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Advancing the Representation of Human Dimensions in Large-scale Land Use Models

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Summary

In most of the current large-scale land use models, different dimensions of human land use are represented in a too simplified way. This is problematic because, today, humans are the most dominant driver of environmental change.

Research challenges

The goal of this thesis is to contribute to advancing the representation of human dimensions in large-scale land use models. Large-scale land use models are geographical, computational models, which simulate the spatial allocation of land use at a geographic extent beyond the local level. This hence includes meso- and macro levels of land use change from e.g. a province to the global level. In particular, this dissertation focused on three aspects of representing human dimensions in large-scale land use models: (1) multi-functionality of land; (2) human decision making; and 3) land use regime shifts. These are shortly described in the following sections.

First, land has multiple functions for humans e.g. production of food, fiber and fuel which are often gained from mosaic landscapes. In models however, the most commonly used spatial data are land cover assessments, which only show the biophysical properties, not the multiple uses and diversity of stakeholders behind the same type of land cover (e.g. forests). We need different approaches and accompanying information to land cover data in order to allow for a representation of the multiple functions and actors related to land.

Second, a key challenge for representing human decisions in large-scale, geographic land use models is the lack of data on both the decisions as well as the context in which these are made. This especially concerns land use

decisions that are related to one another (i.e. series of connected decisions) and land use change phenomena that occur across large spatial extents. New methods are required to collect data and upscale insights on land use decision making embedded in the social, economic and ecological context in which the decisions were made.

Third, Land use regime shifts are abrupt, profound transformations from one enduring land use dynamic to another. There are numerous examples of regime shifts in the past and they are expected to occur in the future, but current land system models face limits in simulating abrupt land use regime shifts.

These three sub-challenges for representing human dimensions in large scale land use models are addressed in this thesis through four studies described in chapters 2-5. Across all studies, two typical large-scale land use change phenomena in Laos are analyzed ranging from the local to the national level: (i) the agrarian transition from shifting cultivation to permanent, commercially oriented agriculture and (ii) sudden outbursts of monocultures i.e. crop booms.

Chapter summaries

Chapter 2 merged land cover data with information from an agricultural census, and an inventory on large-scale land acquisitions. This resulted in a land system classification which characterizes the dominant socio-ecological systems in Laos. By doing so, different types of agriculture, from subsistence and permanent farming of smallholders to different kinds of plantations could be mapped. This was accomplished by a relatively simple method using a heuristic decision tree in a GIS environment, refined with an expert survey to select meaningful threshold combinations. The approach allowed for visualizing and assessing two land systems that are notoriously difficult to map with land cover only: (i) the land use practice of shifting cultivation in which agriculture and forests are intertwined and (ii) large scale land

acquisitions including mining, agricultural, and silvicultural plantations. These forms of land use are typically related to different actor groups, e.g. different types of farmers or commercial stakeholders. Hence the land system classification forms the basis for representing decision making related to the different actor's capacities and goals or the influence on one another when active in the same landscape or region.

In chapter 3, a model application is presented for Laos to explore three scenarios that consider a wide variation in the types of demands that humans exert on land. Through these scenarios, which embody very different visions on what land can provide, the study shows the difference it makes when not only agricultural crops, but also protection of (agro)biodiversity and cultural heritage of a century-old farming practice cultural ecosystem services are considered to be important. The approach addressed methodological challenges in simulating land system regime shifts and complex mosaic landscapes, while accounting for societal demands for multiple types of goods and services from land systems.

Chapter 4 presents an innovative methodology that was developed in collaboration with a research for development project during a 4-months visit to Laos. It is called multi-scale gaming approach and serves to explicitly gain insights into smallholders' land use decision making within their context and scale it up to the regional, emergent level of a large land use change trend (the maize boom). The approach consists of a set of complementary methods and includes a systematic case selection, focus groups, interviews, local serious games with farmers and a metagame that is played with agricultural experts. The metagame is 'a game about the local games.' It synthesizes and scales up knowledge which the research team gained through all earlier steps. By playing the metagame, the insights could be validated by Lao agricultural and land use experts. Along with the contribution of a new methodology, this study simulated the land use regime shift 'maize boom' in the form of an analogue model (the metagame).

Chapter 5 used core insights and data from the multi-scale gaming approach about the emergence of the maize boom. For this study, a new application was set up for the Province Sayaboury with the spatial land system model CLUondo. It served to retrospectively examine and learn about the causes for the maize boom between 2000 and 2016, and, in particular, the clustered location of the boom. This allowed for an exploration of how factors that influence decision making about adopting maize mono-cropping can be represented and analyzed in a large-scale land use model. While crop booms are commonly associated with high commodity prices and improved market accessibility, the simulation results suggested that the combination of the geographic and economic factors we tested partially contribute to explain the location and spatial extent of the maize boom. Yet, a full explanation has not been found. Interestingly though, temporal dynamics, such as increases in land productivity and profitability had the largest effect on model performance regarding the size of the maize boom area. Productivity and profitability increased thanks to political economic support for the introduction of a series of techniques (i.e. hybrid maize cultivars, herbicides, mechanical tillage and sowing). We conclude, that these made maize mono-cropping disproportionately competitive in comparison with other land management options. Chapter 5 addressed all three research challenges. It used land systems to represent multifunctional land uses, included characteristics of human decision making and modelled a land use regime shift.

Key scientific contributions

A number of key insights and novel approaches to land system science emerged from this work. This includes, among others, a novel, yet simple land system classification approach (chapter 2 and 3) to spatially assess the extent of shifting cultivation on the landscape scale (meso-level). Serious games and participatory approaches in general have been acknowledged for their power to elicit context of land use decision making but criticized for their lack of suitability to generalize and scale up this knowledge. The new multi-scale

gaming methodology developed in chapter 4 is a counter example and overcomes this limitation. Chapter 5 showed that there is potential for large improvements with simple means (i.e. low-hanging fruits') during the parameterization phase of land use modelling: human decision making (in the context of the maize boom) is better emulated when the supply side of the model is parameterized based on the profits gained instead of the mass of the harvest (tons of grains). Furthermore, representing the variation of productivity improves model performance by a large degree, which suggests that static representations of productivity or supply at large should be avoided.

Knowledge & tools to support different societal stakeholders

The integrative nature of the analyses may help to inform conversations and actions across the boundaries of sectors, such as conservation and agriculture. It therefore reveals potential for interactions and collaboration. One tool for this could be the national land system classification, which locates different agricultural land systems in relation to conservation areas such as national protected areas (NPA). The maps created in this thesis could be a basis to identify stakeholders of the area and to invite them to a multi-stakeholder dialogue. Scenarios are another tool to stimulate debate across different disciplines by considering not only economic demands for commodities, but also societal demands on the land (e.g. protecting agro-biodiversity and cultural heritage and ecosystem services).

The knowledge gained on the drivers of crop booms may help governmental as well as non-governmental or not for profit organizations related to sustainable land management. It could be used to design holistic interventions based on the systemic understanding gained through multiscale gaming (chapter 4) and the crop boom model (chapter 5). Rapid land degradation and deforestation could be addressed by supporting smallholders not only through finance and knowledge on sustainable land use itself, but by combining this

with financially supporting the farmers in their long-term socio-economic goals and for example the education of their children. The promotion of agro-ecological alternatives to boom crops must be competitive to the dominating cash-crops in terms of profitability, labor and capital efforts. Based on insights in this thesis that imitation behavior is one of the dynamics that let crop booms emerge, a strategy to scale up sustainable land use in the long run could especially support interested pioneers of sustainable land use. These may inspire other farmers to do the same. However, it must be carefully considered whether it is necessary to introduce new technology for land management. While machinery and other means to reduce labour efforts lead to a short-term increase in yield, they can change land system patterns significantly in the long term and – as was the case of tilling – lead to rapid expansion of maize mono-cropping and severe soil erosion. The means of production which often include machinery, chemical inputs and (modified) seed varieties are offered by traders, who also are the market outlets to farmers in Laos. Consequently, traders and their access to farms are factors that play a large role for a crop boom to unfold. Including traders as key stakeholders may be essential in efforts to avoid crop booms. A key reaction on the political and societal level should be to avoid the support of a mono-crop market and, instead, stimulate a diversification of the market for the land systems to be more resilient to crop booms and become (or remain) diverse.

This summary is a highly condensed version of the dissertation. You are invited to explore the introduction, single empirical chapters and synthesis for more in-depth information.