Companion Modelling for Collective Learning & Action in Water Management: Lessons learnt from three case studies in northern Thailand and Bhutan[1]

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Abstract

The purpose of the interdisciplinary Companion Modelling (ComMod) approach in renewable resource management is to facilitate collective learning, negotiation, and institutional innovation about concrete problems faced by rural communities. The objective of this communication is to present and to compare the effects of the ComMod approach on collective water management at three different pilot sites located in upper northern Thailand (two sites) and west-central Bhutan. At these sites, water management is a cross-cutting problem: the processes of agricultural commercialization and increased pressure on the land led to the need for stakeholders to agree on new rules for the management of limited water resources. In the Lingmuteychu watershed of Bhutan, water sharing at rice transplanting has been a perpetual issue, without a way forward, while in montane northern Thailand a looming water scarcity is linked to the increased demand from expanding irrigated horticultural cropping systems.

The paper compares the way this approach was flexibly adapted and implemented at the three sites according to the local contexts. The main effects of the ComMod process at the three sites are then presented according to a common framework analysing the processes of collective learning, negotiation, and coordinated action that were stimulated. It emphasizes the following effects : learning about the current situation and awareness of a problem to be solved collectively, understanding each other's perceptions and common agreement on the nature of the problem, exploration of new management rules to solve the problem, and concrete implementation of institutional innovation. The discussion focuses on the factors contributing to, or limiting, the achievement of institutional innovation. The role of the local institutional context and the possibility to establish inter-institutional dialogue among multiple levels of organization is highlighted. Finally, we point out the need for specific monitoring & evaluation procedures adapted to such a highly participatory and adaptive process.

Introduction

Purpose of the interdisciplinary Companion Modelling (ComMod) approach

Companion modeling (ComMod) is an approach making use of simulation models in a participatory way to understand and facilitate the collective decision making process of stakeholders sharing a common resource (Bousquet et al. 2005). The principle is to identify the various points of view and subjective criteria to which the different stakeholders refer implicitly

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or even unconsciously, and to integrate this knowledge into simulation models to be used within the context of platforms for collective learning. The different stakeholders, including researchers, aim at working out a common vision of the common resource management that highlights the diversity of interests and perceptions to take into account when setting up agreed upon indicators, shared monitoring procedures, and ultimately concrete action plans.

Our higher-order development goal is to understand and to improve interactions between the social and ecological subsystems for resilient water management at the catchment scale. Holling (1978) and Ostrom (1994) have shown that resilience depends on the adaptive capacity of the system, and that it can be enhanced through better coordination among stakeholders. Such coordination is a necessary condition for the sustainability of livelihoods, social equity, and environmental integrity in mountainous regions.

During the past three to four years, we have been using the innovative ComMod approach to examine different kinds of water management problems at two sites in montane upper northern Thailand and one location in west-central Bhutan. Our common objective is to develop methodologies to enhance adaptive management capacity of local communities. New knowledge acquired on stakeholders' perceptions of water dynamics allows to pinpoint critical interactions between social and hydrological subsystems. These critical interactions provide key entry points for better stakeholder coordination and efficient use of limited water resources in these mountainous areas.

Presentation of the three case studies : local context & water management problem

The two highland catchments in upper northern Thailand are located in Mae Hae of Chiang Mai Province, and Mae Salaep of Chiang Rai Province In this region, small-scale poor minority farmers are being rapidly integrated into the market economy and their former agrarian system based on swiddening replaced by (semi-)permanent cash-crop based agriculture on steep slopes. The diversity of farmers (economic status, agricultural practices, etc.) is already extensive. An increasing number of individual or collective stakeholders with differing water-use strategies interact in the dynamics of this diversifying sloping-land agriculture, and there are more and more conflicts over the access to this key resource. In Mae Hae, the water management problem reinforced by a recent drought involves people from several Hmong and Karen villages. Downstream farmers complain about the increasing share of water being captured by upstream vegetable growers and well-off farmers setting up irrigation pipes system further upstream. In Mae Salaep, tensions occur within the community as only a minority of relatively well-off farms have access to water to irrigate their lychee and tea plantations. This is due to the "first arrived first served" current rule that stipulates that once a farmer has set up irrigation pipes in a stream, other villagers cannot get water from the upstream section.

The high altitude Lingmuteychu watershed in west-central Bhutan is drained by a stream that originates as a spring from a rock face at an altitude of 2400 m. It is totally a rainfed stream since the ranges that confine the watershed are below the snow line. 12 irrigation canals irrigate about 180 ha of terraced wetland belonging to six villages. These villages share irrigation water within a broadly respected customary regime evolved during a time when demands were lower. Under the current processes of market integration, decentralization, and environmental conservation policies, and changes in villagers' social needs, the customary water-sharing rules are not adapted to current farming conditions anymore and are causing a repetitive social conflict every year as it remains unresolved. Under the national Community-Based Natural Resource Management (CB-NRM) policy, this watershed has already been selected as a pilot site to set up a coordinated network of water users' groups.

Recently, participatory modelling workshops, focusing on land-use changes and water management, and involving representatives from all categories of male and female farmers, were

organized at these three sites to test the feasibility of the proposed ComMod methodology (Trebuil et al. 2002, Barnaud et al. 2005, Promburom et al. 2005, Raj Gurung et al. 2005) .

The main objective of this communication is to present and to compare the effects and the impact of the ComMod approach on collective water management at these three different pilot sites. After a presentation of the principles of the Companion modelling approach, the paper compares the way this approach was flexibly adapted and implemented according to the local and research contexts. The main effects of the ComMod process at the three sites are then presented according to a common framework analysing the processes of collective learning, negotiation, and coordinated action that were stimulated. Finally, the discussion focuses on the factors contributing to, or limiting, the achievement of institutional innovation. The role of the local institutional context and the possibility to establish inter-institutional dialogue among multiple levels of organization will be highlighted, before concluding with a discussion of the challenging need to establish monitoring and evaluation procedures adapted to ComMod processes.

Materials and methods

The ComMod methodology combines the use of different tools such as multi-agent systems (MAS), geographical information systems (GIS), participatory mapping, and role-playing games (RPG). It has been tested and used in a dozen of case studies in five different Asia countries during the past four years (Bousquet et al. 2005), as well as in various institutional and cultural contexts around the world (Etienne et al. 2003, in Southern France, Dray et al. 2006 in South Pacific).

Under the ComMod approach, models are used in a cyclic process made of three stages which can be repeated as many times as needed: (i) Review of existing knowledge about the problem to be examined and gap filling field studies to specify the questions to be addressed and to supply information and hypotheses for modelling; (ii) Modelling, i.e the conversion of current knowledge into a formal tool to be used as a simulator (computer MAS model or Role Playing Game); and (iii) Simulations, conducted according to an experimental protocol, to challenge the initial understanding of the system and raise new questions for new field studies, etc (Bousquet et al., 2002).

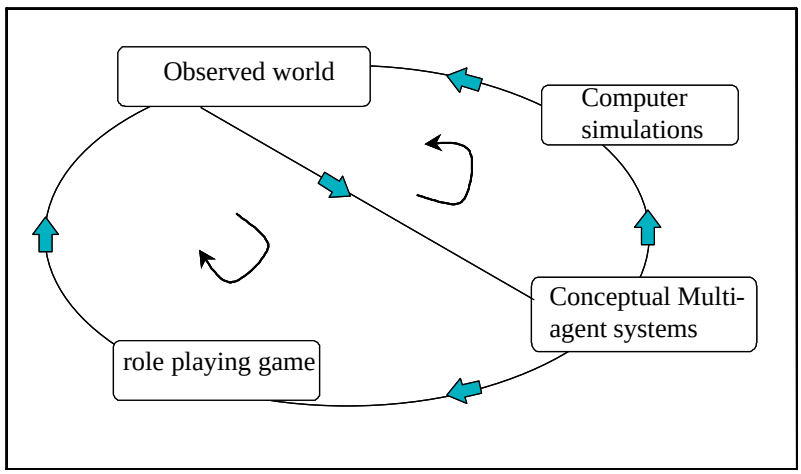

Figure 1. The companion modelling cyclic and iterative process.

Table 2 presents a description of the respective features of the ComMod process implemented in the three case studies. They all have in common this cyclical approach in which at the end of a cycle local stakeholders identify new questions or new challenges to be collectively examined in the next cycle. In Mae Hae and Mae Salaep, the initial questions addressed in the first cycles dealt with land-use and were not directly linked to water management. But in both experiments the participants requested to focus on problems related to water. In this paper, we make use of

only the ComMod cycles that were then implemented to address water problems. In Lingmuteychu, the two cycles focused on water management but evolved from a negotiation between 2 villages to a process involving 7 villages and aiming at setting up a Watershed Management Committee (WMC). Both cycles are analysed in the paper.

Two kinds of simulation tools were used in these three case studies: Multi-Agent Systems (MAS) and Role Playing Games (RPG). MAS are computer models that are particularly appropriate to represent and simulate complex natural resource management (NRM) problems because they focus on interactions among heterogeneous social agents and their common environment (Lansing *et al.*, 1994). In the three case studies, MAS models were implemented by using the CORMAS platform (See http://cormas.cirad.fr) tailored to simulate NRM systems.

According to Duke (1974), RPG is a mode of communication more capable than others to convey complexity as it allows multiple stakeholders to interactively apprehend the complex systems from which they are part. It triggers discussions among players and allows them to test alternate scenarios, but this quickly becomes very time consuming. To remove this constraint, a computer MAS model, very similar to the game in its rules and features, is far more time-efficient to run simulations of scenarios. This association is possible because MAS and RPG have similar components: agents corresponding to roles, the spatial interface to the gaming board, the time step in a simulation to a game round, etc. (Barreteau *et al.*, 2001).

The characteristics and use of the RPG at each site are presented in table 3. In the three sites the objectives of the RPG were twofold : a better understanding of local stakeholders perceptions & decision making processes, and the facilitation of negotiation among them. But each RPG stresses more or less on one of these objectives. The objective of the 7 villages RPG in Lingmuteychu is even clearly oriented toward collective action, as it is a pilot site in a CNB-NRM policy. Another difference among the three case studies is the distance between the game and reality. All RPG refer to a simplified but explicit reality. However, the chosen level of abstraction can be quite low like in Mae Salaep RPG (3D board representing a catchment, players planting & selling crops, setting up pipes systems, etc.), average like in Mae Hae with a quite abstract 2D gaming board, or very high like in the “7 villages” game in Lingmuteychu (players manipulating only water : no explicit crops, no money, etc.). The third main difference is the use of the MAS model. In Mae Salaep, the RPG and the MAS model were developed in parallel: the RPG played by local stakeholders was a way to “open the black box” of the model, i.e. to allow them to understand its structure and operation, and to give them a chance to validate, criticize, and improve it. Both RPG and MAS models could then be used with local stakeholders to explore possible scenarios. In Lingmuteychu and Mae Hae case studies, RPG was the main tool used to stimulate collective learning. The knowledge acquired during the gaming sessions (about stakeholders’ decision-making) was integrated in a MAS model built to explore more scenarios in the lab.

Results

The different effects of the ComMod approach at the 3 sites are presented in table 4 according to a common framework. This framework is adapted from an analysis of processes of collective learning and negotiation process suggested by Leeuwis (2004).

Learning about the current situation & awareness of a problem to be solved collectively

According to Röling and Wagemakers (1998), such awareness is a prerequisite to get people involved in a collective learning process. The RPG efficiently increases this awareness as it puts players in the problematic situation that they face in reality In the three case studies, players spontaneously acted in the game like in reality and produced the rules posing problems. In Mae Hae and Lingmuteychu, farmers from the upstream villages applied the ancestral rule and took as much water as they needed without taking into account the needs of downstream villages, and in Mae Salaep, the wealthiest villagers rushed to buy and set up water pipes and did not allow other

players to get water from the upstream section according to the "first arrived first served" rule. The type of experiential learning in which people can observe by themselves the feedbacks resulting from their actions is considered as one the most efficient way to learn (Kolb 1984). Leeuwis (2004) distinguishes between positive feedback, information that indicates that one is on the right track, and negative feedback indicating the existence of a problem. Such negative feedback was a starting point in the three experiments and stimulated participants willingness to solve the problem. Figure 2 presents the lessons learnt by the participants after two successive participatory workshops with the "2 villages game" in Lingmuteychu and it displays their increasing awareness of the problem of water sharing between the two communities.

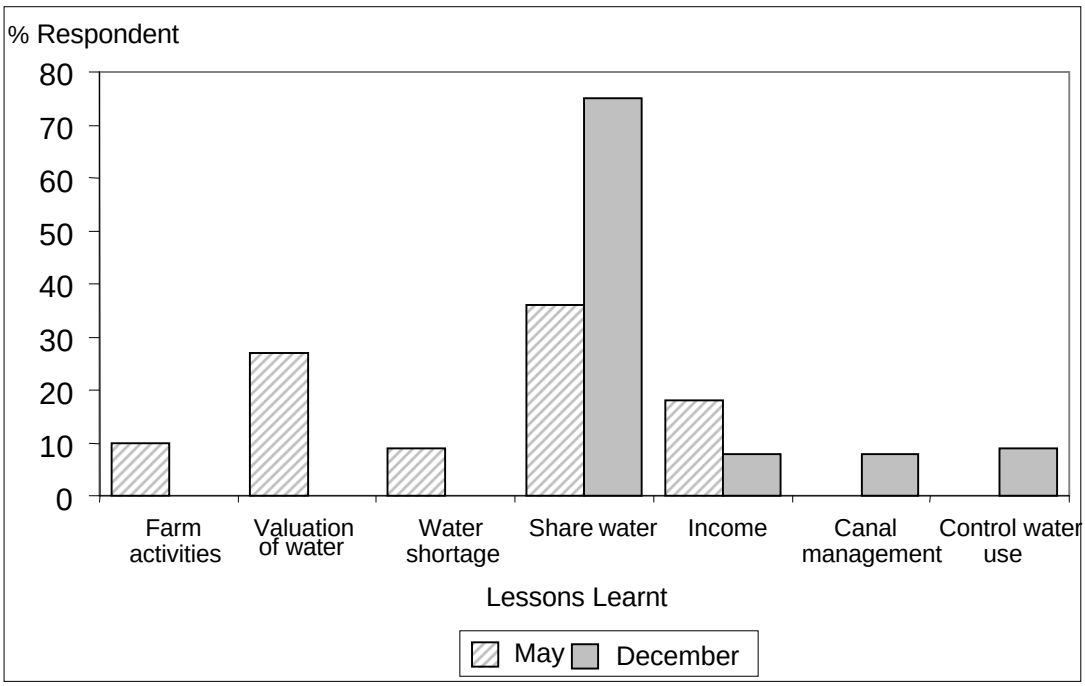

Figure 2. Lessons learnt by the stakeholders in Lingmuteychu watershed after two participatory workshops conducted in May and December 2003.

Understanding each other's perceptions & common agreement on the nature of the problem

In the three case studies, the RPG designed to integrate the main interacting dynamics and stakeholders allowed the players to get an overview of these various interacting dynamics that they do not have in their everyday life. At all sites, during individual interviews, participants repeatedly claimed that the most important thing they learnt from the game was related to other stakeholders' situations, strategies and /or problems. Such a statement is quite surprising when this concerns people living in the same village. But as a village leader in Mae Salaep declared: "in everyday life every one has his/her own problems, people go to fields and don't have such opportunities to think about other's situations". This is less surprising (but all the more crucial) in Lingmuteychu where, because of the old conflict opposing them, villagers from the two communities hardly want to speak to each other. The first challenge here was to gather people in the same room. Swapped roles between upstream and downstream villagers efficiently triggered such an exchange of perspectives. In Mae Hae, farmers usually communicate and find arrangements within small groups of neighbours, but they do not go and discuss with other farmers that are too far up or downstream. The game allowed up and downstream farmers using water from the same stream to have a better understanding of their interdependency.

Such an understanding of each other's perception of the problem facilitated discussions to formulate a common agreement on the nature of the problem. A particular interesting similarity

of this phase in the three cases is that participants did not directly (not openly at least[2]) spoke about the core problem. In the collective debriefing following the gaming session in Lingmuteychu for the "2 villages" game, the participants discussed a lot about exchange of labour, a feature that was missing in the game, but did not openly addressed the question of water sharing. In Mae Salaep, in the first collective debriefing, no one directly said that the "first arrived first served" rule was the reason why so many people could not access water, they said instead that the problem was "the lack of water" and emphasized the need for new infrastructures. In Mae Hae, they did not either directly address the question of water sharing but formulated the problem saying that farmers cultivated too much irrigated vegetables. This illustrates that accommodation of multiple interests is a process that is rarely achieved in one meeting and emphasizes the need for a continuous and iterative process.

Identification and negotiation of new rules to solve the identified problem

Collective agreement on the various perceptions expressed by stakeholders enrich the process of identification of solutions. The analysis of this phase in the 3 cases shows that it is not a straightforward process. In Mae Hae, the participants first suggested that "every one should lower his cultivated area" without fixing any rule, and realized later the need to set up such rules and agreed on "maximum 3 plots per farmer". In Lingmuteychu, after the "2 villages" game, players suggested to change the ancestral rule towards a more equitable access to water, but they didn't sign any agreement. Later on, because some powerful upstream villagers refused to change their current practices in the absence of this official document, they realized the need for a written agreement. Therefore, during the second game, they collectively decided to set up a Watershed Management Committee that was printed and signed by all participants.

Such iterative and continuous process is also important to deal with power relations. According to Van Der Veen (2000), a particular attention to power relations is needed at this phase of collective selection of solutions, because at this stage, there is a risk that, even if people really exchanged their views before, most influential people speak first and impose their view. It is therefore important not to stop at the first so-called consensus that first emerges, because it often reflects the interest of the most powerful ones (Wollenberg, Anderson et al. 2001). In Mae Salaep, the Tambon Administrative Organisation (TAO) representative spontaneously acted as spokesman and tried to impose his idea of building a single large reservoir. Other villagers were reluctant for fear that it would benefit only a minority but they did not dare to say anything against him. It was important for the facilitator to wait a little, asks for other suggestions, and make people vote. All participants voted then for a second suggestion: to build small weirs on different streams and to share water in groups of households.

Exploration of scenarios

This phase of exploration of selected scenarios (with the game and /or the MAS model) also deals with experiential learning as participants can assess the impacts of their suggested solutions. In Lingmuteychu, an essential positive feedback was that upstream players could see that when they shared the water, they could maintain their incomes even if they used less water[3]. In Mae Hae, people first experimented a positive feedback when they saw the results of their collective rule, but it turned to a negative one in a following gaming session when they broke the "3 plot maximum per farmer" rule because of price incentives.

[2] Even if participants did not directly openly speak about the core problem, they probably had this core problem in mind and refer to it in their discussions, but an external observer, even if well aware of the situation in the village, might not notice all these references.

[3] The calibration of agro-ecological features in the game was based on results from on-farm experiments conducted before.

The test of a solution often raises new discussions. This aspect was crucial in Mae Salaep' experiment and illustrates once more the importance of iterative processes. The test of the "small weirs" scenario in the second gaming session made players discuss about the rules to allocate water among the beneficiaries. It is only at this stage that participants started to discuss about the core but delicate problem of allocation rules. The suggestion to set up small weirs and to discuss rules among households was an indirect way to put into question the current "first arrived first served rule". As a villager leader explained: "the only way to change the rule is to build a collective infrastructure that forces people to discuss and set up new rules."

Implementation of solutions

In Mae Hae and Mae Salaep, the ComMod process stimulated a collective learning and negotiation process. Participants were highly willing to set up collective action, but the new rules were not implemented yet as they require the support of key institutions at a higher level in the administrative hierarchy. In Lingmuteychu, the second "7 villages" game implemented in May 2005 led to a formal agreement to set up a Watershed Management Committee (WMC). Later on, the bylaws of this WMC were developed and village representatives selected. In December 2005, the WMC was formally established and the first concrete action plan initiated.

Discussion : ComMod and institutional innovation

From questioning ancestral rules to setting up agreement on new rules and then obtaining signed agreements, institutional innovation is a long and enduring process. It seems that in Lingmuteychu the collective learning and negotiation processes stimulated by ComMod was helpful to achieve such institutional innovation. But the limited impacts of the same kind of processes in Mae Hae and Mae Salaep so far let us think that some institutional contexts are more favourable than others. Ostrom (1994) emphasizes the importance of coordination among stakeholders at different levels of organization for resilient institutional innovation. This raises two types of interrelated problems that will be analysed in this section: the problems related to coordination among the various local water users at the community level, and the problems related to dialogue between the communities and the higher levels of organization.

The first difficulty in institutional innovation is how to reach an agreement among heterogeneous water users at the local level within and among communities? In Mae Hae where several villages were involved, the players rapidly broke the rules they had set up. Upstream villagers probably considered their individual interests were more important than the preservation of their relationships with the lowland villages. But even within a community, collective agreement is not an easy task, because of the existing power relations and the unequal ability of villagers to stick to their interest. A particular attention to these aspects was drawn in Mae Salaep experiment, where there is a gap between an Akha woman who cannot speak Thai and never went out of her village, and a TAO representative used to negotiations. The problem of unequal ability to participate was solved to a certain extent and the less influential people could influence the process. But there is still a risk that at the very end the TAO representative sets up the project according to his own interest. And because he has the power to allow some of the villagers to get more benefits than others, villagers will not dare say anything for fear that they will not get these benefits. This problem is related to the crucial question of accountability of representatives towards communities that is particularly relevant when dealing with dialogue with higher institutional levels (Ribot 2001).

The second level of difficulty faced when stimulating institutional innovation is how to set up dialogue with higher institutional levels? Such a dialogue is needed because community institutions are embedded in a broader institutional level. Community institutions have to be recognized by authorities, and may need their support to implement new rules. In Lingmuteychu's case study, it was only when the WMC was formally recognized and its bylaws

signed that the implementation of its first action plan started. The introduction of such a dialogue between communities and institutions at higher levels should be progressive. There is indeed a risk that the presence of officials too early in the ComMod process put discussions among villagers to a standstill. But this is not the only factor to take into account. In Mae Salaep case study, we set up a dialogue with TAO only when villagers felt sufficiently confident and requested the presence of TAO. But then we faced another problem: despite numerous discourses about the importance of villagers' participation in previous interviews, the TAO chair adopted a paternalist and top-down attitude during the workshop and the ComMod process failed to generate a genuine bottom-up dialogue. The main lesson from this was the need for a better initial analysis of these higher level institutions, in particular their perception of the suggested ComMod process and degree of willingness to participate in it. An important factor explaining the successful institutional innovation process in Buthan was the occurrence of the ComMod process when a new water policy to decentralize management was being prepared at the government level. The fact that the institutional context was evolving at that level supported institutional innovation in the field. Despite a process of decentralization initiated in 1994, this was not the case at the other two Thai sites.

Conclusion

The comparative approach adopted in this paper highlighted the flexibility of the ComMod approach to promote adaptive water management in different contexts, the importance of the continuous and iterative characteristic of the approach to facilitate collective learning and negotiation, and the need for the support from higher level institutions to achieve institutional innovation at the community level. Facilitation of institutional innovation requests collective learning and negotiation not only at the local level of communities, but also with higher levels of organization. One of the challenges is to ensure that the diversity of interests and perceptions at the community level are taken into account when dealing with these institutions at higher level. This calls another broader challenge : how to measure this? How to measure the learning effects and the impacts of ComMod? There is a need to develop monitoring and evaluation procedures adapted to such highly participatory and adaptive processes.

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Table 1. Main characteristics of the agricultural systems at the three sites in Bhutan and northern Thailand.

Case study	Lingmuteychu / Bhutan	Mae Hae / Chiang Mai	Mae Salaep / Chiang Rai
Type of agroecosystem	- Highland rice-based production system on terraces with potato as new cash crop, - Elevation: 1300-2050 m, - Area: 34 km^2, - Forest cover: 69%	- Sloping uplands, 3 sub-watersheds with (semi-) permanent production of cash crops, - Elevation : 980-1,630 m, - Area : 32 km^2 - Forest cover: 70 %	- Advanced transition from shifting cultivation to permanent farming of annual & perennial cash crops on steep uplands, - Elevation: 500-850m, - Area: 3,69 km^2 - Regenerating forest cover: 7 %
Population	- 7 villages : Ngalong (western Bhutan people) and resettled Sarchop (east Bhutan), 6 and 1 villages respectively, - Total population:1,200 - Density: 35 hab/km^2 (total area)	- 14 villages: Hmongs and Karen, 251 and 299 households resp., - Total population: 2,985 - Density: 91 hab/km^2 (total area), 299 hab/km^2 (farm land area)	- 1 village made of 2 hamlets : Akha people (1 hamlet converted to Christianity) - Total population: 590 - Density: 160 hab/km^2 (total area), 194 hab/km^2 (farm land area).
Agricultural productions	Rice, potato, wheat, mustard, maize, vegetables.	Rice, lettuce, cabbage, parsley, zukini, leek, persimmon, asian pear.	Maize, upland rice, lychee, Assam tea, Oolong tea.
Farm size (Ha)	0.5 – 2.0	2.1 – 3.2	0.8 – 11.2
Land/labour(Ha)	0.2 to 1.0	0.7 (average)	0.4 to 3.2
Off-farm income (% total income)	Moderately high (25%)	Average (17%)	Very high (> 50%)
Main ecological constraints	- Shortage of irrigation water for rice transplanting in June-July, - Weed control in rice.	- Soil erosion on steep slopes, soil nutrient degradation & water shortage due to intensive vegetable production.	- Soil erosion on steep slopes, - Shortage of water in dry season for irrigation of plantation crops (lychee, Oolong tea).
Main ecological opportunity	- Potential for local varieties of red rice, - Potato as winter cash crop (double cropping).	- Potential for improved irrigation in 2 out of 3 sub-watersheds, -Water availability allows production of vegetables & fruit (persimmon).	- Potential for perennial crops (Assam & Oolong tea, lychee) - Oolong tea & lychee yields & product quality can be high if water is available.
Main socioeconomic constraint	- Stringent traditional water sharing system, - Villages under 3 different districts,	- Price fluctuations (fruits & vegetables) - Large and diverse communities, 14 villages, 3 sub-district.	- Unequal capacity to invest in perennial crops & irrigation facilities among farmers, - Price fluctuations for lychee.
Main socioeconomic opportunity	- Pilot site for coordinated water users network under CB-NRM policy. - Market for potato cash crop.	- Support from The Royal Project Foundation to market products, - Numerous research & development projects.	- Support from local development agency to introduce perennial crops, - Off-farm employment opportunities in Taiwan.
Type of water management problem	- Shortage of water in dry season, - Unequal access to irrigation water : problem of sharing among irrigators within villages (social status) & among villages (up/downstream location)	- Shortage of water in dry season, - Unequal access to irrigation water : problem of sharing among irrigators (up/downstream location, priority to farmers with pipe systems)	- Shortage of water in dry season, - Unequal access to irrigation water : problem of access to the stream (10 % only of irrigators : well-off farmers arrived first to set up water pipes, access forbidden to other villagers)

Table 2. Characteristics of the companion modelling approach implemented at each of the three sites.

Case study	Lingmuteychu / Bhutan	Mae Hae / Chiang Mai	Mae Salaep / Chiang Rai
Main iterative phases (this paper focuses on **cycles related to water**)	- **1st cycle**: with 2 upper villages to mitigate an old down stream - upstream water sharing conflict (2003, 2 months) - **2nd cycle**: based on earlier positive results involving all the villages and focusing on water management at the whole watershed scale (2005, 2 months)	- 1st cycle land & forest management (2004, 5 months) : scenario visioning with participants highlighted water issue - **2nd cycle on water problem** (2005, 5 months)	- 1st cycle on soil erosion risk & crop diversification (2002, 3 months) - 2nd cycle on access to credit to expand non erosive perennial crops (2004, 5 months) : need to address problem of water to irrigate these perennial crops - **3rd cycle on water problem** (2005, 8 months)
ComMod sequence of activities (for cycles focusing on water)	- Initial discussions with different stakeholders, farmers. Followed for both cycles by secondary data analysis & gathering of additional data by structured survey, conceptualization of role-playing games, participatory gaming workshops, plenary discussion on rules for resource management, monitoring of effects.	- Preliminary analysis diagnostic. - Water cycle: interviews of water users to understand current water use & management, conception and implementation of the Role Playing Game (RPG) with local officials as observers, collective discussion after the game (including officials)	- Water cycle: surveys on local water dynamics, conception of RPG and MAS, gaming sessions to validate the model and stimulate discussions, adjustment of MAS model, participatory MAS simulations of scenarios, monitoring of effects, MAS simulations within small groups of villagers to accompany evolution of discussions.
Institutional context of water management	- New water policy charter to decentralize water management prepared at the government level - An old water sharing conflicts between downstream and upstream villages - Conflict reinforced by the recent adoption of potato as a cash crop in the upper village (double cropping) - Multiple stakeholders: 4 types of farmers, district officers, researchers.	- Market-driven intensive horticultural production, increasing demand on water : conflicts between up and downstream villages, unequal access to water - Multiple stakeholders : Royal Forestry Department, Royal Project Foundation, Land Development Department, Sub-district Administration Organization, heterogeneous farming communities (Hmong & Karen people), researchers.	- Expansion of irrigated perennial crops (lychee, Oolong tea) & increasing demand on water : tensions within the community ("first arrived first served" rule) - Villagers request a dialogue with local Subdistrict Administration Organization (TAO) that could finance water facilities - Multiple stakeholders : 3 types of farmers, TAO president & members, researchers.
Origin of the demand / legitimacy of the approach	- Villages have been going to the courts for many years to settle their conflict but the traditional law is ineffective, - RNR Researchers decided to propose an innovative approach to reach an agreement.	- Demand from local university & development agencies following previous field research at this site on land degradation and food security aspects. - Water scarcity topic adopted after a long drought (2003-2004) & scenario visioning with players	- Process initiated by researchers on soil erosion (after field research on this topic) - Increasing legitimacy along the process : players selected water issue & researchers re-designed the models accordingly.
Promotion of the approach	Local agricultural research agency (RNRRC, Bajo) funded by a European Union Project, with support from CIRAD.	Chiang Mai University research team funded by The Ford Foundation with support from CIRAD.	Researchers from Chiang Mai University, CIRAD & Paris X University, with a local development agency.

Table 3. Use of role-playing games (RPG) in the companion modelling approach implemented at each of the three sites.

Case study	Lingmuteychu / Bhutan	Mae Hae / Chiang Mai	Mae Salaep / Chiang Rai
Key question examined in the RPG	Is there a way to solve the inter-village conflict in irrigation water sharing?	How do stakeholders behave & interact when facing varying levels of water scarcity & price fluctuations?	Which collective agreements could reduce tensions due to water shortage and unequal access to irrigation in the village?
Main objectives of the RPG	- To promote a common understanding of the problem & facilitate negotiation, - To encourage collective action in the field of water management.	- To verify water use & related practices by observing individual & group actions facing water shortages & price fluctuations, -To facilitate negotiation.	- To stimulate exchanges of viewpoints between researchers & local stakeholders, - To facilitate negotiation among farming households & with sub-district officials.
Conception of the RPG	- Led by researchers from RNRRC, Bajo - Method : surveys & analysis of resource-actors interactions formalized in UML diagrams	- Led by Thai PhD student, Chiang Mai Univ. - Method : co-construction among researchers of UML diagrams representing results from surveys	- Led by French PhD student, Paris X Univ. - Method : back and forth between field survey (agrarian system analysis) & UML formalism
Distance between the RPG and reality : level of abstraction & calibration	- Game "2 villages": high level of abstraction : 2D playing board, spatial distribution of land based on farm types, players manipulate crops, water cards, money, labour. - Game "7 villages": very high level of abstraction : 2D playing board, players manipulate only water - Calibration realistic but use proportions (farm size, frequency of each farm type, etc.)	- High level of abstraction: simple 2D board, farm plots allocated top-, mid- or downstream, number & location of plots depends on farm types, players manipulate crops & money, and have to deal with random fluctuations of price & precipitations. - Water availability calibrated to create resource scarcity situation similar to reality	- Average level of abstraction: 3D playing board representing a catchment with rivers (but not their real catchment), number, size & location of plots depends on farm types, players manipulate water pipes, crops, money, labour force, off-farm cards. - Calibration realistic, with an attention to create resource scarcity similar to reality
Rules of interactions among players	- In both games, 3 gaming sessions played with different modes of communication: intra-village, inter-village & swapped roles	- Interactions among players were set free. - Swapped roles between dow & upstream players in the afternoon gaming session.	- Interactions among players were set free, - No swapped roles.
Who facilitated the RPG?	Researchers from RNRRC, Bajo assisted by local development officers.	Thai Ph.D. student assisted by 3-4 university students and one local assistant.	Team : French Ph.D. student & Thai researchers, assisted by university students.
Role of the facilitating team	Mobilize the participants, explain rules & allocate roles, distribute information, maintain gaming atmosphere, manage unexpected behaviour, manage modifications of rules if needed (players invited to suggest rules modification), control time, pay attention to power relations & full participation, facilitate discussions.		
Analysis of the gaming sessions	Collective debriefing just after the game to get feed back from the players, individual interviews conducted the day after the gaming session to assess the RPG and to better understand the reasons behind the players' actions, players' actions during the game plotted on Excel histograms, analysis of individual and collective behaviours based on observations and video recording.		
Relation between MAS model and RPG	- Knowledge acquired during the 1st game used to conceive a MAS model (quite similar to the game) - MAS model built mainly for academic purpose : exploration of simulations in the lab	- Knowledge acquired during the game is being used to develop a MAS model (more complex and comprehensive than the game, linked to a GIS)	- a MAS model, very similar to the game, was built in parallel with the RPG. - RPG "opens the black box" of the MAS. - Participatory MAS simulations to explore more scenarios (3rd day of the workshop)
After the gaming workshop	- Monitoring (of effects) system in place for 6 months after the 2nd game only. - Perspective : out-scaling in another watershed decided by the RNRRC research team.	Perspective : to develop a MAS model to be used in meetings of local & official actors for scenario exploration and negotiation.	- 3 weeks & 3 months later : interviews to monitor effects & MAS simulations with small groups to discuss water management rules, - Perspectives: transfer of the game to local stakeholders if motivated.

Table 4. Effects of the companion modelling approach on collective learning and stakeholders' behaviour at each of the three sites.

Case study	Lingmuteychu / Bhutan	Mae Hae / Chiang Mai	Mae Salaep / Chiang Rai
Understanding of the current situation & awareness of the problem to be solved collectively	- The 1st game highlighted that traditional intra-village water management rules led to inequitable share and underutilization of water. - In the 2nd game, the effects of a collective versus individual mode of water management were understood.	In the first two game rounds, all players could observe that there was not enough water, and that players downstream had crop failure & low incomes because upstream players had a priority access to water.	The first gaming session highlighted current conflicts due to the "first arrived first served rule" : the first well well-off farmers who installed their pipes did not allow others to get water from the upstream section.
Understanding other parties perceptions & common agreement on the nature and causes of the resource management problem	- In both games, 3 gaming sessions played with different modes of communication: intra-village, inter-village & swapped roles - Swapping roles between the upstream and downstream villages allowed actors to better understand the perception of other stakeholders.	- Players realized the high number of farmers using water from the same stream and their interdependency. - Since down stream players could not solve problem individually or among small water user group, they requested a discussion with the whole group.	- Players without water could see that many villagers had the same problem & they could think about it collectively. - But the "first arrived first served rule" was not openly put into question. - Discussion & summary by the TAO member: "problem is the lack of water".
Identification and discussion of new rules to solve the problem	- 1st game: firstly, discussions about exchange of labour, then new rule for allocating water agreed upon, but later rejected by the upper village because no official document was signed! - 2nd game: collective discussion led to a formal agreement to set up a Watershed Management Committee (WMC)	- 1st suggestion: all players should reduce their cultivated area. But without rule, the problem remains. - 2nd suggestion: to set up the rule "maximum three plots per farmer".	- 1st suggestion (TAO member): one reservoir for the village. Idea rejected by others for fear that it would benefit only a minority. - 2nd suggestion (Christian leader): small weirs & water sharing among groups of households. Idea accepted after voting.
Exploration of scenarios to solve the problem	- New collective management rules tested in the game : payers realized that a collective water management would minimize the amount of unused water & bring economic benefits.	- The agreed ruled was implemented in the game and solved the problem. - However, stable good price stimulated players to increase production, then the problem re-occurred.	- Weirs scenario tested in the game. - MAS simulations to explore the rules to allocate water among the beneficiaries of the weir (equal or proportional to plantations size?)
Implementation of the selected new rules & community mobilization	- Bylaws of WMC developed in late 2005 & village representatives selected. - WMC formally established in December 2005 & implementation of the first concrete action plan initiated.	- Participants & officials all wished the collective action become true, but the rule has not been implemented yet. - Some expressed that "we could discuss but rich people may not agree".	- A project to request fund to TAO for water facilities is under preparation. - But there is a risk that the TAO member imposes his idea of a unique reservoir (instead of multiple weirs).