

Status and Future of the IHDP-IGBP LUCC project

By Helmut J. Geist
LUCC International Project Office
Louvain-la-Neuve, Belgium
geist@geog.ucl.ac.be

In its year 7, the LUCC project (www.geog.ucl.ac.be/LUCC) entered a phase in which science outcomes on the causes of global land use change for some important land change classes (Focus 1) were systematically integrated and synthesised with those on global land cover dynamics (Focus 2). Increasing thus the realism of simulations of processes leading to land-use change, the LUCC project shall be able soon to provide the modelling (Focus 3) and the wider science community with quantitative, spatially explicit data for scenario development.*

Focus 1: Understanding land use dynamics – Comparative case study analysis

LUCC's understanding of the patterns and drivers of land-use change has changed in a major way, for example, spatial concentration in 'hot spots' of change rather than land change 'occurring everywhere' (Lambin et al. 2001; Lambin and Geist 2001; Geist 2002). In the quest for new knowledge on the causes of land-use change, the number of endorsed case studies has been enlarged from 39 to 47 in 2002, and 2 new regional networks have been developed. In these case studies, the approach to link household-level information to remote sensing data has become an important tool, not only to increase the understanding of land-use dynamics (Fox et al. 2002), but also to explore and monitor sustainability transitions (Lambin and Geist 2003). In order for information to be comparable across different locations and scales, questionnaires used in the case studies must share similar qualities. For this purpose, access to questionnaires was made possible by some LUCC researchers, and the project reaches out for the wider community to make their household questionnaires publically available – see www.indiana.edu/~act/focus1. Similarly, to achieve conformity of methodological approaches, LUCC was represented, for example, at the FAO/IPCC/CIFOR/IUFRO expert meeting on harmonizing forest-related definitions – see www.fao.org/forestry/climate. In addition to primary research, the synthesis of knowledge through comparative analysis of cases has been broadened and improved in the form of two additional meta-analyses on agricultural change (land use intensification) in the tropics and dryland degradation (desertification). They complement LUCC's first comparative analysis of the proximate causes and underlying driving forces of tropical deforestation (Geist and Lambin 2002).

Meta-analyses of the causes of land-use change: The quest for new knowledge on the causes of land-use change through comparative analysis of cases was speeded up by means of two major meta-analyses, i.e. statistical techniques to synthesize results from individual studies. Following a first meta-analysis (N=152 cases) of the causative pattern behind tropical forest losses, a comparative study of cases of desertification (N=132) generated results on causes, drivers, rates and indicators of dryland degradation. The causative factor analysis included proximate causes, underlying driving forces, mediating factors, and properties of systems dynamics such as feedbacks and thresholds. Rates of dryland change were standardized on an annual percentage basis to allow for comparison between cases and to hold apart slow from fast variables of change. A comparative examination of cases studies of agricultural change was done for the tropics (N=108), in an effort of coding some four dozen variables and analysing data in terms of both outcomes (e.g., intensification) and identification of the biophysical and socio-cultural factors associated with the various outcomes. As for both

meta-analyses, results are currently written up (Geist and Lambin 2003; McConnell and Keys 2003).

Focus 2: Land cover dynamics – Empirical observations and diagnostic models

Efforts focused on producing a synthesis of knowledge on areas of rapid land-cover change, and on integrating rates of change (for example, Ramankutty et al. 2001, 2002; Klein Goldewijk and Ramankutty 2003; Achard et al. 2002; DeFries and Achard 2002) with causal patterns, both on the basis of the meta-analyses carried out under Focus 1, and by validating results through regional expert consultations. First, an international workshop was held at LUCC-IPO's host university in conjunction with the annual SSC meeting (including some ten scientists from the broader IGBP and IHDP community), that dealt in particular with 'Linking causes, drivers and pathways with rates and patterns of land change' (Louvain-la-Neuve, Belgium, 11-13 April 2002). Four major classes of land change were explored, being of value, too, for the LAND project (Ojima et al. 2002) as integrative core project activities (*i-iii*): (*i*) conversion, degradation and fragmentation of tropical forests (Cervigni 2001), (*ii*) land degradation and desertification (Reynolds and Stafford Smith 2002), (*iii*) fire and other ecosystem disturbances (Lavorel et al. 2003), and (*iv*) land use intensification, including the rural-urban fringe. Second, an international regional expert and validation workshop was held to assess areas undergoing rapid land/cover change during the past 15 to 20 years, meant as input into the work of Millennium Ecosystem Assessment (Lepers 2002; Leemans et al. 2003). Furthermore, gaps and priority issues could be identified which relate to the difficult-to-measure land cover modifications (e.g., forest and dryland degradation, land use intensification), with detailed regional studies at best providing the level of information required.

Global synthesis of the areas of rapid land-cover change: In February, *A synthesis of knowledge of rapid land-cover and land-use change* (a joint LUCC and GOF/GOLD project for the Millennium Ecosystem Assessment) was started, with major work done at LUCC-IPO. The project maps, at a global scale, areas which have experienced rapid land-cover change during the last fifteen to twenty years. The exercise, based on existing databases, helps to focus attention on 'hot spots' of land-cover changes and to identify change processes for which poor information and data are available. Within one year's time, a synthesis shall be achieved of all previous works on the subject (e.g., deforestation, intensification, soil degradation, desertification, urban expansion, exceptional fires). In the final product, the areas affected by significant land-cover change will be outlined on top of the new GLC 2000 global land cover map (Mayaux et al. 2002). Different thematic codes will be used for different processes of change. For each change patch, a description of the nature of the change, date, causes, impacts, detection method and references will be included. In June, all existing data were compiled, and all information brought into a common format. Draft results were made available in the internet and as CD-ROM for review and comment – see 'MA project' at: www.geo.ucl.ac.be/LUCC. Following internet consultation, an international validation workshop bringing together representatives of all the major regions of the world has been held in Washington, D.C. (November 24-26). The initial map was validated and refined, and the areas of change which have been detected were documented. Moreover, the maps have been compared with finer-scale datasets (Landsat-based change maps and published case studies of deforestation). In the next few months, the maps will be improved by adding new census datasets, especially for the northern latitude. The product will be at latest finished in September 2003.

In addition, issue no. 8 of the LUCC Newsletter (December 2002) was designed to be a special issue on new global-scale datasets on land-cover change. The issue presents the work of a number of LUCC-endorsed or otherwise LUCC-related teams that have started, after several years of methodological research on monitoring techniques and environmental indicators, to produce datasets on a range of land change processes. Their works typically merge remote sensing information with

fine scale statistical data or expert opinion, such as the Lucc-endorsed TREES project (Achard et al. 2002). In May, Lucc was represented at an FAO/UNEP consultation on strategies for global land cover mapping and monitoring – see www.fao.org/sd/2002/EN0802_en.htm.

Focus 3: Regional and global integrated models

The modelling of land-use change made great strides with the application of new technologies (Veldkamp and Lambin 2001), for example, in the field of agent-based modelling and cellular automata. As a major step, the agent-based modelling framework got incorporated into the study of land-use change and land-cover change processes. An approved breakout session during a NAS colloquium on agent-based modelling in Irvine, CA (October 2001) led to Lucc Report #6 (2002) and a primary science publication (Parker et al. 2003). In addition, Lucc administers the ‘M(ulti)A(gent)Space Listserv’ which was created as a forum for discussion, and which currently has some 200 subscribers – see www.indiana.edu/~act/focus1. The listserv initiative complements Lucc-IPO’s effort to sharpen and harmonize the training of the next generation of land change researchers in modelling.

‘Modelling Land Use Change’ (MODLUC): With support from the European Commission, DG XII Environment and Climate Programme, Lucc-IPO organised the Advanced Study Course MODLUC at the University of Louvain, Louvain-la-Neuve, Belgium, from 27 October 2002 until 2 November 2002. MODLUC brought together more than 40 post-graduate students from all over Europe and about 17 key lecturers for training in modelling techniques within the context of global environmental change research. MODLUC provided a state-of-the-art synthesis of land-use change modelling as part of environmental modelling in the domain of global change research, covering five broad types of models: (i) empirical-statistical & GIS based models / transition probability models, (ii) optimisation models / linear programming, (iii) dynamic simulation models, (iv) agent-based models & cellular automata, and (v) hybrid/integrated models. The course allowed students to evaluate the strengths and limitations of the different model types, to assess their explanatory and predictive powers and thus their applicability to specific problems of global change. Course materials such as downloadable tools, data, documents and teaching materials are still kept available at: <http://www.geo.ucl.ac.be/MODLUC>.

Following the SSC Meeting and workshop in April, the concept of land-use transition is being developed to support scenario development (Lambin 2002). The workshop suggested that the concept offers an integrative framework to link a set of theories and models of particular components of the land-use system, thereby allowing a detailed examination of the dependence of drivers of land-use change on the specific land use history of a location. By linking causes, drivers and pathways of land-use change with rates and patterns of land-cover change, the concept provides a better empirical foundation to predict future or alternative trajectories of land change. A joint paper was drafted and circulated in June, with the intention to contribute to the identification of gaps and prioritisation of Lucc as well as LAND research.

Outlook

The Lucc project is about to integrate science outcomes on global land use change (Focus 1) with those on global land cover dynamics (Focus 2), and shall be able soon to provide the modelling (Focus 3) and the wider science community with quantitative, spatially explicit data for scenario development. The concept of land-use transitions is being developed to support such scenario development. Furthermore, the work of meta-analysing causal synergies and synthesising rates of change is crucial for the next decade of integrated land change research (Ojima et al. 2002; Turner 2002; Moran 2003).

Until completion of the Lucc project in October 2005, two more meta-analyses will be designed under Focus 1, in order to have comparative case study information (i) on the rates and

causes of urban land cover change (urbanisation), and (ii) on the vulnerability of people and ecosystems to land use-driven environmental change. The NASA Land Cover Land Use Change (LCLUC) program and the LUCC project agreed to start an annual international colloquium series on land change issues, with particular emphasis on remote sensing (RS) and GIS capabilities and the interactions between humans and ecosystems ('land use in coastal zones', 2003). The initiative can help to deepen and further advance the understanding coming from RS-based LUCC case studies, and to fill gaps in recently identified land-cover modification studies such as desertification (topic suggested to be dealt with in 2004), thus contributing to LUCC synthesis. Similarly, a series of workshops at the 3rd IGBP Congress in Banff, Canada (19-24 June 2003) can contribute to LUCC synthesis and also push development of research within the LAND project. For the purpose of integrating the synthesis of results from meta-analyses on causes of land-use change with rates of land-use and land-cover change into modelling, a focussed workshop on modelling synthesis is planned to be organized under the new Focus 3 Office at Wageningen University, once the supportive infrastructure has been built up in 2003. As a further step in modelling, additional efforts will be started for a new generation of regional and global land-use change scenarios. The development of the concept of land-use transitions as an integrative framework will be continued so as to support empirically informed scenario development.

Notes & acknowledgements

This text is an extended version of the IHDP newsletter article 'LUCC - Meta-analyses of the causes, synthesis of the rates' by H. Geist, E. Lepers, W. McConnell, E. Lambin, and N. Ramankutty (Update, 4/02) – see www.ihdp.uni-bonn.de for a version to be downloaded. It also draws from the editorial of LUCC newsletter No. 8, written by E.F. Lambin ('New global-scale datasets on land-use/cover change'). I wish to thank NASA for taking over travel and accomodation costs for attending a later-on workshop in Washington, D.C., which made possible my participation in the Science Team Meeting just next door.

References

Achard, F., Eva, H.D., Stibig, H.-J., Mayaux, P., Gallego, J., Richards, T. and Malingreau, J.-P. (2002) Determination of Deforestation Rates of the World's Humid Tropical Forests. *Science*. Vol. 297: 999-1002.

Cervigni, R. (2001): *Biodiversity in the Balance – Land Use, National Development and Global Welfare*. – Edward Elgar: Cheltenham, UK, Northampton, MA, USA, 271 pp.

DeFries, R. and Achard, F. (2002): New estimates of tropical deforestation and terrestrial carbon fluxes – Results of two complementary studies. – LUCC Newsletter No. 8, pp. 7-9.

Fox, J., Rindfuss, R.R., Walsh, S.J. and Mishra, V. (eds) (2002) *People and the environment: Approaches for linking household and community surveys to remote sensing and GIS*. Kluwer Academic Publishers: Boston, Dordrecht, 344 pp.

Geist, H.J.(2002): The Land-Use and Land-Cover Change (LUCC) project. – in: A. Badran et al. (eds): *The Encyclopedia of Life Support Systems Vol. 5: Global Sustainable Development - Land Use and Land Cover*. – UNESCO-EOLSS Publishers: CD-ROM & URL: www.eolss.com

Geist, H.J. and Lambin, E.F. (2002) Proximate causes and underlying driving forces of tropical deforestation. *BioScience*. Vol. 52 (2), pp. 143-150.

Geist HJ, Lambin EF 2003. Proximate causes, underlying driving forces, and systems properties of desertification, *in preparation*.

Klein Goldewijk, K. and Ramankutty, N. (2003): Land Cover Change over the Last Three Centuries Due to Human Activities – Assessing the Differences Between Two New Global Data Sets. *GeoJournal, in press.*

Lambin, E.F. (2002): ‘Linking causes, drivers and pathways with rates and patterns of land change’. – *LUCC Newsletter*, No. 8, p. 16.

Lambin, E.F. and Geist, H.J. (2001): Global land-use/land-cover changes – What have we learned so far? - *IGBP Global Change Newsletter*. No. 46, pp. 27-30.

Lambin, E.F. and Geist, H.J. (2003): The land managers who have lost control of their land use – Implications for Sustainability. - *Journal of Tropical Ecology*. Vol. 19, *accepted.*

Lambin, E.F., Turner, B.L.II, Geist, H.J., Agbola, S., 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.D., Svedin, U., Veldkamp, T., 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*. Vol. 11 (4): 261-269.

Lavorel, S., Flanningan, M., Lambin, E.F. and Scholes, M. (2003): Regional vulnerability to fire - Feedbacks, nonlinearities, and interactions. - *Science, accepted.*

Leemans, R., Lambin, E.F., McCalla, A., Nelson, J., Watson, B. and Zurek, M. (2003): Drivers that determine changes in ecosystems and ecosystem services. Conceptual Framework Report, Millenium Ecosystem Assessment.

Lepers, E. (2002): Millenium Ecosystem Assessment – Synthesis of knowledge of rapid land-cover and land-use change. – *LUCC Newsletter* No. 8, pp. 2-3:

Mayaux, P., Bartholome, E., Massart, M. and Belward, A.S. (2002): The land cover of Africa for the year 2000. – *LUCC Newsletter* No. 8, pp. 4-6.

McConnell, W. and Keys, E. (2003): Meta-analysis of agricultural change. – In: Moran, E. (ed): *Seeing the Forest and the Trees - Human-Environment Interactions in Forest Ecosystems, in preparation.*

Moran, E.F. (2003): Progress in the Last Ten Years in the Study of Land Use/Cover change and the Outlook for the Next Decade. In: Diekmann, A., Dietz, T., Jaeger, C.C. and Rosa, E.A. (eds) *Studying the Human Dimensions of Global Environmental Change*. MIT Press: Cambridge, MA, *in press.*

Ojima D, Lavorel S, Graumlich L, Moran E 2002. Terrestrial human-environment systems: The future of land research in IGBP II. *IGBP Global Change Newsletter*. No. 50, pp.31-34.

Parker, D.C., Manson, S.M., Janssen, M.A., Hoffmann, M.J., Deadman, P. (2003): Multi-Agent System Models for the Simulation of Land-Use and Land-Cover Change: A Review. – *Annals of the Association of American Geographers*. Vol. 93 (2), *in press.*

Ramankutty, N., Goldewijk, K.K., Leemans, R., Foley, J. and Oldfield, F. (2001): Land cover change over the last three centuries due to human activities. - *IGBP Global Change Newsletter*. No. 47, pp.17-19.

Ramankutty, N., Foley, J.A. and Olejniczak, N.J. (2002) People on the land: Changes in global population and croplands during the 20th century. – *Ambio*. Vol. 31(3): 251-257.

Reynolds, J., Stafford Smith, M. (eds) (2002) Global desertification: Do humans create deserts? (= Dahlem Workshop Report No. 88). Dahlem University Press: Berlin, 438 pp.

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. In: Steffen, W., Jäger, J., Carson, D.J. and Bradshaw, C. (eds) Challenges of a Changing Earth. Proceedings of the Global Change Open Science Conference, Amsterdam, The Netherlands, 10-13 July 2001. Springer: Berlin, et al., pp. 21-26.

Veldkamp, A. and Lambin, E. (eds) (2001): Predicting land-use change. - Agriculture, Ecosystems & Environment. Vol. 85 (1-3).