes.

These papers will summarize and provide a state of the science/art, identify uncertainties, and provide input into the development of new research thrusts.

- Model intercomparisons

Several research teams are developing their own land-use change models. Much could be gained from organizing model intercomparison exercises, to analyze the concepts and functions used in each model and to compare the performance of each model under a variety of forcing conditions. In some cases, each team would run its own model on a similar database. The comparison of results and, more importantly, the analysis of circumstances under which each model best performs, would help the entire community to improve their own models. This effort would facilitate the development and refinement of integrated models of land-use/land-cover changes at the regional scale. Initial intercomparisons could, for example, target models of tropical deforestation and rural land allocation.

- Collaborations with other IGBP and IHDP projects

Several IGBP and IHDP projects are already tackling scientific questions connected to the LUCC science questions. There is a need not only to forge a link between the natural and social science endeavours, but also, as IGBP and IHDP come of age, to create workable partnerships among the various programmes and projects involved in global change science. Linkages among Core Projects are an important aspect of the current emphasis on integrative science within the IGBP and IHDP, and within LUCC. Joint implementation teams will have to be set up to deal with issues of the impact of land-use changes on, for example, biodiversity, trace gases, water, human security, and food production. Among the most important linkages, we can immediately identify the following:

IGBP Core Projects

- PAGES (Past Global Changes)

Focus 3: Human interactions in past global changes. Many of the LUCC objectives and questions need the long-term reconstructions of: (i) major human causes of land-use change in different geographical and historical contexts, (ii) land-cover changes induced by human use over the last 300 years, and (iii) inter-relationships among land-use/land-cover, biogeochemistry and climate on different time scales and in different regions. Concrete fields of joint LUCC-PAGES activities can be: (1) base-line, time-slice global reconstruction of land cover for 200-300 years ago; (2) improved quantitative understanding of historical land-use changes and their role as drivers of global change using a regionally differentiated approach, identifying priority regions where LUCC and PAGES can share expertise, establishing time frames and research needs in terms of data, methodologies and model development. The analysis of processes over a range of time scales (decadal/century/millennial) improves the understanding of the interactions between climate variability and human activity (e.g. triggers to change, shifts to steady state, climate shocks), as well as the non-linear responses to land cover changes, thresholds and extreme events over very long time scales. Finally, LUCC-PAGES interactions can provide the means to inter-calibrate methods, observations and models, and to exchange data relevant to major questions shared by both projects.

- GCTE (Global Change and Terrestrial Ecosystems)

The understanding and analysis of landscape processes dovetails nicely with all the GCTE foci. For the theme of landscape complexity and ecosystem function the relationship between land-use changes and landscape processes should be examined. It is important to know the landscape-scale effects of changes in disturbance regimes on vegetation dynamics as a consequence of land-use change. Issues such as the impact of land-use changes on habitat reduction and fragmentation, and the consequences thereof on biological diversity, ecosystem functioning and ecosystem services should also be studied jointly. The linkage between land-use change and biodiversity can be established through the DIVERSITAS programme as well. Landscape disturbances should also be addressed together with GCTE-Focus 2 (Ecosystem structure). Issues related to food security and environmental vulnerability should be addressed jointly with GCTE-Focus 3 (Global change impact on agriculture, forestry and soils). Impacts of land-use changes on biodiversity and socio-economic feedbacks of these impacts are to be addressed in co-ordination with GCTE-Focus 4 (Global change and ecological complexity). Finally, LUCC can provide valuable inputs to GCTE-Focus 1 (Ecosystem physiology and global change) from its understanding and databases on the land-use change impacts on the terrestrial branch of the carbon cycle.

- LOICZ (Land-Ocean Interactions in the Coastal Zone)

Focus 4: Economic and social impacts of global change in coastal systems. Scientific findings on the links between socio-economic drivers of environmental change - including land-use changes - and nutrient and sediment/water fluxes should be brought together. Because coastal areas are subject to a great deal of natural variability, socio-economic pressures serve to exacerbate problems associated with dynamic change in coastal sinks for particulate matter and morphology.

Scenarios should be developed of coastal zone development under changing climate, land use, river inputs and biophysical forcing functions. This information will be used to investigate possible feedbacks on coastal populations and environments. Finally, the extent to which scientific understanding of coastal zone changes could contribute to the formulation of more integrated resource management strategies should be assessed. Such strategies would better enable the achievement of sustainable utilisation of coastal resources and environments.

- BAHC (Biospheric Aspects of the Hydrological Cycle)

There is evidence that human disturbance due to agriculture, grazing, forest practices and urbanisation have significantly altered the natural landscape. Such changes have altered the albedo and have had a direct effect on Earth's surface energy budget, and have altered not only regional climate, but cumulatively have had an impact on global climate. This influence, the drivers and the feedbacks of this influence on climate, are complex and require a broad range of scientific expertise to understand and predict. Impacts of land-use changes (e.g. landscape fragmentation) on the hydrological cycle must be studied in depth, as well as the impacts of changes in the hydrological cycle on society in terms of risk and vulnerability. Specific initiatives will also be developed regarding mountain regions in relation to land-use changes and the hydrological cycle.

- GAIM (Global Analysis, Integration and Modelling)

LUCC will help GAIM by providing projections of future land-cover changes over the next 50 years, at regional to global scales, as an input to global models aimed at better understanding the biophysical implications of human activities in the Earth system. These inputs will be integrated in the IGBP-synthesis activities managed by GAIM, such as the Earth Observing Network and the Earth System Models of Intermediate Complexity.

- IGAC (International Global Atmospheric Chemistry)

The impacts of land cover change (e.g. intensification of agriculture) and landscape disturbances (e.g. savannah and forest fires) on surface-atmosphere fluxes and their feedback on land-use should be further studied. In this context, new results on biomass burning and inter-annual variability of land-cover change processes provide important input. Data on changes in farming practices in relation to land-use changes are also essential to understand emissions related to agriculture.

- IGBP-DIS (IGBP Data and Information System)

IGBP-DIS is currently collaborating with LUCC in the development of DAPLARCH, where the conceptual framework for addressing land-use/land-cover change research data needs is being addressed. Within the DAPLARCH framework, IGBP-DIS will help LUCC in communicating such identified needs to the appropriate data holders and funding institutions. In addition, collaboration and technical assessment will be increasingly needed for allowing the generation of the large and diverse databases required for research on land-use/land-cover changes. Other fields in which IGBP-DIS may collaborate with LUCC are those related to data management, like the development of meta data servers.

IHDP Core Projects

- IDGEC (Institutional Dimensions of Global Environmental Change)

There is an important complementarity between the LUCC and IDGEC-Focus 1 objectives. A particular area of interest is the interaction of property rights regimes and macro-economic institutions as a source of change in patterns of land use. The role of formal and informal political institutions that have both the authority and the power to mandate changes in land use is also a major concern for both projects. It is these political institutions that often determine who may appropriate forest resources and what rules apply to the actions of various appropriators. For its part, the IDGEC-Focus 3 covers a variety of issues pertaining to the role of institutions in guiding human responses to major changes in land cover and in the environmental services provided by ecosystems. LUCC shares with IDGEC a thematic focus on the problem of fit between social practices and the ecosystems that sustain them.

- IT (Industrial Transformation)

Cooperation with IT involves the relationship between food production and land-use changes should be further developed, as well as the urban-rural interface in the context of a changing environment and technology. Industrial Transformation involves changing structures of production, modes of regulation of production and material and energy transformations. These changes are reflected in their impact on the environment in terms of land-use/land-cover changes. Industrial Transformation requires efforts in addition to the traditional patterns of industrial development such that dissipative losses are restricted to levels that do not exceed carrying capacities, or to levels compatible with societies' capability to adapt to any resulting environmental change. Food production and interconnections between intensification and disintensification processes in land use should also be addressed jointly by the two projects. Finally, the role of cities and rural/urban dynamics in land-use/land-cover changes is another major point of collaboration.

- GECHS (Global Environmental Change and Human Security)

Links should be established to share mutual understanding about the impacts of land-use changes on human vulnerability and vice versa. In concrete, topics like the relationship between migratory movements and environmental degradation; land-use intensification and availability of water resources; and adaptation processes to global environmental change should be commonly addressed. Furthermore, human health issues lay in the threshold of both projects. It has been demonstrated, for example, that land-cover changes affect the spread of vector-born diseases.

START (Global Change System for Analysis, Research and Training)

Collaboration with START on the identification of regional issues, concerns and research priorities, as well as the development of regional scientific networks is also essential.

- Contribution of LUCC to the IGBP synthesis of the year 2000

IGBP is preparing a major synthesis of its research results. Each programme element is preparing a synthesis of their achievements and results. For LUCC, as it is a young project, this means taking each of its science questions in turn and capturing and assessing the baseline knowledge on these questions. This synthesis will require the compilation of many studies and model experiments with an eye to extracting the key research findings. This synthesis is a major event as it will compel the scientific community: (i) to explore links between different programme elements and disciplines, and (ii) to communicate to policy-makers and society, in clear and accessible language, the main findings of the research on global change.

2. Outreach activities

The following actions are intended to promote the LUCC research agenda and to ensure that a sufficiently broad and diverse scientific community is engaged in LUCC-related research

- *Progressive expansion of the Scientific Steering Committee*, to include the most active scientists worldwide on land-use/land-cover change research, and to reflect the regional and disciplinary diversity of the LUCC research agenda.

- *Comparative case studies* (under Focus 1, see below), as a way to bring to the table researchers who have made progress on land-use/land-cover change research in a specific locality but who have not, to date, seen their work as part of the global change research agenda.

-*Regional and thematic electronic conferences on land-use/land-cover change*, to communicate and exchange information on a specific theme relevant for land-use/land-cover change research, in a specific region.

- *Regional workshops on land-use/land-cover change*, often in collaboration with START, as a medium to catalyze the scientific community in a specific region and stir new efforts on land-use/land-cover change issues of relevance for the region.

- *Open Science Conferences* to bring together the scientific community to crystallize achievements and to promote the multidisciplinary and multisectorial interests of LUCC.

- *Focused workshops* on important LUCC scientific questions, which engage issues within each Foci and then across the Foci. This should include training workshops on specific topics (e.g. on integrated land-use modelling) in collaboration with START.

- *Wide diffusion of the LUCC Newsletter and web site*, as a medium to advertise achievements of the LUCC research, to exchange views and promote new concepts, and to engage researchers into LUCC Activities.

- *Development of course material, examples of land-use/land-cover change case studies, and computer-based interactive land-use change simulation games* to reach, respectively, students, local case-study researchers and land-use managers.

3. Regional networks

A major path of implementation of the IGBP scientific agenda is through regional networks. Regional networks also provide an ideal framework for IGBP-IHDP inter-project collaborations. LUCC can encourage and help coordinate multiple research endeavours with differing perspectives in the same geographical region, especially through collaboration with START. This regional approach lays the foundations for specific projects in priority regions, which will trigger a focus for funding efforts, and provide a mechanism to engage regional concerns and priorities into the overall LUCC agenda. A number of regional networks have been started or have had initial workshops for organising the science plans: LBA, Yucatán and Central America Region, Miombo Woodlands, Sustainable Rangelands in Southern Africa, Land-Use/Land-Cover Changes in West and Central Africa, Mediterranean Basin, IGP (Indo-Gangetic Plains), Coastal Zones of South Asia, Hindu-Kush Himalaya, Human Driving Forces of Environmental Change in Southeast Asia, LUTEA.

Some of these networks deal with land-cover change processes related to deforestation, which is relevant for post-Kyoto policies and for the IGBP synthesis (e.g. LBA, Yucatán and Central America, Southeast Asia). Others are more focused on land-use intensity and food security (e.g. IGP, Coastal Zones, Rangelands and LUTEA) or ecological transects with gradients in human vulnerability (Miombo, Mediterranean and Hindu-Kush Himalaya).

Many of these regional networks cover ecological transects - i.e. they are based on ecological gradients of global change driver factors, on gradients in land-use intensity or on gradients in human vulnerability. LUCC will become closely involved in these regional networks and propose a sound approach for integrating the land-use/land-cover change research into the broader experiments and models developed on these transects.

4. The endorsement of research projects

A procedure to review and endorse research projects has been set up by LUCC (see LUCC web pages at: http://www.uni-bonn.de/ihdp/lucc/index.html). The criteria for endorsement are: (i) the scientific excellence of the project, as being evaluated through a peer review process and (ii) the contribution of the project to the objectives and priorities of LUCC, as defined in this Implementation Strategy. Endorsed projects should be linked in to LUCC scientific networks built around Tasks and Activities.

Three categories of projects may seek endorsement: (i) research proposals that are not yet funded and that will greatly increase their likelihood of being funded if they are endorsed; (ii) research projects that are already funded and which will benefit - e.g. in terms of scientific exchanges with a network of colleagues and dissemination of results - by being part of a large international network through endorsement; and (iii) workshops, conferences or any other open scientific initiative that would benefit in terms of visibility and appeal to the larger scientific community by being endorsed by LUCC.

In addition to this, LUCC will also endorse doctoral dissertations which contribute to the LUCC research agenda in order to encourage young scientists to participate in the project.

Endorsement of a project provides benefits both for LUCC and for the investigators of the project:

- *Benefits for LUCC:* The endorsed projects constitute a portfolio of scientific investigations which contribute to progress on the science questions of LUCC. They also demonstrate methodologies to generate new knowledge on land-use/land-cover change processes, and they generate databases which can be shared within the LUCC community. Finally, most of these projects deal with a specific region of the world, for which a better understanding of land-use/land-cover change processes is gained.

- *Benefits for the investigators of the project:* The endorsement of a project is a recognition of the scientific value of the research and its contribution to an international scientific agenda dealing with priority issues. This provides three categories of benefits: (i) it facilitates funding of the research as it guarantees to the funding agency that the research is part of a broader scientific agenda and that it will receive critical review from the scientific community; (ii) it also signals that the investigators are part of an international scientific network and are invited to all LUCC activities which add value to individual research projects (workshops, networks, data sharing, etc.); and (iii), it facilitates the dissemination of the research results throughout the LUCC scientific community.

The principal participants in the LUCC project are the community of scientists engaged in research on processes of land-use/land-cover change. The SSC provides scientific guidance to and oversees the development, planning and implementation of the LUCC project and it coordinates the Foci activities. The SSC is also charged to demonstrate progress and achievements of the project through the definition and monitoring of milestones and results. Focus offices promote more specifically the research agenda under their responsibility. They coordinate networks and initiatives through which the community proceeds to answer the LUCC science questions. These networks and initiatives are run by Activity and Task leaders.

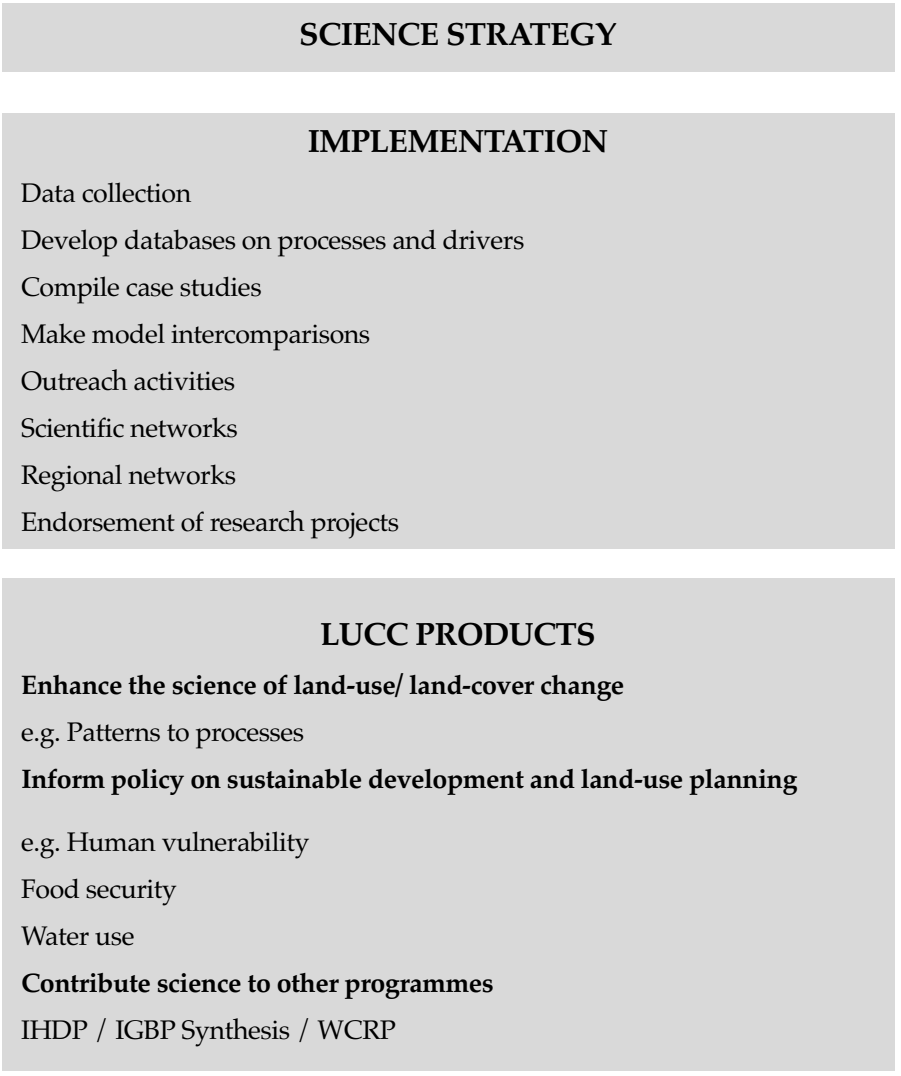
The LUCC IPO administers the project on a day-to-day basis and coordinates the implementation of the project under the long-term guidance of the SSC. It also coordinates specific research efforts, provides project advocacy and promotion, enlists wide international participation in the project, maintains needed connections with relevant national and re-

gional networks, ensures effective coordination with other components of the IGBP/IHDP and other relevant international research programmes, disseminates information and research results, and monitors and assesses the progress of the project.

By establishing good communication and a rapid and efficient flow of information among all these actors, LUCC can add substantive value to the research of the scientific community.

Figure 5

Phased sequence of the LUCC Research Agenda. Note: the phases can and should ideally occur concurrently



Focus 1: Land-use dynamics

Case studies to analyze and model the processes of land-use change and land management in a range of generalized situations globally

Introduction

Land-use dynamics are a major determinant of land-cover changes. Land use involves considerations of human behaviour, with particularly crucial roles played by decision-makers, institutions, initial conditions of land cover, and the inter-level integration of processes at one level with those at other levels of aggregation. For example, a human community connected by paved roads to world markets will feel the pressure of commodity price shifts internationally a great deal more than communities with poor road infrastructure, and are likely to make very different decisions about land use. Without understanding the dynamics behind land-use change, we cannot understand changes in land cover, nor predict the outcome of policy interventions.

In order to understand the dynamics of land use, it is necessary to undertake a coordinated international project to identify, and test, the generality of drivers of change across a sample of the world's regions, and a broad diversity of land-use strategies. This is necessary to inform global models that integrate biophysical with human dimensions of global changes in land cover. It is necessary, but not sufficient, to develop global models of land-use and land-cover change. Not only are global models likely to simplify (deliberately) the drivers of human behaviour but we also know that the processes that are responsible for explaining most of the variance at different levels of analysis change over time and in space. Thus, a purely global model, for example, would not inform us about the best forest conservation policy interventions at national or regional scale. A coordinated effort across a sample of cases worldwide, characterized by different biophysical endowments, and contrasting socio-economic traditions, is necessary to develop models more sensitive to regional variability, and more effective in identifying the best points for policy intervention, and for inter-level articulation.

In 1995 LUCC developed a Science Plan which has gained considerable support in the interim. The following Implementation Strategy for Focus 1 benefits from the dialogue that the scientific community has had with the LUCC SSC. To carry out this programme, the following Activities and Tasks are foreseen.

Activity 1.1: Understanding land-use decisions

The critical element in land use is the human agent. It is agents, such as individuals, households, and firms, that take specific actions according to their own calculus or decision rules that drive land-cover change. These agents are engaged in a very complex game in which they evaluate economic and non-economic alternatives. In this Activity 1, Focus 1 will seek to characterize the human agents, in their rich diversity, but also in ways that facilitate comparison so that, at the end of this activity, it will be possible to have a coherent understanding of the dynamics of decision-making on land use in a variety of contexts.

Task 1.1.1: Develop standardisation of methodologies and experimental protocols for effective evaluation of how people make land-use decisions (priority task)

One of the first tasks here will be to arrive at joint understanding of minimum data sets that allow for standardization of protocols for data collection and analysis within a basic hierarchical organisation. Part of this Task was addressed in DAPLARCH. Completion of this Task is a high priority to ensure comparability of results generated by individual studies. It includes the following actions:

- Search for availability of data in past case studies. A significant body of knowledge already exists in the scholarly community on land-use decision making. This literature will be reviewed and the conclusions from existing studies brought to bear on this activity. One of the difficulties is that many of these data are not accurately georeferenced. A useful task would be to determine how best to make use of these data, even when they are not spatially explicit.

- A set of case studies will be selected that either already exist or are well underway at present in which the collection of most of the minimum data being collected can inform this Activity and provide a showcase for these efforts by others. Ongoing LUCC endorsed projects can serve as a starting point in identifying these case studies. This Task will be done jointly by the SSC, Focus 1 and the principal investigators.

- Unpack social drivers (e.g. institutions at a number of scales). It has been all too common that social drivers such as population, institutions and economics are stated as drivers but their differential forms at different levels of analysis are not unpacked. This activity would seek to make explicit the specific ways in which population and other drivers are expressed, either in terms of density per square kilometre of agricultural land, or as a total fertility rate, or in terms of a population's demand for fuelwood. Commodity price shifts might be critical to

the explanation of the behaviour of agents in one area, while changes in wage rates might be more important in another. Likewise, at one scale of analysis, prices and wages may be seen as exogenous drivers in the system, while at another they are determined by the interplay of decisions taken in the aggregate.

- Examine data that is not spatially explicit. All of the above assumes that the focus of LUCC efforts must emphasize the development of data sets that are spatially-explicit. However, to fully understand the decision-making processes of agents it will be necessary to incorporate those features of human behaviour that are not spatially explicit. Moreover, the heterogeneity between actors is a fundamental aspect of decision-making processes. How best to capture this information and incorporate it into decision models that affect land-use and land-cover change remains a challenge requiring the LUCC community expand to incorporate anthropologists, economists, geographers and sociologists interested in these issues.

This Task will be facilitated through a series of workshops under the LUCC Data initiative. These workshops will be organized around review papers.

Task 1.1.2: Develop a strategic framework for achieving a globally distributed network of case studies and identify gaps in knowledge (priority task)

The next task is to evaluate the current LUCC portfolio by land-use type. This task entails a rigorous examination of the current set of LUCC endorsed projects to identify major gaps in land-use systems, geographic coverage, or historical depth. New projects and collaborators, whose work is consistent with LUCC, will then be incorporated to ensure that the portfolio represents the rich variety of cases that have broad impact on global land cover. Any cases that are sought out should represent the new state of knowledge on land-use and land-cover change studies, i.e. that they be characterized by spatial explicitness to ensure that they can be of broad value to the global change community. Priority needs to be given to studies located in areas that are characterized by very large impacts, high vulnerability, or broadly distributed patterns of land use.

Case studies need to be framed in a wide set of dimensions for comparisons along a sustainability-vulnerability axis, along the local-regional-global continuum, along a continuum describing the pace of land-use change process and time horizon of the study (e.g. 300, 50 and 5 years), and along dimensions describing the major drivers and processes of change.

The Focus 1 office undertook a preliminary assessment of the current portfolio and presented results to the SSC at the IGBP Meeting in Japan (May 1999). Actions will be taken to identify and invite research teams to be part of LUCC as well as actions taken to ensure that science projects are developed in the near future.

The identification of gaps follows directly from the previous set of actions. It should lead to new studies, to fill the gaps. This includes the following actions:

- Find the most critical data needs and transmit these needs to funding agencies or data providers (such as the census bureau or the Ministry of Agriculture). This is particularly important for those data that research shows are likely to be major drivers but that are available either at the wrong scale, or not at all. A sig-

nificant constraint has been identified in terms of data that when recorded in a spatially explicit way, may violate confidentiality. Once such data are stripped of identifiers, they often lose their value for a spatial analysis. The research community needs to address this task by developing explicit ways to gain access to the data, while protecting informants' confidentiality and privacy. An assessment based on DAPLARCH will be undertaken and brought to the attention of other LUCC research projects for their response. Subsequently these suggestions would be transmitted to funding agencies.

- Identify the types of drivers that are compelling resource communities to either become more vulnerable and/or more resilient in the face of global change. Food vulnerable communities, often depending on the land as a livelihood source, for example, may be compelled during times of scarcity, to make undue demands on the landscape. There is a need to develop networks of various social and physical scientists (e.g. particularly those working in the development field) to ensure that we begin to trace and understand the drivers underpinning such land-use changes. Agencies such as CARE and others have already developed systems and indicators (e.g. FEWS) that can provide valuable insights into links between sustainable livelihoods and resultant land use.

These actions can be completed through the same series of workshops under the LUCC data initiative mentioned above.

Task 1.1.3: Comparative examination of cases. This Task includes the following actions:

- Examination of how institutions influence local actors' land use. The recent development of a Core Project within IHDP focusing on institutions (IDGEC) is indicative of the importance, and relative neglect so far, of this variable in work on the human dimensions. Focus 1 will interact with the new IPO on institutions, located at Dartmouth (USA), and with the USA National Committee on the Human Dimensions at the National Research Council which is planning a synthesis workshop on institutions in the year 2000.

- Comparative examination will also be needed on how economic and political signals influence land use. These socio-economic considerations will require close integration with comparative examination of how biophysical processes influence land use (e.g. El Niño). The work currently being funded by NOAA's Human Dimensions Program explicitly prioritizes funding of work on human responses to climate variability. Close partnerships with GCTE will also be necessary to fully take advantage of studies examining terrestrial ecosystem variables.

In pursuing these issues, the following would be useful: (i) comparative case studies in one land-use type, (ii) comparative case studies across land-use types, and (iii) comparative case studies cross-culturally. One way to ensure the execution of this Task is to strengthen LUCC/IGBP networks with regional networks. Appro-

priate components of various LUCC regional studies will be linked together with other projects to form a network around this Task. The portfolio of sites funded under the NSF National Center on the Study of Institutions, Population and Environmental Change will provide a specific context within which to evaluate these three modes of comparison.

Activity 1.2: From process to pattern

Linking local land-use decisions to regional and global processes (link to Focus 2)

Task 1.2.1: Develop linked activities to Focus 2 to achieve a meso-level integration of upscaling processes by Focus 1 and downscaling by Focus 2

It was clear from DAPLARCH that one of the challenges to LUCC lies in coming to some agreement on the land-cover classes to be used at different scales of analysis. Land-cover researchers can infer land use from digital satellite data, but only with considerable input from ground-level observations and case studies. Likewise, land-use researchers can infer land cover from use of satellite data and their considerable expertise in fieldwork. However, as these two communities proceed, their respective inferences may be inconsistent because of a failure to agree on the units of aggregation at the regional scale. There is even poor agreement on what a region is. This task will be undertaken by organizing a Workshop of Focus 1 and Focus 2 researchers aimed at developing common understandings of the regional unit of analysis and of a hierarchically-based land-cover classification system. Other priority tasks to be undertaken at the workshop include:

- Developing a flexible set of land-use process descriptions that can be aggregated and disaggregated hierarchically;

- Creating a network of inter-scale researchers, concerned with spatial disaggregation, pattern recognition, use of field point measurements, and flexible legends of land-cover classification.

Task 1.2.2: Characterize agents and land users appropriate for regional modelling (priority task)

For any major geographical region, there are distinctive typologies of land users that describe the agents present in each region and that are well established in the literature. This can provide an entry point for understanding agents. However it will also be necessary to examine the ways in which these agents are present in other regions, perhaps under different names, and the extent to which they represent the same kind of agent, or distinct ones. The differences may in fact represent the most important differences in land-use strategies. Among the tasks to undertake:

- Develop intelligent agent-based models of local land use and regional land use. This task involves the use of spatially explicit models of agent's behavior in a topographically explicit landscape wherein they encounter new challenges, their decision environment is uncertain, their behavior is adaptive, and they learn over time. The Focus 1 Office, in coordination with the Center for

the Study of Institutions, Population, and Environmental Change at Indiana University, will undertake assessment of intelligent agent-based models for study of land-use change. This will also entail collaboration with researchers at other institutions working on these approaches.

- Develop regional models based on aggregate behavior, as expressed through the interplay of market forces, institutions, and demographic structural change. These models should take advantage of the networks of LUCC projects and other regional networks.

This Task should be completed through LUCC research projects in different regions of the world. Focus 1 will coordinate with principal investigators of major regional LUCC projects the task of spatial dynamic regional models.

Task 1.2.3: Examine international agreements and national environmental or territorial policies, and whether they have affected land use (how, why, where, when, how long?)

There is a growing role for international agreements and national environmental policies in shaping the behaviour of agents and in shaping land-use decisions by changing the incentives to the agents. However, there is a poor understanding of how these well-intentioned agreements and legislation affect the routine behaviour of agents. There is some evidence to suggest that in some cases these constitute mere "window-dressing" to satisfy pressure groups of various sorts and that implementation is poor. But there are also cases that had a prompt and effective impact, such as the Montreal Agreement on CFCs. This Task seeks to organize knowledge to inform LUCC. It will be conducted through the following actions:

- Evaluate a number of key international agreements: how they came into being, the process of ratification by countries, and the challenges to implementation that each faced. Evaluate the local and regional outcomes in land use, land cover of each one. Since this is a particular interest of the IHDP-IDGEC (institutions) project, Focus 1 will collaborate with that project to gain insight into these issues and translate the results to the LUCC community of scholars.

- Lessons learned about the scaling down process from a range of international agreements to national and local levels. Is it the issue that matters? Or is it rather the way it is negotiated or internalized in the economy?

- Are national environmental and territorial policies (e.g. spatial planning, large public investments in infrastructure or conservation management) more effective when linked to international agreements or vice versa? What are the main characteristics of effective national environmental and territorial policies? These should be linked to the EPAT/AID project of the early 90's which explicitly asked these questions but which ended before its findings could be widely disseminated.

This Task should be completed through LUCC research projects in different regions of the world. The Focus 1 Office will organize a workshop on this issue that brings together these widely differing experiences.

Activity 1.3: The future

Sustainability and vulnerability scenarios (the link to Focus 3)

Task 1.3.1: Identify key biogeochemical and climate variables associated with changes in land cover over long time periods (hundreds and thousands of years)

This Task seeks to link LUCC to the PAGES Core Project in order to connect human behavioural dimensions at present and in the recent past with the longer term record accumulated by archaeologists, historians, palaeobotanists, and others on the long-term impact of our species on land cover. To do this the following will be needed:

- Develop a set of environmental histories and palaeo-histories that provide temporally-deep understanding of land-use trajectories especially over long stable periods or rapidly degrading ones. Results from studies of major civilizations which appear to have had long, stable reigns, and sudden collapses need to be brought to bear on the questions of land use and land cover. Much can be learned from historical studies that include major land-use discontinuities. This task will involve a request for state-of-the-art review papers on what is known about stable and unstable periods in past civilizations and their discussion at a major international conference. Results will be disseminated to the LUCC community.

- Intercalibrate recent past land-cover change with palaeo methods at 50-100 years temporal resolution. Identify sources of variability in land use. It would appear that the methods that have been developed to reconstruct the long-term record may be applicable to more recent changes in land cover. Where that is the case it would be very helpful to intercalibrate the results of land-cover classification with the evidence from pollen records for the mutual benefit of both. Select a number of locations where this Task can be tested for its merits and the lessons learned extended to the rest of the LUCC community of scholars.

- Construct a set of environmental histories with historians to assess the past 300 years at demonstration sites. Identify key driving forces. The development in the past 20 years of environmental history provides a unique opportunity to understand complex dimensions of land-cover and land-use change. Selection of studies that seem to fit well with other major efforts in LUCC are likely to be especially productive. Efforts will also be made to select successful projects and to integrate them within the LUCC Project.

- Develop methods to translate historic records into spatially explicit form. This task should be completed through LUCC research projects in different regions of the world. A workshop will be called together after assessment of the readiness of the community to synthesize current approaches and their readiness to be disseminated. Moreover, *a fast track, historic land-cover/land-use database* will be generated *(priority sub-task).* The database will cover the last 300 years, at a spatial resolution of half a degree. This database will consist of a compilation and harmonization of readily available regional data sets. This first-order com-

pilation will be achieved during a workshop with regional experts on historical land-use/land-cover changes. Gaps will be filled in by developing coarse estimations from combined environmental and historic administrative data. Other IGBP projects, such as GCTE, GAIM and PAGES will assist in accomplishing this urgently-needed data set (e.g. the IGBP Carbon Initiative). Once completed, its quality, limitations and usefulness will be assessed through a workshop with experts from different Core Projects, who intend to apply the database.

Task 1.3.2: The transition to a sustainable world: simulation modelling of land-use/land-cover change to identify sustainable future scenarios

There are few challenges as important as the discovery of ways to assure a sustainable future. The current trends in land use, energy use, and population growth are just some of the dimensions that demand scrutiny. Yet, we are unlikely to choose to change our behavior if we do not see benefits, and this is the challenge of the transition to a sustainable world. The many cases that will be part of the LUCC enterprise provide an opportunity to uncover those periods and circumstances in history when humans have achieved a balance, however, temporary, between their needs and the capacity of the resource base to provide those needs sustainably. LUCC will:

- Engage in dialogue with the other members of the scholarly community also wrestling with this challenge;

- Focus 1 will select case studies that illustrate stable and sustainable land-use/land-cover changes to identify institutional, economic, political and biophysical interactions and disseminate the lessons learned for testing elsewhere;

- Model key determinants of sustainability at local and regional scales. Work with LUCC projects to ensure that regional dynamic models include concerns with sustainability.

Task 1.3.3: Growing vulnerabilities: simulation models that identify key interactions associated with degradation and vulnerability (priority task)

The other side of the coin of sustainability is the likelihood that, until we can uncover effective strategies for sustainability, we will live in an increasingly vulnerable world. These vulnerabilities are already evident in the inability of some populations to deal with climate variability, the potential for sea level rise, extreme events, resistant strains of viruses and bacteria, and growing inequities in entitlements to natural resources. In what ways will a growing urban population achieve its needs, and what demands do they place on the productive base of the planet?

- LUCC will review the concepts of vulnerability and analytical methods that can complement land-use/land-cover change studies, including a set of hypotheses drawn from the literature;

- LUCC will seek out case studies that illustrate vulnerabilities and unsustainable land-use scenarios to identify institutional, economic, political, and biophysical conditions that exacerbate vulnerability;

- Model key determinants of non-sustainable and vulnerable systems at local and regional scales. Focus 1 will work with scientists modelling dynamic regional systems to include considerations of unsustainability and vulnerability in their scenario building.

Task 1.3.4: Validate and intercalibrate global data sets

The strong reliance on global monitoring systems using coarse scale instruments such as AVHRR, ATSR, VEGETATION, MODIS, ERS and JERS SARs, Radarsat, DMSP, and GOES, while effective in providing complete global coverage, also create a challenge in linking human behaviour to the observational systems. Use of finer resolution satellites and field data is essential to ensure that global data sets generate accurate land-use data and do not disenfranchise large numbers of people and processes.

- This Task will develop a network of scholars who are committed to collecting high quality data that can be used to intercalibrate data collected at coarser scales.

- Focus 1, with the assistance of LUCC's SSC and principal investigators will choose rich case studies to intercalibrate global land cover and land-use interpretation.

- Fieldwork validation procedures will be standardized under a structured protocol to facilitate ground-truthing work to validate land-use/land-cover change datatsets.

Figure 6

Series of Activities and Tasks to be developed within the Focus 1 of LUCC

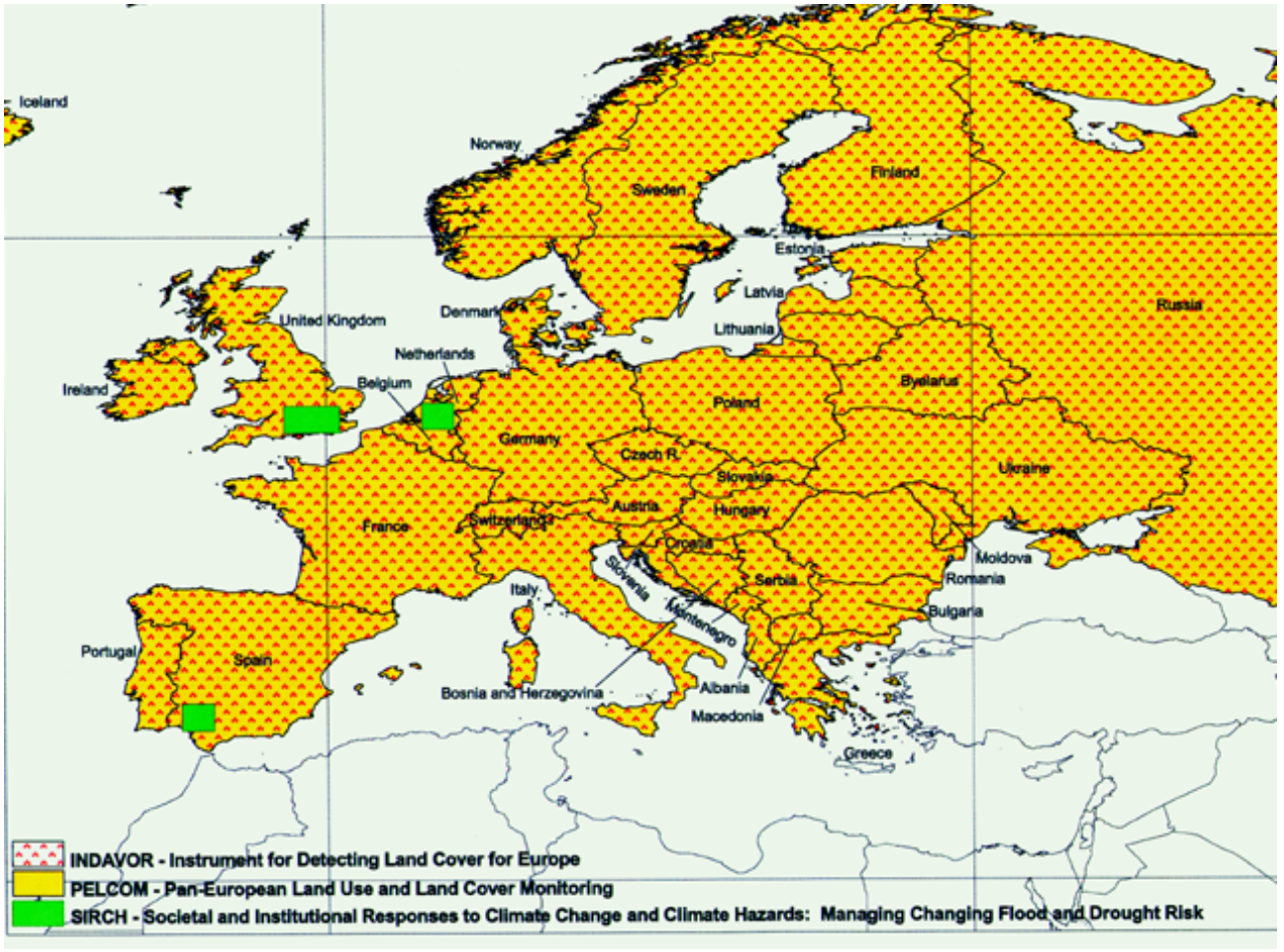
FOCUS 1: LAND-USE DYNAMICS

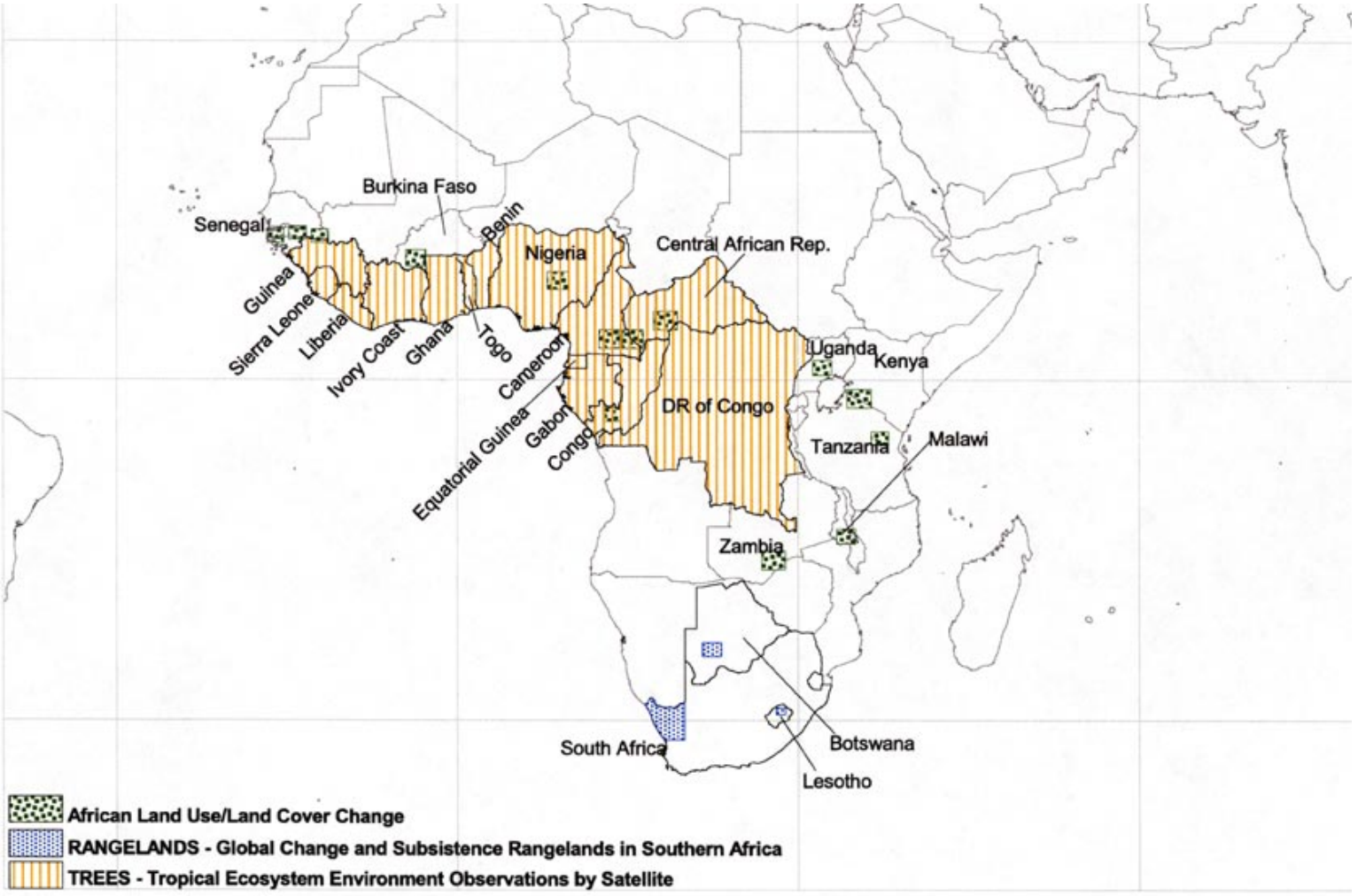
Case studies to analyze and model the processes of land-use change and land management in a range of generalized situations globally

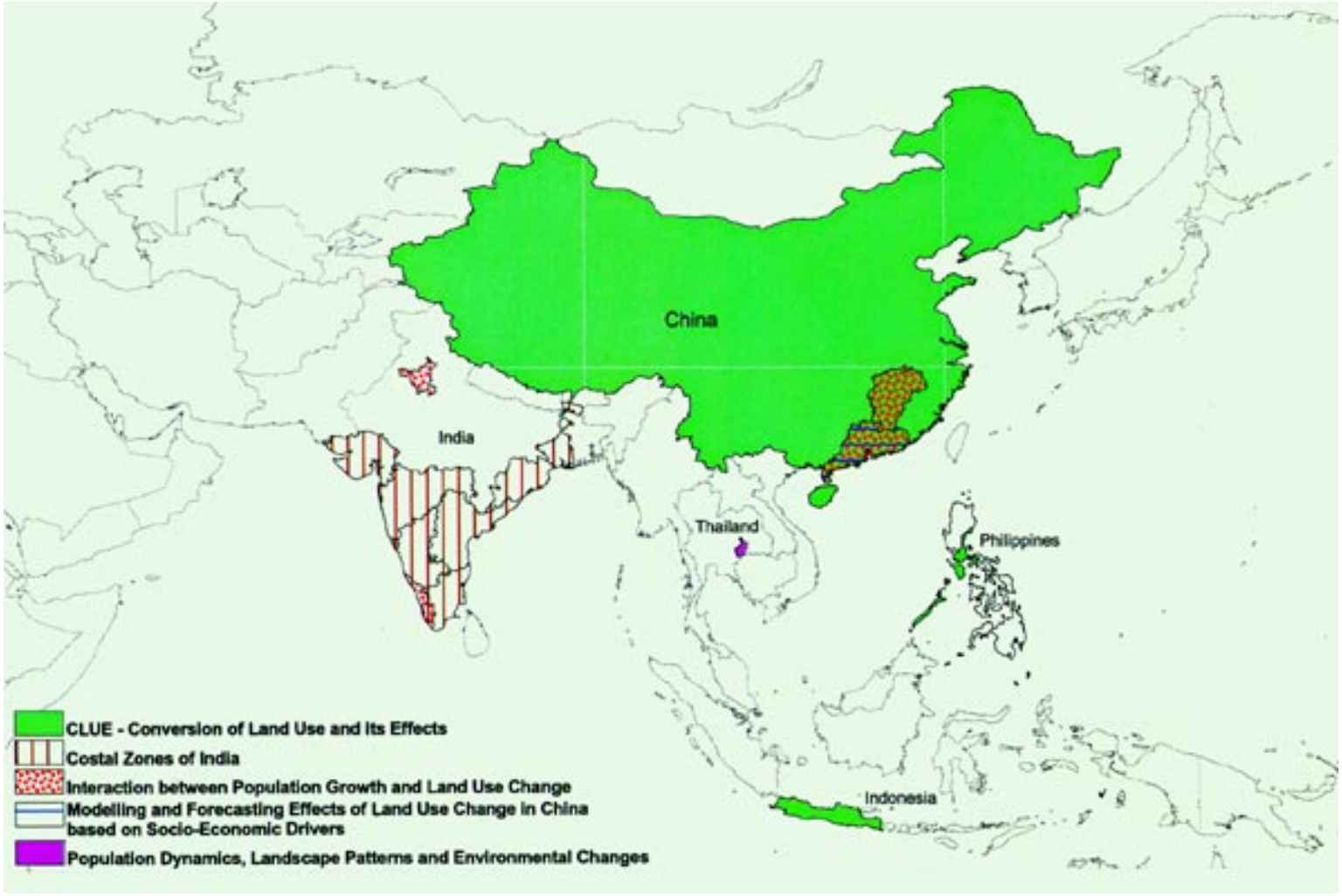
ACTIVITY: 1.1		Understanding land-use decisions
TASKS:	1.1.1	Develop standardization of methodologies and experimental protocols for effective evaluation of how people make land-use decisions
	1.1.2	Develop a strategic framework for achieving a globally distributed network of case studies and identify gaps in knowledge
	1.1.3	Comparative examination of cases
ACTIVITY: 1.2		From process to pattern: linking local land-use decisions to regional and global processes (link to Focus 2)
TASKS:	1.2.1	Develop linked activities to Focus 2 to achieve a meso-level integration of upscaling processes by Focus 1 and downscaling by Focus 2
	1.2.2	Characterize agents and land users appropriate for regional modelling
	1.2.3	Examine international agreements and national environmental or territorial policies, and whether they have affected land use (how, why, where, when, how long?)
ACTIVITY: 1.3		The future: sustainability and vulnerability scenarios (link to Focus 3)
TASKS:	1.3.1	Identify key biogeochemical and climate variables associated with changes in land cover over long time periods (hundreds and thousands of years)
	1.3.2	The transition to a sustainable world: simulation modelling of land-use/land-cover change to identify sustainable future scenarios
	1.3.3	Growing vulnerabilities: simulation models that identify key interactions associated with degradation and vulnerability
	1.3.4	Validate and inter calibrate global data sets

Figure 7

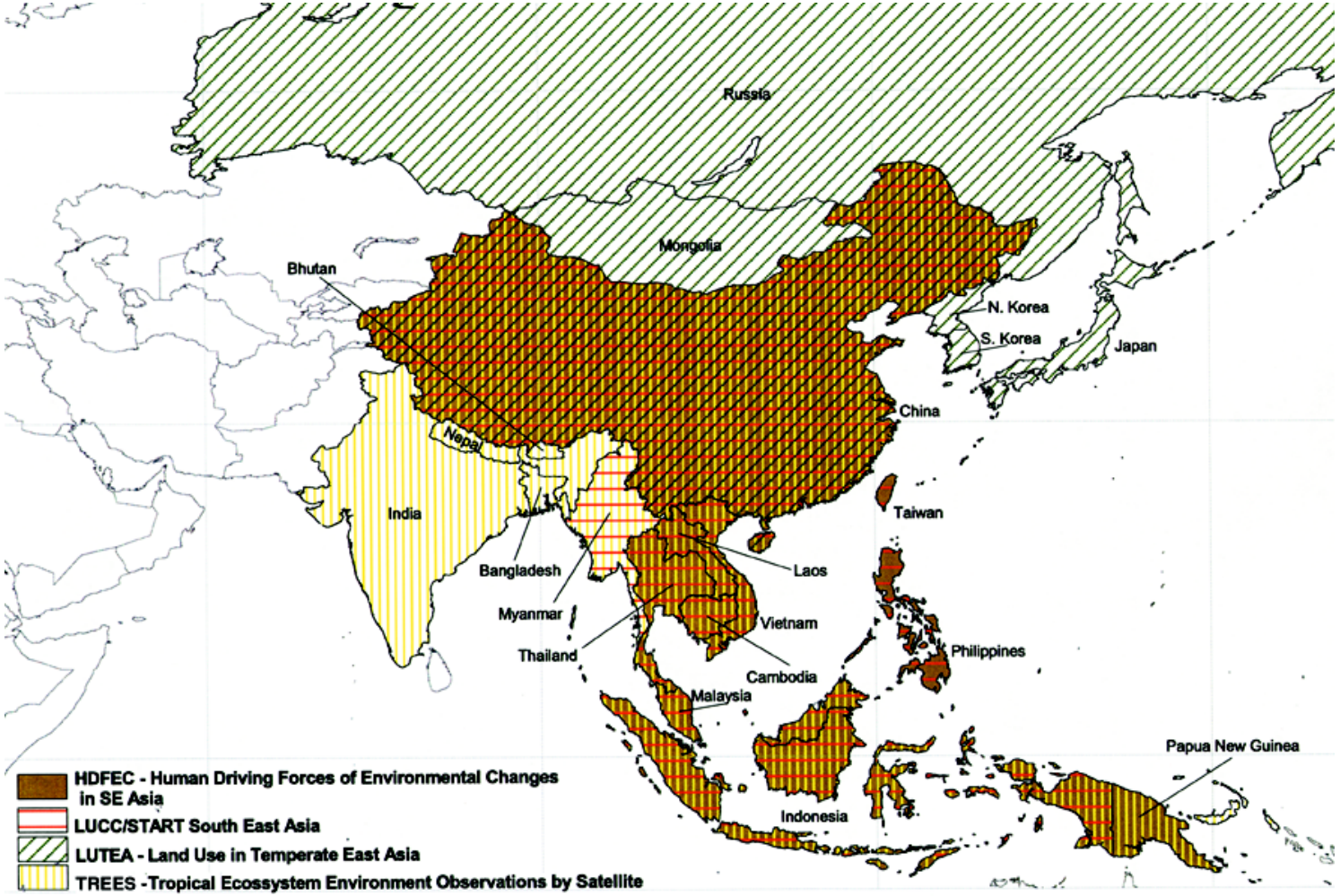
6 Maps of LUCC case studies. Maps produced by Focus 1 Office.

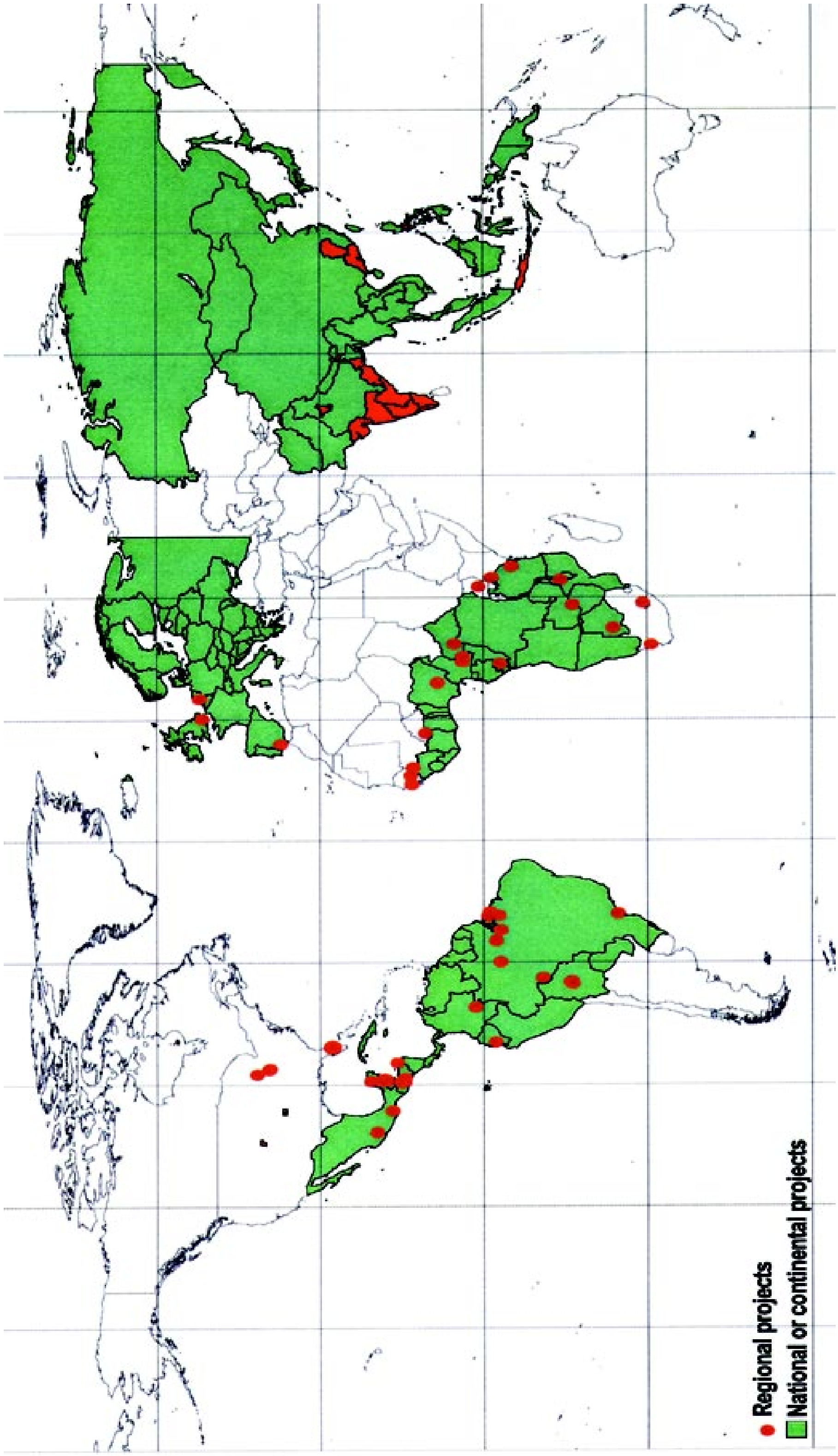



Burkina Faso
Senegal
Benin
Nigeria
Central African Rep.
Guinea
Sierra Leone
Liberia
Ivory Coast
Ghana
Togo
Cameroon
Uganda
Kenya
Equatorial Guinea
Gabon
Congo
DR of Congo
Tanzania
Malawi
Zambia
South Africa
Botswana
Lesotho
African Land Use/Land Cover Change
RANGELANDS - Global Change and Subsistence Rangelands in Southern Africa
TREES - Tropical Ecosystem Environment Observations by Satellite


China
India
Thailand
Philippines
Indonesia
CLUE - Conversion of Land Use and its Effects
Costal Zones of India
Interaction between Population Growth and Land Use Change
Modelling and Forecasting Effects of Land Use Change in China based on Socio-Economic Drivers
Population Dynamics, Landscape Patterns and Environmental Changes


United States
Mexico
Cuba
Jamaica
Belize
Honduras
Nicaragua
Guatemala
El Salvador
Costa Rica
Panama
Colombia
Ecuador
Guyana
Suriname
French Guiana
Peru
Brazil
Bolivia
Paraguay
CLUE - Conversion of Land Use and its Effects
Institutional, Demographic and Biophysical Dimensions of Forest Ecosystems Change in the Western Hemisphere
Interaction between Population Growth and Land-Use Change
LBA - Large Scale Biosphere-Atmosphere Experiment in Amazonia
LCULUC/SYPR - Land-Cover and Land-Use Change in Southern Yucatán Peninsular Region
LUCCI - Land Use and Climate Change Impacts on Carbon Fluxes
TREES-Tropical Ecosystem Environment Observations by Satellite


Russia
Mongolia
Bhutan
N. Korea
S. Korea
Japan
China
Nepal
India
Taiwan
Bangladesh
Laos
Myanmar
Vietnam
Thailand
Philippines
Cambodia
Malaysia
Papua New Guinea
Indonesia
HDFEC - Human Driving Forces of Environmental Changes in SE Asia
LUCC/START South East Asia
LUTEA - Land Use in Temperate East Asia
TREES -Tropical Ecossystem Environment Observations by Satellite


Regional projects
National or continental projects

LUTEA. Land Use in Temperate East Asia

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Specific objectives include

- Investigate the causes of land-use/land-cover changes and estimate the relative contributions of demographic, socio-economic and climate drivers over historical time
- Develop models of land-use changes given current socio-economic conditions
- Analyze the policy implications of land-use/land-cover changes for climate dynamics, ecosystem integrity, sustainable development, and economic growth and stability

Project Structure: to utilize gradients of important driving factors, such as climate, land use and economic development. The North East China Transect will be available.

Major topic areas of research

- Changes in pastoral systems. Nomadic pastoralism was the dominant activity. Recent socio-economic changes have caused changes in how pastoral systems operate. Currently, there is a range of pastoral systems, encompassing a range of grazing patterns. These systems have incorporated new breeding stocks that are potentially not suitable to certain climate regimes. Recent changes have resulted in a more sedentary livestock management system. What will result from these changes is unclear, and the effect on the human and natural resources need to be determined.
- Intensification of agriculture. Agricultural practices like fertiliszers, high yielding varieties or irrigation systems has undergone radical increase in crop yields. The ability to maintain this increase is questioned and in many areas soil fertility and water availability has declined. Changes in social structures may alter

the environment due to a loss of coherency among land users with the rural communities. The manner in which further agricultural developments are implemented or maintained is a critical issue.

- Urban-rural interfaces. The tremendous growth of urban centers is staggering to perceive in the coming decades. The urban growth is modifying the surrounding area, with impacts on croplands, fuel resources, and water supply. How these areas plan to cope with this problem, and what effects will have in the rural areas in the coming decade?

Integration activities

- Development of critical databases on physical, ecological and socio-economic factors.
- Development of analytical procedures: scaling of information between biophysical and socio-economic data: differences in defining boundaries within ecological and human systems. This creates data integration problems, however, methods are being developed. Evaluation of these techniques need to be applied.
- Strategy for modelling activities: models need to be able to evaluate land use and ecological integrity along a gradient of environmental factors.

Global change and subsistence rangelands in southern Africa:

Resource variability, access and use in relation to rural livelihoods and welfare

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Access to water resources, changes in land tenure, pressure from commercial farming, access to and quality of communal grazing, fencing, etc. are common factors that appear to drive land-use/land-cover changes. All these changes and threats are occurring in the context of incipient but indeterminate global climatic change, including changes in inter-annual rainfall.

Objective:

- to analyze the relationships between rangeland state and rural livelihoods and to identify policy options and interventions that would optimize, sustainably, the welfare of the range communities while maintaining rangeland productivity.

Project approach and research design

- Fieldwork takes place in 3 countries:
  - **South Africa:** animal husbandry and range management, agro-environmental management and rural sociology.
  - **Lesotho:** ecology, snow hydrology, micrometeorology, soil dynamics.
  - **Botswana:** savannah and rangeland ecology and pastoralism.
- Historic information and current datasheets will be collated and analyzed. Data will be sought primarily at the community and regional level.
- A separate desk study on the impact of government, social and economic policies and resource management priorities.
- Modelling and synthetic techniques will be used to build up a dynamic picture of the constraints, flows and interactions.

These sites may evolve into longer-term sites for monitoring change.

Work packages

- Biophysical data collection and analysis: water sources and hydrology, soil fertility and erodibility, ecological analysis, biomass productivity, rangeland composition and productivity, other rangeland products, climatic data.

- Socio-economic data collection and analysis: social structures, land tenure and water access, structure of the agropastoral system, source of rural livelihoods, impact of rangeland state and variability, develop long-term datasets relating to land-use/land cover change and population growth.
- Resource management and policy analysis: influence of different land-use practices on rangeland resources, and policy and institutions on rangeland resources, and determine the impact of government intervention.
- Integration and synthesis: process-based models; long-term data sets relating to climate change; global change scenarios; development opportunities and interventions.

* also endorsed as a GCTE research project.

Focus 2: Land-cover changes

Direct observations and diagnostic models of land-use/land-cover changes

Introduction

In the last twenty years land-cover change – whether it is deforestation in the tropics, urbanization, intensification of agriculture or land degradation – has been accelerating as a result of population pressure and economic development. It has been consistently singled out as a key element of many areas of global change research, and is central to many other international policy issues. Yet, in spite of the growing need for precise estimates of rates of land-cover change to support both international policy and basic scientific research, comprehensive and systematic information is not available on a global or regional basis. The latest IPCC report, for example, considers the rate of tropical deforestation to be one of the key unknowns in global climate change assessment. The objective of Focus 2 is to better measure the rates of land-cover changes and to integrate these empirical data into diagnostic models aimed at better understanding the processes leading to these changes.

The importance of this Focus comes from the recognition that our current knowledge of land-cover change dynamics is inadequate due primarily to:

(i) Lack of accurate measurements of its rate, geographic extent, and spatial pattern; and (ii) poor capability to model change from empirical observations. By advancing our knowledge of the rate and spatial pattern of land-use/land-cover change, and the factors that are associated with this change, both global change questions and regional development questions can begin to be addressed. For both of these purposes, it is important to improve our quantitative analyses of rates and spatial patterns of land-cover change, and our understanding of the land-use practices that are associated with these changes.

Taking these into account, Focus 2 research addresses the following questions:

- What are the rates and spatial patterns of land-cover change, and how will they likely progress?

- Where is land-cover change presently occurring, and where will it likely occur in the future?

- Which natural and cultural landscape attributes contribute the most to the explanation of land-cover change?

The first step in addressing these questions requires the identification of land-cover dynamics at broad scales, to identify areas of high rates of land-cover change or high sensitivities to change. We label these critical zones or land-cover change hot spots. Once identified, it is necessary to assess the current state of land-cover in these critical areas and to determine the rate of change in their land-cover attributes. These activities can be pursued, in part, using remotely sensed data, due to their ability to provide spatially explicit and repeated measurements at different spatial scales. However, numerous socio-economic indicators need to be measured, as well, and these by other means. The observed changes in land-cover can then be spatially and temporally associated with potential *proximate* causes that can be mapped and integrated into a Geographic Information System (GIS). Analysis of these spatially and temporally explicit data, using multivariate statistics, will help identify the circumstances under which land-use change is most likely to take place. Once robust representations of the proximate causality processes are achieved, these results can serve as a basis for identifying locations of high rates of future change. These land-cover change risk maps can then be overlaid on maps of environmental attributes such as biodiversity, sensitivity to erosion, and forest cover to identify regions that should be studied with more detailed case studies and/or structural models through Focus 1 and Focus 3 Activities. To carry out this program the following Activities are foreseen (Figure 8, page 65). Several of these Activities and Tasks can be implemented for a number of regional networks, in a sequential and/or integrative manner.

Activity 2.1: Land-cover change, hot spots and critical regions

The assessment of land-cover change on a global scale is a daunting and monumental program, particularly in terms of the observations required to document land-cover changes exhaustively. Therefore, the first activity of this Focus is to develop a strategy for identifying important regions and time periods. This can be accomplished using high temporal and low spatial resolution data (e.g., AVHRR, MODIS, VEGETATION, ATSR, ERS and JERS SAR), and can be coupled with broad scale, census and related data, since satellite observations alone cannot explain the socio-economic and institutional factors that influence land-cover change. Nor can they identify the factors that affect regional trends or local dynamics.

Task 2.1.1: Monitoring biophysical and socio-economic variables (priority task)

A priority for LUCC is the development of a monitoring system through direct collaboration with the space agencies and the Committee on Earth Observing Systems, international observing systems through the International Global Observing Strategy of GTOS/GCOS/GOOS, and through collaboration with selected international agencies that can provide land-cover (e.g. GOFC) and socio-economic (e.g.

FAO, UN, OECD) data. To measure land-cover change by remote sensing, one needs: (i) biophysical indicators strongly related to land-cover conditions which can be measured by remote sensing; (ii) a reference state for the land cover at every location as a standard against which to compare current situations; and (iii) a technique to detect changes. Land-cover change analysis requires the measurement of a set of indicators of the biophysical attributes of the surface, the seasonality of these attributes and their fine scale spatial pattern. One example of the use of remote sensing products to produce global maps is the TREES project, which is producing repeated mapping of forest cover for the entire tropical belt. This experience can be expanded to a multi-temporal analysis of global land cover, which would lead to the identification of critical areas to be monitored on a repeated basis so as to generate a series of snapshots of land use over time. Another example is the DMSP derived nighttime lights products which have recently led to a number of land-use applications. In addition to measurements of rates of land-cover change, there would be great benefits in incorporating metrics of changes in the spatial configuration of the landscape (e.g. its fragmentation). Actually, such measurements would facilitate the assessment of impacts of land-use changes on biodiversity and ecosystem functioning.

Monitoring based on remote sensing alone would ignore much information necessary for land-use/land-cover change analyses. In particular, information on population, income, production, consumption, trade, and migration are also necessary components of a monitoring system. This Task requires close collaboration with Focus 1. However, difficulties arise in that census data and other information on institutional. Social and economics indices are not all collected at the same time. They are not collected in collaboration with the remote sensing measurements, typically they are not georeferenced, and below a certain level of resolution confidentiality becomes an issue. Also, new ways to record variance in these variables, along with aggregated data, must be designed to incorporate measures of the heterogeneity between actors and locations. For obvious reasons, there is no global socio-economic monitoring *instrument*. The main sources of these data are the various national censuses, surveys by individual research programs, UN organizations such as the FAO, and international organizations such as the World Resources Institute. LUCC cannot attempt to take on the role of collecting these data routinely. However, LUCC can play a role in bringing together the various interests who collect, as part of their regular statistics program, data that bear on land-use questions. LUCC can also take the lead in defining some common characteristics of an observation strategy, such as common land-use/cover classification schemes, spatialisation methods, and ways to derive inter-censal information. In addition, data collection efforts within specific projects should be assisted by LUCC, in collaboration with DIS, to locate and organize integrated socio-economic datasets. Finally, through a federated collaboration of the key national census and survey agencies it might be possible to provide a pointer service and metadata information. Thus LUCC can play an important collaborative and coordination role.

Task 2.1.2: Definition of land-cover change indicators

An indicator of environmental conditions can be defined as a phenomenon or statistic associated with a particular environmental condition. Indicators of land quality change may include direct and indirect indicators. A direct indicator will generally be a specific set of descriptors of the physical environment itself (e.g. decrease in soil organic matter content as an indicator of land degradation). Indirect

indicators may reflect secondary interactions or consequences that arise in adjoining systems (e.g. increase in the frequency of dust storms as an indicator of dryland degradation). In the complex environmental conditions associated with desertification, for example, an indirect indicator, such as worsening nutritional status, could indicate changing economic status linked in a secondary set of consequences of desertification. These secondary consequences might include loss of assets in the form of livestock and poor yields exacerbated by drought.

There are two general classes of indicators, which are relevant for LUCC research. Indicators of land cover (e.g. fractional vegetation cover, leaf area index) can be used for detection of change and for providing information on shifting trends or trajectories in land-use/land-cover change. Indicators of land quality (LQI) can be used to determine whether land-use potential is changing. The potential degradation of land is an important dimension of LUCC research.

Several organizations are in the process of developing scientifically credible and technically feasible LQIs, and LUCC can play an important role in assisting in the scientific aspects of this work as well as its coordination. Such research must identify, test and recommend indicators that are the most useful and cost effective, and based on available data and information. Indicators should be designed so as to inform important policy questions, to be comparable across regions, and to be sufficiently robust to stand up to scientific scrutiny and to be useful over time.

A workshop will be organized on data analyses, testing and refinement to develop Core LQIs as international reference standards. This will be based primarily on making better use of data available from national and international sources, including remote sensing as necessary.

Task 2.1.3: Hot spot detection and alarm system (priority task)

A land-cover change hot spot can be conceived of from different perspectives (Lambin and Ehrlich, 1997). First, it could be defined according to high rates of land-cover changes being observed at present, or in the recent past. For example, Myers (1993) identified 14 tropical deforestation hot spots, defined as areas undergoing deforestation rates of four percent or more per year by comparison with the biome-wide rate of less than two percent. Second, hot spots could be defined as areas where land-cover changes are likely to occur in the near future. This anticipative approach is more difficult to implement since it requires a predictive model applicable at a broad scale. Yet, it is useful to support policy interventions aimed at mitigating the adverse effects of dramatic land cover changes. Third, to define a location as a hot spot, one could not only look at the observed or anticipated rate of change but also at the likely severity of the impact of the change. The concept of hot spot would therefore be tied to specific issues of interest - e.g. biodiversity loss, carbon release, hydrological cycle alterations, cultural heritage destruction or socio-economic impacts. For example, for some areas, even a moderate rate of land-cover change could have dramatic impacts on biodiversity.

While there are many reasons for focusing research on hot spots, study of regions with very low rates of land-cover change has the potential for providing a good deal of information about land-use processes. It provides an important contrast in terms of land-use/cover dynamics.

This Task will require a major LUCC research project, in close coordination with existing efforts on this issue, such as the TREES project on tropical deforestation. However, this effort will need to address not only deforestation but other types of environmental sensitivity.

Activity 2.2: Socializing the pixel

To grasp the complexity of landscape mosaics and changes in land use, it is necessary to focus attention on a sample of areas for which a large number of remote sensing. Field observations would be collected and where an in-depth understanding of land-use dynamics would be generated - avoiding the superficiality of some of the broad scale approaches. While regional analyses provide information on the general trends in land cover conversion, cases studies nested in the regional analysis provide insights into fine spatial and temporal dynamics of transition sequences. Intensive studies over selected regions should lead to the identification of generic trajectories and processes of change, which might then be carefully generalized at broader scales.

Task 2.2.1: Transition probability models

High spatial resolution satellite remote sensing provides a uniform approach to measuring and mapping land-cover change over large areas at fine spatial resolution (100 m or fewer), tracking land-cover conversions (and some modifications) at a sub-national level with a high degree of accuracy. Classic change detection techniques are based on the comparison of sequential maps or land-cover classifications derived from remote sensing data for the same area. When applied at coarse resolutions (1km^2), this approach has significant limitations: (i) the comparison of successive maps does not allow the detection of subtle changes within broad land-cover classes (and most coarse spatial resolution maps only represent broad classes), (ii) the change map product exhibits an accuracy not greater than the product of the accuracy of the coarsest map, and (iii) the individual classifications may be affected by exceptional, short-term events (e.g. vegetation stress, flooding or burning) which may lead to the detection of spurious changes. To overcome these limitations, preferred land-cover change detection approaches rely on a comparison of remotely-sensed land-cover indicators of surface conditions.

Markov chain models provide one approach to empirical models of the land-cover conversion process. The central mechanism of a Markov chain is a probability function which refers to the likelihood of transition from one cover to another cover. The probability function can be static over time (assumes stationarity) or can be adjusted dynamically on specific temporal intervals to account for changes in the stationarity of the processes controlling the transition sequences. The probability function and transition sequences can be derived from direct observations using satellite data. Simulated landscape modifications could also be introduced, to assess the expected impacts of policies or specific disturbance regimes on land cover.

This Task should be completed through LUCC research projects on specific case studies in different regions of the world.

Task 2.2.2: Spatially-explicit models

To advance the analysis of landscape dynamics, spatial statistical models of land-cover change should be developed. Such models support the following aims: (i) to test over an entire region hypotheses on change processes and on the influence of some driving forces, (ii) to suggest specific issues that should be investigated further through Focus 1 and Focus 3 work, (iii) to identify areas that are likely to be

subject to dramatic land-cover modification in the near future, and (iv) to predict likely impacts of these transformations. The last two points are particularly important for land-use planners since, in order to focus policy interventions, one needs not only to measure the rates and identify the factors of land-cover changes, but also to anticipate where conversions are more likely to occur next. Such predictive information is essential to support a timely policy response - e.g. where land cover changes are associated with a degradation of land quality and the depletion of essential resources.

The main goal of these spatial, statistical models is the projection and display in a cartographic form of future landscape patterns, which would result from the continuation of current trends. The approach consists in analyzing the location of different categories of land-cover changes in relation to maps of natural and cultural landscape variables. Maps of changes in land cover are derived from multitemporal sequences of remotely sensed data. Changes in land cover are categorized and their spatial occurrences are correlated with landscape and locational attributes. Multivariate statistical analysis is used to determine the variables most closely associated in space with deforestation patterns (Lambin, 1994). If long-time series of remote sensing observations are available, complex trajectories of land-cover change can be identified and modeled (e.g. cycles such as forest - agriculture - secondary growth - forest -agriculture - etc. or degradation paths such as forest - small-holder agriculture - ranch - degraded land).

This Task should be completed through LUCC research projects on specific case studies in different regions of the world.

Task 2.2.3: Linking patterns of land-cover change to household-level data (link to Focus 1) (priority task)

Within any case study, data on social, economic and ecological processes leading to land-use changes should be collected (see Focus 1). For this reason, collaboration between remote sensing specialists and social scientists conducting long-term, field-based land-use studies is extremely productive. While the remote sensing scientists identify patterns of land-cover changes and, using GIS, relate observed patterns of change to natural and cultural landscape attributes, social scientists model or explain the structural processes of change in the human behavior and decisions that lead to a particular land-use outcome. However, in contrast to remote sensing, social science data is more difficult to collect in a spatially explicit way and to relate to an exact region of influence, although appreciation of spatial data and integration of GIS is growing rapidly in these disciplines.

By “socializing the pixel” we mean to discern information embedded within spatial imagery that is directly relevant to the core themes of the social sciences, including the LUCC questions, and use it to inform the concepts and theories pertinent to those themes. Creating a direct link between spatially-explicit land cover information, as derived by remote sensing, and information on land-use change processes requires the development of new methods and models which are merging landscape data with data on human behavior. A major issue concerns the definition of appropriate spatial units (or levels of aggregation) to establish the correspondence between biophysical and socio-economic variables. This has to take into account the unit of decision-making, human mobility (e.g. in the case of pastoralism or if the agricultural plots of households are dispersed), units of landscape transformation, the spatial scale of ecological processes (e.g. a watershed) and data availability.

This Task requires methodological advances, perhaps through a workshop of scientists conducting case studies on this theme. This workshop should be organized around a review paper on the state-of-the art on this issue. The Task should then be completed through LUCC research projects in different regions of the world.

Activity 2.3: From patterns to processes

Task 2.3.1: Dynamic, causal models and short-range projections

Direct measurements and empirical analyses alone will not provide enough understanding to analyze the driving forces of land-cover change. Thus, moving from empirical models - which just highlight spatial and temporal associations between variables - to system models that represent causal relationships provides a comprehensive approach to understanding land-cover change and, at the same time, provides important inputs to policy. The primary utility of models is to provide a systematic approach to understanding a research problem. An important aspect of the work described here is the link between direct observations, case studies, and models in an effort to test or identify dominant processes in land-use/land-cover changes.

Development of causal models can lead to an improved understanding of the current and recent situation and at the same time provide credible, geographically-referenced predictions. The length of time over which a prediction is valid is a function of the persistence of the observed phenomena. There is evidence to suggest that much, if not most, land-cover change is temporally persistent over 10 to 15 year intervals. However, it should be noted that certain events can alter trends significantly and rapidly. Changes in political, institutional, and economic conditions can cause rapid changes in the rate or direction of land-cover change. Therefore, an effort to understand the primary kinds of influences which cause land-cover change trends to diverge rapidly is also an important component of this program.

This Task should first be completed through methodological advances, e.g. through a focused workshop on methodologies. The methods should then be tested through LUCC research projects on case studies in different regions of the world.

Task 2.3.2: Definition of risk zones and potential impacts

Once a spatial model of land-cover change has been calibrated, it may possible to generate a spatially explicit projection representing the surface probability of future land-cover changes. This projection can then be overlaid on the land cover map corresponding to the current situation to highlight, at a fine spatial scale, areas at risk of being subjected to land-cover changes. Locations characterized by a high probability concentrate the spatial attributes that, in the recent past, have been associated with a high frequency of a specific land-cover change. Such projection is therefore a spatial projection of future land-cover changes at a fine spatial scale (e.g. landscape scale).

On this basis, the simulation of the potential impacts of land-cover changes can be performed in two ways: first, by assessing the impacts on specific landscape attributes of the changes which are projected to occur in the dependent variable (i.e. changes in land cover and landscape attributes) and, second, by simulating antici-

pated changes in one or several of the independent variables (i.e. driving force or proximate cause of land-cover changes) and assessing their projected impacts on specific landscape attributes through changes in the dependent variable.

This Task should be completed on case studies through collaboration with other IGBP projects which are concerned about impacts of land-cover changes, e.g. on biodiversity, biogeochemical cycles, hydrology, coastal zones, and spread of landscape disturbances.

Figure 8

Series of Activities and Tasks to be developed within the Focus 2 of LUCC

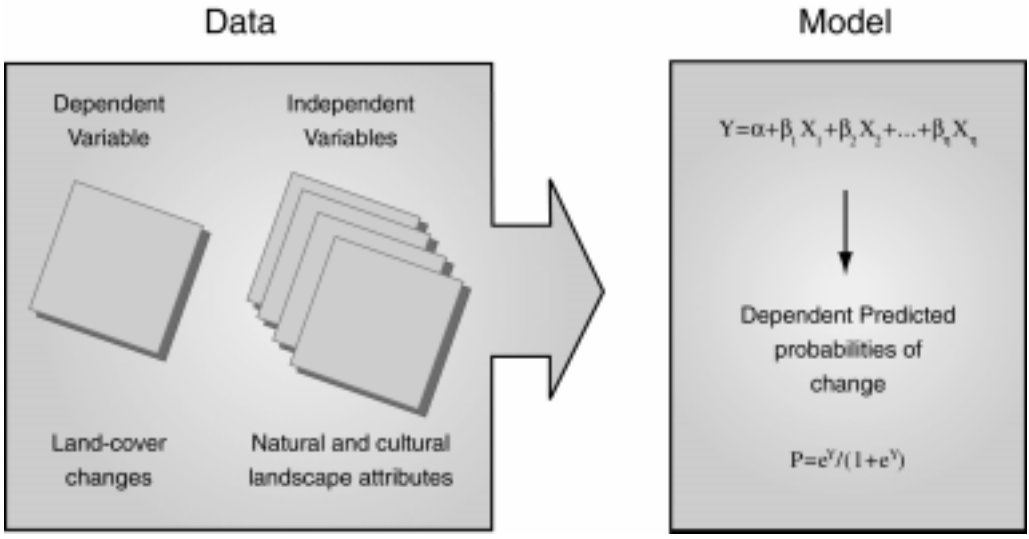
FOCUS 2: LAND-COVER CHANGES

Direct observations and diagnostic models of land-use/land-cover changes

ACTIVITY:	2.1	Land-cover change, hot spots and critical regions
TASKS:	2.1.1	Monitoring biophysical and socio-economic variables
	2.1.2	Definition of land-cover change indicators
	2.1.3	Hot spot detection and alarm system
ACTIVITY:	2.2	Socializing the pixel
TASKS:	2.2.1	Transition probability models
	2.2.2	Spatially explicit models
	2.2.3	Linking patterns of land-cover change to household-level data (link to Focus 1)
ACTIVITY:	2.3	From patterns to processes
TASKS:	2.3.1	Dynamic, causal models and short-range projections
	2.3.2	Definition of risk zones and potential impacts

Figure 9

Spatial modelling (adapted from Mertens and Lambin, 1997).



TREES. JRC TRopical Ecosystem Environment Observations by Satellite

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The project, is dedicated to the development of techniques for global tropical forest inventory and for monitoring deforestation using satellite imagery.

Objectives

- Produce relevant and accurate information on the state of the tropical forest ecosystems
- Analyze this information in terms of deforestation trends and its possible impacts
- Make the information available in an appropriate format to the user community

Secondary objectives

- The stimulation of *ad hoc* research in the field of remote sensing and GIS for monitoring tropical forest
- Development of validation techniques for quality assurance
- Development of communication links between the project and a range of users
- Improvement of explanatory models of deforestation

The first world map of tropical forests

Baseline assessment of humid tropical forest cover using coarse spatial resolution (1 km) remote sensing satellite data. From the resulting global database, three regional vegetation maps have been published or are under elaboration at 1:5M scale: Central Africa, South America and Continental Southeast Asia

Monitoring tropical forests from space

It seeks to develop a reliable method for global forest change assessment in the humid tropics using Earth Observation techniques. The approach is based on a statistical sampling of sites with a higher sampling rate for fast changing areas. A pre-stratification was performed using two parameters: the forest cover area (from the 1 km resolution maps) and areas where changes are expected to be higher based on individual expertise: the 'Hot Spot Report'. Forest cover change during the period 1992-1997 will be estimated from the ninety-five sampled sites using fine spatial resolution satellite imagery.

Tropical Forest Information System (TFIS)

All the detailed multi-annual data collected have been integrated into TFIS. TFIS is ideal for analyzing zones of rapid deforestation.

Expected results and outputs

- Map products have been published
- Forest area statistics have been derived from the tropical forest maps.
- Regional deforestation hot-spot delineation for forest change assessment: a global stratification of "deforestation hot spot areas" was performed based on individual expertise. More automatic procedures using Earth observation data will be developed for the detection and delineation of current fast changing areas.
- Forest cover change during the period 1992-1997 will be estimated.

SYPR. Land-cover and land-use change in the southern Yucatán Peninsular region

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Objectives

- To understand the dynamics of deforestation and other land-use/land-cover change in the region and
- To produce new spatially explicit models that explain these dynamics and project their near-term outcomes under different scenarios

Part 1: Historical and household studies for econometric models

- To create an historical narrative of regional changes in LU/LC
- To create an in-depth household data base on production systems and decisions
- To use these data and information to develop models that can be linked to remote sensing data
- To compare the robustness and costs of this modeling approach with that of Part 2.

Part 2: Remote sensing imagery studies for empirical diagnostic models

- To create a land cover (and land-use) classification and accuracy assessment
- To create biophysical and social data layers to couple with the remote sensing results through GIS
- To create probability models of land-use/land-cover change
- To compare the robustness and costs of this modelling approach with that of Part 1

Part 3: Forest and land-cover ecology

- To create a detailed land cover classification, including vegetation structure and composition as a function of climate, soils, and disturbance history
- To evaluate the ecological impacts of land use on ecosystems
- To link this information as inputs and outputs to the modelling efforts
- To provide information for studies on the long-term history of vegetation, land use and natural disturbance

Study area: Southern Yucatán Peninsular Region

Population dynamics, landscape pattern and environmental change: Relationships between people, pixels and biophysical gradients

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Objectives: To study interrelationships among:

- Population dynamics at the individual household and community levels
- Patterns and organization of land use and land cover with emphasis on deforestation and its resulting land fragmentation
- Village location, water and transportation accessibility, land competition and land suitability
- Biophysical gradients (e.g., soil fertility, moisture, and topographic structure)
- Social and economic change over the past two decades in Nang Rong, Thailand.

Research aims

- Combine social surveys, administrative records, and satellite digital data characterising inter-annual and interseazonal conditions at multiple resolutions into a GIS
- Use integrated dataset to explore dynamic interrelationships between land use, population, geographic location, environmental gradients, spatial organisation, and socio-economic change
- Investigate the spatial organisation of the biophysical landscapes associated with villages in relation to spatial, social, and environmental forces and their scale dependence
- Examine land suitability and assess the rice agricultural risks
- Estimate an individual and community-level model linking land use and migration
- Examine the relationship between fertility land availability and land fragmentation

Project approach and research design

It draws upon a host of methodologies to meet the objectives of an interrelated set of projects. They include:

- Remote sensing to map land use and land cover
- Spatial metrics to quantify land use/land cover spatial organization at the class and landscape levels
- GIS
- GPS to position landscape features and field data for integration into the GIS
- Population surveys at village and household levels to define their demographic characteristics

The overall intent is to develop models of social behavior by integrating population-environment domains, simulating change in social systems through perturbations in the environment, and understanding the influence of internal and external forces on decisions affecting the patch, village, village groups, and district.

Expected results and outputs: to link the behaviour of individuals, households, and communities to land cover dynamics at the appropriate spatial and temporal scales (remote sensing).

Study area: Nang Rong District, Northeast Thailand.

Focus 3: Regional and global models

Development of a framework and tools for integrative assessments

Introduction

If the dynamics of land-use/cover change are to be understood in the context of the broader issues of global environmental change, then a framework is needed that will enable comprehensive regional to global modelling studies and that will take into account broad scale socio-demographic, institutional and economic variables. Focus 3 is designed to interact with the other Foci, drawing on understanding derived from Focus 1 and Focus 2, and informing their activities on dynamics of driving forces operating at regional to global scales.

Developing the basis for a new generation of models is a major task in terms of both database compilation and methodological innovation. There are near-term needs for more precise land-use and land-cover change projections arising from the IPCC, the Framework Convention on Climate Change (UNFCCC), and other international bodies. Focus 3, therefore, must start by reviewing existing regional to global scale agricultural, grassland and forestry models to benefit from the large current and past investments in model development and to give more reliable land-use/land-cover change projections over the short term (2-3 years). Beyond this basic stock-taking and identification of the main gaps in current methodologies, Focus 3 seeks to create new modelling structures and tools capable of more completely capturing and explaining land-use and land-cover change and its main driving forces (Figure 10, page 82).

Activity 3.1: Review and comparison of past and current regional modelling studies

The Activities of Focus 3 are organized to benefit in the shorter term from the experience and investment accumulated in a number of global scale analyses, e.g., in global change impact studies of the agriculture and forestry sectors. Substantial intellectual and finan-

cial efforts have gone into the development of existing regional and global models, and a modest additional investment could make some of them significantly more useful to the global change community, especially for land-use/land-cover change projections.

Task 3.1.1: Inventory and review of regional/global models used for projections of land use/cover and report on state-of-the-art regional modelling (priority task)

Here, the aim is to foster a process of communication among regional modelling activities as well as to review and document methodologies that have been implemented in past regional/global-scale studies related to land-use/land-cover changes. Furthermore, the objective is to document various features of these models, including:

- Purpose of the model, its spatial characteristics, and chosen time horizon;

- Modelling approach;

- Data types used in past regional/global studies and their sources;

- Importance of land-use/land-cover change and vegetation attributes;

- Importance of demographic, economic, and institutional factors in the models.

There is a need for a state-of-the-art report on regional modelling of land-use/land-cover changes with the aim of comparing past and current achievements in regional model development to the requirements discussed in the LUCC Science Plan. Such a report will provide a sound basis for identifying critical limitations of current modelling approaches and data.

In order to carry out this Task and to prepare for the workshops described under Task 3, a research position should be established at the LUCC Focus 3 office. Research positions should also be established within a few regional centers, to undertake the model review within, for instance, the Americas, Europe and Africa, and Asia and the Pacific.

Task 3.1.2: Model comparison workshops (priority task)

Based on a thorough state-of-the-art review (i.e., the results of Tasks 1 and 2), workshops will be organized to develop strategies for harmoniszing and enhancing the methodological basis and for prioritizing regional efforts on data and model development. These workshops will also serve to communicate the issues identified across Foci, and to establish the collaborative efforts needed for Activity 2.

Activity 3.2: Major issues in methodologies of regional land-use/land-cover change models

This Activity is conceived as an evolutionary process based on, and extending from, the results of Activity 1. Its initial priority is establishing a sound theoretical basis and empirical methodology for addressing the LUCC modelling challenge at the national and transnational level. Land-use/land-cover change takes place under the influence of a number of driving forces such as population, technology, political changes, consumption income, and trade data, and all at a regional level of spatial desegregation. Some of these data are typically generated from household surveys, highlighting another important link to work undertaken in Focus 1.

Task 3.2.1: Coping with heterogeneity and scales in regional models

Spatial structure and spatial scales have rarely been the concern of economics. In LUCC research, finer regional differentiation and description of the spatial structure of the economy become essential. It is important to know not only how land is allocated among uses in a given area, but also how the usage pattern varies within that area. This is especially true when a given study area is heterogeneous and large in size such as to be considered in Focus 3. The integration of spatial heterogeneity is approached through Focus 2. It should be linked with the development of integrated land-use change models under this task.

Consumers, producers, commodities, and resources must each be represented at suitable and mutually consistent levels of aggregation. A high level of aggregation sacrifices detail for a lighter data burden and computational efficiency. For regional modelling of land-use/land-cover changes, a suitable aggregation must provide for an enhanced level of detail with respect to land managers, land resources and land-intensive activities such as agriculture and forestry. A lower level of detail suffices for other activities. Several studies have demonstrated that key relationships between driving forces and land-use/land-cover change are scale-dependent. Multi-scale approaches are therefore necessary and should be promoted. The scale of analysis also has an influence on the pattern dynamics. This issue can be investigated with activities conducted under Focus 2.

For each group of actors, modelling the key behavioural responses and constraints is necessary. This will call for innovative thinking in conjunction with Focus 1 and 2 on the application of decision theory, micro-economic principles, social dynamics simulation concepts and spatial statistical analysis. For example, representing the role of decision agents and decision strategies in models requires a much wider approach than econometric optimisation. It also poses new demands on data collection and accessibility.

This Task will review and develop data concepts and methods for dealing with theoretical issues which are especially critical in regional land-use/land-cover change studies. These involve questions of aggregation over:

- commodities and factors (commodity heterogeneity);

- agents (social and cultural heterogeneity);

- landscapes (spatial heterogeneity);

- and inherent conflicts about observational units (e.g. administrative versus landscape/watershed) as well as time and spatial scales.

Social, institutional and economic analyses of land and water use requires a socio-economic data set which is comprehensive and internally consistent. Classifications of actors, of production sectors, factor inputs to production, incomes and expenditures must be complete and all-inclusive. One format for this is The Social Accounting Matrix (SAM) which has proven to be a useful format in which to group the required data, but there are others. In any event, information about markets for land and water must be added to the usual production, consumption, income, and trade data, and all at a regional level of spatial disaggregation. Some of these data are typically generated from household surveys, highlighting another important link to work undertaken in Focus 1.

Note that the issue of heterogeneity is a generic one for land-use/land-cover change research, and goes far beyond the development of models. It is thus an important cross-cutting theme throughout the three Foci.

The LUCC Implementation Strategy emphasizes a regional approach. Therefore, it will be essential for Focus 3 to participate from the outset in establishing regional LUCC networks, and to articulate in meetings and workshops the requirements of comprehensive regional analysis. To facilitate the activities within the regional networks, Focus 3 will collect examples of best practice in successful data compilation and aim to provide tools for data analysis and integration.

Task 3.2.2: Improving the environment-economy linkage (priority task)

An important aspect of the link between human activity and the environment can be found in the production relationships within an economy for land-dependent commodities such as crops, livestock, and timber. It is important to know how environmental resources and factor inputs are transformed into commodities which are either consumed locally or traded on international markets, and to know which new states of environmental resources and capital stocks will result from the scale of these activities. To strengthen the environment - economy linkage, this task addresses the estimation of spatial production relations for land-based commodities at the sub-regional level and their representation in aggregate economic regions. The emphasis on land-use/cover change makes it necessary to ensure that geographic detail on conditions within a region is retained in the socio-economic analysis. The differentiation should preserve major differences in ecological and institutional features of production conditions.

Thus, an objective of Focus 3 is to improve the linkage between economic, demographic, cultural and biophysical models. Both simulation and process-based models will be investigated. This involves finding acceptable and consistent ways of embedding biophysical/chemical process understanding in models of land-use change and of testing methods of incorporating information derived from biophysical models into land-use change models. The environmental impacts of land uses and their ultimate feedback on these uses need careful consideration, not only because they are inadequately represented in most economic technical parameters and relationships pertaining to land-dependent production with avail-

able empirical data so as to obtain realistic estimates of production potentials and input response functions at the regional level. To be empirically grounded, this requires appropriate data sets and advanced methods of spatial statistical analysis, and needs to build on information derived from Focus 1 and 2 Activities.

For practical implementation, it will be most effective that regional LUCC networks establish activities such as these in their research agendas, with support from the Focus 3 office in the form of regional workshops and demonstration projects.

Task 3.2.3: Dealing with technological change

The role of technological progress in land-based production sectors has been intensification along multiple dimensions. For instance, higher yields per hectare of harvested area have resulted from improved seeds, increased application of fertilizers, better plant protection, improved tools and mechanization, and biotechnological engineering. Given that the larger part of incremental food production is projected to come from intensification, models must be sensitive to technological change, which is treated with only simple exogenous assumptions in most existing regional or global models. In addition to improving the ways in which models incorporate technological change, it is necessary to develop scenarios of technological development specific to different land- based sectors and environments (e.g. prospects for improvements of cereal cultivars for dry-land farming).

Focus 3 will organize workshops to evaluate the technological prospects of land-based production sectors and to develop regional scenarios of technological progress which are sensitive to the socio-economic setting and environmental conditions. The workshops will also provide a forum for discussing methodological issues involved in making technological progress endogenous to the models and of including learning and adaptive behaviour of agents.

Task 3.2.4: Policies and Institutions - representing the regulatory context in regional models of land-use / land-cover change

The agricultural and natural resource sectors of economies are almost universally the sectors associated with the highest level of policy intervention. In addition, because environmental amenities and functions these foreseeable demographic and economic trends will call for a doubling of global food supply within the next four to five decades. While such expansion may well be within the capacity of the global resource base and technical capability, it will require considerable financial and human resources, imply massive impacts on regional ecological complexity, and will intensify the competition for water. In addition, anticipated social and economic changes will alter the conditions under which land managers operate. In this activity we consider a few of these interrelated issues, but others will emerge as LUCC research advances. For example, the interaction between land-use changes, and nutrient budgets and dynamics is highly relevant to incorporate C and N fluxes and balances at regional to continental scales.

Activity 3.3: Land-use/land-cover change and the dynamics of interrelated systems.

Population growth and the expected increase in the real incomes of much of that population will have manifold consequences for land-use/cover change in the coming decades. It is fairly safe to assume that these foreseeable demographic and economic trends will call for a doubling of global food supply within the next four to five decades. While such expansion may well be within the capacity of the global resource base and technical capability, it will require considerable financial and human resources, imply massive impacts on regional ecological complexity, and will intensify the competition for water. In addition, anticipated social and economic changes will alter the conditions under which land managers operate. In this activity we consider a few of these interrelated issues, but others will emerge as LUCC research advances. For example, the interaction between land-use changes, and nutrient budgets and dynamics is highly relevant to incorporate C and N fluxes and balances at regional to continental scales.

Task 3.3.1: Rural-Urban dynamics (Land-use synergies and tensions)

Urbanization is among the most important drivers of change in rural areas. Regional land-use/land-cover change models must devise suitable mechanisms for recognizing the distinction between urban and rural sectors and for representing the opportunities and tensions that derive from their interaction. The increasing urbanization of the world population has triggered major qualitative and quantitative changes in the pressures on land use and land cover that must be modeled through a more complete representation of the relevant processes.

Growing urban agglomerations cause multiple impacts on land use and social structures in the peri-urban areas and their hinterlands. These relate to the provision of non-farm job opportunities, shifts to higher-valued farm commodities (such as vegetables, fruits, or livestock) to meet the demands of urban consumers, and the provision of environmental services and landscape amenities. They also relate to rapid and often chaotic changes in land use along the urban peripheries, and place heavy demands on the ecological system in terms of resource extraction, disposal of waste, and discharge of pollutants. Such alterations of the environment do not come without consequences for land use and land productivity.

Within this Task, three themes with major direct or indirect implications for LUCC will receive attention:

- Impacts of urbanization and commercialization on rural social structures and land use;

- Impacts of growing urban agglomerations on the environment, and

- Rural/urban life-style differences and their implications for future demand.

Note that, if the issue of rural-urban interfaces is of particular importance, the interaction between human mobility in general (including rural-rural migrations) and land-cover change should be better understood and modeled.

An adequate representation of such mechanisms in regional land-use/land-cover change models depends on the availability of data and empirical findings. Focus 3

will link to other IGBP/IHDP core projects and regional programs where these themes are also of great relevance, e.g., such as the Integrated SARCS Study. High-priority regions for research on environmental impacts of urban agglomerations are South-, Southeast-, and East-Asia.

A further aim is to develop region-specific scenarios of demand for land-based products and services. Ideally, the demand scenarios will be sensitive to the cultural setting, take into account rural-urban life-style differences, and be based on available empirical results. The role of Focus 3 will be to collect and review available studies, to link with Focus 1 when implementing their case studies, and to collaborate with regional LUCC networks and programs in developing these particular study elements. Focus 3 will provide software for demand scenario development and should be proactive in collaborating with regional LUCC networks to organize workshops for comparison and dissemination of demand projections related to land-based commodities and services.

Task 3.3.2: Water issues in regional land-use/land-cover change (Integrating land and water)

Agriculture has been and continues to be the principal consumer of water worldwide. Especially in semi-arid and arid environments, when insufficiently managed, water use by agriculture has been the source of major aquifer depletion. It is of critical importance, therefore, to improve our understanding of how in the long-term competition for water, its distribution mechanisms and price, and water-related policies may affect land-use/land-cover change, and conversely, how land-use and -cover change may influence the water cycle, water supply and water quality.

In many cases, therefore, it will be essential to provide an assessment of water resources and use in the regional LUCC studies which must consider three main elements: hydrological resources, water infrastructure, and water demand.

On the whole, modelling of regional hydrology on the basis of a number of river basins is well developed. However, three topics are of particular interest to LUCC:

- Which of the available meso-scale methodologies used in hydrological modelling are sensitive to land-use/land-cover change?

- What are appropriate methods for linking assessments and models operating at the watershed level to data and models depending on geographical units delineated by administrative boundaries?

- How can process information on hydrology be embedded in regional land-use change models, and at what spatial and temporal resolution?

Land-use changes will affect the demand for water directly, in terms of irrigated agriculture, and indirectly with the water demand from altered socio-economic activities and, possibly, changed life-styles. Water use for non-agricultural purposes generally is of higher economic value than agricultural water use, and, where ample water supply is lacking, under market conditions may out-compete and limit water availability for irrigation.

Various programs focusing on the water sector are currently underway. Hence, Focus 3 does not intend to concentrate on modelling hydrology, but rather to develop suitable interfaces and to benefit from past experiences. This will be done jointly with the emerging IGBP Water Group and the IGBP BAHC project. This task is best addressed through a review of existing hydrological models and an assessment of their sensitivity to land-use/cover change, as well as their ability to link with land-use/land-cover change models.

Task 3.3.3: Expanding the global food and fibre production

It is fairly safe to assume that the foreseeable demographic and economic trends call for at least a doubling of global food supply within the next four to five decades. While such an expansion may well be within the capacity of the global resource base and the technical capability of farmers, it will require considerable financial and human resources, imply massive impacts on ecosystems, and will intensify the competition for water.

However, there are major regional differences in current land-use dynamics and future requirements regarding food and fiber production. In OECD countries technical progress in agriculture has by far exceeded increases in demand. As a consequence, two kinds of processes have resulted, intensification in high potential areas and abandonment of marginal areas. In Asian countries most suitable land (except for the forested areas in Southeast Asia) has been brought into agricultural production. Dynamics there are characterized by intensification on one hand, and losses due to degradation and urbanization on the other hand. In contrast, Africa has vast land resources, albeit often limited by moisture conditions and soil fertility. The rapid population growth, the lack of capital resources to achieve effective intensification on current cultivated land, and loss of cropland due to degradation suggest a large probability of future land conversion to increase food production. South America is land-rich as well. Yet the situation is different again, as major driving forces result from world trade and international capital.

The role of Focus 3 will be to link LUCC scientists to ongoing efforts in IGBP's cross-cutting theme on food and fiber, and to stimulate, participate in and galvanize regional studies concerned with the technological options, economic viability and ecological impacts of expanding global agricultural production. Focus 3 will undertake an in-depth analysis of region-specific land-use processes to produce informed projections of trends in land conversion and intensification in response to growing human food and fiber demands.

Activity 3.4: Scenario development and assessments of critical environmental themes

Research on mid- and long-term prospects of land-use/land-cover change cannot be limited to only observing and describing. This Activity addresses the need to develop regional scenarios and assessments for identifying land-use patterns with certain optimality characteristics satisfying simultaneously various economic, social and environmental goals. This activity has also to tackle the issue of uncertainty and thresholds in land-use/land-cover change: under what conditions do the dynamics of a land-use system become unpredictable or radically change its mode of functioning?

Task 3.4.1: Scenario development in the context of a growing world population (priority task)

There are large uncertainties regarding the long-term evolution of key driving forces, such as population growth and distribution, or per capita income growth. For assessments of land-use/land-cover change, it is important to establish a number of well-defined and spatially explicit scenarios of socio-economic development. These will provide the basis for assessing and framing the plausible range of land-use/land-cover changes and their environmental impacts over a time horizon of 30 to 50 years and beyond.

Scenarios will have to cover both historically important driving forces as identified through Activity 1 as well as new potentially emerging factors. The complexity of the issues and the large number of possible assumptions on key driving factors conceivable in a spatially explicit model of land-use/land-cover change calls for careful selection and methodological innovations in scenario design and presentation.

There are different types of scenarios, e.g. *normative* (desirable landscapes according to prescribed goals, which serve as models or targets), *reference* (alternative scenarios, that frame the range of plausible driving forces serving to highlight model sensitivity and the robustness of policy interventions), *predictive* (trend-based and probabilistic scenarios, which are time-dependent) and *responsive* (created by stakeholders for their own planning). Note that global scenarios can differ drastically from local scenarios, as not all global trends will be realised simultaneously in every region.

Within this Task various regional development scenarios should be analyzed to identify those trajectories of land and water use that qualify as sustainable transitions. Links will be established with IPCC and other institutions generating economic or conservation scenarios (WRI, IUCN, etc.).

Task 3.4.2: Land-use/land-cover change in global environmental assessments

There are a number of global environmental issues that cannot effectively be analysed without a serious land-use/cover change assessment. The themes calling for LUCC participation include:

- Regional/global food security;

- Global climate change impacts on regional land and water use;

- Climate variability and regional vulnerability;

- Post-Kyoto carbon issues;

- Regional biodiversity loss;

- Socially and/or environmentally fragile regions.

All the above themes are of an inter-disciplinary nature and center around land resources, land-use change, and transformation of ecosystems. Where possible, Focus 3 will seek collaboration with relevant programs and other IGBP and IHDP core projects. The role of Focus 3 will be to link LUCC scientists to ongoing efforts, and to stimulate, participate in and galvanize regional studies on these issues.

Figure 10

Series of Activities and Tasks to be developed within the Focus 3 of LUCC

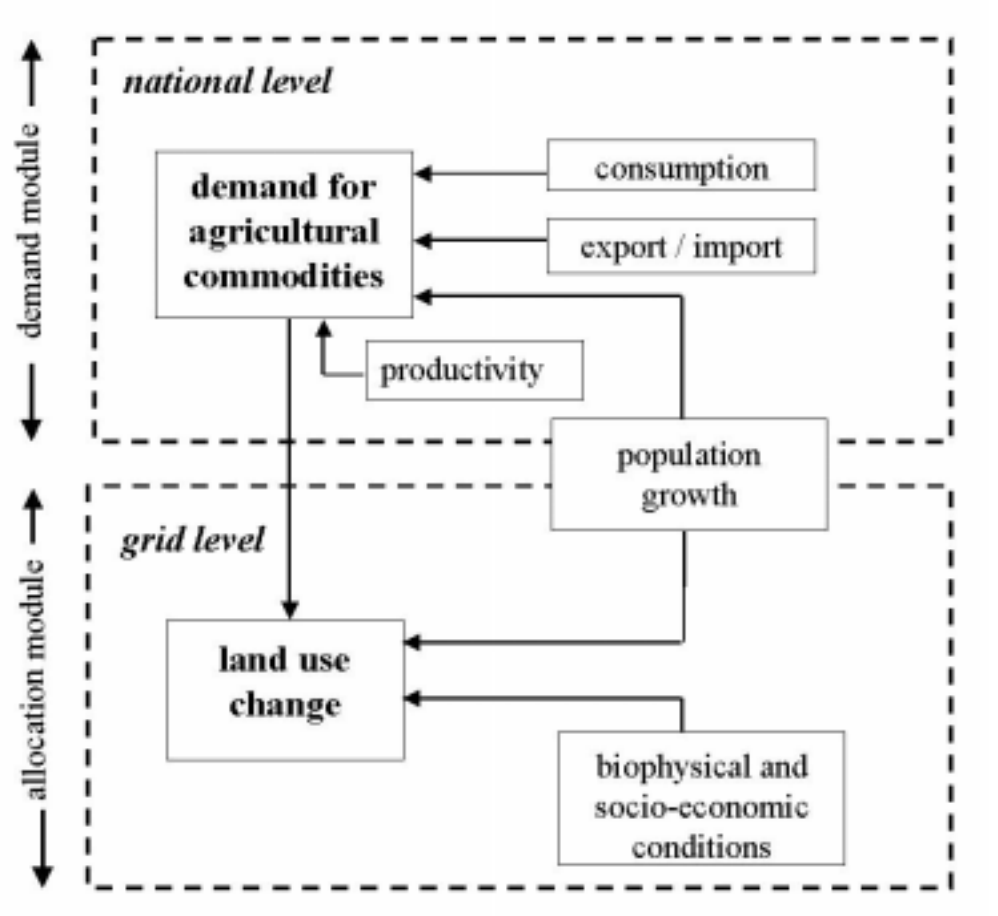
FOCUS 3: REGIONAL AND GLOBAL MODELS:

Development of a framework and tools for integrative assessments

ACTIVITY: 3.1		Review and comparison of past and current regional modelling studies
TASKS:	3.1.1	Inventory and review of regional/global models used for projections of land use/cover and report on state-of-the-art regional modelling
	3.1.2	Model comparison workshops
ACTIVITY: 3.2		Major issues in methodologies of regional land-use/land-cover change models
TASKS:	3.2.1	Coping with heterogeneity and scales in regional models
	3.2.2	Improving the environment - economy linkage
	3.2.3	Dealing with technological change
	3.2.4	Policies and institutions - representing the regulatory context in regional models of land-use/land-cover change
ACTIVITY: 3.3		Land-use/land-cover change and the dynamics of interrelated systems
TASKS:	3.3.1	Rural-urban dynamics (Land-use synergies and tensions)
	3.3.2	Water issues in regional land-use/land-cover change (Integrating land and water)
	3.3.3	Expanding the global food and fiber production
ACTIVITY: 3.4		Scenario development and assessments of critical environmental themes
TASKS:	3.4.1	Scenario development in the context of a growing world population
	3.4.2	Land-use/land-cover change in global environmental assessments

Figure 11

General structure of the CLUE-model



IIASA-LUC. Modelling land-use and land-cover changes in Europe and northern Asia

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Land-use and land-cover change is significant to a range of themes and issues central to the study of global environmental change. Besides their long-term global cumulative dimensions, changes in land use and land cover can have profound regional environmental implications already during the life span of current generations, such as the lowering of groundwater tables, problems of land and water contamination, reduced land productivity due to soil degradation, and reduced biodiversity. It is therefore widely acknowledged that a better understanding of land and water use dynamics over the next 30-50 years is central to the debate of sustainability.

This recognition, and the general understanding that an innovative and interdisciplinary approach to study the nature of land-use and land-cover changes is needed, have prompted IIASA to establish its Land Use Change (LUC) project.

Objective

The goals of LUC have been two-fold: first, to develop new concepts which address the methodological challenges of projecting complex human-environment systems, and second to apply these within a science-based assessment of economically viable options for land use and food policy in China.

Project approach and research design

Land use represents a critical inter-section of the economy and the environment. Land-use changes are foremost economic decisions. This recognition has prompted LUC to choose an economic framework as the organizing principle. This has resulted in a broad set of project activities geared towards providing a biophysical basis to the representation of land-based sectors in the economy.

- Exploration of a hierarchy of modelling approaches, each well established within their disciplines, which could enrich and provide information to the formulation of a land-use model based on dynamic welfare optimization.
- Development and application of software tools for multi-criteria model analysis related to agricultural land uses.
- Implementation of a set of land evaluation techniques known as Agro-Ecological Zoning (AEZ). LUC has compiled detailed results for the territory of the former Soviet Union, Mongolia and China employing the most recent digital databases on climate, soils, and terrain.

- A water assessment to generate in-depth information on availability and demand, particularly indispensable when projecting land use and food system prospects for China.
- Analysis of various human drivers of land-use change in China, such as past and future demographic trends, urbanization and life-style changes, and the high population concentration and rapid economic development in the agricultural areas of Eastern China.

Project design of the LUC-China study

Topic 1

Food security and prospective land-use changes in China.

Main external collaborators

Chinese Academy of Sciences, Institute of Geography (CAS-IOG), Beijing, China.

Centre for World Food Studies (SOW-VU), Amsterdam, The Netherlands.

Topic 2

The land-use/water resource linkage for China's agricultural development.

Main external collaborators

University of Colorado; Boulder, USA.

Chinese Academy of Sciences, Institute of Geography, Beijing, China.

CLUE. The Conversion of Land Use and its Effects

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Objectives

- Framework for a spatially explicit, multi-scale, quantitative description of land-use changes
- Determination and quantification of the main biogeophysical and human drivers of agricultural land use, on the basis of the actual land-use structure
- Results are incorporated in a dynamic model, describing changes for different land-use types.
- To explore land-use changes in the near future (20 years) under different development scenarios

Subsequent objectives

- To determine the effects of land-use/land-cover changes for global biogeochemical cycles by linking output of the model to global climate models.
- To link with methodologies that assess the effects on the natural resource base (e.g. biodiversity, erosion, soil fertility and water availability), to address issues of sustainable food production.

Project approach and research design: The project is organized in case studies. For each study area, data are stored in a GIS. The relation between surface areas of different actual land-use types and their biogeophysical and human drivers are determined through statistical analysis. A multi-scale approach is used, where scales are aggregation levels of the data collected at the base resolution. The multi-scale relations are implemented in a dynamic model that allocates specific land-use changes. Changes are steered by changes in the local drivers of agricultural land use. The model is used to explore land-use dynamics in different scenarios related to demographic, economic and social topics. Model outputs quantify and visualize land-use changes. Cooperation is established with experts from national and international organizations.

Programme design

Two regions with different response to increased demand

- (South)-East Asia (China, Java): land-use intensification is dominant
- Latin-America (Costa Rica, Ecuador, Honduras): expansion of agricultural land

Expected outputs

- A working methodology for quantitative descriptions of the spatial structure of actual land use, indicating the biogeophysical and human land-use drivers at different scales.
- A spatially explicit and dynamic model is constructed for the calculation of land-use changes under changing (inter-)national and sub-national conditions.
- The outputs of such a model are maps with related databases containing quantitative information on changes in pre-defined development scenarios.
- These maps indicate 'hot spots', that may indicate areas of interest for further research.
- Could indicate sources and sinks of greenhouse gases, and changes in the water and energy balance.
- Models addressing the effects of land-use change on the natural resources base.

IMPEL. Integrated Model to Predict European Land Use

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Background

The project aims to integrate physical and socio-economic modelling approaches to evaluate the impact of climate change on soils, crop production and agricultural land-use distribution in Europe at the regional scale.

Objectives

- To develop an integrated, spatially-distributed model to evaluate the impact of climate change on regional land-use systems, especially the impacts on:
  (a) soils, their hydrology and vulnerability to degradation;
  (b) crop productivity, including the influence of soil water availability, soil degradation and land management;
  (c) land-use distribution based on physical, socio-economic and management considerations.
- To demonstrate the use of the model in representative European regions for a range of climate change scenarios, and to produce maps illustrating the key model outputs (soil hydrology, crop productivity, land degradation and land-use distribution) for the current and potential future climate.
- To use the model to evaluate adaptation strategies of land use and management to climate change.

An interdisciplinary modular approach

IMPEL integrates the physical and socio-economic aspects of land-use systems based on a modular approach. The modules comprise:

- A climate module of European-wide baseline and climate change scenario datasets linked to a regional weather generator (EUROSCEN);
- A soil and crop module to evaluate the soil water balance and crop yields for a wide range of European crops at the scale of soil map units (ACCESS);
- A socio-economic module to estimate changed land use and optimal management requirements (including machinery, labor and fertiliszer use) at the scale of individual (generic) farms (SFARMOD);
- A land degradation module to evaluate the impact of soil erosion and changes in soil quality on crop productivity at the scale of soil map units (ImpelERO);

IMPEL is a spatially-distributed model that will be demonstrated in the following European regions by the project participants: Central England, UK; Languedoc-Roussillion, France; Sevilla Province, Spain; The Venice basin, Italy; Denmark; The Plain of Thrace and the Island of Lesvos, Greece; The Romanian Plain.

The challenge ahead

Emerging theories of land-use/land-cover change processes

The most fundamental obstacle to progress in the understanding and prediction of human impacts on terrestrial ecosystems lies in the lack of a comprehensive and integrative theory of human-environment relationships. The role of a theory is to explain experimental findings and to predict new results. Land-use/land-cover change research is embedded within human-environment relationships. To date, these relationships have proven difficult to conceptualize in a meta-theoretical framework (e.g., Blaikie and Brookfield 1987; Turner 1997). Specific kinds of relationships and the processes involved with them have been effectively addressed through theories of particular components of a land-use system. These include, but are not limited to, household economics, small holder and peasant behaviour, land allocation, technological innovation, fertility change, institutional regimes associated with land resource management, national markets, and international accords (Brown & Pearce 1994; Kasperson et al., 1995; Palo and Mery 1990). These suites of theories need to be reviewed, related, and compared in a series of compendiums made available to the scientific community.

The integrative character of LUCC science requires understanding and modelling that incorporates the principles from such theories. However, the variability in how these principles come together in a place or region at particular times is not conducive to research strategies aimed at a test of simple hypotheses that might equate LUCC to population, economic structures, technology, political structures, or environment. These and other drivers of LUCC are always present but interact differently according to the temporal and spatial dynamics of the situation. A thorough understanding and modelling of these complex interactions is a prerequisite to generate realistic projections of land-cover changes, e.g. 50 years into the future. As such, the more important hypotheses for LUCC are those that frame the integration and synthesis of the science.

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Acronyms

AID	Agency for International Development
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
BAHC	Biospheric Aspects of the Hydrological Cycle (IGBP)
CARE	Cooperative for Assistance and Relief Everywhere
CFC	Chlorofluorocarbon
CLUE	The Conversion of Land Use and its Effects
DAPLARCH	Data Plan for Land Use and Land Cover Change Research (LUCC)
DIS	Data and Information System (IGBP)
DMSP	Defense Meteorological Satellite Program (US)
DIVERSITAS	An International Programme of Biodiversity Science
DTM	Digital Terrain Modelling
ENRICH	European Network for Research in Global Change
EPAT	Environmental and Natural Resources Policy and Training
ERS	Earth Resource Satellite
EU	European Union
FAO	Food and Agriculture Organization of the United Nations

FEWS	Famine Early Warning System
GAIM	Global Analysis, Interpretation and Modelling (IGBP)
GECHS	Global Environmental Change and Human Security (IHDP)
GCOS	Global Climate Observing System
GCTE	Global Change and Terrestrial Ecosystems (IGBP)
GIS	Geographic Information System
GOES	Geostationary Operational Environmental Satellite
GOFC	Global Observation of Forest Cover
GOOS	Global Ocean Observing System
GPS	Global Positioning System
GTOS	Global Terrestrial Observation System
IDGEC	Institutional Dimensions of Global Environmental Change (IHDP)
IGAC	International Global Atmospheric Chemistry Project (IGBP)
IGBP	International Geosphere-Biosphere Programme
IGP	Indo-Gangetic Plains
IHDP	International Human Dimensions Programme on Global Environmental Change
IMPEL	Integrated Model to Predict European Land Use
IPCC	Intergovernmental Panel on Climate Change
IPO	International Project Office
IT	Industrial Transformation (IHDP)
IUCN	International Union for the Conservation of Nature
JERS	Japanese Earth Resource Satellite
LBA	Large Scale Biosphere-Atmosphere Experiment in Amazonia
LOICZ	Land-Ocean Interactions in the Coastal Zone (IGBP)

LQI	Land Quality Indicators
LUCC	Land-Use and Land-Cover Change (IGBP/IHDP)
LUCCI	Land Use and Climate Change Impacts on Carbon Fluxes
LUTEA	Land Use in Temperate East-Asia
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
OECD	Organisation for Economic Co-operation and Development
PAGES	Past Global Changes (IGBP)
PELCOM	Pan-European Land Use and Land Cover Monitoring
SAM	Social Accounting Matrix
SAR	Synthetic Aperture Radar
SARCS	Southeast Asia Regional Committee for START
SIRCH	Societal and Institutional Responses to Climate Change and Climatic Hazards
SSC	Scientific Steering Committee
START	Global Change System for Analysis, Research and Training (IGBP, IHDP, WCRP)
SYPR	Southern Yucatán Peninsular Region
TFIS	Tropical Forest Information System
TREES	Tropical Ecosystem Environment Observation by Satellite
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

VEGETATION	A sensor aboard SPOT 4
WCRP	World Climate Research Programme
WRI	World Resource Institute

Annex 1

How to contact the LUCC project August 1999

The Land Use and Land Cover Change International Project Office

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Annex 2

How to get involved in the LUCC project

1. Being Part of the Network

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The LUCC website can be used to obtain further information on the LUCC Project. Additional information can be found concerning our regional and endorsed projects, related publications, and how to apply for project endorsement. All publications produced by the LUCC Project, including the *LUCC Report Series* and *LUCC Newsletter*, are available for download or may be read on-line. If you wish to be placed on our mailing list to receive our newsletter and future updates on the LUCC Project, please contact us at the temporary address above.

2. Applying for Formal Status in the LUCC Project

The IGBP-IHDP Project on Land Use and Land Cover Change welcomes applications by research groups, institutions and agencies worldwide to join the LUCC community through formal status with the LUCC International Project. A successful application gains access to the LUCC network of projects, programmes (including various international and regional workshops) and potential funding initiatives through the various correspondences (electronic and hardcopy) of the LUCC International Project Office (IPO). While the IGBP and IHDP do not fund research *per se*, formal LUCC status may assist individual projects in their search for funding.

Applicants must be contributing to the LUCC research effort as defined in the LUCC Implementation Strategy. The objectives and outputs of the activities endorsed have as their central objectives those identified within the formal LUCC agenda, or provide important insights for various parts of that agenda.

There are two ways to apply for formal status within the LUCC network, either:

a) By following the application guidelines stated below, or
b) By submitting the research proposal itself or a shortened version which includes the information required in the Application Form.

Completed applications should be sent to the LUCC International Project Office, which works with the Scientific Steering Committee (SSC) to review the application. Applications will not take more than one month for processing and reply. Questions and completed applications should be addressed to the LUCC International Project Office.

LUCC Project Application

1. Project Identification

1.1. Project title.
1.2. Name and address of the Principle Investigator/Project Leader. Lead research institution(s).

2.Project Description

2.1. Objective/Summary. (250 words)
2.2. Project approach and research design. (500 words)
2.3. Programme design - location of research/fieldwork, various research units/ institutions involved and their tasks, duration of project and work schedule. (500 words)

3.Project Output

3.1. Expected results and outputs. (250 words)

3.2. Application of results/outputs beyond the science community. (250 words)

4.Contributions to the LUCC Science Plan

Identify by research foci and/or integrated activity. (250 words)

5.Project Associations and Affiliations

5.1. Relations to other IGBP and IHDP projects.

5.2. Relations to research projects and programmes other than those of the IGBP and IHDP.

6.Project Budget and Funding

6.1. Overview for budget by year and unit.

6.2. Source and scheduling of financial support.

7.Resume

7.1. Biosketch and five publications pertinent to project for each principal investigator and major unit investigators. (250 words

Unit-sketch for each major research unit involved. (250 words)

Annex 3

The LUCC Endorsed Projects
as of June 1999

Tropical Ecosystem Environment Observations by Satellite (TREES)

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Instrument For Detecting Land Cover For Europe (INDAVOR) and Non-Fossil Europe (NFOSEUR)

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A Strategy for the Global Observation of Forest Cover (GOFC)

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The Interaction Between Population Growth and Land-use Change

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Societal and Institutional Responses to Climate Change and Climatic Hazards: Managing Changing Flood and Drought Risk (SIRCH)

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Global Change and Subsistence Rangelands in Southern Africa: Resource Variability, Access and Use in Relation to Rural Livelihoods and Welfare

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Modelling and Forecasting Effects of Land Use Change in China Based on Socio-Economic Drivers

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Institutional Demographic and Biophysical Dimensions Of Forest Ecosystem Change In the Western Hemisphere

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Population Dynamics, Landscape Patterns and Environmental Changes: Relationships between People, Pixels and Biophysical Gradients

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Land Use Change: Methodological Approach to Understand the Interactions Nature/Society in Coastal Areas (ALENCOAST)

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Annex 4

Regional Networks with a LUCC Contribution
as of June 1999

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The Large-Scale Biosphere-Atmosphere Experiment in Amazonia

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Coastal Areas and LUCC
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