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Chapter 6 | Synthesis

6.1 Introduction

The goal of this dissertation was to contribute to advancing the representation of human dimensions in large-scale land use models. More specifically, it focused on three aspects of this overall challenge including representing the multi-functionality of land, human decision making and land use regime shifts.

The subsequent sections answer the cross-cutting research questions of this dissertation and include reflections on methods and societal impact of this work. Section 6.2.1 elaborates on how human-environment interactions were operationalized by a land system representation in maps and/or models to represent the multiple functions of land. Section 6.2.2 discusses the different pathways used in this dissertation to advance representation of human decision making. Section 6.2.3 shows how different types of models helped to analyze and simulate two different types of land use regime shifts: the agrarian transition from shifting cultivation to commercial agriculture and the maize boom in northern Laos. Section 6.2.4 reflects on synergies and differences between the methods of the research chapters and finally, section 6.2.5 discusses the potential societal impacts of the insights gained within this dissertation.

6.2 Relevance to Research Challenges

6.2.1 Multiple functions of land

Land is an essential source of many benefits to humans as it provides food, fiber, feed, recreation, and many more ecosystem services, often at the same time (Foley et al., 2005). Within scientific analyses the same piece of land often ends up being categorized based on a single category (e.g. either

agriculture or forest), disrespecting the multi-functional character of land (Comber et al., 2008; Wartmann and Purves, 2018). To link ecosystem services with a given land area, characterization of the land plays a crucial role. The first research question of this dissertation addressed this issue by asking: How can the multiple functions of landscapes be represented in land use maps and models? To answer this question, chapters 2, 3 and 5 operationalized the land systems concept as a means to characterize socio-ecological units that are relevant to land use in Laos. Chapter 2 developed a land systems classification for Laos on the national scale, while Chapter 3 integrated this classification into a land systems model to explore scenarios of future land use change. Chapter 5 then harnessed this methodology for a land systems model application addressing the maize boom in Sayaboury province in Laos.

Improving the representation of human activity in land use models starts with making human activities on land visible. Remote sensing derived land cover assessments characterize only the biophysical properties of the surface of the earth (Nachtergaele, 2008). Chapter 2 advanced beyond such physical representations by implementing the land systems concept for Laos, a country that relies to a large degree on types of agricultural land use, such as shifting cultivation or plantations, that cannot be easily characterized based on remote sensing alone. This chapter complemented land cover data with information from an agricultural census and an inventory on large-scale land acquisitions. By doing so, different types of agriculture, from subsistence and permanent farming of smallholders to plantations of different kind could be mapped using a heuristic decision tree in a GIS environment, refined with an expert survey to select meaningful threshold combinations. This land systems approach resulted in a nuanced picture with agricultural mosaics, different degrees of forest cover and large-scale land acquisitions mapped within one assessment. The national scale land systems classification depicts a diversity of land functions. Shifting cultivation for example, is a land use that serves to produce upland rice and other crops, but also as feeding area for livestock, hunting and

gathering of several additions to diet and medicine. While land system classifications have been developed before (Ellis and Ramankutty, 2008; Václavík et al., 2013; Van Asselen and Verburg, 2012), these were mostly designed for the global scale, where semantics of agriculture and forest differ substantially from types of agricultural and forest land use meaningful to single countries.

Governmental institutions are levels of human organization that significantly characterize a social-ecological system through policies and planning as these institutions determine who may use the land how (McGinnis and Ostrom, 2014; Moran, 2010b; Sternlieb et al., 2013). In Laos, a national scale land system classification allowed to distinguish very different types of land systems than possible with data and analyses on global scale. The resulting classification of chapter 2 may therefore be closer to the semantic (understanding) of agricultural realities which the government has to consider such as shifting cultivation and large-scale land acquisitions in the case of Laos.

Classic land use studies that employ spatially explicit, geographic models mainly explore economic questions on how and where the demands for commodities (food, timber) can be supplied by land (Heistermann et al., 2006). In chapter 3, a model application was built for Laos to explore three scenarios that consider a wider variation in the types of demands on the land. Through these scenarios that embody very different visions on what land can provide, this study showed the difference it makes when not only agricultural crops but also protection of (agro)biodiversity and cultural ecosystem services are considered to be important. The scenarios indicate how different ways of accounting for multiple functions of land can either lead to more multifunctional land use futures or a stronger separation of functions to different areas.

A further nuancing in the use of land for agriculture was made in chapter 5. To characterize the dynamics of a boom crop it was vital to have spatial data on the location and distribution of two major agricultural land uses – shifting cultivation (rotational cropping) before the boom and maize mono-cropping during the boom. While both land uses contain arable land in terms of land cover, they represent very different land systems. The cultivation practices, capital investment and potential benefits are very different in terms of the impacts on the environment and the socio-economic system, depending on whether farmers produce mainly for themselves or for the market (Cramb et al., 2015; Rigg, 2005; Thongmanivong et al., 2009). If only spatial assessments of arable land or agricultural land would have been used, it would not have been possible to meaningfully represent the boom crop, that brought about a transformation of the socio-ecological system, i.e. a land use regime shift.

6.2.2 Human decision making

Representing human decision making within large-scale models of land use is related with a series of interconnected challenges that includes issues of theory integration between natural and social sciences and the lack of data to specify human decision making at the extent of large regions up to the global level (Müller-Hansen et al., 2017; Rounsevell et al., 2014). Methods are needed that allow to collect data and gain insights on decision making within the immediate social-ecological contexts. Consequently, the second, cross-cutting challenge addressed in this dissertation refers to the question: How can human decision making on land use be represented, analyzed and scaled up in its social-ecological context? Different insights into this question are provided by chapter 2, 4 and 5. Chapter 2 mapped land systems with related key land use actors in Laos, while chapter 4 developed a methodology to study and scale up understanding of farmer's decision making which in turn was the basis for the land system model of chapter 5.

The national scale land system classification of chapter 2 and chapter 3 provide a spatial node to represent decision making. While it does not characterize land use decision making per se, it shows where different kinds of actors influence the land use. This is an entry point to explore contexts of human decision making by reflecting ‘which actor group is prevalent in the area and in which geographic context’? The land systems identified in chapter 2 represent a range of actors and roles; from shifting cultivators and farmers practicing permanent agriculture to large agribusinesses or institutions that manage protected forest areas. Each of them have different capacities, agendas, natural capital and follow different land use practices. The land system classification consequently represented a variety of decision makers within the context of the landscapes they enact their decisions in.

Chapter 4, in turn, presents a methodology to explicitly gain insights into land use decision making. It is called multi-scale gaming approach and designed for exploring local and individual contexts of a series of land use decisions and scaling main findings up to the regional level. The multi-scale gaming approach is 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’ and synthesizes knowledge which the research team gained through all earlier steps. On the one hand, the multi-scale gaming methodology helps to collect data during focus group discussions and individual interviews about specific land use decisions such as the amount of land allocated for maize cropping in a certain year. On the other hand, the building and facilitation of local game and metagame allows to operationalize and test frameworks or hypotheses about land use decision making. For example, a combination of six factors was tested and validated by agricultural experts during a workshop session of the metagame about the maize boom. As such, the multi-scale gaming methodology is a way to both collect data and start the building of frameworks and theory about the socio-ecological feedback mechanisms that are part of a specific land use change process.

Further modeling approaches can build on both the conceptual framework and the parameters gained through this methodology. There is a variety of ways to empirically parameterize agent based land use models and they all have their advantages and disadvantages (Robinson et al., 2007). Serious games and participatory approaches at large have been acknowledged for their power to elicit context and tacit knowledge but criticized for their lack of suitability to generalize and scale up knowledge on decision making (Robinson et al., 2007; Rounsevell et al., 2014). The multi-scale gaming methodology developed in chapter 4 provides an approach to overcome this limitation.

Chapter 5 used knowledge and data from chapter 4 about the emergence of the maize boom. This allowed to explore how factors that influence decision making to adopt maize mono-cropping can be represented and analyzed in a large-scale land use model. The spatial land system model approach tested the role of factors influencing farmer's decisions, such as the availability of a market outlet i.e. an offer by a trader. On top of that, possible impacts of further factors such as technological developments were represented by simulating the increase and decrease of yields. Experiments within this modelling exercise indicated that considering characteristics of human decision making in the parameterization stage of modelling contributes to improving model performance. In a land use change process like the maize boom commercial objectives of actors involved dominate. Therefore, parameterizing the supply side of the model based on the profits gained more closely mimics human decision making than using the mass of the harvest (tons of grains) as a factor influencing adoption or expansion of a crop. Furthermore, representing the variation of productivity improves model performance by a large degree, suggesting that static representations should be avoided.

6.2.3 Land Use Regime Shifts

Land use regime shifts are an emerging concept in land system science which suggests that abrupt, non-linear transitions from one land system to another

occur when internal tipping points are reached or external shocks affect the system (Müller et al., 2014; Ramankutty and Coomes, 2016). Typical land use regime shifts of Southeast Asia are transitions from subsistence oriented to market oriented regimes as for example in Indonesia, where the onset of oil palm expansion transformed the land systems run by smallholders into partially commercialized systems (Müller et al., 2014). However, due to the difficulty in predicting such shifts, they are hardly included when modelling land use, and this has implications for environmental governance programs, such as REDD, whose assumptions are based on trends in business-as-usual scenarios (Müller et al., 2014). According to Ramankutty and Coomes (2016), anticipating land use regime shifts is an important role of land system science that requires several efforts. They suggest a research agenda that supports modelling future regime shifts by developing databases with empirical knowledge on past regime shifts, an improved theoretical framework and exploration of regime shifts on multiple scales (Ramankutty and Coomes, 2016). The research conducted in this dissertation contributes to this agenda and explored the question: How can models represent and help to understand land use regime-shifts?

Three chapters of this dissertation look at land use regime shifts from different angles and at different spatial levels and extents. Chapter 3 explored land use regime shifts at the national level for a set of (fictive) shifts of political priorities. Chapter 4 explored the individual level decision making within the maize boom, one of the prominent land use regime shifts in Laos. Chapter 5 tested this knowledge on individual decision making and wider geographic and economic factors at a provincial extent. All of these chapters used models of a different nature to study land use regime shifts – from digital simulation models to analogue serious games, and from scenarios about the future to learning about the past.

Chapter 3 tackled regime shifts, by sketching three different development options for political, social or economic priority setting in order to see, in how far these would shift land use patterns on the national scale in Laos.

The first scenario continued the trend of the last two decades where short-term economic growth is prioritized and integration with international and regional markets is aimed for. This TREND scenario simulated the land use consequences of the assumed steadily growing demands for built-up area, staple crops and cash crops.

The second scenario, called ASEAN, envisions maximum priority of opening up to international development agendas. This implies, that Laos would take the international demand for protection of biodiversity into account besides a strong commitment to respond to market demands for cash crop production, not only by smallholders but also by international investors.

The third scenario, called GREEN, steered towards long-term socio-economic growth and more concern for a domestic 'green growth' or sustainable development agenda. This included a higher significance of demands for staple crops to ensure food security. Furthermore, it considered not only interest in biodiversity protection but also the local agro-biodiversity and cultural ecosystem services of traditional landscapes and mosaics. All three scenarios assumed an effective (perfect) implementation of forest conservation within the boundaries of protected areas. The results of the model simulations suggested that all three scenarios arrive at land use patterns that are very different from the initial year and agricultural use expanded and intensified in different ways. These trajectories lead to new regimes of land use.

For example, the ASEAN scenario exhibits a strong separation of dense forest land systems and intensive agricultural land systems by large agribusinesses (plantations), particularly in the South of the country. Smallholder farming is

almost entirely dedicated to permanent cultivation and overall, diversity of land use is reduced.

In contrast, the GREEN scenario expands agricultural activities not only through plantations. Diversity is higher and particularly permanent-cultivation-mosaics occur more often than in the other scenarios. The exact environmental impacts of each land use, of course, depend on land management practices (irrigation, pesticide use, tilling etc) which are not considered in this modeling exercise. The land system model simulated landscape composition and types of actors with associated capacities and socio-economic consequences that should in the first place be seen descriptive, not necessarily normative.

Chapter 4 studied the maize boom in northern Laos, a specific land use regime shift that was ongoing in different phases at the time of field work. The study yielded methodological contributions, data and a framework rooted in empirical knowledge about this specific case.

The multi-scale gaming methodology is designed on the one hand for exploring and collecting data on micro-level perspectives from within the system by means of the field studies that include focus group, individual interviews and local games. On the other hand, a distilled version of the land use regime shift is modeled by means of building and facilitating a session of the metagame that integrates the different phases of the crop boom. Therefore, the multi-scale gaming approach is one way to understand and model a land use regime shift beyond the context and phase of a certain locality.

To parameterize the local games and metagame, Chapter 4 collected data at village level and individual household level through focus groups and interviews. These datasets served to parameterize also a part of the crop boom model of chapter 5.

The conceptual model underlying the meta-game contributes to theoretical understanding of the maize boom and potentially other crop boom dynamics. While this is not a theory in itself, it is a contribution to theory development and adds an ‘inside perspective of the farmer’s view’ at the microlevel to a phenomenon whose system dynamics have been studied on the macrolevel by other authors, particularly scholars who adopted a political-ecological perspective (Byerlee, 2014; Cramb et al., 2015; Hall, 2011; Mahanty and Milne, 2016).

Chapter 5 tested the factors identified in chapter 4 using a data driven approach and a model to learn about the specific case of the maize boom in Sayaboury province. Testing the effects of the factors involved, deepens our knowledge on past regime shifts, so as to better anticipate future regime shifts and enable governments and other stakeholders to take action in a systemic manner. This way, land use modelling can function as a learning tool, even if it does not (yet) predict crop booms.

6.3 Methodological reflections

Various methodologies were developed and applied as part of this PhD dissertation. This section discusses differences and complementarities of the approaches and how these helped to gain insights on land use patterns and processes in Laos.

A national scale land system classification for Laos was developed in chapter 2 and used to model land system change in chapter 3. An important difference between the classification in both chapters had to be made for analytical reasons. The classification developed in chapter 2 contains the class ‘other land systems’ which essentially represents locations where the agricultural census data suggests permanent agriculture, but, according to an accessibility dataset, these locations are further than 2 hours travelling time away from a

village center. This makes permanent cropping hardly feasible due to the daily effort it would require to cultivate the fields. Occurring far away from settlements rendered the farming style at those locations unlikely. Given that there were no further data to determine the land use at these locations, they indicate uncertainty.

However, in the modelling context of chapter 3 such a category called ‘other land use’ cannot be linked to demands for goods and services. Integrating the accessibility dataset already in the classification would have resulted in circular reasoning in the logistic regressions for the suitability maps because accessibility and population density are important explanatory factors for the spatial distribution of land use. Furthermore, it is hard to meaningfully explain where ‘other’ occurs, because the outcome of interest is too unclear and regression models would not be useful. Hence, while it is important to better represent human dimensions in land use assessments with meaningful categories, there are limitations as to what data can be used within the classification process if the product of this work is harnessed for modelling (Van Asselen and Verburg, 2012). In turn, creating a classification independent from modelling exercises allows to use data that helps to identify the uncertain classes and as such, it is useful for refining the understanding of model uncertainties. The two versions of the land system classifications are complementary in this respect.

The methods and outcomes of chapter 2 (land system classification) and chapter 4 (multi-scale gaming) were designed for very different goals, but together they may be compatible and useful for transdisciplinary work that aims at informing stakeholders about the consequences of different development pathways, change of land management, interventions and investments.

The land system classification has a relatively coarse resolution of 2x2 km and the shape of pixels overruns administrative boundaries, that normally imply

important differences on regulations, tenure and hence contexts for decision making. From a practitioner's point of view working at the local level, the land system classification may therefore be considered irrelevant. A planner, farmer or professional who is working to implement a certain vision on land use, probably would prefer a more 'detailed' map with a fine resolution.

Rightly so, the meso-scale land system classification is not designed to serve detailed planning tasks. Instead, it could help to make various stakeholders, including farmers, think about their landscapes in relation to other parts of the country – and raise their awareness to the trends and integrated dynamics at the landscape or meso-scale. Together with images or videos about other landscapes, it may be worth trying to stimulate discussions about integrated landscape level management such as the relation between upland fields to paddy fields, livestock feeding areas and forests. It could also help to ignite debates about how different parts of the country undergo the agrarian transition in different land use trajectories.

Participatory approaches in turn, can produce very detailed land use maps as successfully demonstrated by the TABI project (<http://www.tabi.la/>). These maps, however, are hardly available at the spatial extent of a whole country. Combining the two approaches could benefit the goals of several projects. Serious games or other participatory methods could help to validate the way land systems are characterized in spatial data or parameterized in models. This would be a way to co-produce maps and models and thereby increase the assessment's use and trust by local stakeholders.

The models in chapter 3 (modeling scenarios) and chapter 5 (modeling a crop boom) operate at national scale and at province scale respectively. The methodology of these chapters in creating land system maps as input to the model was very similar. Both integrated land cover data with variables of the agricultural census using a heuristic decision tree. However, the questions and purposes of the two models were quite different. Chapter 3's national scale

model looked into the future and explored visions, that were designed by the research team. Chapter 5's province scale model replicated land change of the past and more care was required in finding and calculating data to approximate the past process in search of causality.

Chapter 4 and 5 studied the same land use regime shift (maize boom) with different methods. Each of the methods brought about different potentials and insights. Serious games (chapter 4) opened up opportunities to directly talk to decision makers (to farmers in this case) and verify the knowledge gained with them and further stakeholders (local agricultural experts in this case).

Moreover, games can induce shifts of perspective, both for players and those who design the games, because game designers need to keep on switching from individual to systemic view and back.

Overall, the multiscale gaming approach mainly sought to understand and represent the viewpoint of individuals or communities and as a result did not consider larger patterns such as the role of (temporary) productivity increase through the introduction of new technology. The crop boom model took over the role of including larger trends. It is much better suited to isolate factors and quantify their effects. The CLUMondo model, however, is a large-scale land use model and not designed to represent the farmer unit itself. Therefore, it is not possible to represent the feedback from the land use choice to a farm household and further to the next land use choice.

Also, the crop boom model is limited by data and by the fact, that important aspects of decision making are hard to quantify and representable in spatial data, e.g. trust or strength of governance. By role playing, this is possible to represent in games. As such, both methodologies contributed complementary insights on the maize boom.

One of the key insights brought about by the multiscale gaming approach was that most farmers engage in the maize boom to seize the opportunity when

offered by a trader in a contract farming scheme in order to improve the smallholders lives and those of their families – an opportunity to move away from poverty. The cash income from maize cropping on upland fields was invested in education, housing, mobility and expansion of paddy fields as this land use produces higher yields, costs fewer work hours and is connected with obtaining more secure land rights. The crop boom model, in turn, helped to compare the magnitude of effects of factors such as accessibility to maize traders, productivity increases and differences in farmgate prices. Out of these factors, productivity increases signaled the largest improvement in model performance and from this we (carefully) concluded that these measures enabled the maize boom to a large degree.

6.4 Societal impacts

Most societal impacts related to the work presented in this dissertation are indirect through attaining a better understanding of the role of human decision making in land use change and by providing new methods for analyzing and modelling these. However, there are a number of insights and products that either directly or potentially serve different stakeholder groups, particularly in Laos or other agrarian societies in tropical and subtropical latitudes. An overview of these is provided in Table 6.1 and a selection of these are described in the following.

The integrative nature of the analyses may help to bridge sectoral differences in policy and science and help think across the boundaries of sectors such as conservation and agriculture and reveal the possible interactions. The land system map of chapter 2, for example, is a tool to locate different agricultural land systems in relation to conservation areas such as national protected areas (NPA). This can further help to identify stakeholders of the area for invitation to a multi-stakeholder dialogue.

It is challenging to break out of old ways of thinking and behaving, particularly on a societal level (Scheffer 2009, p. 255). Scenarios, such as in chapter 3, could play an important role in this respect as they support the process of innovation in decision making by answering ‘what-if’ questions. The national scale land system scenarios introduced ideas such as including societal demands on the land (protecting agro-biodiversity or considering cultural ecosystem services of shifting cultivation) along with the classic commodity demands. The results suggested that this could lead to higher diversity of land uses in comparison to business as usual and a scenario of prioritizing international interests which lead to more segregation of land use functions. In such a way, the LS scenarios can be a tool (boundary object) for initiating debates with various stakeholders on the multifunctionality of land uses on the landscape scale, ecosystem services beyond commodity production and therewith stimulate to think in different visions of the future. The spatial visualizations of these alternative futures by means of land system classifications and models are powerful communication tools to achieve this in discussions with policy makers.

The CLUmondo application set up for Laos has been picked up for a project to teach and train land system modelling within several Universities in Southeast Asia with the aim to build capacity locally. This project slightly simplified the settings used in chapter 3, but it created a user-friendly version of the application and made it available for free download at the information portal Greater Mekong Subregion Environment Operations Center (Greater Mekong Subregion, 2017).

As a side product during the research process, the fieldwork supported many changes of my own perspectives. Perhaps one of these new perspectives could help in the societal debate on the contested land use practice of shifting cultivation.

Characteristic in this debate are two opposing viewpoints. On the one hand, shifting cultivation is seen by certain stakeholder groups as an ‘outdated’ way of farming that should be modernized (Hall, 2011) as well as a driver of deforestation, an argumentation that underlies many land use policies (Fox et al., 2009). On the other hand there are arguments to protect shifting cultivation and its agro-ecological knowledge (Altieri, 2002).

The fieldwork phase allowed to learn about this issue from the viewpoint of the people whose land and behavior this discussion is about. Witnessing how and why smallholders turn from shifting cultivators to crop boomers highlighted that, beyond the image of forest destroyers and romantic self-sustainers, we can add another story: a large part of the people practicing this land use would like to transform to different lives and/or farming styles themselves but they see a lack of available good alternatives in their specific contexts. Considering and acknowledging that the land users with any kind of behavior have agency and visions themselves may bring a constructive mindset to debates on land use and help to innovate when getting stuck in the controversy.

The knowledge gained on the drivers of crop booms may help non-governmental organizations (NGOs) and others working on sustainable land management. It could be used to design holistic interventions based on the systemic understanding gained through multiscale gaming and the crop boom model. The rapid land degradation & deforestation could be addressed by supporting smallholders in their long-term socio-economic goals (e.g. education of children). The promotion of agro-ecological alternatives to boom crops need be competitive to the dominating cash-crops in terms of profitability, labor and capital efforts. Furthermore, particularly supporting pioneers of sustainable land use, may be fruitful as these can inspire other farmers to do the same (imitation behavior). However, it must be carefully considered as to whether and which technologies for land management are introduced. While they reduce labor efforts and at least in the short-term

increase yields, they can change land system patterns significantly and – as was the case of tilling – lead to severe soil erosion.

Navigating the complexity of achieving sustainable land use systems is a challenge that can be both exciting and intimidating, particularly when global dynamics are at play that seem uncontrollable while at the same time local impacts are at stake. Crop booms are such a challenge that are highly connected to processes of globalization, international market and political dynamics. The outcomes of the research of chapter 4 and 5 in this dissertation however suggest that, in order to buffer the local impacts, there are things that can be done. A key reaction on political and societal level should be to avoid the support of a mono-crop market and instead stimulate a diversification of the market if the landscape should remain or become diverse as well.

Table 6.1 Potential use of insights and products of the dissertation for different stakeholder groups.

	Governmental organizations & policy makers	Non-Governmental organizations (NGOs)	Research (for development)	Private sector, multi-national corporations	Farmers/Community leaders
LS Classification	Concise map of national coverage with all major land uses/systems together. Facilitates focus in debates and consideration of relevant stakeholder groups.	Basis to map stakeholders within and around national protected areas or other land systems of interest. Basis for strategy to support, provide funding or work in particular land systems & locations Tool (boundary object) to stimulate landscape level thinking with farmers Material for awareness campaigns on trade-offs of different development pathways and the impact of considering more than agricultural produce as demand on the land but also biodiversity and cultural ecosystem services.	Basis on which to decide where to: (i) carry out in depth case studies, (ii) select samples of a certain land system type (iii) for meta-studies to analyse patterns in research e.g. which land systems studied most or least	Information about which land system type a business location is (would be) based in. Can be used e.g. to anticipate impact on social and ecological setting	Compare own land systems to other situations in the country, province, district.
Scenarios	Indications which locations and regions may change considerably or stay stable. For planning of services/support to regions. Awareness of trade-offs and potential country-wide land use regime shifts. Simulation of governance options beyond business as usual Being participant in mahasaly meta-game enables to (i) understand crop booms as drivers of deforestation (ii) identify needs of policy adaptation after having been ,in the shoes' of farmers. Findings could lead to changes in policy design and governance including: - stimulating diversity of markets, - strengthening governance capacity to deal with e.g. traders who break contracts and enforce herbicide/filling regulations	Material for awareness campaigns on trade-offs of different development pathways and the impact of considering more than agricultural produce as demand on the land but also biodiversity and cultural ecosystem services.	Basis for further scenario work e.g. coupling participatory scenario development with afterwards simulating the scenarios in the CLUmundo model application of Laos	Become aware of changes that may be ahead to economy, society, environment and take into account in decision making on own land and in community. e.g. communal forests are at risk	
Multiscale gaming	Being participant in mahasaly meta-game enables to (i) understand crop booms as drivers of deforestation (ii) identify needs of policy adaptation after having been ,in the shoes' of farmers. Findings could lead to changes in policy design and governance including: - stimulating diversity of markets, - strengthening governance capacity to deal with e.g. traders who break contracts and enforce herbicide/filling regulations	NGOs supporting sustainable land use: Knowledge on factors of decision making during crop booms as a basis for systematic approach: address long term socio-economic goals e.g. link between land use options and education of children agro-ecological alternatives to boom crops need be competitive and/or timed well imitation behavior: support pioneers of sustainable land uses	New method for generalizing and upscaling knowledge from field studies in context of a regional/global change process	Land degradation is a risks for any business that established itself in a certain area. To help avoid it, avoid business models relying on only a single crop. Instead, broaden set of goods traded/produced. Will make (trading) businesses depending on agricultural products more resilient	Awareness on adverse effects (danger) of following a crop boom fully: ecologically (soil erosion, deforestation) and financially (indebtedness)

Crop boom model	Governmental organizations & policy makers	Non-Governmental organizations (NGOs)	Research (for development)	Private sector, multi-national corporations	Farmers/Community leaders
	Supporting technical developments such as tilling that favor mono-cropping land uses is fuelling crop booms Avoid support of tillage/herbicides to avoid crop booms	Novel technology that increases yield and reduces labor efforts is very powerful. Can change land system patterns significantly and has to be carefully considered when thinking of interventions towards sustainable land use.	Trader routes and locations are more significantly influencing location of crop booms than general accessibility to roads. Thus, data collection of trader locations are key.		