Companion modeling and multi-agent systems for collective learning and resource management in Asian rice ecosystems

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It is widely admitted that poor coordination among stakeholders leads to inefficient resource use, economic and environmental damage, negative externalities, and social conflict. Diverse stakeholders use resources for different purposes, with differing perceptions of their dynamics, and adopt various strategies to cope with problems. Consequently, the number of social conflicts is increasing and they are frequently reported in the national and international media, for example, the cases of water sharing at rice transplanting among farmers and villages in Bhutan, and conflicts over land use between highlanders and lowlanders in northern Thailand uplands. To manage these problems, new legislative frameworks decentralizing the management of renewable resources are being introduced in many countries. To be efficient, these new systems of governance of local resources require a greater involvement of the concerned stakeholders. Their success depends on the quality of the local coordination among stakeholders, who often lack tools, methods, and trained managers to achieve success.

Thus, there is a demand for innovative approaches and tools to improve coordination processes among an increasing number of stakeholders using common resources at the rice agroecosystem level. Our hypothesis is that an understanding and modeling of the diversity of stakeholders' perceptions, associated with participatory simulation sessions, can be used to improve resource management through better coordination of people's actions in any type of rice ecosystem.

The proposed companion modeling approach

Usually, models are used to assemble scientific knowledge and for scientists to propose recommendations to a given decision-maker and the role of other stakeholders is usually limited to the discussion of options to be assessed with the model. In our case, we propose to build models with the concerned protagonists and to use them to represent the different perceptions of various stakeholders in order to facilitate the coordination of their actions on a common resource. Some experiments were conducted by using geographic information systems (GIS) (Abbot et al 1998, Gonzalez 2000), but very few of them dealt with the use of simulations (Costanza and Ruth 1998). The main lesson learned is that these tools, like many technological innovations, can both marginalize and empower people and communities depending how they are used.

Companion modeling (ComMod) is a methodology for the collective implementation and use of simulation models, and, more precisely, multi-agent simulation systems (MAS) which are suitable to represent complex heterogeneous and open systems and for integrating knowledge from various sources (Barreteau 2003). The ComMod approach proposes an iterative and evolving modeling process: participatory modeling is used to facilitate stakeholders' interactions and to identify and scope resource management problems to be discussed and negotiated. Then, simulation models are used to collectively assess scenarios selected by stakeholders. This may lead to new questions, new discussions, changes in the model, and so on.

ComMod combines the use of different tools such as agent-based modeling (ABM), GIS, participatory mapping, and role-playing games (RPG). From a methodology development point of view, the ComMod approach has been tested and used in several places, leading to concrete policy recommendations or collective actions by communities (Aquino (d') et al 2002, 2003, Etienne et al 2003). The use of ComMod implies the execution of the following set of activities in an iterative way:

- *Framing*. Preliminary diagnostic analysis at the system level. Identification and understanding of the system's ecological and social dynamics and of key issues, concerns, and intervention points with stakeholders. Collection of relevant existing data. Identification of knowledge gaps to be filled through specific surveys.
- *Prioritization and visioning*. Participatory selection of a key concrete problem to be examined. Establishment of a common vision shared by all key stakeholders through RPG and participatory simulation workshops. Delimitation of initial areas of agreement, disagreement, uncertainty, and room for coordination and negotiation. Production of qualitative guidelines for monitoring and evaluation of the subsequent ComMod activities.
- *Participatory field work and modeling*. Implementation of an iterative, integrated, flexible, and user-friendly modeling approach combining participatory workshops and laboratory work. Joint validation of the simulation tool with all concerned stakeholders, followed by participatory identification of relevant resource management scenarios to be simulated and assessed collectively, taking into account the competing uses of resources by multiple users.
- *Collective exploration and discussion of trade-offs displayed by the simulated scenarios*. Choice and design of an *action plan* to be implemented to tackle the resource management problem under consideration.
- *Assessment of local impact.* Assessment of the local impact of the approach for participatory and integrated renewable resource management (IRRM).

Case studies

For the past three years, the ComMod approach has been used to examine various resource management problems in different Asian rice ecosystems (Bousquet et al, in press).

Water sharing at rice transplanting in Lingmuteychu, Bhutan

Lingmuteychu is a catchment covering 34 km^2 in west-central Bhutan, which is drained by a totally rainfed stream originating from a rock face at an altitude of 2,400 m. Five small irrigation systems formed of 12 canals irrigate about 200 ha of terraced paddies belonging to 121 households of 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 resource conservation policies, and changes in villagers' social needs, this customary water-sharing set of rules is not adapted to current farming conditions anymore and causes repetitive social conflicts, particularly at rice transplanting, as these conflicts remain unresolved. There is a definite contrast in perceptions of users on the water resource: some consider it an infinite resource, many consider this resource as an exclusively common pool with a free-access regime, whereas the state considers it as its property. The Draft National Water Policy pronounces water as a state property while it emphasizes integrated management. Under the new national community-based NRM policy (CB-NRM), this watershed has been selected as a pilot site to improve coordination among water users. It is located near the Bajo Renewable Natural Resources Research Center (RNR-RC), which is leading the national effort in the field of CB-NRM, and the Natural Resource Training Institute (NRTI) at Lobeysa, the principal institution for higher education in agriculture and resource management in the kingdom. Participatory land-use planning and rural appraisal activities were carried out by the RNR-RC Bajo team at this site. More recently, an analysis of existing water dynamics, water-sharing arrangements, and farming practices has been implemented and a first participatory workshop was held in the two upper villages (where the conflict over water use is acute) in May 2003 to test the proposed ComMod methodology for supporting farmers from the two villages to examine collectively the problem of water exchange at rice transplanting (Gurung, in press). Based on the successful outputs, another participatory workshop was held in December 2003 to modify water-sharing rules. Figure 1 shows the assessment of the ComMod process on the perceptions of the water-sharing issue by the local stakeholders who took part in both workshops.

By using a MAS model reproducing the RPG played and validated by the farmers, simulations were carried out later to examine the relative effects of social networks, communication protocols, and climate conditions on water-use efficiency. Results indicate that communication protocols constitute the most sensitive factor.

Soil and water conservation in diversifying highlands of northern Thailand

Mae Salaep is a highland village in Mae Fah Luang District of Chiang Rai Province, where small-scale poor Akha farmers are being rapidly integrated into the market economy. While their former agrarian system based on swiddening is being replaced by semipermanent agriculture on steep slopes, the risk of increased land degradation through soil erosion by concentrated runoff is a major problem. The diversity of farmers (economic status, agricultural practices, etc.) is already extensive, and their economic and institutional environment is becoming more complex (Trébuil et al 2002). An increasing number of individual or collective stakeholders with differing land- and water-use strategies interact in the dynamics of diversifying sloping-land agriculture. In collaboration with Chiang Mai University and the Department of Public Welfare (a government development agency looking after highland ethnic minorities), a spatially explicit multi-agent model linked to a GIS was built to represent the key interacting ecological and agronomic dynamics (slope characteristics, rainfall, main cropping systems and succession of practices, farmer differentiation, etc.) to assess the risk of soil degradation. This MAS model was later simplified and translated into an RPG to be used with farmers to validate the understanding of the agricultural dynamics by the research team. In December 2002 and May 2004, two participatory modeling workshops, focusing on land-use changes (particularly the transition from annual crops to perennial plantations) and the organization of the credit system at the village level, respectively, were held with representatives from all categories of farmers and development agencies. From the first to the second workshop, at the request of the participants, the emphasis shifted from achieving a shared representation of the IRRM problem and its causes to the use of ComMod for improving the allocation of new village funds to improve the current situation and especially the access of small farmers to plantation crops to limit erosion risk (Barnaud 2004). Figure 2 shows how MAS simulations are now used to examine the respective influence of changes in the allocation of formal and informal credit on the welfare of different kinds of stakeholders.

Conclusions

The ComMod approach seems to be well received by both scientists working in the field of IRRM and local stakeholders. It is important to distinguish between the use of this approach in two specific contexts: (1) to produce knowledge on complex rice systems and (2) to support evolving, iterative, and continuous collective decision-making processes for IRRM. Where the land policy favors a decentralized management of resources, such a MAS-based companion modeling approach has great potential to improve the collective learning and management of rice lands. It can be used to facilitate dialogue, to mitigate conflicts, and to establish coordination mechanisms regarding multiple uses of the land by multiple stakeholders. It is also a powerful tool to integrate knowledge from different disciplines, sources, and across levels of organization. ComMod facilitates the collective assessment of desirable scenarios and identification of suitable innovations to overcome current IRRM problems in rice ecosystems.

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Notes

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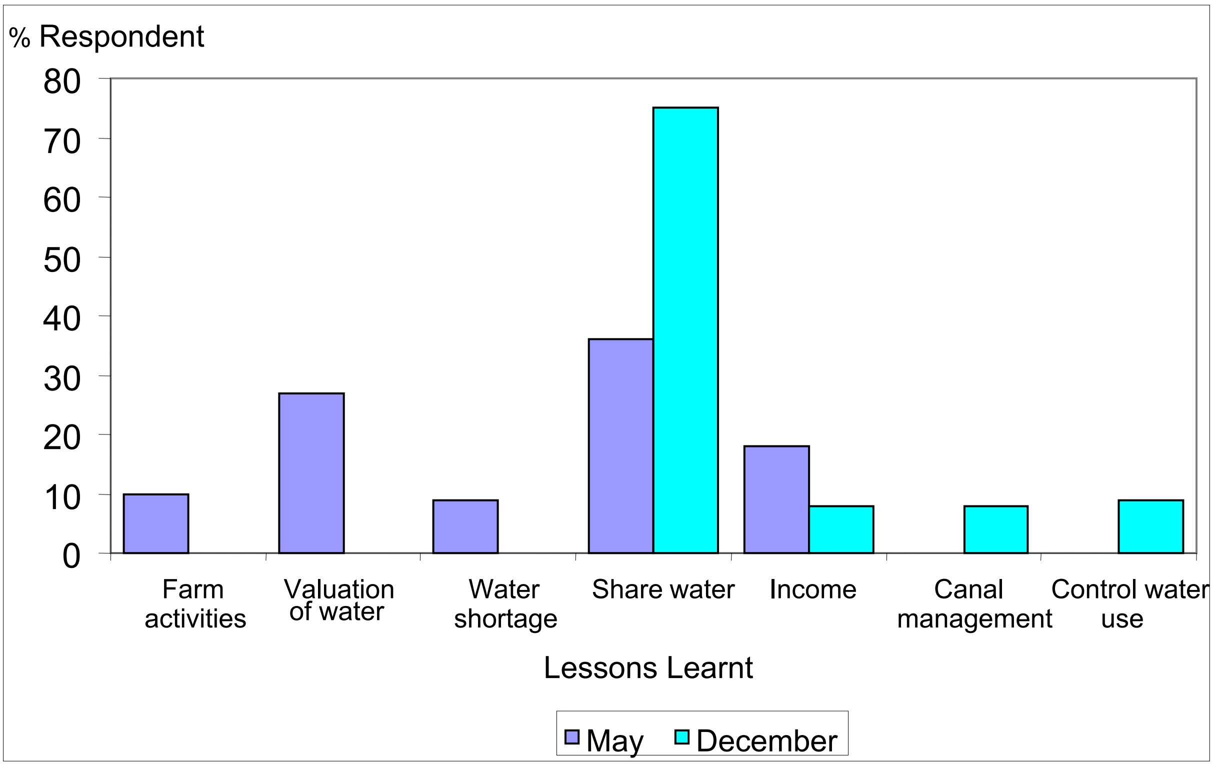
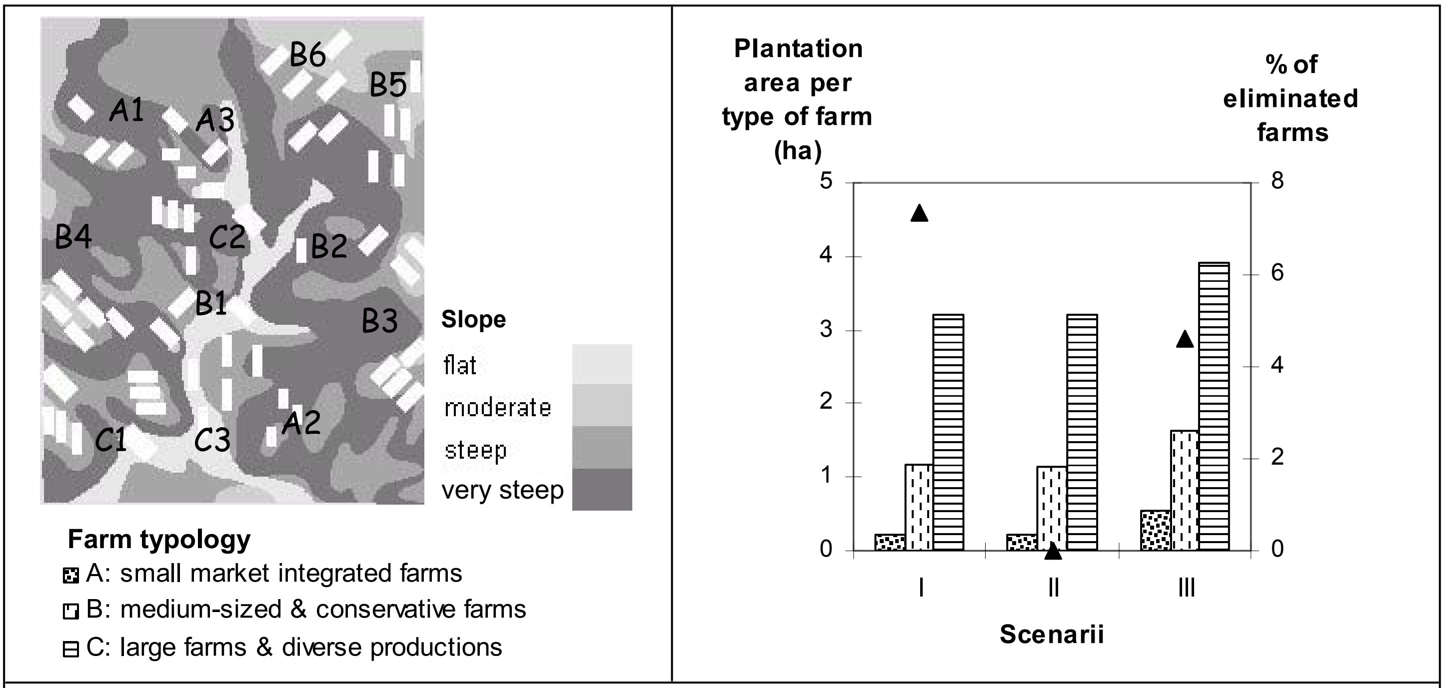
Fig. 1. Lessons learned by the stakeholders after two participatory workshops.

Fig. 2. Spatial interface of the multi-agent model and results of simulations exploring the effects of changes in the allocation of formal and informal credit on farmer differentiation in Mae Salaep agricultural system of Chiang Rai Province, 2004.

Figure 1. Lessons learned by the stakeholders after two participatory workshops.





Description of scenarii
Scenario I: simulation of the current situation and rules regarding the allocation of credit among villagers.
Scenario II: simulation with modified rules for the allocation of informal credit through larger and mixed networks of villagers.
Scenario III: simulation with modified rules for the allocation of formal credit, longer period for reimbursement and more equitable distribution.

Figure 2. Spatial interface of the multi-agent model and results of simulations exploring the effects of changes in the allocation of formal and informal credit on farmer differentiation in Mae Salaep agricultural system of Chiang Rai Province, 2004.