

## THE LAND-USE AND COVER-CHANGE (LUCC) PROJECT

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### Summary

To understand recent changes in Earth's system and provide adequate policy advice, quantitative and spatially explicit data are needed on how land cover has been changed by humankind and how it will be changed in the next 50 to 100 years. The LUCC project pursues a dual approach to achieve this (1995–2005), either by (in)direct observations or through projection by models. The four main groups of strategic actions applied during project implementation comprise the development and coordination of scientific networks, various outreach activities, coordination of research in regional networks, and integration in scientific networks of individual projects, which are relevant for LUCC through project endorsement.

## 1. Introduction

The human impact on Earth is vast and unprecedented. Changes in land cover and land use are among the most important. They are a significant cause, or forcing function, of global change, and the medium through which many human responses to global change will occur; this is an essential component in all considerations of sustainability. Though land change is likely the most ancient of all human-induced environmental impacts on the biosphere, land-change science was one of the last subjects to be formally established by the global environmental-change science community through LUCC.

The LUCC (Land-Use and Land-Cover Change) project is an interdisciplinary joint core project of the International Geosphere–Biosphere Program (IGBP) and the International Human Dimensions Program on Global Environmental Change (IHDP). Following preparatory work in the early 1990s, the project was formalized in 1995 through a Research/Science Plan and got an Implementation Strategy in 1999. It will continue in its present form until 2005. Note that, throughout this paper, "the present" is AD 2001.

The three missions of LUCC are: (a) to build a compendium of information about local land-use and cover dynamics, (b) to identify a (small) number of robust principles that can better knit together local insights into a predictive science, and (c) to foster the development of common (or community) models which may then become widely available to scientists. The broader research themes are summarized as follows (Figure 1).

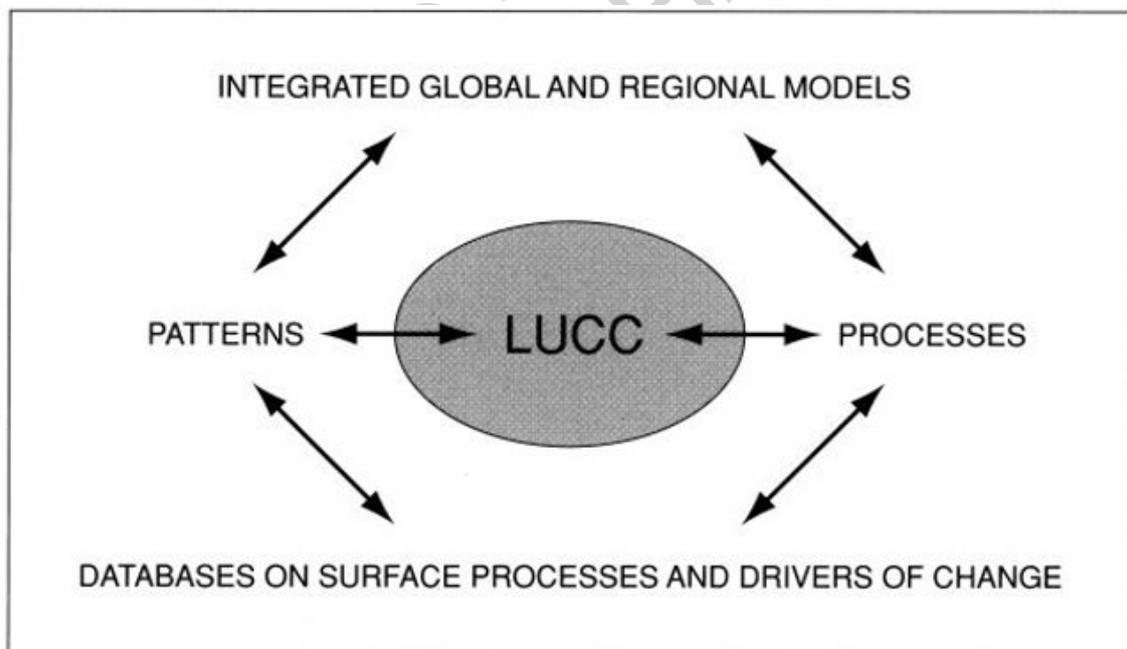


Figure 1. The broader research themes of LUCC

LUCC has defined six overarching science questions, which are central to the project. They relate to the next 100 years as well as to the past 300 years, as the latter period 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 landscapes configurations:

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

### Summary of the LUCC Implementation Strategy

<b>“BIG ISSUES”</b>	<b>FOCUS 1</b>	<b>FOCUS 2</b>	<b>FOCUS 3</b>
<b>Transition to a Sustainable World</b>	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
<b>Biogeochemical Cycles and Biodiversity</b>	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
<b>Critical Regions and Vulnerable Places</b>	Task 1.3.3: Simulation models that identify key interactions associated with degradation and vulnerability	Activity 2.1: Land-cover change, hot-spots 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
	<b>Land-Use Dynamics</b>	<b>Land-Cover Changes</b>	<b>Regional and Global Models</b>

Figure 2. Series of activities related to three focus areas of LUCC

In order to implement the science plan, a series of tasks and activities was set up to meet the broad objectives. Three interlocking strategies are encapsulated in the three research foci of LUCC (Figure 2). These are the 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 1: Land-use Dynamics), the development of empirical, diagnostic models of land-cover change through direct observations and measurements of the explanatory factors (Focus 2: Land-cover Dynamics), and the utilization of analysis from Focus 1 and 2 for the development of integrated and prognostic regional and global models (Focus 3: Integrated Modeling).

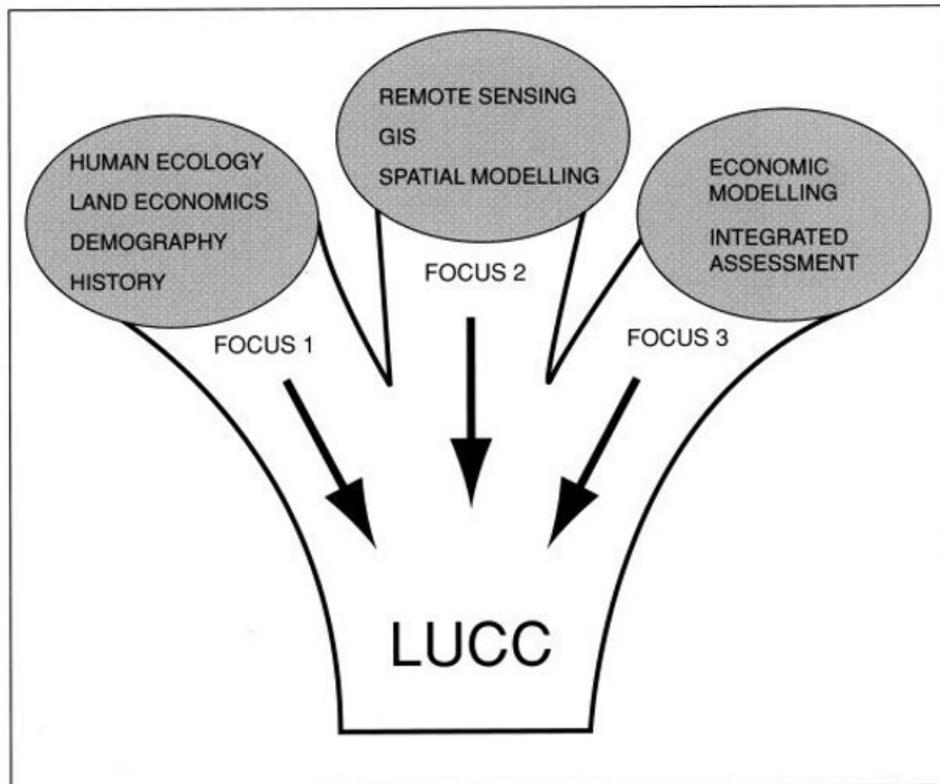


Figure 3. The LUCC community

To meet its mission goals, the LUCC project pursues the specific objectives of reaching a still larger scientific community, and of generating a wealth of results on fundamental science questions. The strategy for implementing this is to facilitate interdisciplinary research work, in particular between social and natural sciences (Figure 3), and to globalize research on land change processes by contrasting results obtained in a variety of regions and geographic situations. Thus, an increased ability is provided for a strong scientific basis to support policy decision making.

Historically, the operational time of LUCC can be subdivided into three periods. During the first three years (1995 to 1998), major efforts were made to establish the foundations of the project through the establishment of basic support infrastructure (project office, SSC core group, regional networks), develop and catalyze land science, and move towards full implementation.

Following completion of the Implementation Strategy, during the years 1999 to 2001 major headway has been made towards synthesizing land-change results and methodologies, while support infrastructure, including the dialogue with funding agencies in America, Europe, and Asia, continued to be maintained. Foreseeably, the last three years (2002 to 2005) will be characterized, on the one hand, by complete implementation of LUCC's mission goals (synthesis work), and, on the other hand, by the transformation of "classical" LUCC research into systematic and integrated land science, which is consistent with the emerging research agendas centered around the transition to sustainability and Earth System Science.

## 2. Scientific Networks

The development and coordination of scientific networks is one of LUCC's four cornerstones or main strategic actions to achieve full implementation. Concerning scientific networks as well as other strategic actions (see sections 3 and 4 below), LUCC is working with agencies, projects, programs, and universities worldwide to create new funded research projects, organize workshops and training facilities, and maintain project offices. Examples are the dialogue with various national ministries, with the European Commission (EC) under its several Framework Programs, with the U.S. Global Change Research Program initiatives on LUCC, with the US National Science Foundation (NSF), with the Science Council of Japan, with Centre National de Recherche Scientifique (CNRS) in France, and with the START Office, Global Change System for Analysis, Research, and Training.

### 2.1. Prioritization of Research and Identification of Gaps

To identify priority areas for research on land change, numerous workshops around the world were organized in 1993 and 1994, involving a large number of scientists from different regions and disciplinary backgrounds (see *Outreach Activities*). The results of these activities are the Research/Science Plan (1995) and Implementation Strategy (1999) of the LUCC project. Laid down in these documents are LUCC's six overarching science questions and its general mission, as well as specific tasks and activities. They began (and continue) to serve as a basis to help individuals and groups seeking research funding, to suggest new research lines, especially for young researchers who have not yet acquired a broad overview of the key and current questions in a discipline, and to initiate important new science programs.

International prioritization of LUCC research is verified, for example, through doctoral dissertations adopting LUCC research questions at university faculties worldwide, through the establishment of a study group on land change within the International Geographical Union (IGU-LUCC), and through the translation in 1996 of the project's documents into Chinese, which triggered off a new generation of young LUCC researchers. Clearly, the Land-cover Land-use Change Program (LCLUC) of the U.S. National Aeronautics and Space Administration (NASA) became initiated in direct response to LUCC.

The continued discussion of priority questions for land-use/cover change research at meetings of the LUCC SSC further helped to sharpen the setting. With the LUCC project now being more than half way through its operational time, one can summarize in broad categories what was known before on land change, and what is known today (Table 1).

Before 2001	Today (2001)
Land-cover conversions	Land-cover modifications generally more prevalent over the recent past
Mostly of tropical forests	All cover types, including rangelands, open forests,

	peri-urban areas, wetlands
Assumed to be pristine before	Landscapes altered by humans for millennia
Permanent changes	Complex and reversible trajectories of change; land covers in a constant state of flux
Spatially homogenous	High spatial heterogeneity; landscape fragmentation is important
Due to population growth	Also due to people's responses to changes in economic opportunities and policies, with biophysical and socio-economic trigger events
Mostly local	With influences from remote urban centers, amplified or attenuated by globalization, with strong local-global interplay
Mostly expansion of agriculture	Land use intensification and diversification are common responses to pressures and opportunities
With impact on carbon cycle	With impacts on human health, biodiversity, albedo, H <sub>2</sub> O cycle, emissions of C, methane, NO <sub>x</sub> , etc.
Impact depending on magnitude of biophysical change	Impact depending mostly on vulnerability of people and places
Everywhere	Spatial concentration in "hot spots" of change

Table 1. Changes in our understanding of land-use/cover changes  
 Source: Lambin E.F. and Geist H.J. (2001). Global land-use and land-cover change: What have we learned so far? *Global Change Newsletter* **46**, 29.

## 2.2. Definition of Data Requirements and Data Coordination Efforts

During its first three years, the LUCC project held a series of open workshops on data development for land-change research under the EC's European Network for Research in Global Change (ENRICH) program. Other international agencies and programs contributed under the Data Plan Development for LUCC research (DAPLARCH). The plan aimed at data requirements, data gathering and compilation, organizational needs, and data systems. The period of data orientation included strong collaboration between LUCC and IGBP-DIS (Data and Information System), which has been built up in a number of areas.

Regional data networks were developed with IGBP-DIS, national space agencies, and START, using the LUCC regional teams and networks. They included, among others, regional CD-ROM publications for Southeast Asia and Southern Africa (Miombo), IGBP-DIS groups developing around LUCC regional case studies, website developments in cooperation with IGBP-DIS, and regional data and training workshops.

The period of data orientation ended with full implementation in 1999. Much of the work to date has focused on methodological and technological issues and software and hardware development, dramatically improving the documentation and monitoring of

land changes, as well as the means of modeling and projecting the observed changes through an improved understanding of proximate causes and underlying driving forces.

Complementing data definition, the LUCC project is developing a data strategy in order to access and produce needed data sets. For this, it was (and still 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.

Regional data sets were being developed in collaboration with IGBP-DIS, START and space agencies. Regional versions of products such as DISCover (1 km global land cover) and DIS FIRE products were provided to regional teams, for example in the Southeast Asian LUCC network. Data from space-agency pilot projects such as CEOS-DIS High Resolution Data were made available to the LUCC science community through special projects, and existing, mainly remote sensing data (e.g., Landsat and Spot) were provided to regional scientists. The LUCC project, mainly through an internal IPO initiative, worked with the latter to ensure future sample data sets.

LUCC continued its efforts to develop consolidated global data sets through IGBP-DIS, START, and LUCC networks (e.g., LBA-DIS, especially the Flux Network of LBA, The Large-Scale Biosphere-Atmosphere Experiment in Amazonia), and the project's involvement in observing and monitoring systems worldwide. Concerning the latter, an important step was (and still is) the participation of LUCC in several global observing systems being developed to support integrated global observations under the International Global Observing Strategy (IGOS). Probably, most important is LUCC's leadership, mainly through the project's chairs, in the GOF C program (Global Observation of Forest Cover), which is implemented as a panel of the Global Terrestrial Observing System (GTOS). GOF C intends to direct and facilitate the implementation of a suite of forest cover products from both remote sensing and in-situ measurements leading to operational forest monitoring. This aims at supporting global change research, national, regional and global forest management and inventory, and policy and decision making regarding global forest resources. In 1996, efforts were started to emphasize the potential scientific value of remotely sensed data for addressing questions in social science areas related (but not limited) to LUCC.

Following implementation in 1999, LUCC-IPO was getting involved in extending the scope of remotely sensed data from primarily biophysical dimensions to entail socio-economic analysis and applications, and use it for observing and monitoring the transition to sustainability. LUCC established better links to projects that combine empirical case study analysis and infrastructure development to monitor human-environment interactions such as HERO, Human-Environment Regional Observatory Project, or IHDP's Sustainability Geoscope. Major headway has been made in the form of publications and workshops to explore the methodological and practical aspects of linking people, pixels and policies through the combination of remote sensing, household and other data. Complementing this, a better understanding has been gained through data from structured case study comparisons about the proximate causes and underlying driving forces of land change.

### 2.3. Standardization of Methodologies and Definition of 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. Efforts were made to standardize land-use surveys and driver assessments, and harmonize land-cover classification methodologies as well as databases.

Besides having developed a standard social-survey design to be used and further developed under Focus 1, LUCC applied and continuously improves its conceptual research framework linking human activities and land-use/cover change. This was done in the case of proximate causes and underlying driving forces of tropical deforestation, and is currently done in the fields of agricultural intensification, urbanization, land degradation, and rangeland modification (desertification).

As a major step towards the harmonization of land-cover information—clearly, a practical necessity of recent developments in Earth observation and analysis—the LUCC project identified the FAO land-cover classification to be a useful tool based upon a well-thought-out strategy, and endorsed it in 2001. Work has been started to further investigate coding robustness and reliability of LCCS, FAO's Land-Cover Classification System, and to translate (local and national) results into LCCS for international use.

LUCC was involved in the development of two fast-track global databases of land-cover history. Similar databases, covering the past 300 years, are important elements in the project's case-study-backed efforts and are harmonized at present. The synthesized database will provide a comprehensive picture of the growing dominance of human land use on land-cover, which can be used in many global-change research projects.

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#### Bibliography

Fox J., Rindfuss R.R., Walsh S.J. and V. Mishra (eds.) (2002) *People and the Environment—Approaches for Linking Household and Community Surveys to Remote Sensing and GIS*. 344 pp. Boston: Kluwer Academic Publishers. [This book addresses researchers conducting population and environment research by examining theories and practices through case studies.]

Geist H.J. and Lambin E.F. (2001). *What Drives Tropical Deforestation? A Meta-Analysis of Proximate and Underlying Causes of Deforestation based on Subnational Case Study Evidence*, 116 pp. Louvain-la-

Neuve, Belgium: LUCC International Project Office (LUCC Report Series No. 4). [This is one of LUCC's structured case study comparisons that use 152 subnational cases and follows the "classical" LUCC conceptual framework, hereby quantifying the proximate and underlying causes of tropical deforestation.]

Indian National Academy of Sciences, Chinese Academy of Sciences, US National Academy of Sciences (2001). *Growing Populations, Changing Landscapes. Studies from India, China, and the United States*, 299 pp. Washington, DC: National Academy Press. [The final report of this LUCC-endorsed project is a consistent comparison of six cases from the world's most populous countries which identifies intertwined population, consumption, and technology effects, and stresses the importance of government policy rather than population growth.]

Kasperson J.X., Kasperson R.E., and Turner B.L. II (eds.) (1995). *Regions at Risk. Comparisons of Threatened Environments*, 586 pp. Tokyo: United Nations University Press. [This is one of the first consistent comparisons of cases of social and environmental change with a view upon human driving forces, qualitative trajectories of change, vulnerability, and societal responses in altogether nine regional (subnational) cases.]

Lambin E.F., Baulies X., Bockstael N., Fischer G., Krug T., Leemans R., Moran E.F., Rindfuss R.R., Sato Y., Skole D., Turner B.L. II, and Vogel C. (1999). *Land-Use and Land-Cover Change (LUCC). Implementation Strategy*, 125 pp. Stockholm, Bonn: IGBP and IHDP Secretariats. [Following LUCC's Research/Science Plan, this document lays out the pathway of how to implement LUCC research globally].

Lambin E.F., Turner B.L. II, Geist H.J., Agbola S.B., Angelsen A., Bruce J.W., Coomes O., Dirzo R., Fischer G., Folke C., George P.S., Homewood K., Imbernon J., Leemans R., Li X., Moran E.F., Mortimore M., Ramakrishnan P.S., Richards J.F., Skånes H., Steffen W., Stone G., Svedin U., Veldkamp T.A., Vogel C., and Xu J. (2001). The Causes of Land-Use and Land-Cover Change—Moving Beyond the Myths. *Global Environmental Change: Human and Policy Dimensions*. **11**(4), 5–13. [Based on the expertise of 25 international case study experts, this paper explores myths of causality in land change and provides pathways of land development in the fields of tropical deforestation, rangeland modification, urbanization, and agricultural intensification.]

Liverman D., Moran E., Rindfuss R., and Stern P. (eds.) (1998). *People and Pixels—Linking Remote Sensing and Social Science*, 244 pp. Washington, DC: National Academy Press [This volume for the first time addresses the value of remotely sensed data for human dimensions research on global environmental change, emphasizing LUCC.]

Meyer W.B. and Turner B.L. II (eds.) (1994). *Changes in Land Use and Land Cover—A Global Perspective*, 537 pp. Cambridge: Cambridge University Press. [This book represents a state-of-the-art overview on global land change just before the start of the LUCC project.]

Turner B.L. II (2002). Toward Integrated Land-Change Science—Advances in 1.5 Decades of Sustained International Research on Land-Use and Land-Cover Change. *Advances in Global Environmental Change Research* (ed. W. Steffen), pp. 21–26. Berlin, New York: Springer Verlag. [This paper makes a first step from "classical" LUCC research into an integrated land science perspective.]

Turner B.L. II, Clark W.C., Kates R.W., Richards J.F., Mathews J.T., and Meyer W.B. (eds.) (1990). *The Earth as Transformed by Human Action—Global and Regional Changes in the Biosphere over the Past 300 Years*, 713 pp. Cambridge, New York, Port Chester, Melbourne, Sydney: Cambridge University Press. [The volume views, collects and, for first time, synthesizes LUCC research on a regional to global scale.]

Turner B.L., Moss R.H., and Skole D.L. (eds.) (1993). *Relating Land Use and Global Land-Cover Change—A Proposal for an IGBP-HDP Core Project*. IGBP Report; 24/HDP Report 5, 82 pp. Stockholm: IGBP Secretariat. [The still much-cited preparatory document lays the foundation for the Research/Science Plan of LUCC.]

Turner B.L. II, Skole D., Sanderson S., Fischer G., Fresco L., and Leemans R. (1995). *Land-Use and Land-Cover Change—Science/Research Plan*. IGBP Report; 35/HDP Report 7, Stockholm, Genf : IGBP & HDP Secretariats. [This document is central to create better understanding in the fields of land-use and cover change science.]

Veldkamp A. and Lambin E.F. (2001). Editorial—predicting land use change. *Agriculture, Ecosystems and Environment*. **85** (1–3), 1–6. [This editorial introduces into a special issue on predicting land-use changes, providing a state-of-the-art overview on recent LUCC modeling achievements.]

Walsh S.J. and Crews-Meyer K.A. (2002). *Linking People, Place, and Policy—A GIScience Approach*, 360 pp. Dordrecht: Kluwer Academic Publishers.. [This book collects cases which bring the people and pixels approach one step further towards integration of policy impact and of GIS methodology.]

#### **Significant Websites**

<<http://www.geo.ucl.ac.be/LUCC>>. [This is the official website of the LUCC project, providing downloadable documents and links to focus area activities, regional networks, and endorsed research projects, among others.]

<<http://sedac.ciesin.columbia.edu/tg/guide-main.jsp>>. [This is a web-based Land Use Thematic Guide, co-developed by CIESIN and the LUCC project, which provides access to selected scientific articles, grouped under a series of overview pieces which provide synopses of current issues in the field.]

<<http://lcluc.gsfc.nasa.gov>>. [This is the website of the Land Cover Land Use Change Program of the U.S. National Aeronautics and Space Administration (NASA LCLUC), which has become an interdisciplinary scientific theme within NASA's Earth Science Enterprise (ESE) in direct response to the LUCC project.]

#### **Biographical Sketch**

**Helmut J. Geist** is executive director of IHDP and IGBP's joint core project LUCC (Land-Use and Land-Cover Change), running an International Project Office at the University of Louvain, Louvain-la-Neuve, Belgium. He holds a PhD in human–environmental studies, and his research interests are focused on the empirical study of coupled human biophysical driving forces of global and regional environmental change (tropical deforestation, land degradation, desertification, and transitions to sustainable land use).

Dr. Geist has lived, taught, and conducted research at five different universities in Belgium, Germany, and the US. He worked as a consultant to the World Banks' Human Development Network and as a visiting scholar at the German-American Center for Visiting Scholars at Johns Hopkins University (Washington, DC).