Proceedings of the 2005 International Conference on Simulation and Modelling
V. Kachitvichyanukul, U. Purintrapiban, P. Utayopas, eds.

SYNERGIES BETWEEN MULTI-AGENT SYSTEMS AND ROLE-PLAYING GAMES IN COMPANION MODELING FOR INTEGRATED NATURAL RESOURCE MANAGEMENT IN SOUTHEAST ASIA

François Bousquet

CU-CIRAD Project
Dept. Biology, Faculty of Science
Chulalongkorn University
254, Phyathai Road, Pathumwan
Bangkok 10330, Thailand

Guy Trébuil

CU-CIRAD Project
Dept. Biology, Faculty of Science
Chulalongkorn University
254, Phyathai Road, Pathumwan
Bangkok 10330, Thailand

ABSTRACT

A key challenge in integrated natural resource management (INRM) consists in reconciling ecological and socio-economic dynamics for a collective, sustainable, and equitable management of the land. Diverse stakeholders have different legitimate points of view and representations of the system they exploit and its management is better seen as a collective learning process.

We have tested a "companion modeling" (COMMOD) approach combining multi-agent systems (MAS) models and role-playing games (RPG) to examine concrete INRM problems with stakeholders. This participatory process consists in repetitive back and forth steps between the model and the field to facilitate dialogue, shared learning, and collective decision-making through interdisciplinary and action-oriented research.

The methodological features of this approach are described and two applications in rural Thailand are presented. Among the lessons learnt, we argue that COMMOD users need to distinguish between two specific contexts: (i) The production of new knowledge on a given complex system and (ii) Supporting evolving, iterative, and continuous collective decision-making processes. Such MAS-based and bottom-up COMMOD approach offers a great potential where land management policy frameworks encourage the decentralized management of natural resources.

1 INTRODUCTION

In the field of integrated natural resource management (INRM) a key challenge consists in reconciling ecological and socio-economic dynamics to promote a collective management of the land favoring a sustainable and equitable use of renewable resources. Because concerned stakeholders have multiple legitimate points of view and representations of the complex agro-ecological system they exploit, its integrated management can be seen as a collective learning process. To deal with the increased complexity and rapidity of its changes and the frequent increase in the number and diversity of stakeholders, new types of models articulated with an understanding of the real world gained from other participatory action-research tools, can be used to facilitate such a process and to strengthen the adaptive management capacity of local communities.

For the past three years, in collaboration with several southeast Asian universities, the authors have been testing a "companion modeling" (COMMOD) approach, an hybrid model between multi-agent systems (MAS) models and role-playing games (RPG), to examine several concrete INRM problems with stakeholders. This participatory process is made of repetitive back and forth steps between the model and the field situation. It aims at supporting interdisciplinary and action-oriented research to facilitate dialogue, shared learning, and collective decision-making among multiple stakeholders. The paper describes the principles and key methodological features of this approach before to present two on-going applications in rural Thailand, through their specific RPG and associated MAS models. The first aims at understanding the dynamics of land-use changes in the upper northeastern region. The second case study focuses on highland farmers' decision-making under the influence of crop diversification and market integration influencing the risk of land degradation on steep slopes.

Some preliminary lessons learnt are presented in conclusion. Particularly, the authors argue that it is important to distinguish between the use of this approach in two specific contexts: (i) The production of new knowledge an d understanding on complex systems and (ii) Supporting evolving, iterative, and continuous collective decision-making processes. They also consider that where the land management policy framework is encouraging a decentralized management of natural resources, such a MAS-based and bottom-up COMMOD approach offers a great potential for improving the collective governance of the land. It can be used to facilitate dialogue, to mitigate conflicts, and to establish coordination mechanisms regarding multiple uses of the land by multiple stakeholders with various interest and strategies. It is also a powerful tool to integrate knowledge from different disciplines and sources, and to facilitate the collective assessment of desirable scenarios and suitable innovations for the future.

2 PRINCIPLES OF THE COMPANION MODELING APPROACH

There is an old debate between two scientific paradigms (Checkland 1981, Funtowicz and Ravetz 1994, Roling 1996). Schematically, on the one hand, researchers following a positivist paradigm try to discover the objective truth and to unravel natural laws that drive the system under study. This knowledge is used to develop and deliver new technologies or new management rules. As a consequence, definitions of sustainability emphasize bio-physical attributes of ecosystems and often focus on the estimation of thresholds beyond which land use becomes unsustainable. Hard sciences can show that an ecosystem is endangered, but the sustainable land use can also be seen as the outcome of human interactions and agreement, learning, conflict resolution, and collective action (Roling 1996). Soft systems (Checkland 1981) are based on the assumption that people construct their own realities through learning and social processes. This way, the role of interdisciplinary teams comprising natural and social scientists is to understand and strengthen the collective decision-making process through platforms of interactions. In a very interactive fashion, the different stakeholders, including scientists, work out a common vision on resource management that would lead to new indicators, shared monitoring procedures, information systems, and concrete alternatives for action. The scientists' role is partly to feed this platform with "objectively true" knowledge on the bio-physical subsystem, and to provide ways to compare, assess, and implement the collectively decided concrete alternatives (Figure 1).

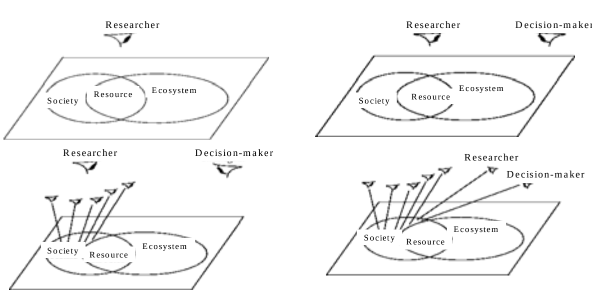


Figure 1. Evolution of scientists' role in decision-making processes. Top left: the scientist is perceived as having the objective point of view. Top right: the decision-maker is taken into account, the scientist provides him with knowledge. Bottom left: with the introduction of social scientists, society is no longer considered as made of homogeneous mechanistic entities but as a set of interacting actors having various points of views. Bottom right: the scientist and the decision-maker are both considered as stakeholders and interact with other ones to improve the management of the ecosystem.

In the recent past, several approaches for collective ecosystem management were developed.

- Adaptive management (Holling 1978, Walters and Hilborn 1978) is an approach based on the recognition that ecosystem management requires flexible, diverse, and redundant regulation, monitoring that leads to corrective responses, and experimental probing of the continually changing reality. Although adaptive management was conceived by ecologists, they recognize that adaptive capacity is dependent on knowledge—its generation and free interchange— the ability to recognize points of intervention and to construct a bank of options for resource management. Thus, interactions among stakeholders for the generation and interchange of knowledge is required. The social process of generation and free interchange of knowledge may lead to the emergence of new kinds of interactions and thus to the issue of devolution of power.
- Co-management (Berkes 1997, Borrini-Feyerabend, et al. 2000) is defined as a partnership in which local communities, resource users, governmental agencies, non-governmental organizations, and other stakeholders share, as appropriate to each context, the authority and responsibility for the management of a specific territory or a set of resources.
- Patrimonial mediation is presented as an approach contributing to the understanding and practice of co-management (Borrini-Feyerabend, et al. 2000). Ollagnon (1991) defines "Patrimonial" as "all the material and non-material elements that work together to maintain and develop the identity and autonomy of their holder in time and space through adaptation in a changing environment". A patrimonial representation of a territory or a set of resources links past, present, and future generations of managers, focuses on the owner's obligations more than on the owner's rights, and promotes a common vision of sustainability that reconciles the needs and opinions of various actors. Mediation is a negotiation method that brings in a third, neutral, party in order to obtain agreement among the other parties involved in the process; it is an approach in which each party's views on the problem being examined are trans-

lated for the others to understand (Babin and Bertrand 1998).

Thus adaptive management not only consists in the objective of increasing the adaptiveness of the ecosystem but also deals with the social processes leading to this ecological state. In other words, what is important are solutions emerging from interactions. And with them comes a different portfolio of interventions including mediation to resolve conflicts, facilitation of learning, and participatory approaches that involve people in negotiating collective action. Computer-enhanced modeling has recently become a tool for such interactive learning (Bousquet, et al. 1994) instead of models seen as tools for piloting the system. A very classic use of simulation is for prediction, but this is not the option we have chosen to deal with complex systems. The very long term cannot be predicted in the economic and social field, though it is partially decidable.

As Weber and Bailly (1993) said: "Because the very long term is beyond the scope of prediction, if we wish to take it into account in the analysis of environmental problems, we must give ourselves very long-term reference points or objectives to guide the possible or impossible pathways of development. The long-term approach must inevitably be based on a scenario". Because governing rules result from interactions among stakeholders, they are legitimate in the eyes of all stakeholders and incorporate particular perceptions. It is on the basis of a shared conception of how the present situation should evolve that stakeholders are able to agree and "decide" on very long-term objectives. On that basis, scenarios enabling to reach these common objectives can be discussed. The entire mediation approach presupposes the elicitation of the initial situation. At the beginning of the mediation process, the stakeholders are clearly informed about the issues dividing them and of their common dependence upon a solution to the problem. The challenge of the initialization phase is to enable stakeholders to express their perceptions of the current situation and its evolution. When a "map of perceptions", all equally legitimate and equally subjective, has been established and discussed, the stakeholders are asked to discuss the acceptability of prolonging existing trends.

Like with any kind of representation, MAS models can be used to increase scientific knowledge about the ecological and social processes under study. But the collective creation of a common artificial world can also serve to create a shared representation of the system to be managed and to simulate various scenarios with stakeholders, the scientists being one group among them. Within this framework, any decision, particularly if it is a collective one, is context-dependent and should be seen as a stage at a given time “t” in the continuous process of management of a complex issue. As Roling (1996) said: “Based on their intentions and experience, people construct reality creatively with their language, labor, and technology. Different groups do this in different ways, even if they live in the same environment. The same people change their reality during the course of time in order to adjust to changing circumstances”.

In summary, a central feature of the COMMOD approach is to use simulation models integrating various stakeholders’ points of view to develop a shared representation of the systems to be managed and of the problem to be examined, and to use them in an interactive process within the context of platforms for collective learning.

3 MUTI-AGENT SYSTEMS AND ROLE-PLAYING GAMES

MAS simulation was selected as a key tool because it focuses on interactions among heterogeneous agents having different representations and status in the interaction process. They act and transform their environment, which will be modified for the other agents (economists would called this the generation of externalities), and this common environment has its own dynamics of change.

Figure 2 shows that we use these MAS simulations in a cyclic process made of three stages which can be repeated as many times as needed (Barreteau 1998, Barreteau 2003):

1. Field studies and literature review supplying information and hypotheses for modelling and to raise questions to be solved by using the model;
2. Modelling, i.e. converting the existing knowledge into a formal tool to be used as a simulator;
3. Simulations, conducted according to an experimental protocol, which results challenge the understanding of the system and raise new questions for a new round of field work.

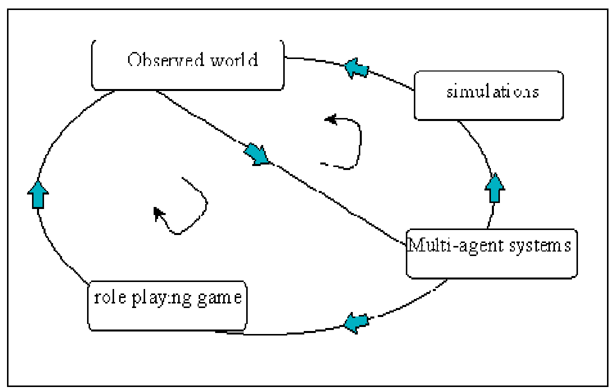


Figure 2. The companion modeling (COMMOD) cyclic process.

We named it “companion modelling” because it is used as a tool to facilitate the process of mediation (the social dimension of the companion) and because it is co-evolving with the social process (temporal and adaptive dimensions). A key question was how to use these models in an interactive way with stakeholders? In agreement with the above-mentioned principles, a model, which is a given representation among other possible ones, should be presented in an explicit and transparent way to avoid the well-know "black box" effect among model users. To do that, we got inspiration from research done by several scientists working on environmental studies who developed and used role-playing games (RPG) for the purpose of collective learning or collective action (Burton 1994, Meadows and Meadows 1993, Mermet 1993, Piveteau 1994). Intuitively, a MAS model is a RPG simulated by the computer. Bousquet et al. (1996, 1999) proposed to build RPG similar to the MAS model for real stakeholders to play them in order:

- To understand the model, and more precisely to perceive the difference between the model and their real circumstances,
- To validate the model (both the individual behaviours and the properties of the system emerging from interactions) or to propose modifications,
- To be able to follow computer-aided MAS simulations and to propose desirable scenarios to be assessed.

Different applications were conducted to assess whether models and RPGs can be successfully articulated to support collective decision-making, as well as to explore different uses of these associated tools. In 1998, a first application dealing with the viability of an irrigated scheme in Senegal was proposed by Barreteau (Barreteau et al. 2001). He simplified a complex MAS simulation model to construct a RPG to be used with several stakeholders, and then he proposed a new MAS model allowing the exploration of scenarios with the stakeholders. Several months later d'Aquino (Aquino (d') et al. 2002, 2003) used RPG and a MAS model in the delta of the Senegal river with a different perspective: the objective was the collective construction of a RPG with the stakeholders to be translated into a MAS model for scenario simulation. This was done during three-day long workshops with different resource users and local decision-makers. Boissau and Castella have recently started applications (called SAMBA) on land-use changes in northern Vietnam (Boissau and Castella 2003, Castella, et al. 2001). Aubert (Aubert, et al. 2002), Etienne (2003, Etienne, et al. 2003) also conducted several applications using different ways to associate MAS simulations and RPG. Following the multiplication of the number of case studies a research group was created (http://cormas.cirad.fr/en/reseaux/ComMod/index.htm) and two ethical and methodological issues emerged.

Like in other participatory approaches the status and legitimacy of the researcher and of the process is questionable. Following the development of a first set of applications, the COMMOD group of researchers felt necessary to publish a charter to explicit their scientific posture (This document is available at: http://cormas.cirad.fr/en/reseaux/ComMod/charte.htm). This charter postulates that all the assumptions backing the modelling work have to be voluntarily and directly subjected to refutation. For COMMOD users, having no *a priori* implicit experimental hypothesis is an objective and this implies the adoption of procedures to unveil such implicit hypotheses. The impact of the approach also needs to be taken into consideration as soon as the first steps and be assessed in terms of research objectives, quality of the approach, quantitative monitoring and evaluation indicators. Particular attention should be paid to the process of validation of such a research approach, keeping in mind that a general theory of model validation does not exist, and that specific procedures, differing from those used in the case of physical, biological, and mathematical models, need to be considered here.

The methodological question concerns the association of various tools, such as RPG and MAS simulation models but also GIS, field surveys, interviews, etc. Table 1 presents a classification of these kinds of combinations as proposed by Barreteau (2003).

	Underlying conceptual models are different	**Conceptual models are the same**
Model and game are used at the same time	- model supporting the game -model included in the game -game as communication between model and reality	-game is the model
Model and game are used after the other	Game to learn how to use the model	-model of the game to repeat it -game to validate the model -model to support game design -game to support model design -co-construction of model and game -model as benchmark

Table 1. Classification of the categories of joint use of a computerized model and a RPG according to the sharing of conceptual model and the relative timing of use.

This table emphasizes the importance of the conceptual model. In some cases the RPG is used in a process of collective conceptualisation (Aquino (d'), et al. 2002), but usually conceptualisation precedes its implementation in a RPG, in a MAS simulation model or in both. Very often, this conceptualisation phase is an interdisciplinary step made of discussions, literature review, and complementary field surveys or field experiments implemented to fill knowledge gaps. The use of the graphic Unified Modelling Language (UML) during this phase has proved to be very useful because it requires precision from the part of the team members and it provides a concrete output of the conceptual model they agreed upon at the end of each round of talk. Precise UML diagrams also facilitate the implementation of the model and make the verification process more easy when one needs to check that the implemented model is an true representation of the conceptual one.

The classification is based on the degree of similarity between the conceptual models of the RPG and the MAS simulation model. When it is not the same, one tool is usually used to support the other one. This is the case when MAS models provide a dynamic environment to the RPG players or, conversely, when a RPG is used to explain what are the contents of the MAS model. When the RPG and MAS conceptual models are different, there is a mutual support in the design and the analysis of both tools. RPG makes the sharing and modification of the conceptual model with the stakeholders more easy, while the MAS model allows fast simulations of various scenarios proposed by the stakeholders. In the COMMOD iterative cycle a co-construction of the model and the game is taking place, each one allowing the analysis and the improvement of the other one.

While companion modelling approach proposes principles and tools, it does not impose any fixed methodology which would organize precisely the use of the tools. With this regards, it is in line with the principle that adaptive management is a social process, which needs to take into account the particularities of a given set of stakeholders (the scientist among other) in a given ecological environment at a given period of time. Given the context and the constraints the researcher(s) mobilize the set of tools in different ways.

4 CASE STUDIES

4.1 Land use changes in northeast Thailand

Until recently, northeast Thailand was known to be a major rice and cassava growing region, while sugarcane has been an important industrial crop in Thailand and had been widely grown in the central region. Sugarcane plantation has been expanding throughout the Northeast causing land use changes, in upland areas it replaced cassava and rice in lowland fields. In 2000, sugarcane planted area in the northeast had exceeded 300,000 hectare, compared to only 40,000 hectare in 1973. There is a need for the scientist to understand the driving forces of this process and to assess its potential consequences in terms of risk, profit sharing and food security.

With increasing number of actors and increase in social interactions impacting on ecological management, the purpose is to generate more information on behavior that lead to better policies. The focus of the work is on observation of land use dynamics and on social interactions in the sugarcane commodity chain. For scientists who study the dynamics of the agroecosystem, it is therefore important to conceptualize farmers' decision rules, both related to physical and social conditions, as well as the collective social rules that can explain land use changes. In addition, information on changes in farmers' decision making overtime should enhance the understanding of system dynamics and its adaptive property.

The study method involves secondary data review, rural assessment, stakeholder interviews, role-play in games and MAS modeling. The first step of this research was to assemble scientific knowledge on the different actors at stake and their decision-making. This was processed through a series of interdisciplinary meetings which resulted into a set of diagrams modeling decision making processes (an example is in Fig. 3), distribution of variables and characterization of bio-physical and ecological environment.

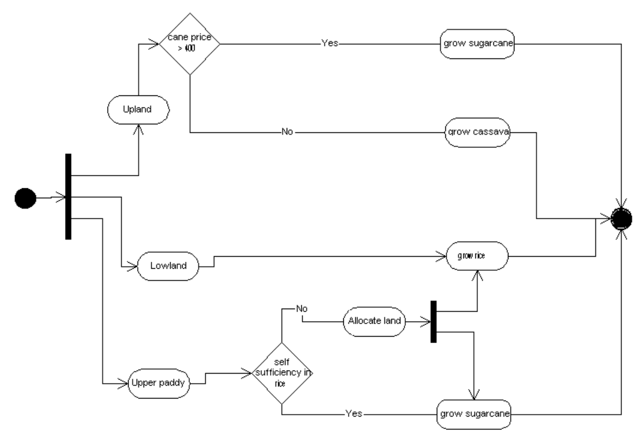


Figure 3. Scientist point of view on farmer's decision-making process on crop allocation depending on the topology.

The conceptual model was then translated into a role-playing game which has been conducted twice from May 28 to 31 and September 10 to 13. It has also been partially done in March 2003 in Ban Hin Lad village for two days (28-29 March). The playing environment of the agents is a 3-dimensional board (Fig. 4) model that represents the local landscape with its main heterogeneities (3 levels of land units).

Figure 4. The playing board.

Design accessories of the game are farm plots, crop price lists and yields, and sticky colored papers (Post-It) predefined for each crop and medium of exchange. For instance, strips of white paper were prepared to represent the farmers' plots. Different colored Post-It were allocated for different types of crops. Each farm was divided into homogeneous areas (0.8 ha each) called "cells", based on the minimum plot size for rice production that is enough to support an average household of 5 persons. The land allocation to players was prepared to mimic the heterogeneity observed in reality. The game is designed for 10-15 players for each session.. Each time a farmer makes a decision, he/she selects a colored Post-It corresponding to the crop type and posts it on a land cell. After all players planted their crop, those who planted sugarcane start informal discussions with quota leaders and bargain the price at which they want to sell the crop as green. When an agreement is made, the exchange price is written on the Post-It and later it was collect by the buyer. This resembles reality in that buyers are the ones who harvest the fields so they take the Post- It to sell to the factory. Two organizers play the role of the sugarcane factory and the market (to buy or store other crops). At the end of each time step, players collect the Post-Its, then sell to the factory or the market. The full set of decisions for cropping can thus be recorded on spreadsheets. At each time step, all crop yields are dependent on the weather randomly defined by the game organizer after the crops are planted. Toward the end of the gaming session, sugarcane prices are announced shortly before harvesting. Players then collected post it paper and sell the crops to the factory or the market accordingly. Prices of other crops were determined at the market. If a player wanted to store rice, the market would keep the Post-It but not return any cash to the players.

After collective and individual interviews of the payers the model was turned into a simple MAS model which allowed the exploration of various scenarios (sugarcane price modification, changes in water management through the introduction of farm ponds).

Among the results of the participatory process :

- Stable production of glutinous rice for family consumption dominates in the poorly drained depressions. Sugarcane and cassava occupy most of the upland areas, and crop diversity is most extensive in the transition zone (Fig. 5).
- Large-scale sugarcane quota leaders influence the crop choice of smaller growers.
- Fewer growers request being quota leaders when the sugarcane price drops.
- The role-playing game raised growers' awareness of the effects of a decrease in sugarcane prices and the need for coping strategies.
- "It wakes up the brain!": the role-playing game is taken seriously by the villagers. Most of them play according to real circumstances (field location, crop allocation, common agricultural practices, price negotiation, social influences, etc.). If given the chance, some farmers implement their projects during the game or test new opportunities. Even 3-hour-long gaming sessions were well-accepted.
- Players say they learned how others were thinking and planning their choice of crops.
- The role game was efficient in stimulating discussions and exchange of views (on land use, price negotiation, etc.) among a diversity of stakeholders.
- Players requested changes in the game rules, such as more options to diversify their farm activities or more stakeholders to be added.
- Most farmers were better able to follow a computer simulation with similar features than the game they played before, and some proposed model improvements.

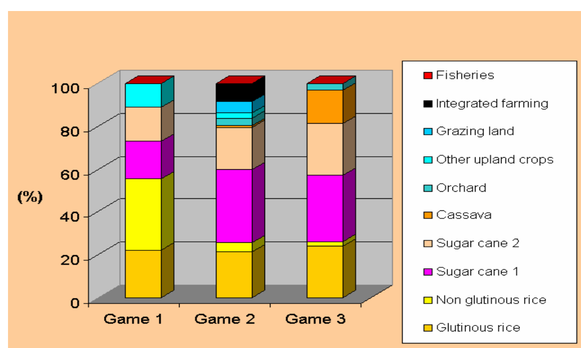


Figure 5. Land use in the transition zone : results of the three-playing games

4.2 Land degradation versus diversification and market integration in northern Thailand

In the highlands of northern Thailand, montane cropping systems are rapidly diversifying and integrated into the market economy and horticultural productions are playing a key role in this process. As most of the farmers' fields are located on steep slopes with angles up to 60%, the risk of serious soil erosion by concentrated runoff is high during the wet season. Understanding farmers' perceptions and decisions-making processes regarding land-use is needed to elucidate the relationship between crop diversification and risk of land degradation. It is also a prerequisite to the identification of appropriate land-use scenarios with the concerned stakeholders to mitigate this problem.

The initial objective of this case study were twofold: (i) To integrate existing knowledge on crop diversification and erosion risk at the homogeneous zone, whole field, farm and catchment levels into a multi-agent model linked to a GIS, (ii) To simplify his model and translate this model into a RPG to validate it with farmers and to improve the researchers' understanding of farmers' individual and collective decision-making processes driving land-use changes.

This first "researcher-driven" version of the MAS model and its associated RPG were described in details elsewhere (Trebuil, et al. 2002). A first 5 days participatory workshop with villagers was held during which the modeling of the interaction between crop diversification and soil erosion risk was validated. A new and simplified MAS model reproducing the gaming sessions was also presented to the farmers-players allowing two kinds of simulations to be run (MAS-GIS based or RPG-based ones). Its spatial interface is shown in Figure 3.

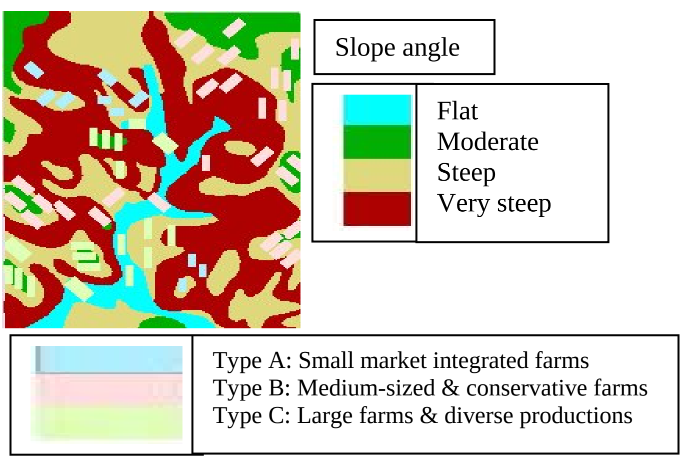
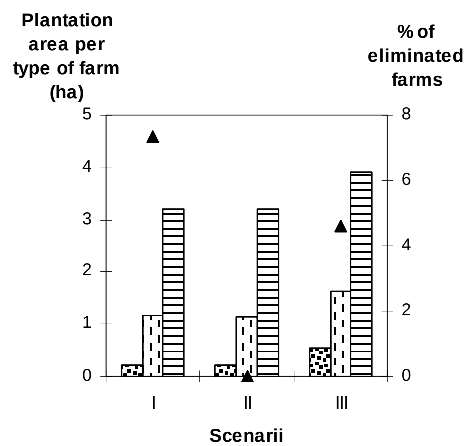


Figure 3. Spatial interface of a multi-agent model to simulate accelerated role-playing game sessions on crop diversification on different types of farms in the highlands of northern Thailand.

But farmers also requested modifications in the model to be made to take into account the introduction of new plantation crops in the area. Furthermore, as new village funds were being made available, they also proposed to use the RPG and the MAS model to simulate different scenarios regarding the allocation of credit among different groups of farmers to facilitate the introduction of perennial crops on all types of farms to decrease both soil erosion and the risk of seeing many resource-poor farmers being eliminated against their will.

The research team carried out the necessary improvements of the model and tailored a new version of the role-playing game focusing on the allocation of credit at the village level that was played with the villagers during a second 3-day long participatory workshop. Following this exercise, different scenarios based on varying collective rules for the allocation of rural credit are being simulated and discussed. Figure 3 displays the results of the simulation of three different scenarios dealing with the expansion of plantation crop areas (the agro-ecological dynamic linked to soil and water conservation) on the three main types of farms and the corresponding rate of elimination of resource-poor farmers due to increased indebtness (a socio-economic indicator of who would benefit from a given set of rules).



NB: Description of the three 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 4. 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.

This example illustrates the iterative and evolving nature of the COMMOD process as well as the implication of the stakeholders in the design of the model itself. It also shows how social relations can be taken into account in COMMOD and the special attention to be paid to the composition of the group of stakeholders-players to be involved in such a collective learning process.

5 DISCUSSION AND CONCLUSION

The COMMOD charter proposes to distinguish between the use of this approach in two specific contexts: the production of knowledge on a given complex system (like in the first example above), and the support to collective decision-making processes (like in the second case study). While the first context corresponds to systems research, the second one deals more with methodological research to facilitate the concerted management of such systems. In each case, a particular relationship to field work is proposed.

In the first kind of situation, the key challenge for COMMOD is to deliver an improved understanding of the processes driving the functioning of the complex system rather than a "turn key" itinerary for renewable resources management. As a consequence, there is a special relationship between the field and the model: instead of proposing a simplification of stakeholders' knowledge, the model is seeking a mutual recognition of everyone representation of the issue under study. Achieving such a mutual recognition is the focus of participatory modelling and this leads to the identification of indicators of the system status which are gradually and collectively built during the implementation of the approach.

In the second type of situation, COMMOD is used to facilitate mediation, even if it is not covering the whole mediating process. Here, beyond the identification of a shared representation of the problem to be examined, COMMOD intervenes upstream of the technical choices and decisions to support the reflection of concerned actors and their exchanges in order to identify possible ways toward a process of collective management of the problem which are acceptable to all parties. In doing so, COMMOD does not include other possible steps in the mediation process that deal with a more technical and quantitative kind of expertise (size of a new infrastructure, estimation of productions and costs, etc.).

REFERENCES

Aquino (d') P., Le Page C., Bousquet F. and Bah A. (2002). A novel mediating participatory modelling: the 'self-design' process to accompany collective decision making. *Int.J. Agricultural Resources, Governance and Ecology* **2**(1): 59-74,

Aquino (d') P., Le Page C., Bousquet F. and Bah A. (2003). Using Self-Designed Role-Playing Games and a Multi-Agent System to Empower a Local Decision-Making Process for Land Use Management: The Self-Cormas Experiment in Senegal. *Journal of Artificial Societies and Social Simulation* <*http://jasss.soc.surrey.ac.uk/6/3/5.html*> **6**(3),

Aubert S., Le Page C., Joly H., Razafindraibe R., Ranaivoson J., Ralalaoherivony S. B., N'Daye I. C. and Babin D. (2002). Conception, adaptation and diffusion of a computer-assisted role game about phytogenetic resources management at a rural level in Madagascar. 7th biennial conference of the International Society for Ecological Economics, Sousse (Tunisia), March 8-10.

Barreteau O. (1998). Un Système Multi-Agent pour explorer la viabilité des systèmes irrigués : dynamique des interactions et modes d'organisation. PhD thesis, Montpellier, Ecole Nationale du Génie Rural, des Eaux et des Forêts, 260 p.

Barreteau O. (2003). The joint use of role-playing games and models regarding negotiation processes: characterization of associations. *Journal of Artificial Societies and Simulation* **6**(2), http://jasss.soc.surrey.ac.uk/6/2/3.html

Barreteau O. (2003). The joint-use of role-playing games and models regarding negotiation processes : characterization of associations. *Journal of Artificial Societies and Simulation* **6**(2), http://jasss.soc.surrey.ac.uk/6/2/3.html

Barreteau O., Bousquet F. and Attonaty J.-M. (2001). Role-playing games for opening the black box of multi-agent systems: method and lessons of its application to Senegal River Valley irrigated systems. *Journal of Artificial Societies and Social Simulation* **4**(2), <http://www.soc.surrey.ac.uk/JASSS/4/2/5.html>

Boissau S. and Castella J.-C. (2003). Constructing a common representation of local institutions and land-use systems through simulation gaming and multiagent modeling in rural areas of northern Vietnam : the Samba-week methodology. *Simulation & Gaming* **34**(3): 342-357,

Bousquet F., Barreteau O., Le Page C., Mullon C. and Weber J. (1999). An environmental modelling approach. The use of multi-agents simulations. Advances in Environmental and Ecological Modelling. F. Blasco and A. Weill. Paris, Elsevier**:** 113-122.

Bousquet F., Barreteau O., Mullon C. and Weber J. (1996). Modélisation d'Accompagnement : Systèmes Multi-Agents et Gestion des Ressources Renouvelables. Quel environnement au XXIème siècle ? Environnement, maîtrise du long terme et démocratie, Abbaye de Fontevraud, 8-11 Septembre.

Burton M. (1994). The irrigation management game: a role playing exercise for training in irrigation management. *Irrigation and Drainage Systems* **7**: 305-348,

Castella J. C., Boissau S., Lan Anh H. and Husson O. (2001). Enhancing communities' adaptability to a rapidly changing environment in Vietnam uplands: the SAMBA role-play. Sustaining Upland Development in Southeast Asia: Issues, Tools & Institutions for Local Natural Resource Management, Makati, Metro Manila, Philippines, 28-30 May 2001, SANREM CRSP/ Southeast Asia.

Etienne M. (2003). SYLVOPAST: a multiple target role-playing game to assess negotiation processes in sylvopastoral management planning. *Journal of Artificial Societies and Social Simulation* **6**(2), http://jasss.soc.surrey.ac.uk/6/2/5.html

Etienne M., Le Page C. and Cohen M. (2003). A Step-by-step Approach to Building Land Management Scenarios Based on Multiple Viewpoints on Multi-agent System Simulations. *Journal of Artificial Societies and Social Simulation* **6**(2), http://jasss.soc.surrey.ac.uk/6/2/2.html

Meadows D. and Meadows D. (1993). Fish Banks News. Durham, NH, USA, Fish Banks Ltd and Laboratory for Interactive Learning University of New Hampshire.

Mermet L. (1993). La nature comme jeu de société, L'Harmattan.

Piveteau V. (1994). L'avenir a long terme des zones rurales fragiles, approche par le jeu prospectif d'une question complexe. PhD, Université Paris 1, 355 p.

Trebuil, G., B. Shinawatra-Ekasingh, F. Bousquet, and C. Thong-Ngam. 2002. Multi-Agent Systems Companion Modeling for Integrated Watershed Management: A Northern Thailand Experience**.** In: Lanscapes of diversity, X. Jianchu and S. Mikesell (editors), Yunnan Science and Technology Press, China. Proceedings of the 3rd International Conference on Montane Mainland Southeast Asia (MMSEA 3), Lijiang, Yunnan, China 25-28 August 2002. 349-358. Available online via <http://www.cbik.ac.cn/cbik/resource/MMSEA_Index.asp> [accessed September 08, 2003].

AUTHOR BIOGRAPHIES

FRANCOIS BOUSQUET has a background in modelling with a speciality in computer simulations of socio-ecological systems. He had his PhD (1994) and degree of Director of research (2001) at University of Lyon 1. During 2001-2004, he was seconded to the IRRI Social Sciences Division with G. Trébuil and was mainly working on using the companion modeling approach for integrated natural resource management in Thailand rainfed rice ecosystems. He is presently based in Thailand for a joint project between Cirad and Chulalongkorn University on Companion Modelling.

GUY TREBUIL is senior researcher in the research unit on renewable resource management and the environment (GREEN) of Cirad, France. He was trained as a systems agronomist and holds a doctorate degree in agricultural economics from INAP-G, France. He is also Director of research in human, economic and regional geography at Paris X University. During 2001-2004, he was seconded to the IRRI Social Sciences Division with F. Bousquet and was mainly working on using the companion modeling approach for integrated natural resource management in Thailand rainfed rice ecosystems.