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Companion Modelling for resilient water management: Stakeholders' perceptions of water dynamics and collective learning at catchment scale

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Abstract: The Mekong river region is facing rapid changes in land and water uses which involve unevenly distributed costs and benefits among various stakeholders, and raise the issue of the resilience of ecosystems and livelihoods in the Mekong river basin. In this region, the production of knowledge on water resource dynamics is mainly based on scientific hydraulic models which struggle to integrate ecological and social impacts of water dynamics at a river basin scale. Our work aims at taking into account a diversity of viewpoints and knowledge sources on water dynamics and their impacts, in order to promote dialogue among stakeholders. In this paper we propose a conceptual framework and a methodology to promote resilient water management, and present the first results of our work in the Nam Theun – Nam Kading (NT-NKD) River Basin, a Mekong river sub-basin located in Lao People's Democratic Republic.

Key basin stakeholders from the public and private sectors at multiple levels were brought together, including those from the hydropower industry, research and administration, as well as local government and villagers, into discussion arenas initiated through a participatory modelling process, called Companion Modelling (ComMod). In ComMod, participatory role-playing games (RPGs) associated with agent-based models (ABMs) are used within an iterative and evolving participatory process where stakeholders are involved in the co-construction of the common representation of the issue context and the co-design of the corresponding simulation tools. In the NT-NKD basin, the most pressing issue identified by stakeholders, and subsequently modelled, was river flood risk. The ComMod approach was implemented primarily through interactive field workshops. During these workshops, stakeholders were asked to co-design and use together a sub-basin model in the form of a RPG for land and water uses management, which includes up- and downstream interests and needs, multiple uses/managements and scales. Based on the same model as the RPG, an ABM was also developed, which made it possible to simulate longer periods, while allowing participants to understand its structure and simulation outcomes. The model is multi-scale, so that each participant considered management not only for his or her local interests but also at the whole catchment level and could link his or her activities, roles and responsibilities with the catchment context, as well as with other stakeholders. By actively playing roles in the participatory workshops, stakeholders could identify knowledge gaps and knowledge needs from other management levels, such as the farmers' level. This improved their understanding of flooding and enhanced their awareness of cross-scale interactions and of the need to collect multiple knowledge sources to approach such complex processes. Overall, the stakeholders had been receptive and were appreciative of ComMod and its modelling tools, because it afforded them the opportunity to engage in discussions of important issues regarding the catchment. This attitude contributes to a conducive environment for long term ComMod initiatives and other participatory processes.

At the end of this first ComMod cycle, the stakeholders requested to further integrate knowledge from many groups of stakeholders to feed the flood risk model. Integrating knowledge from diverse stakeholders first requires understanding of their worldviews about the river basin. The next ComMod cycle will therefore aim at collecting and confronting scientists', farmers' and decision-makers' views in order to highlight the diversity of perception levels and purposes assigned to the environment, allowing them to collectively analyse trade-offs between water and land uses, knowledge gaps, and potentially emerging collective purpose, and thus support discussion on river basin resilience and decision-making.

Keywords: *Resilience, vulnerability, companion modelling, role-playing games, agent-based modelling*

1. INTRODUCTION

The Mekong river region is facing rapid changes in land and water uses, including booming hydro-power development, an increase in industrial plantations, and a transition from subsistence agriculture to cash crops. These changes, along with other interacting political and ecological changes, have complex impacts on linked social and ecological dynamics, such as changes in river regimes and derived livelihood resources, migrations, and increased access to markets and public infrastructures. This raises the issue of the resilience of ecosystems and livelihoods in the Mekong river basin. Such complex dynamics can be analysed at multiple temporal and spatial scales, through varied disciplines, and involve costs and benefits which are unevenly distributed among different stakeholders (Smajgl et al., 2015). In particular, water resources development projects in the Mekong river basin have raised intense debate, in which knowledge production based on hydraulic modelling plays an important role while being highly contested (Johnston and Kummu, 2012; Käkönen and Hirsch, 2009). These models have struggled to integrate ecological and social impacts of water dynamics at a river basin scale due to a lack of data available, as well as to build understanding and involvement of decision-makers and other stakeholders (Johnston and Kummu, 2012). The social and ecological complexity of such river basin dynamics requires multi-level stakeholder platforms that gradually allow transdisciplinary and cross-scale efforts to co-learn and co-manage resource dynamics (Dore, 2007), by integrating a diversity of viewpoints and knowledge sources on water dynamics and their social and ecological impacts at multiple scales. In this paper we propose a conceptual framework and methodology to promote resilient water management, and present the first results of our work in the Nam Theun – Nam Kading River Basin, a Mekong river sub-basin located in Lao People's Democratic Republic (Figure 1).

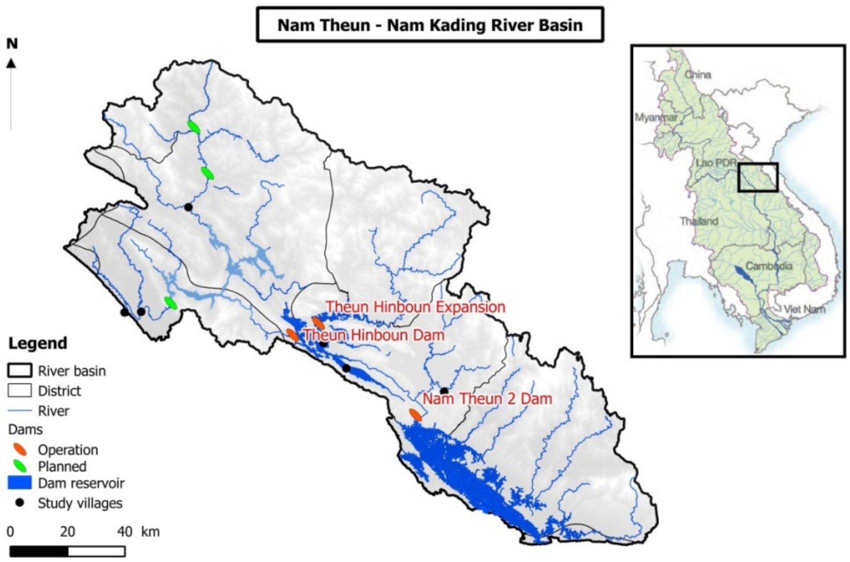

Figure 1. Map of the Nam Theun – Nam Kading River Basin with study villages, existing and planned dams, and location in the Mekong River Basin.

2. CONCEPTUAL FRAMEWORK TO ANALYSE RESILIENT WATER MANAGEMENT

The concepts of resilience and vulnerability are used by researchers and practitioners to talk about complex and uncertain changes affecting ecosystems and livelihoods. A diversity of frameworks of analysis has emerged, which nonetheless concur on a general definition of the two interlinked concepts: vulnerability is the susceptibility to harm as a result of changes, while resilience is defined as the capacity to recover and reorganise following a disturbance (e.g. Folke et al., 2010). An analytical review of several frameworks referring to each concept allowed us to identify their respective contributions to the analysis of social and ecological changes, and to propose our own framework of analysis of a river basin management system involving multiple stakeholders and natural resources, and taking into account contested knowledge and power asymmetries.

The frameworks analysing vulnerability and resilience differ in the approach used by the authors to consider changes in ecosystems and livelihoods. On the one hand, the resilience approach applies a systems approach, aiming at identifying the principles leading the organisation and reproduction of a social-ecological system in a constitutive and dynamic hierarchy of interacting levels, represented by the famous metaphor of panarchy

(Gunderson and Holling, 2002). The authors analysed the capacity of the system to change and undergo regime shifts through learning processes and adaptive management while maintaining the same identity (Folke et al., 2010). On the other hand, frameworks using vulnerability can be differentiated between, first, those which have used a systems approach focusing on causal links between interacting factors of change and their impacts on a geographical area (Turner et al., 2003) and, second, those which have applied an actor-oriented approach focusing on individuals and social groups and their access to the material and immaterial resources which enable them to face risks and which are influenced by social structures and political dynamics (Wisner et al., 2003). In both approaches, some studies have highlighted the subjectivity of system views (Leach et al., 2007) and of definitions of risk (Fineberg and Stern, 1996), which all depend on the actors' viewpoints. In this regard, actors and systems are intertwined notions which call for the consideration of a multiplicity of viewpoints on our river basin management system.Further reflection on systems approaches can tackle these issues. According to cyberneticists, a system is designed by an observer, who defines the purpose of the system depending on his or her own values and objectives, derives the multi-level structure of the system from this purpose, and tries to understand the mechanisms by which the system structure is maintained (Passet, 1996). In this regard, a system can be seen as a constitutive hierarchy of nested levels and purposes, each level contributing to achieve the higher-level purpose, which emerges from the combination of lower-level purposes and in turn influences the lower-level structure (Passet, 1996). From that perspective, social systems, considered as embedded in natural systems, could be organised to achieve a purpose collectively decided by the social sub-systems. But according to Passet (1996), this functional hierarchy rather resembles a power hierarchy when some actors impose their own purpose on the whole system and create norms and values to maintain the social structure. A bottom-up decision process aiming at organising a social system would require to collect the purpose and the resulting structure that different actors would give to the system, that is to say their own view of the system. In the pathways approach (Leach et al., 2007), the systemic views of different actors are collected and confronted through a governance process aiming at defining collectively a common systemic view and its objectives.

Based on Passet's framework and the pathways approach, we consider a social-ecological system as a collection of actors' systemic views, i.e. their views of how different elements of their environment are related and contribute – or should contribute – to a set of nested purposes at particular levels of perception. Thus, we assume that collecting and confronting these multiple systemic views can support the collective decision-making process on river basin management by making it possible to identify multiple levels of perception and purposes, trade-offs between these purposes, and potentially emerging collective purposes.

3. METHODS

The Companion Modelling (ComMod) approach offers methodological support to integrate a plurality of viewpoints into an adaptive management system (Barreteau et al., 2010). In the ComMod approach, participatory modelling tools such as role-playing games (RPGs) associated with agent-based models (ABMs) are used within an iterative and evolving process where stakeholders are involved in the design of the simulation tools. These tools are then used to collectively design, simulate and discuss scenarios of change, and evolve depending on the new issues that emerge from the discussion.

The ComMod process in the Nam Theun – Nam Kading river basin will consist of several iteration cycles over several years. The first one, realized through a research project funded by the Challenge Program on Water and Food (CPWF) from 2011 to 2013, aimed at promoting dialogue among the different stakeholders through complementary activities, which are necessary for a long term in-depth implementation and scaling up of the ComMod process in the site. These complementary activities consisted of:

- participatory modelling workshops with multiple basin stakeholders, which were aimed at promoting knowledge exchange on natural and human dynamics within the basin using RPGs and an ABM, and in particular at generating interest on cross-scale interactions and at identifying knowledge gaps. At the end of each workshop, feedbacks from the participants were gathered about the lessons or knowledge they have gained from the activity, including their interactions with each other.
- the creation of a Core Group, composed of several members of the Nam Theun – Nam Kading River Basin Committee Secretariat (NT-NKD RBCs) i.e. the government body that implements the management plans for the NT-NKD basin, representatives from the hydropower corporations in the basin, and researchers in Laos, which guided the ComMod activities on the ground and allowed for the communication of outcomes of participatory workshops to stakeholders at local to national levels,
- capacity building workshops, which were conducted to familiarize basin stakeholders and interested parties, such as academics and civil society organisations, with the ComMod approach, and to train the project's local partner, the NT-NKD RBCs, on the basic technical and soft skills necessary for conducting

a ComMod process. These training workshops were complementary to the learning-by-doing (Kolb, 1984) exercises that the NT-NKD RBCs was undertaking during the participatory modelling workshops. Knowledge and data gathering activities were also conducted to support the modelling process.

The second ComMod cycle will be initiated this autumn and is aimed at collecting the systemic views of basin stakeholders, using several media such as pictures, RPGs and ABMs. The aim is to further enhance discussion among stakeholders about existing, missing and potentially conflicting knowledge on multi-level river basin dynamics, and about trade-offs between multiple purposes and levels, with the aim of further enriching discussion about acceptable common management objectives at the river basin level.

4. FIRST RESULTS OF OUR WORK

4.1. Steps of the ComMod process

The project's local partner, the NT-NKD RBCs, was interested in determining the key factors that had led to the increase of flooding incidents and magnitude in the basin in recent years, most notably the overflowing of Nam Kading in 2011 (Ward et al., 2013), aside from the operation of hydropower dams. In order to tackle this issue, the ComMod approach was implemented primarily through interactive field workshops involving key stakeholders from the public and private sectors at local, provincial and national levels (Table 1):

- An inception workshop was carried out to introduce ComMod to the Technical Working Group (TWG) of the NT-NKD RBCs, which consists of local government officials at district and provincial levels.
- The first participatory workshop, which involved the NT-NKD RBCs and TWG, as well as village representatives, dam managers and local civil-society organisations, was aimed at conceptualising the river flood issue in the basin using a simple RPG. One of the workshop outcomes was the recommendation that the examination of the issue, as well as the modelling activities, should involve villagers.
- Hence, the second participatory workshop, which was attended by representatives of four villages, was a participatory mapping exercise to construct the map of their respective villages, including flood extent and depth. A knowledge-gathering activity was conducted to identify the local flood factors, which were then used to cluster the villages in the basin. The workshop outcomes were used to improve the RPG.
- The third participatory workshop, which was attended by representatives from eight villages, as well as representatives from one district, was aimed at (i) verifying and validating the flood model using the improved RPG, and (ii) further improving the flood model by identifying the impacts of flood on livelihoods. This was achieved by introducing new game boards representing the villages.
- The fourth participatory workshop, aside from verifying and validating the improvements made on the RPG, was aimed at sharing and linking together knowledge among the basin stakeholders. This workshop was also aimed at identifying flood indicators in the basin, not only for the RPG, but also in reality.
- After this workshop, an ABM was constructed based on the same model as the RPG. Both were presented in a final multi-stakeholder platform (MSP) workshop, which was attended by participants from previous workshops, as well as new participants from different government organisations. The workshop was aimed at illustrating the linkage between the findings from the previous workshops and the ABM, verifying and validating the flood model, as well as seeking recommendations on how to improve it. Participants also discussed in this workshop how they, as a collective group, can address the flooding issue and other basin management challenges.

Table 1. First step : the ComMod workshops and Core Group meetings, with participants, activities and tools (bold).

Workshop		Inception workshop	1st ComMod workshop	2nd ComMod workshop	1st Core Group meeting	3rd ComMod workshop	2nd Core Group meeting	4th ComMod workshop	3rd Core Group meeting	MSP workshop
Partici-pants	National level		Dam managers		Key national stake-holders*	Dam managers	Key national stakeholders *		Key national stakeholders *	Key national stakeholders*, dam managers
	Basin level	RBCs, TWG	RBCs	RBCs	RBCs	RBCs	RBCs	RBCs, TWG	RBCs	RBCs
	Village level		Representa-tive from 1 village	Representa-tive from 4 villages		Representa-tive from 8 villages		Representative from 6 villages		Representative from 5 villages
Activities		Co-design of the process	**First RPG**	Partici-patory mapping	Follow up of the process	**Second RPG**	Follow up of the process	**Multi-level RPG**	Follow up of the process	**ABM** and follow up of the process

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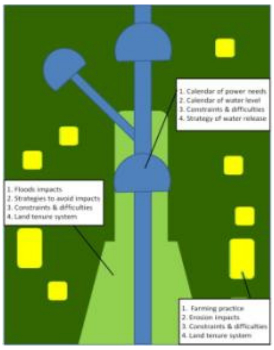
4.2. Description of the series of river basin models

In the first ComMod workshop, a simple river basin model (Figure 2a) was used with stakeholders (Figure 2b,c) to determine several characteristics of land and water uses, e.g. constraints in managing the dams, strategies to release water from the dams, farming practices in the lowland and upland areas, flood and erosion impacts, etc.



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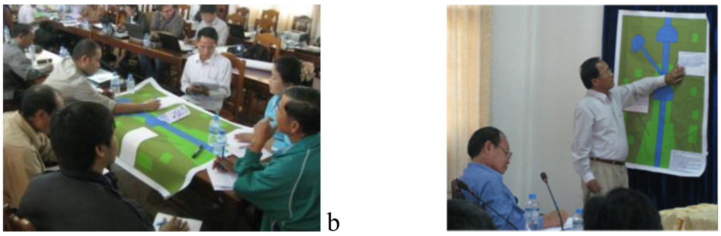
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Figure 2. Basin model used during the 1st ComMod workshop, which consisted of a river (blue lines), three dams (half circular blue areas), upland (dark green), lowland (light green), and upland farms (yellow).

Moving forward with the modelling, the grid-based model support was introduced to the participants and "played" with them (Figure 3) to represent two situations, i.e. regular rainfall and heavy rainfall. In each situation, a facilitator controlled the flow of the game, two people playing as dam managers were in charge of releasing water from the dams, and the rest played as farmers in upland and lowland areas. Farmers were asked to choose their farm plots in the game boards as well as the crops they would plant, either rice or vegetables. Lowland farmers had permanent plots, while upland farmers changed their plots after each game cycle. A game assistant signified the coming of the rain and distributed the rain and sediment tokens onto the game board, then moved the tokens to illustrate flooding and sedimentation downstream. At the end of the session, participants were asked on how to improve the model, e.g. spatial representations and peripherals.

Figure 3. Model support derived from the simple basin model (a-f) used in the first role-play game (g) during the 1st ComMod workshop: two gaming boards representing the upstream part (a) and the downstream part (b) of the river, rain and sediment tokens (c), farm plots (d) with orange paper representing vegetables and green paper representing rice, road tokens (e) and a rain sound maker (f).

During the third ComMod workshop, on the basis of simple gaming materials – a game board at the river basin level and different tokens, participants were asked to modify and complete the basin-level board. Using the location of rivers and dams as references, participants added more details including roads, tributaries, mining and plantation areas, and villages (Figure 4a). Finally, the co-designed map representing the shared understanding of participants of the NT-NKD basin was produced (Figure 4b).

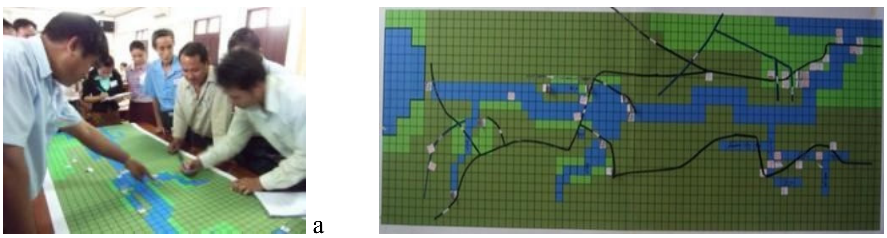
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Figure 4. Villagers locate their respective villages in the basin game board (a), and the basin game board co-constructed by the participants (b) during the 3rd ComMod workshop.

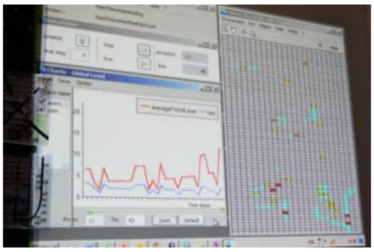
Next, participants were divided into groups and asked to build their respective village's landscape map using cards representing land use types and farming activities (Figure 5). These maps were used to assess flood impacts on livelihoods. Then, each group presented their landscape to other workshop participants, allowing exchange of knowledge and understanding of diverse livelihood contexts among the participants.

Figure 5. The mapping exercise for one village.

Thereafter, all participants were invited to the basin-level game board. Literally with a throw of the dice, the flood level (low, medium, high, or severe) was decided and participants were asked to assess the corresponding flood impacts, including crop and road damages, and to represent those using tokens.

In the fourth ComMod workshop, the same game boards were used. However, more complexity was introduced into the game by adding several elements: various driving factors of flood, such as dam releases, rain, sedimentation, and Mekong river backflow; other land use change drivers, such as land use policies and investment projects; as well as positive impacts of short-duration floods on soil fertility. Minor improvements on the model peripherals were also introduced based on the feedback obtained from the third ComMod workshop, such as addition of national protected areas and mining areas.

An ABM was developed under the Cormas simulation platform based on this latest model version, in order to simulate longer periods, while allowing participants to understand its structure and simulation outcomes. The ABM simulated the degree and impacts of flooding on the villages located near the Nam Theun-Nam Kading river and its tributaries. The spatial graphic interface of the ABM was designed in accordance with the basin game board (Figure 4b) and represented the key land use types co-designed by the participants during the previous RPGs. Simulations based on two scenarios, one with deforestation and one without, were run and their results were presented and contrasted during the MSP workshop (Figure 6).



a

b

Figure 6. Demonstration of flood model within the Cormas simulation platform (a), and one of participants explaining the meaning of computer simulation vis-à-vis the role-playing games (b).

5. DISCUSSION AND CONCLUSION

Our approach has some differences with the ChaRL framework and process which aim at collecting decision-makers' visions about the management of a river basin and at confronting them with scientific work based on primary data (Smajgl et al., 2015). First, in the first cycle of our approach decision-makers were not only involved in the design of the participatory process, but also in the modelling process, which enabled them to identify their knowledge gaps and to call for additional data from other levels, such as farmers and scientists. Second, in the next ComMod cycle, the farmers' and decision-makers' systemic views will be collected and confronted not to assess their feasibility at a focal scale such as the Mekong basin, but rather to highlight the diversity of perception levels and purposes assigned to the environment.

In this regard, our framework aims at giving new insights on the resilience of social-ecosystems, and in particular on cross-scale interactions and trade-offs. It would allow us to assess resilience at different levels: i) at the perception levels of each actor, resilience would be defined as the capacity to achieve identified purposes, based on his or her own indicators of success, in the face of perceived threats or other actors' purposes; and ii) at the level of a group of actors, resilience of emerging collective purposes could be assessed on the basis of collectively decided indicators. This shared viewpoint at a higher level could in return affect the way each actor perceives resilience at his or her own levels, for example by highlighting new threats or resources. The aim will be to allow stakeholders to collectively analyse trade-offs between river basin purposes, knowledge gaps, and potentially emerging collective purposes at different levels, in order to enrich discussion on river basin resilience.

In that perspective, the first cycle of our ComMod process succeeded in generating stakeholders' interest on cross-scale interactions and cross-scale knowledge exchange. During this first ComMod cycle, key stakeholders from the public and private sectors co-designed and used together a model of flood risk in a Mekong sub-basin which includes up- and downstream land and water uses and local livelihood practices. The model is multi-scale, so that each participant considered management not only for his or her local interests but also at the whole catchment level and could link his or her activities, roles and responsibilities with the catchment context, as well as with other stakeholders. By actively playing roles in the participatory workshops, stakeholders could identify knowledge gaps and knowledge needs from other management levels, such as the farmers' level. This improved their understanding of flooding and strengthened their confidence and sense of ownership of the knowledge, which they collectively created. This also enhanced their awareness of cross-scale interactions and of the need to collect multiple knowledge sources to approach such complex processes, which could potentially influence their decision-making and roles in the future. Overall, they were appreciative of ComMod and its modelling tools, i.e. the RPG and ABM, because it afforded them the opportunity to engage in discussions of important issues regarding the catchment. This attitude contributes to a conducive environment for long term ComMod initiatives and other participatory processes aimed at supporting decision-making and future research on river basin management.

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