Modelling land use change and environmental impact

Abstract

Land use change models are tools for understanding and explaining the causes and consequences of land use dynamics. Recently, new models, combining knowledge and tools from biophysical and socio-economic sciences, have become available. This has resulted in spatially explicit models focussed on patterns of change as well as agent-based models focused on the underlying decision processes. These developments improve the use of land use change models in environmental impact studies. This special issue documents these developments: (i) analysing the system properties in a biophysical and socio-economic context at multiple scales; (ii) integrating spatially explicit land use change models in integrated assessment models; (iii) visualising and quantifying the potential effects of land use change in trade-off curves, to support land users and policy makers in their decisions; and (iv) modelling of the actual decision making process with agent-based modelling. A new promising future development is the incorporation of dynamic feedbacks between changing land use and changing environmental conditions and vice versa. Unfortunately such dynamic feedbacks between the socio-economic and biophysical model components are still not or only partially operational in current models and are therefore the most important challenge for land use and environmental modellers.

Keywords: Land use change modelling; Environmental impact; Agent-based models; Decision making processes; Coupled systems

1. Introduction

Land use change is driven by the interaction in space and time between biophysical and human dimensions. The potential large impact of land use/cover change on the physical and social environment has stimulated research in the understanding of land use change and its main causes and effects. Land use change models are tools for understanding the causes and consequences of land use dynamics. Scenario analysis with land use models can support land use planning and policy (Veldkamp and Lambin, 2001). The LUCC project of the International Geosphere–Biosphere Programme (IBGP) and the International Human Dimensions Programme on Global Environmental Change (IHDP) aims at stimulating and coordinating research on land use change (Lambin et al., 1999; Turner et al., 1995). In April 2003 a conference ‘Framing Land Use Dynamics’ was held at Utrecht University, Utrecht (the Netherlands) where the LUCC focus-3 office (regional and global land use/cover change modelling, http://www.lucc.nl/) organised nine conference sessions. The papers in this special issue are selected contributions with relevance for land use change modelling and environmental impact. Papers with emphasis on new spatial modelling techniques were published in a separate special issue (Verburg and Veldkamp, 2004).
Recently land use change models have been developed to simulate the behaviour of individuals and the up-scaling of this behaviour, in order to relate it to changes in the land pattern (Berger, 2001; Parker et al., 2003). Multi-agent models simulate decision-making by individual agents of land use change explicitly addressing interactions among individuals (Bousquet et al., 1998; Barreteau and Bousquet, 2000). The explicit attention for interactions between agents makes it possible for this type of models to simulate emergent properties of systems. If the decision rules of the agents are set such that they sufficiently look like human decision-making they can simulate behaviour at the meso-level of social organisation, i.e. the behaviour of in-homogeneous groups of actors. This special issue demonstrates the current progress of several multi-agent models (Huigen, 2004; Evans and Kelley, 2004; Ligtenberg et al., 2004). Most current models are only able to simulate very simplified, hypothetical landscapes, as the number of interacting agents and variety of factors that need to be taken into account, is still too large to make comprehensive models (Parker et al., 2003). The papers in this issue demonstrate that realistic applications of multi-agent model are starting to develop. Especially model validation of agent-based models is still a largely unexplored terrain of research. Some first attempts for agent-based and empirical approaches are presented by Evans and Kelley (2004).

3. Environmental impact modelling with land use change models

Land use change models are often used as inputs in environmental impact studies. Most commonly the changing land use is used as an input of a model to calculate environmental process impacts such as pollution, emissions, erosion, etc. (King et al., 1989). The problem with such assessments is they are often mono-disciplinary, static and present only a limited number of alternatives. Furthermore, the time horizon is usually fixed and the long-term dynamics of human-environmental systems are ignored.

This special issue demonstrates four developments that can lead to improved human-environmental impact assessments.

(1) Analysing the system properties in a biophysical and socio-economic context at multiple scales (Kok, 2004; Aspinall, 2004).

(2) Integrating spatially explicit land use change models in integrated assessment models (de Nijs, et al., 2004; Solecki and Oliveri, 2004).

(3) Visualisation and quantification of the effects of land use change in trade-off curves, to support land users and policy makers in their decisions (Stoorvogel et al., 2004).

(4) Modelling of the actual decision making process with agent-based modelling (Evans and Kelley, 2004; Huigen, 2004; Ligtenberg et al., 2004).

A fifth almost unexplored possibility is to incorporate dynamic feedbacks between changing land use and changing environment and vice versa. Such dynamic feedbacks between the social and biophysical model components are still rare. Some first experiments have been made where different rates of change in land use have different biophysical impacts and feedbacks (Schoorl and Veldkamp, 2001; Ducrot et al., 2004). The need for this coupling is clear and links between (micro to macro) agent-based and (macro to micro) empirical models are needed (Verburg et al., 2004). This will hopefully lead to more dynamic scenarios that facilitate the identification of mechanisms for better governance and decision-making.

4. Future developments

A different way to allow dynamic coupling between land use and environmental systems is proposed in the science plan of the Global Land Project (Ojima and Moran, 2004). Here it is proposed to develop novel dynamic scenarios tools that allow changing boundary conditions during model simulation instead of fixed often-constant assumptions. Apart from a focus on land use patterns of change there is a shift towards a focus on the actual land use decision making processes itself as addressed in agent-based modelling. This will require future efforts to validate not only patterns and quantities of change but also the change of the agent behaviour. The possibilities and limitations of such an approach remains to be explored. We think that the methods described in this special issue have the potential to significantly contribute to the coming Global Land Project.

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