Chapter 39
Development Trade-Offs in the Mekong: Simulation-Based Assessment of Ecosystem Services and Livelihoods

A. Smajgl, J. Ward, and T. Nuangnong

Abstract This paper presents results from an analysis of development related trade-offs in the Nam Xong catchment, one of the Mekong tributaries in Lao PDR. The study presents results from an agent-based simulation model, which genuinely links bio-physical and socio-economic dynamics, and considers spatial impacts, such as deforestation, hydrological flow and human migration. The results indicate that mining expansions in the upper catchment are likely to trigger larger local income losses in existing livelihoods than income gains from the new employment created. Down-stream dynamics are likely to increase flood peaks and lead to increased outmigration. Two system links emerge as key mechanisms for understanding development trade-offs, the link between livelihoods and ecosystem services, and migration, which emphasises the need to apply methodologies that effectively represent these system connections.

Keywords Mekong · Agent-based modelling · Trade-off analysis

39.1 Introduction

Economic development involves risks of trade-offs as activities by one sector are likely to impose constraints for other sectors. In the context of the Nam Xong—a Lao tributary to the Mekong—local stakeholders observed such trade-offs between upstream mining and rubber and banana plantations, mid-stream tourism and agriculture, and downstream fishing and agriculture. The substantial income generated by tourism activities in and around Vang Vieng were perceived to be endangered due to changes in water levels and water quality. Thus, stakeholders invited and engaged in a participatory research process to understand some of these development trade-offs.

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The research design involves a mixed method approach that was implemented during a participatory process, the Challenge and Reconstruct Learning approach (Smajgl and Ward 2013; Smajgl et al. 2015). The methods included a household survey, a hydrological model (Kallio 2014), and the agent-based model MerSim (Smajgl, Toan et al. 2015; Smajgl, Ward et al. 2015; Smajgl, Xu et al. 2015). This paper summarises results from the agent-based approach, which genuinely links hydrological dynamics, agricultural growth, various ecosystem services, and livelihood related behaviours.

The results emphasise that taking a narrow sector perspective leads to wrong recommendations as income in the upstream district seemingly increase and poverty slightly declines. However, if considering land-use change and the resulting consequences through losses in ecosystem services other livelihoods face losses that substantially outweigh the gains from mining. Importantly, most mining employment is likely to be taken up by persons from outside the district, which were beforehand not under the poverty line. Widening the spatial area emphasises further consequences that add to the local trade-offs. Two types of downstream effects prove critical for the province and national perspective. First, changes in water levels, in particular an increase in flood peaks, trigger agricultural income losses in downstream districts that drive families to migrate out of the Province. The level of poor households in the remaining populations increases as most out-migrating families were not under the poverty line.

From a methodological perspective it becomes evident that the understanding of development outcomes and related trade-offs require a sophisticated approach that captures the socio-economic and bio-physical connections. Two aspects seem particularly important, first the link between livelihoods and ecosystem services, and second migration, which stresses the importance of spatial and temporal dynamics of poverty (Bohensky et al. 2013; Smajgl and Bohensky 2013).

39.2 Material and Methods

39.2.1 Development Context of the Nam Xong

The Nam Xong (also Nam Song) flows into the Nam Ngum, Laos' largest contributor to the Mekong (Lacombe et al. 2014). This sub-catchment is the home of about 200,000 people from various ethnic groups, including Thai Lao, Thai Neua, Thai Dai, Meo Khao (White Hmong) (Schliesinger 2003). Three development strategies are being unfolded by government strategies and foreign direct investments, tourism, mining, plantations, and agricultural intensification.

Tourism is largely centred around the town of Vang Vieng, mid-stream of the Nam Xong sub-catchment. Tourist numbers in this area have more than tripled between 2006 and 2013 (Tourism Development Department 2013) providing many new livelihoods to local households but also putting pressures on the environment as sewage volume increases and urban sprawl replaces natural vegetation, especially along river banks.

Mining investments in the upstream area of the Nam Xong target mainly deposits of gold, copper, and limestone (for downstream cement production) (Kallio 2014). The enormous increase of rubber prices between December 2008 and February 2011 triggered substantial Chinese investments into the northern provinces of Lao PDR. While prices have dropped since then there has been a resurge since early 2016. More recently, banana has emerged as a second cash crop covering wide areas in the Nam Xong and other parts of northern Laos.

The fourth development strategy resulted from the Government's declared goal to lift agricultural productivity (due to its under proportional contribution to GDP growth). Such agricultural intensification would include more suitable crops, irrigation, and improved management (incl. application of fertilizer, herbicides and pesticides).

In combination, these four development strategies harbour substantial potential for trade-offs, in particular when considering constraints related to ecosystem services. For instance, upstream development in mining, plantations, and irrigated agriculture reduce the water levels of the Nam Xong in the tourism areas. Given that many tourists come to Vang Vieng for water sport related activities, such declining flow can suddenly prevent tourists from rafting, canoeing and tubing. The economic gain of upstream expansions would thereby reduce tourism related income in and around Vang Vieng. Similarly, increased tourism can further deteriorate water quality for downstream households, their fishing, and for state of the Nam Ngum 1 reservoir. This pressure is accelerated by upstream development causing deforestation and erosion. Economically, costs can emerge and potentially outpace the gains of upstream gains. These trade-offs follow non-linear and rather complex relationships and understanding thresholds seems essential to manage these trade-offs wisely and to achieve sustainable development.

39.2.2 Participatory Process: Implementing the ChaRL Framework

The development challenges in the Nam Xong result from an array of independent interests and values. The provision of scientific evidence to such a contested decision making space requires an effective process design for engaging with the various stakeholders and interest groups. The Challenge and Reconstruct Learning (ChaRL) framework was chosen to effectively bridge science and policy. ChaRL combines in a five-step process visioning and evidence-based deliberations. The key difference to other processes is that after developing a shared vision assessment results are being presented to elicit causal beliefs, which will then be tested with the various data and methods developed so far. The step of challenging these underpinning causal beliefs is a critical psychological moment that creates the opportunity to redraw the

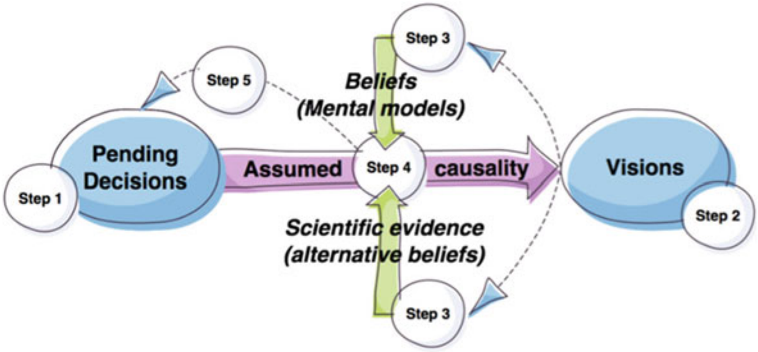

Fig. 39.1 The ChaRL (challenge and reconstruct learning) framework (based on Smajgl and Ward (2013) and Smajgl, Ward et al. (2015))

positions in the cross-sector negotiation and redesign development strategies that minimize trade-offs (Fig. 39.1).

The ChaRL process in the Nam Xong brought together various central ministries (e.g. Department of Water Resources from the Ministry of Natural Resources and Environment, and the National Economic Research Institute form the Ministry of Planning and Investment), various province and district level agencies (e.g. agricultural, environment, planning), and the tourism association. A total of five workshops were conducted between March 2015 and November 2016. The visioning (Foran et al. 2013) involved all participants to identify key drivers, their expected trends, and to develop two most desirable futures (=visions), one most likely future (no major shocks), and one most undesirable future (for the design of risk strategies) of the Nam Xong. The scientific evidence presented during this participatory process was based on a hydrological model, results from a household survey, and an agent-based social simulation model. The following explains the design of the agent-based model MerSim, which is the focus of this publication.

39.2.3 The MerSim Model

The description of the agent-based Mekong region simulation (Mersim) model follows the ODD (Overview—Design concepts—Details) protocol (Grimm et al. 2006; Grimm et al. 2010; Müller et al. 2014) and model details including Java code can be found in Smajgl et al. (2013).

39.2.4 Purpose of the Model

The model design was embedded in a participatory process, which follows the Challenge and Reconstruct Learning approach as outlined by Smajgl and Ward (2013) and Smajgl and Ward (2015). This participatory process helped eliciting the policy indicators and policy scenarios.

- Climate change and increase in flash floods
- Continued deforestation
- Rubber expansion and rubber price increase
- Mining expansion
- Tourism drop
- Tourism expansion.

The results aim to inform the basin development plan and specific sector strategies for mining, forest management and agriculture.

39.2.5 State Variables

The participatory process placed the stakeholder priorities at the core of the model design and determined the state variables as: poverty, forest cover, rubber production, water flow, water quality (dissolved oxygen), rice production, migration, land use, household livelihoods and fish catch.

39.2.6 Emergence

Corresponding with stakeholder-defined modelling goals, emergent phenomena include the temporal and spatial poverty patterns, the spatial extend of forest cover and rubber plantations, and water quantity and quality changes in response to the expansion of mining and rubber plantations upstream. One core policy focus is the trade-offs between upstream investments and mid-stream tourism income, which is emerging from modelled interactions.

39.2.7 Household Data for Parameterisation

The parameterisation process is described based on the framework provided in Smajgl et al. (2011).

Figure 39.2 shows the principle parameterisation steps required in an empirical model (boxes) and which particular options were implemented for this study (arrows).

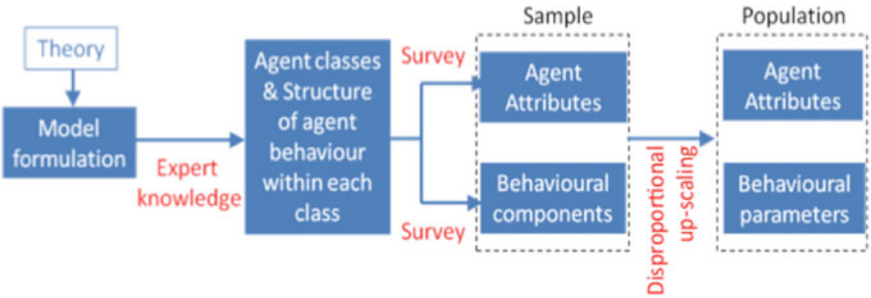

Fig. 39.2 Parameterisation sequence for the Mersim model, adapted from Smajgl et al. (2011)

The Mersim model formulation is based on theory articulated by Castellani and Hafferty (2009) that conceptualises social-ecological complexity, in particular the focus on a disaggregated systems approach that allows non-linear system components to interact and, thereby allowing for emerging phenomena, i.e. Funtowicz and Ravetz (1994) and Sawyer (2005).

Experts helped to identify principle agent classes, such as household agents, government agents and spatial agents. This expert-based process also identified principle agent behaviour such as the harvesting of tea and the tapping of rubber. These livelihood-related activities were put into annual calendars and linked to associated regions and altitudes where necessary.

The next step involved the specification of household attributes and household behaviours. A random sample of 1,000 households (20 randomly selected households from 50 randomly selected villages) across the Nam Xong sub-basin were surveyed to elicit their key characteristics (i.e. location, household size, livelihoods, production, and income), their self-selected attributes of subjective wellbeing, the principle human values that guide their lives, and their adaptation intentions. Intentions represent responses to questions that frame a specified hypothetical change. In this case the change households were asked to imagine:

- Flash floods started to occur frequently
- Deforestation continued
- Rubber prices would increase
- More mining jobs would be available
- Tourist numbers would drop
- More jobs in the tourism sectors would be available.

Households had four principle response options: either.

- To maintain their livelihood activity in their current household location;
- To change their livelihood in their current household location;
- To migrate out but maintain their current livelihood; or
- To migrate out and change their livelihood activity.

In each of these categories, responses to follow-on question informed estimates of the magnitude or type of livelihood response, the impediments to adaptation and/or the location for migration. The intentional data and behavioural changes elicited from household survey responses delimited the cognitive complexity of household agents to a more parsimonious depiction of largely reactive agents in the model.

The sample data for attributes and behavioural rules was mapped into the total agent population by disproportional up-scaling. Proportional up-scaling refers to a technique in which the proportions of responses in the sample is maintained to parameterise the whole population by simply replicating (or cloning) each response by sample size divided by population size (in this case multiplied by about 200). Disproportional up-scaling on the other hand changes proportions as some responses are used more often than others due to some scaling factors. In this case the proportions were amended to match the actual land use, in particular rubber plantations, rice paddy and the urban population. Otherwise a random approach would map intentional data from a tourism-dependent household into a non-tourism area and responses from a rubber farming household into an urban area. This GIS-based adjustment was intended to represent a more realistic spatial distribution of simulated household behaviour.

39.2.8 Adaptation and Objective

Given the way we reduced agent cognition, agents step through a simple adaptation process, which allowed a reduction in the run time of the model so that live runs were able to be performed during the participatory modelling process (Smajgl, Ward et al. 2015). Figure 39.3 depicts the steps for household agents.

Household agents respond to income levels derived from paid labour or agricultural activities. Households' objectives are implicit to their behavioural response functions (or rules). Modelled agents respond to livelihood related changes based on intentional data derived from the household survey responses. No additional optimisation or satisficing assumption is implemented. As a corollary, household expectations and learning are not explicitly represented but implicitly captured by the empirically derived response strategies.

39.2.9 Adaptation and Objective

Most parameters are assumed to be stochastic to resemble more realistic model assumptions, including crop prices, productivity, and wages. The ranges were developed by experts in conjunction with time series data.

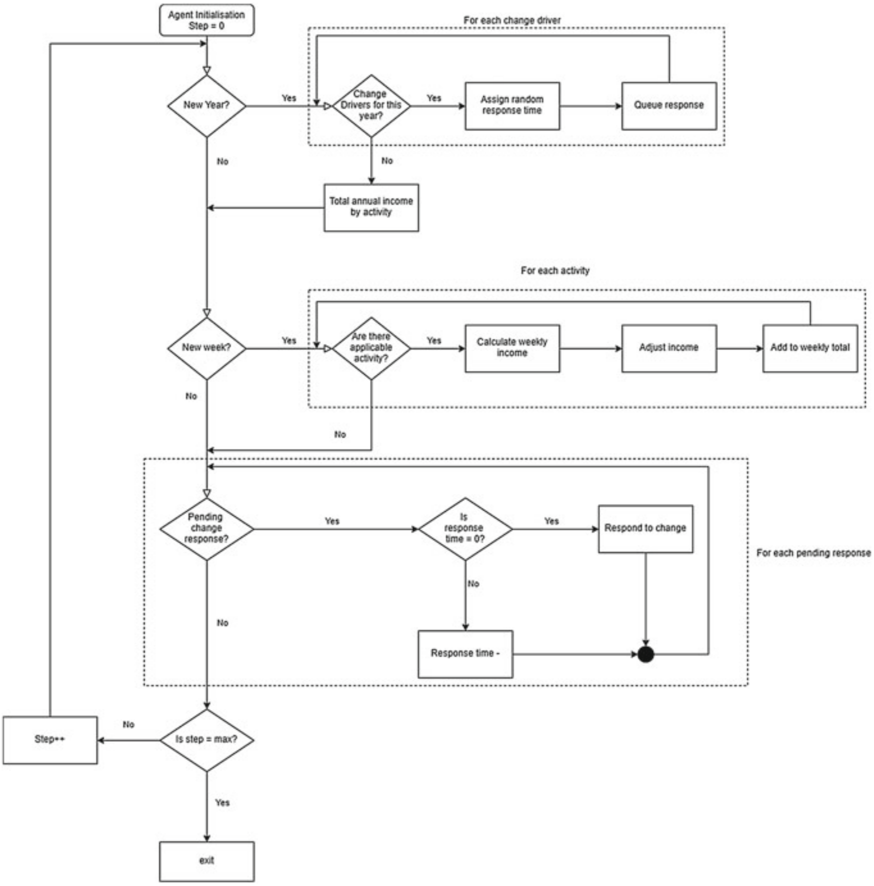

Fig. 39.3 Flowchart for household agents

39.2.10 Initialisation and Submodels

The Mersim model utilises five sets of GIS data: (1) administrative boundaries down to administrative villages, (2) soil data, (3) land cover data, (4) rainfall projections, and (5) a digital elevation model. These datasets were used to specify the artificial landscape while the household survey provided the necessary data on household attributes and behavioural responses.

Five essential submodels were integrated to deliver the processes stakeholders had requested: hydrology, crop growth, water quality, livelihood, and income. The hydrology module calculates in daily time steps the run off for each spatial polygon based on rainfall, slope, inlet and outlet node, land cover and soil type. Based on this method flood and drought risk for the tourist town of Vang Vieng can be estimated, which triggers tourism numbers to divert from a projected trend. Based on rainfall, soil type and land cover livelihood-relevant crops (e.g. rice, rubber, trees, grass) grow following established growth algorithms. The combination of water flow and particular land cover provides the necessary information for calculating dissolved oxygen, which is calculated for Vang Vieng town and for Hinheup where the Nam Xong is partly diverted into the Nam Ngum 1 dam and partly continues its flow into the Mekong. The livelihood module follows crop and job specific calendars, which involves, for instance planting and harvesting. Household livelihoods only change based on intentional data elicited through the household survey. The income module calculates the weekly income for all household members and assigns how many are below the poverty line. This calculation includes the monetisation of subsistence production to avoid a misleading, under-estimated quantification of poverty.

39.3 Results and Discussion

For this paper we selected as the scenario the expansion of mining activities in the Nam Xong based on pending investment proposals. This would involve a doubling of mined areas, mostly located in the district of Kasy. Figure 39.4 shows the projected poverty rate for 2015–2029 for the baseline and for the selected mining expansion scenario. From a narrow sector perspective mining income is likely to reduce local poverty in Kasy only marginally. However, as mining involves the replacement of forest cover and, thereby the loss of forest-based livelihoods there are also losses that impact on the poverty rate. In total, poverty is likely to increase slightly by about 1.3% across this timeframe.

Figure 39.4 also shows the impact of the mining expansion on poverty rate further downstream in the district Vang Vieng. Here the poverty rate is likely to increase by

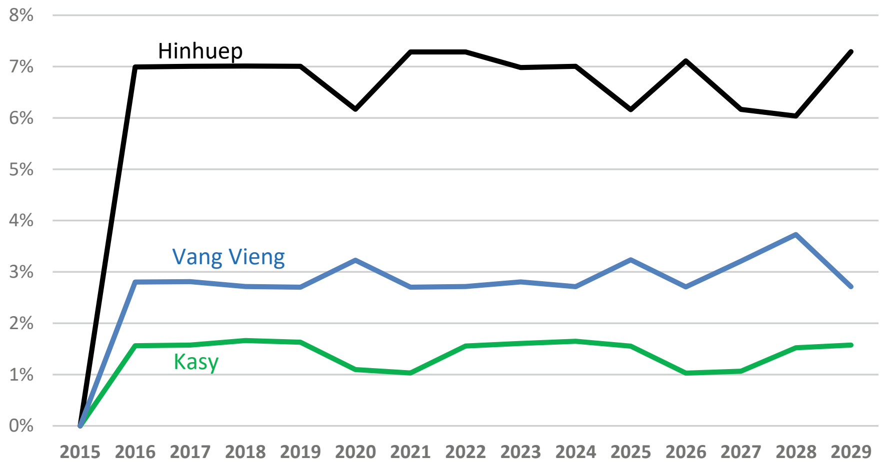

Fig. 39.4 Impact of Mining expansion on poverty in Kasy, Vang Vieng and Hinheup, 2015–2029

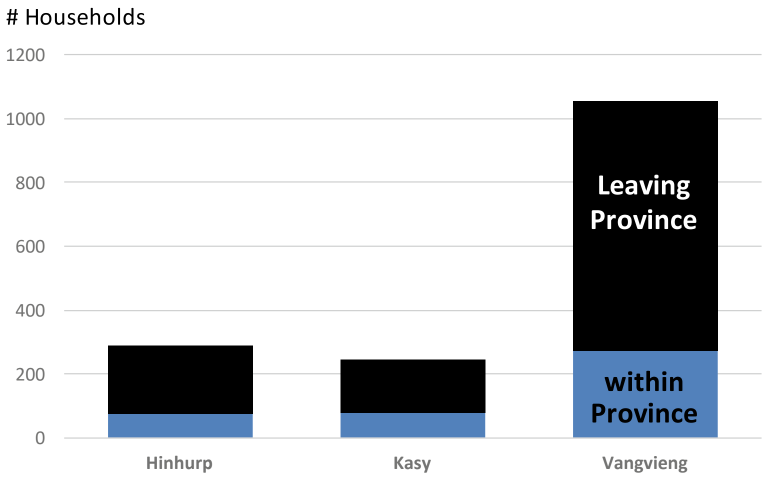

Fig. 39.5 Impact of Mining expansion on poverty in Vang Vieng

2.7% in average over the considered time period. In Hinheup, at the end of the Nam Xong sub-basin, poverty rates are likely to increase in average by 6.4%.

Figure 39.5 shows migration movements during this 15-year period. In total nearly 14% of households are likely to migrate due to the mining expansion strategy and its biophysical and socio-economic ripple effects. Some groups move between districts, which involves largely households seeking employment in the growing mining sector in Kasy. Additionally, it involves households that lose their previous livelihoods or land. A larger portion of migrating households decide to leave the Province, mostly heading for urban and industrial areas, including the capital Vientiane.

39.4 Conclusions

The modelling results emphasise (1) the relevance of social factors of poverty changes, and (2) the need to understand spatial and temporal dynamics of poverty. The expansion of mining activities is often promoted as a poverty alleviating strategy. This study shows that most households under the poverty line would either not apply for a mining job or would not be employed for educational reasons. The majority of households newly employed in the mining sector replace other livelihoods and were initially not under the poverty line. The cumulative impacts are that poverty is increasing due to the loss of existing forest-based livelihoods. This social constraint (mainly attitudes and skills) limits the ability of this mining-focused strategy to alleviate poverty in this province.

The dynamic perspective reveals that without an explicit inclusion of migration any analysis of poverty impacts is likely to deliver misleading results. In this case most households that seek mining employment in Kasy are non-poor households from Vang Vieng and Hinheup. This migration results already in increasing poverty rates in downstream communities (as proportionately more poor households are left behind). Concurrently, poor people lose their livelihoods and leave this area, which translates into rural outmigration. This process is likely to shift poverty into urban and peri-urban areas of Lao PDR if skill-sets of migrating households mismatch employment opportunities in urban areas. This study did not include any additional costs caused by these spatial changes in poverty over time, which can be substantial as many urbanisation experiences in southeast Asia have shown.

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