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Comparative Model Evaluation in LUCC Research

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Abstract

Capable approaches to assess the likely future of lands on various spatial scales, from global to local are required. The aim of integration was formulated 10 years ago in the LUCC Science Plan. An effort was made to structure 30 land use and land cover change models many out of them originating from Asia according to their spatial and temporal range as a first attempt to structure individual models or case studies. A simple scale time matrix proposed 9 classes from long range and long term to short range and short term. Models within the same classes are considered for comparative studies and thereby provide more information than for the purpose they were written for. However, when coming to the more detailed level, even "near" models from time scale evaluation are far away from to be integrated. They are separated and LUCC community should develop simple modelling standards to make case studies comparable to each other in the future.

Introduction

Climate change, food production, health, urbanisation, coastal zone management, transboundary migration, and availability and quality of water are addressed in the research of the Land Use and Cover Change Program (LUCC) a partial program within

the International Geosphere Biosphere Program (IGBP) and the International Human Dimension Program (IHDP). Their impacts on the quality of human life are investigated. LUCC studies time and space dynamics of land-use and land-cover changes. An effort is made to define sustainability in relation to various land uses. Some projects aim to understand the interrelationship between LUCC, biogeochemistry and climate, while other projects explore the opinions of decision makers in LUCC. LUCC established three research foci to address these questions: Focus 1 Land-Use Dynamics, is a comparative case study approach aimed at improving our understanding of variations in the nature-society dynamics of land management. Focus 2 Land-Cover Dynamics, involves regional assessments of land-cover change as determined from direct observation (e.g., satellite imagery and field studies) and models built from these observations. Focus 3 Regional and Global Models, aims to improve upon existing models and build new ones, and to integrate a variety of approaches while strengthening agricultural sector models by including water, urban, biophysical, and other such linkages, and coupling these models to forest/timber and livestock sector models. Global, regional and local changes have to be considered in a combined effort.

In the following we bring forward a position deriving from a highly developed, rich country, namely Japan, including various experiences from case studies in developing countries and we make even use from previous evaluations of models in LUCC program.

Global Scale Issues

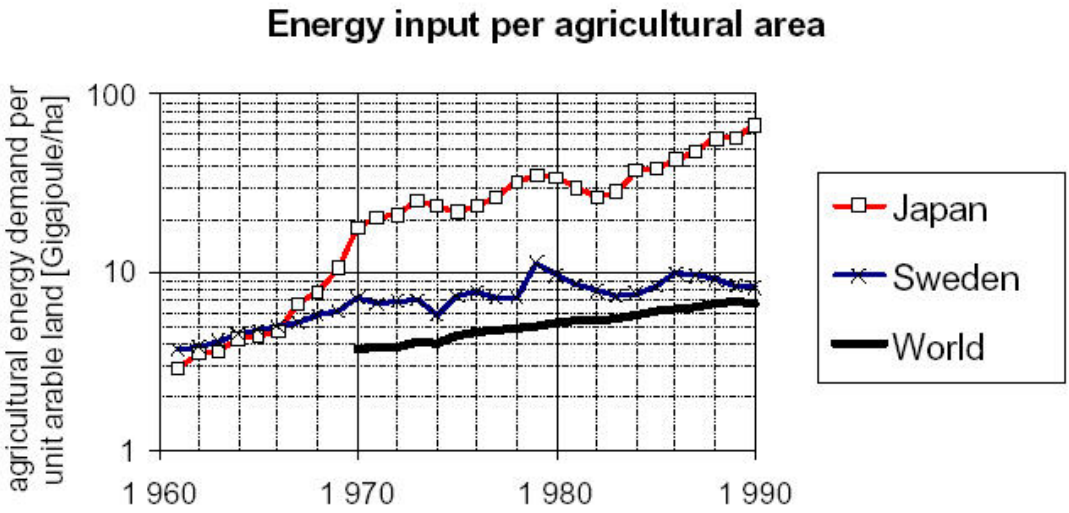
Some of the major challenges are still in place, despite the many efforts to cope with: resource consumption and population growth. Today a population of 6.2 billion people (US Bureau of census 2001) cultivates 700 million hectares of cereal land. An expected increase of global population to 10 billion and more will result in a major intensification in agricultural land uses with a multiplication of current input levels. Development, or, more broadly, modernisation, is changing the structure of economies and settlement particularly in the developing world. An increasingly significant proportion of land-use and land-cover change is a result of urban demands for agricultural or forest products rather than rural subsistence needs. Some 25% of the world's population were until recently engaged in peasant agriculture (Cancian 1989), covering a significant proportion of the earth's land surface. On the other hand, 44% of the world's population lived in an urban setting in 1990 compared with 34% in 1960 (Simpson 1993). By 2025 some 60%,

and by 2050, some 75% of the developing world's population is likely to be urbanised. The share of population practicing agriculture will be very low then. The loss of arable land is likely to be compensated by the deforestation of tropical forests. Recent estimates propose, that some 60 million hectares will be converted in the next 30 years from cropland to urban land. This in turn will require another conversion of 100 to 200 million of forest and pasture land to cropland in marginally suitable areas (Döös 2002). The reduction of labour force is likely to result in a higher resource demand and an increased rate of greenhouse gas emissions. The recent development in agriculture of Japan could itself become a model for the world.

National Scale Issues

In the case of Japan the development goes towards rural depopulation. The number of farm households diminished from 6 million in 1960 to 3 million in 2002. (Statistical Handbook of Japan 2003). Only three out of four farms were also selling products to the market. In total agriculture contributes no more than 20% of the total household income and this despite heavy subsidies to agriculture. The pattern of life style changed within farm households: the age group of people under 30 years in agricultural households has sharply dropped and is today close to zero. In Japan, agriculture is predominantly female, having a share of 60% of people working in agriculture. Most men in working age try to get jobs and income outside agriculture. Modern agriculture is highly dependent on resource inputs, which are not sustainable in the long run.

Figure 1:



Source: G. Ahamer (1995), Global Change Database

Figure 1 indicates the change within one category of land use based on the energy required on one ha agricultural land in Japan, in Sweden and in the World. While a rice field may look similar in shape and form to the one decades ago, the resource use accompanied with it changed drastically. In particular due to agricultural machinery, the use of fertilizers and pesticides the situation changed from low input cultivation to high input cultivation. In three decades the energy demand increased in Japan from 3 GJ per hectare to 70 GJ per hectare. Every 10 years the energy demand increased 3 times, while it increased only by 1.5 times on the global scale and 1.3 times in the case of Sweden. If Japan should become a model for China or Indonesia, major changes in the overall condition of global environment have to be expected.

Local scale

On the more local scale, we would like to bring an example representative for entire Japan what concerns the retreat of human beings from remote areas. The example is the village Kamiseya in Kyoto prefecture situated in the mountains bordering to the Japan seaside. Kamiseya is one of the 140,000 Japanese smaller scale administrative units and it covers a few square kilometres. From some 300 people living there in 1960, some 30 still live in the village. Depending on the age of population one can anticipate, when the village will disappear and how much land will by then be out of control.

The change during 1970 and 1995 was described recently (Fukamachi et al. 2002). Resource use and machinery input in modern agriculture made it considerably easier to cultivate the land. But certain uses ad the edge of profitability disappeared. Forest use is one of them. Previously the forest was the source of energy and nutrition for cultivated plants. Today the variety of different plants got lost as the cultivation work necessary for particular ecological conditions got lost. Forest work in steep terrain is not suitable for the aged farmers. The younger generation that could manage the land, but lives several hours away in the cities and hardly finds incentives to return. The question arises, if agriculture and forestry is likely to disappear and what happens thereafter.

LUCC Research

LUCC's interdisciplinary research agenda is implemented through case studies, development of models and integrative analyses.

The LUCC Science Plan calls for a set of integrative research foci to improve understanding of: (i) the driving forces (exogenous variables) of land use change and the role of land managers; (ii) the land-cover implications of land use; (iii) the spatial and temporal variability in land-use/cover dynamics; and (iv) nesting of local models in regional and global models and up scaling of local models to larger scales with projections of land-use/cover change. A true interdisciplinary approach was considered to retain all aspects.

Selection of case studies

We employ 2 recent reviews of LUCC models by Parker et al. (2002) and Verburg et al. (2002) and introduced several other models, some of them related to our own work or from colleagues and co-researchers which we considered to be part of LUCC framework. In total we had 30 models/case studies at our availability and the selection does not cover the whole range of LUCC research, which we consider to be even larger. We assume nevertheless that these models are somehow representative and suited for an evaluation. From the first glance it seemed to be difficult to compare the models as they were isolated and some of them were included as LUCC project after they were finished and not before. So we had first to orientate on a minimum requirement out of the four conditions described in the science plan and later on we wanted to go further in depth. We choose to evaluate them from the spatial and temporal variability. If the temporal or spatial patterns of models do not fit, it will be difficult or impossible to transfer the approaches and methods between each other.

Each model was designed for a particular purpose. In a closer analysis it became obvious, that some of the aims described in the LUCC science plan and related to the integration of various models, could not be completely achieved. Each of the 30 studies was concentrating on the inner logic of the model rather than on the overall aim of the LUCC program to become interchangeable and highly integrative with other models.

Another reason for coming up with an evaluating structure for classes is that the amount of models and case studies in LUCC community is expected to grow and a more specific search according to scale and time is wanted to filter out just suitable models.

Table 1: Overview of case studies and models

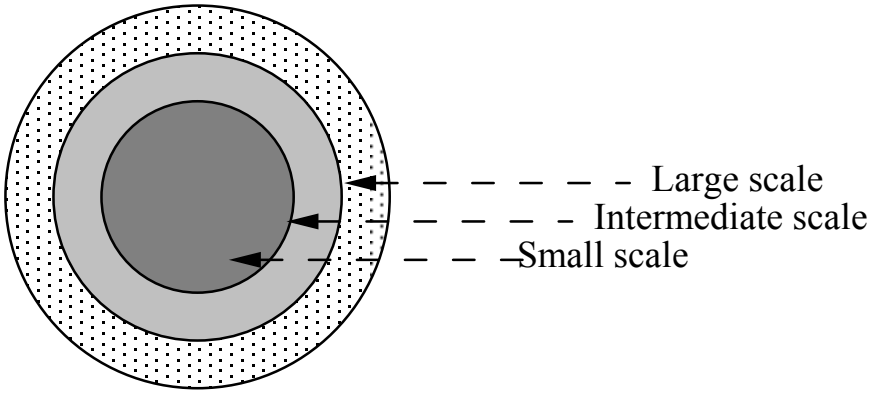
	Publication	Model
1	Balmann(1997) Balmann et al (2002)	Cellular Automata Model applied in Hohenlohe
2	Breiling (1993)	Statistical models, multiple regression analysis
3	Benoit Mertens and Eric F. Lambin (2000)	Logistic Multiple Regression Model
4	Berger (2001)	Multiple Agent Modeling Applied to Agro-Ecological Development
5	Berger(http://www.csiss.org/events/other/agent-based/papers/berger.pdf)	Multiple Agent Modeling Applied to Agro-Ecological Development
6	Clarke and Gaydos (1998)	Urban Growth Model (UGM)
7	d'Aquino et al	The SelfCormas Experiment
8	Deadman et al. (2001)	LUCITA
9	Dean et al. (2000)	Agent-based Model
10	Engelen and others (1999)	GEONAMICA
11	Fischer and Sun (2001)	IIASA-LUC
12	Fukamachi et al. (2002)	Statistical models, cluster analysis
13	Hoffmann et al. (2002)	Agent-based Model applied in Indiana
14	Hua (2001)	CA Model with AHP-Derived Transition Rules
15	Huigen （1997）	MameLuke
16	Kohler et al. （2000）	Agent-based Model applied in Mesa Verde
17	Ligtenberg et al. (2001)	Multi-actor-based land use modelling
18	Lim et al. (2001)	Agent-based Model of Household Decision Making
19	Lynam (2002)	Multi-Agent Model by Lynam
20	Manson (2000)	SYPR (Southern Yucatán Peninsular Region)
21	Parker et al. (2001)	LUCIM
22	Polhill et al. (2001)	FEARLUS
23	Rajan and Shibasaki (2000)	AGENT-LUC
24	Rouchier et al. (2001)	Multi-Agent Model by Rouchier
25	Sanders et al. (1997)	SIMPOP Multi Agent Model
26	Sato and Li (2002)	Diffusion-based model
27	Torrens (2002)	SprawlSim
28	Veldkamp, Verburg and others (1996)	CLUE
29	Veldkamp, Verburg and others (1997)	CLUE-s
30	Wada (2002)	ABM for Luangprabang

*Source: Partly Arranged from Parker et al. (2003), and Parker et al. (2001)

Scale and time evaluation of models/case studies

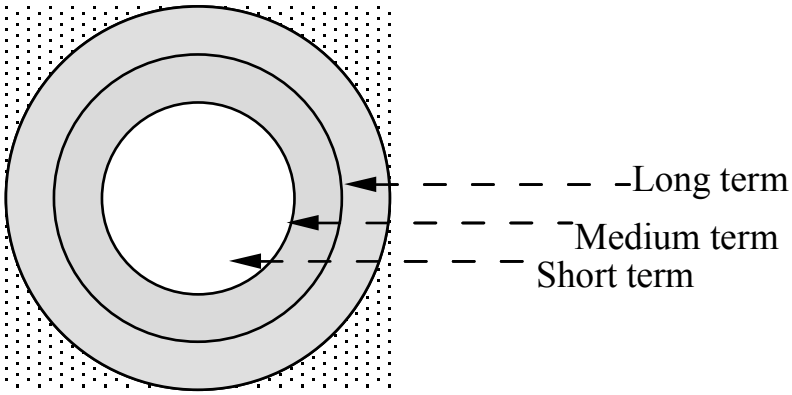
Considering scale and time, we find many terms referring to regional or local, but they differ according to the understanding of the author. In a first approximation, we evaluate scale and time just in a very rough way with larger, intermediate and smaller scales.

Figure 2: Spatial understanding of LUCC models



In figure 1, we assume three spatial scales of relevance, large scale which refers to regions of the world covering 100,000 km² or more, intermediate scale = national scale analysis or larger regions covering the range of 100,000km² to 1,000 km², and small scale referring to less than 1,000 km². We can call the large scale global, the intermediate scale regional and the small scale the local scale according to the borders we set. In our evaluation the scale refers to the largest extension of the model or case study, which will be subdivided into more hierarchies and units. At this point we disregard the endogenous spatial structure of the models.

Figure 3: Process understanding LUCC models

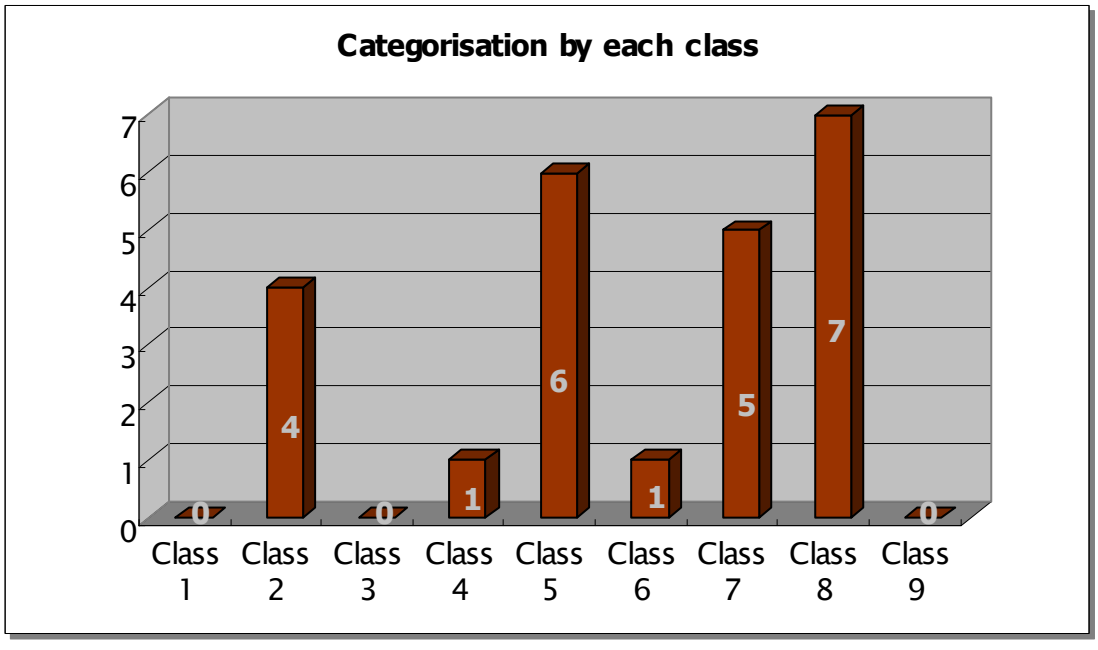


Second component is time. As long time horizon we propose 50 years. A medium time horizon will look 10 to 50 years ahead and short time planning will cover 10 years or less and come quite close to a "usual" time understanding urban and regional scale planning. Analogue to spatial scales, these borders were chosen by us and include the entire reference period. Any model will divide the overall period into sub-periods, depending on the collection of data and monitoring of the factors involved. This will define the operational frequency of a model. At this point we disregard the endogenous temporal structure of the models.

Table 2: Spatial Scale & Time Scale Evaluation for LUCC models

	Long term (longer than 50 years)	**Mid term** (10–50 years)	**Short term** (shorter than 10 years)
	Class 1	5,11,23,28 Class 2	Class 3
	27 Class 4	3,8,14,20,28,30 Class 5	7 Class 6
	2,6,15,21,22 Class 7	4,10,11,17,25,26,29 Class 8	Class 9

Figure 4: Categorisation by Each Class



We found a concentration of models in certain classes, while some classes like long term and large scale had no hits. Out of 9 classes four classes appear frequently, while other combinations seemed less popular.

Assuming the amount of case studies will further increase in the future, only the relevant LUCC models regarding their spatial and temporal characteristics will be considered. This will help newcomers in LUCC research to develop their own strategies, based on a few selected models, which fit to their range of interest. Even though the individual approaches might still not precisely match the scale and time, they are much closer to each other than of any other group.

Conclusion:

LUCC program became a global platform for individual case studies of land-use and land-cover change. The necessity to explore land-use and land-cover change phenomena is widely recognised.

The LUCC science plan was overoptimistic with its goals: The level of possible integration between individual models remains limited. The simple scale time evaluation can already give some explanation why this is the case without going into details with driving forces.

Beside a LUCC strategy, a simple modelling standard should be defined if we really want to compare models. Easiest: the same period and a similar size of territory should be compared. If this works the standard can be gradually become less scarce.

Having such a standard, the amount of models/case studies - in particular from developing countries where we have fewer models - will become more useful. For now the mentioned examples remain isolated what concerns modelling.

The period of 300 years or even 150 years once considered as favourable from LUCC researchers is too long and does not match the period in models we evaluated. In particular when concerns developing countries a shorter time period is desirable as it might be difficult to get information going back 50 years or more.

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