Key Findings of LUCC on its Research Questions

Question 1: How has land cover been changed by human use over the last 300 years?

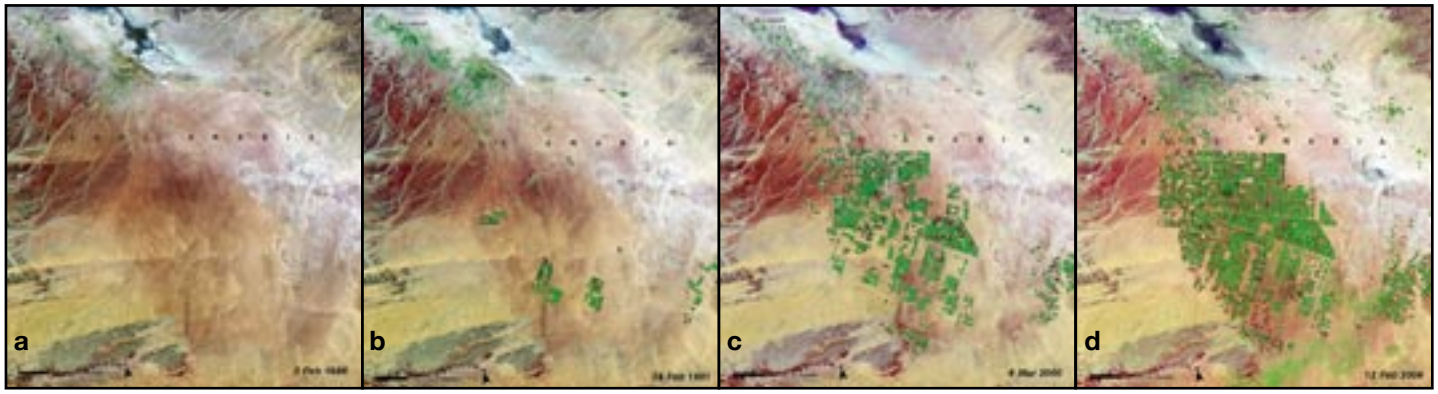
Human activities have transformed our planet's landscapes for a long time. The pace and intensity of land cover change increased rapidly over the last three centuries, and accelerated over the last three decades. Since the 1960s and the Green Revolution, an intensification in land use practices has been observed. The rapid land cover changes that have been observed (mostly in humid forests) are not randomly or uniformly distributed, but clustered in particular locations; for example, on forest edges and along transportation networks. Spatially diffuse land-cover changes, especially in drylands, are more difficult to observe.

Different processes of land cover change have taken place in different parts of the world in the last two decades (for example, decreases in cropland in temperate regions and increases in the tropics), and have had different impacts. Land cover modifications (subtle changes that affect the character of the land cover without changing its overall classification) are as important as land cover conversions (the replacement of one cover type by another). Reliable data at a global scale is lacking on changes in (sub)tropical dry forests (e.g. Miombo and Chaco forests); forest cover changes caused by selective logging, fires and insect damage; drainage or other alterations of wetlands; soil degradation in croplands; changes in extent and productive capacity of pastoral lands; dryland degradation; changes related to urban infrastructure; and lifestyle-driven changes. Moreover, many parts of the world are inadequately represented in existing land cover change data sets.

Question 2: What are the major human causes of land cover change in different geographical and historical contexts?

Land use change is always caused by multiple interacting factors originating from different levels of organisation of coupled human-environment systems. The mix of driving forces of land use change varies in time and space, according to specific human-environment conditions.

At decadal time scales, land use changes mostly result from individual and social responses to changing economic conditions, which are mediated by institutional factors. Opportunities and constraints for new land uses are created by markets and policies and are increasingly influenced by global factors. New technologies can lead to rapid shifts in land use practices. Institutions (political, legal, economic and traditional) at various scales, and their interactions with individual attitudes, values and knowledge systems, have a major impact on land use change. Globalisation can either amplify or attenuate the effect of driving forces of land use change. Migration is the most important demographic factor causing land use change at the timescale of a few decades. At a centennial timescale, both increases and decreases of a given population have a large impact on land use. Demographic change is also associated with the development of households and features of their life cycle.



Development of irrigation greening the desert region of Al Isawiyah, Saudi Arabia, showing (a) the desert landscape of 1986, (b) the beginnings of irrigation in 1991, (c) expansion by 2000, and (d) the transformation by 2004. Images from "One Planet, Many People: Atlas of Our Changing Environment", UNEP.

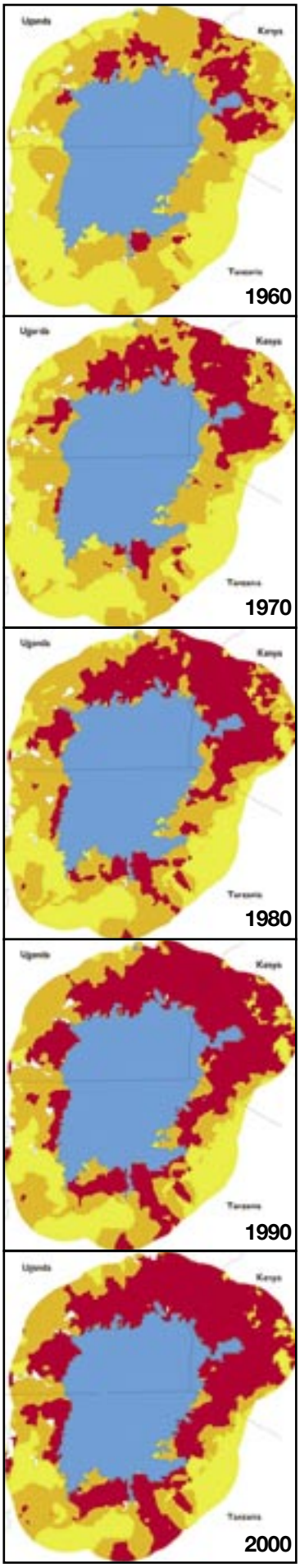
A restricted set of dominant pathways of land use change can be identified, as certain human-environment conditions repeatedly appear in case studies. For example, development of the forest frontiers by weak state economies, for geopolitical reasons or to promote interest groups; loss of entitlements to land resources (e.g. expropriation for large-scale agriculture, dams, or wildlife conservation) that lead to ecological marginalisation of the poor; induced innovation and intensification, especially in peri-urban and market-accessible areas of developing regions; urbanisation followed by changes in consumption patterns and income distribution with differential rural impacts.

Question 3: How will changes in land use affect land cover in the next 50–100 years?

Improved understanding of the complex dynamic processes underlying land use change has led to more reliable projections and more realistic scenarios of future change. A wide range of land use change models, for different scales and research questions and based on a variety of approaches, is now available. Different models of land use change address different questions, for example, location of change versus quantity of change. No model is able to answer all questions. Some models consider an area of land as the unit of analysis, while others are centred on individuals as decision making agents.

Only a few models of land use change can generate long-term projections of future land use/cover changes at the global scale, and so a regional approach is usually adopted. Crucial to projections of future land use is understanding the factors that control positive and negative feedback in land use change. Model reconstructions of past land use patterns are now better than random patterns or "no-change" assumptions.

Scenarios of land use change help to explore possible futures under a set of simple conditions by summing up current knowledge in the form of consistent, conditional statements about the future. Scenario building can involve



Population growth in the 100 km zone around Lake Vict oria in East Africa. These population growth rates are the highest for the entire continent. Images from "One Planet, Many People: Atlas of Our Changing Environment", UNEP.

policy makers and stakeholders to define and negotiate relevant scenarios. Existing land use change scenarios indicate the possibility of long-term and large-scale changes in land use and land cover with implications for many aspects of the Earth System. They indicate that long-term trends may be reversed after some decades. Urbanisation and associated changes in lifestyles are likely to become the dominant factor in land use change in the decades to come.

Question 4: How do human and biophysical dynamics affect the coupled human-environment system?

Human-environmental systems are complex adaptive systems in which properties, such as land use, emerge from the interactions amongst the various components of the entire system. These properties themselves feed back to influence the subsequent development of those interactions. Land use changes have multiple impacts on ecosystem goods and services at a variety of spatial and temporal scales. There are trade-offs between immediate human needs satisfied by land use, and maintaining the capacity of the biosphere to provide goods and services in the long term. Adopting a long-term view of land use change history in a given region is essential to understanding current changes and to predicting future ones as legacies of past land use changes. Institutional and technological innovations may lead to negative feedback loops that decrease the rate of land use change. There are several historical and contemporary examples of land use transitions associated with other societal and biophysical changes.

Question 5: How might changes in climate (variability) and biogeochemistry affect both land use and land cover, and vice versa?

Slow and localised land cover conversion takes place against a background of high temporal frequency regional-scale fluctuations in land cover conditions caused by climatic variability,

and it is often linked through positive feedbacks with land cover modifications. Abrupt, short-term changes, often caused by the interaction of climatic and land use factors, have important impacts on ecosystem processes.

Towards a Theory of Land Use Change

The complexity of causes, processes and impacts of land change has so far impeded the development of an integrated theory of land use change. Much progress has been made in understanding under what conditions different theoretical orientations, borrowed from a variety of disciplines, prove useful. However, the need to address land change from the perspective of a coupled human-environment system (or societal-ecological system) is now widely recognised, with the hope that one or more overarching theories of land change may emerge. Such theories must address the behaviour of people and society (agency and structure) and the uses to which land units are put, as well as feedbacks from one to the other. Theories must be multi-level with respect to both people and land units, recognising that they can combine in ways that affect their collective and individual behaviours. They must incorporate the extent to which people and pixels are connected to the broader world in which they exist, and must incorporate both history and the future.

Policy Implications

The use of land is a highly political activity. Misguided or uncoordinated sectoral policies are one of the major causes of land degradation. Lifestyle choices and consumption patterns affect land use choices, and universal policies for controlling land use change will not be effective when implemented. Rather, a detailed understanding of the complex set of causes affecting land use change in a given location is required prior to any policy intervention. Policy intervention should address the underlying causes as much as the proximate causes of land use change. To design effective response strategies in the face of rapid land use change, one needs to understand: (i) environmental perception, information processing and transfer by agents; (ii) determinants of decision making and individual behaviour with respect to land management; and (iii) portfolios of available and feasible responses to land use change for the different categories of agents. Good and efficient communication of the location of adverse impacts of land-use change to policy makers can allow them to react in a timely manner.

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Conclusion of LUCC

At the end of October 2005 the Land Use and Cover Change (LUCC) core project co-sponsored by IGBP and IDHP will conclude its work; this is an occasion both for reflection and celebration.

When LUCC was formulated in the early 1990s, there was much debate in the global change community about whether land use and land cover had any role to play in Earth System dynamics. Now, a decade later, one the most important overall findings of IGBP research, highlighted in the 2001 Amsterdam Declaration, is that "Global change is more than climate change. It is real, it is happening now and in many ways is accelerating". More than any other IGBP project, the research of LUCC gave rise to that conclusion, and led the way in integrating human and environmental interactions, and ultimately the growing synergism between IGBP and IHDP.

The past decade of LUCC has been one of superb science, excitement and surprise, and has raised new questions and challenges that have caused us to reflect on the nature of IGBP itself and its ability to rise to these new challenges. As a result IGBP has restructured in recent years, with the outstanding success of LUCC providing a critical bridge to the new structure. Significant parts of LUCC and the Global Change in Terrestrial Ecosystems (GCTE) communities are spearheading the Integrated Land Ecosystem-Atmosphere Processes Study (iLEAPS) and the Global Land Project (GLP). The latter has recently been officially launched in Bonn at the IDHP Open Science Conference, and its project Science Plan and Implementation Strategy has been published (see Centrefold this issue).

Others from the LUCC community are playing significant roles in the development of the ESSP joint project on Global Environmental Change and Food Systems (GECAFS), which has a much strong emphasis on food system typologies, food vulnerability, scenario-building and decision support systems. Additionally, LUCC has contributed to the reformulation of AIMES and PAGES, and to the emergence of an integrated Earth System perspective in IGBP. The forthcoming LUCC synthesis book in the IGBP Series will provide a through and comprehensive account of the project's achievements.

IGBP thanks all those who contributed to LUCC over the years (especially those who served on the Scientific Steering Committee or staffed the Project Office), and welcomes and encourages their continued involvement in the activities of the restructured IGBP.