CHAPTER VIII

THE FOUR SEQUENCES OF THE COMPANION MODELLING PROCESS IMPLEMENTED IN THE LAM DOME YAI WATERSHED

The research team was inspired by an initial discussion with villagers during a field survey in the Lam Dome Yai watershed conducted in the dry season of 2000, and by attending several short training courses on Multi-agent systems, computer science and INRM in 2002-2003. In the study area, labour shortage is an important limitation to farming as many working-aged people migrate to other regions to seek more profitable employment, leaving only children and elders in the village. Based on those initial discussions with villagers, the research team decided to analyze the problem of labour shortage in relation to land and water use because 80% of the land is dominated by agricultural uses, requiring a relatively high number of labourers. Fundamentally, the ComMod process was implemented at this study site because of the researchers' poor understanding of interactions between land/water use and labour migration that could lead to the failure of state-funded development of water infrastructures in the Lam Dome Yai Watershed.

From the researchers' point of view, the main objective of the ComMod activities was to better understand the interactions between land/water use and labour migrations across diverse farm types. The results of this research could then guide the design and adaptation of local water resource development projects in the future at a time when government authorities are planning ambitious and costly projects in this field. In this ComMod process, RPGs and ABMs have been the main modelling tools used with the various stakeholders to create a shared representation of the system via a platform of knowledge sharing and collective learning process used to co-design integrative models with local rice farmers. Such a shared representation promotes the importance of stakeholders agreeing on the functioning of the system under study and thus being able to be in a position to efficiently explore possible future scenarios of their choice. At the same time, stakeholders' adaptive management capacity can also be improved through this modelling process.

Following a preliminary diagnostic-analysis on the local agrarian system—comprising a review of the existing literature and a farm survey to fill knowledge gaps—carried out in 2004, an initial conceptual model was formalized in early 2005 and used to design a first RPG. The first participatory modelling workshop using this RPG was organized in July 2005 and was the entry point of the four successive sequences of that ComMod process. In this chapter, the selection of the study site and the participants are first presented. Then, detailed information on the process design and implementation is provided, before a final section that recapitulates the evolution of the modelling tools over the whole three year process.

8.1. Selection of Study Site and Participants in Lam Dome Yai Watershed

Ban Mak Mai village is located in the north of the Lam Dome Yai watershed. This village was selected for a series of participatory workshops because it is representative of the dominating RLR ecosystem of lower northeast Thailand. Participants were farmers living in this village, representing diverse farm types. Based on the farmer typology (See chapter V), these participants were selected to cover all existing farm types found in this SAES. A total of 11 farming households (husband and wife) were invited to participate in this ComMod process. Eight small holders belonged to farm type A, two households represented type B, and one was a type C farmer (Table 8.1). A wealthy large land owner belonging to sub-type C1 was also invited, but she did not join in the activities because this ComMod process was initiated during the rice transplanting period when she was too busy in her paddies. The same reason also limited the number of participating type B farmers and sub-type C1, who had labour shortage problems. On the other hand, due to less labour constraints, more type A farmers could join the process. This selection also represented the majority and minority groups of farmers existing in the village.

Table 8.1 Characteristics of the farming households from Ban Mak Mai village who participated in the ComMod process.

Household number	Farm type	Area planted to rice (ha)		Farm pond (m^3)	Annual gross income (euros)	Social Network	Number of family members	
		KDML105	RD6				Workers	Dependents
1	A1	0.8	0.8	0	400	No	3	3
2	A1	0.96	1.6	300	510	Yes	5	1
3	A1	1.6	0.8	144	860	No	2	2
4	A2	1.6	1.6	500	970	Yes	3	1
5	A2	0	1.6	158	570	Yes	6	0
6	A3	3.2	1.6	240	1,550	Yes	6	2
7	A3	2.4	1.6	450	1,300	Yes	5	3
8	A3	1.6	1.6	1,350	850	Yes	2	4
9	B1	7.04	1.92	2,400	2,200	Yes	2	4
10	B2	4.8	1.92	2,200	2,500	No	5	0
11	C2	6.4	2.4	3,840	2,900	Yes	5	1

8.2. Process Design and Implementation

A farm survey was conducted in 2004 to characterize the different main types of household-based agricultural production systems and the determinants of labour migrations among these different categories of farming households. The data showed that the farmers' decision-making regarding land and labour management was similar among the farmers belonging to the same type (similar livelihood objectives, farming strategies and means of production). These decision-making processes were essential to conceptualize the operational rules in the ComMod models. In early 2005, an initial conceptual model was formalized by using the diagrammatic UML.

A key feature of ComMod processes is the iterative alternating between field and laboratory activities. After each field workshop, field investigations were carried out, to acquire additional information (including a new farm survey in 2005 during the prolonged drought of the 2004-2005 crop year), as well as monitoring and evaluation activities to analyze the effects of the ComMod activities on participating farmers as well as to keep in touch with them (Figure 8.1). For more details about monitoring and evaluation activities carried out in this ComMod process, see Thongnoi (2009).

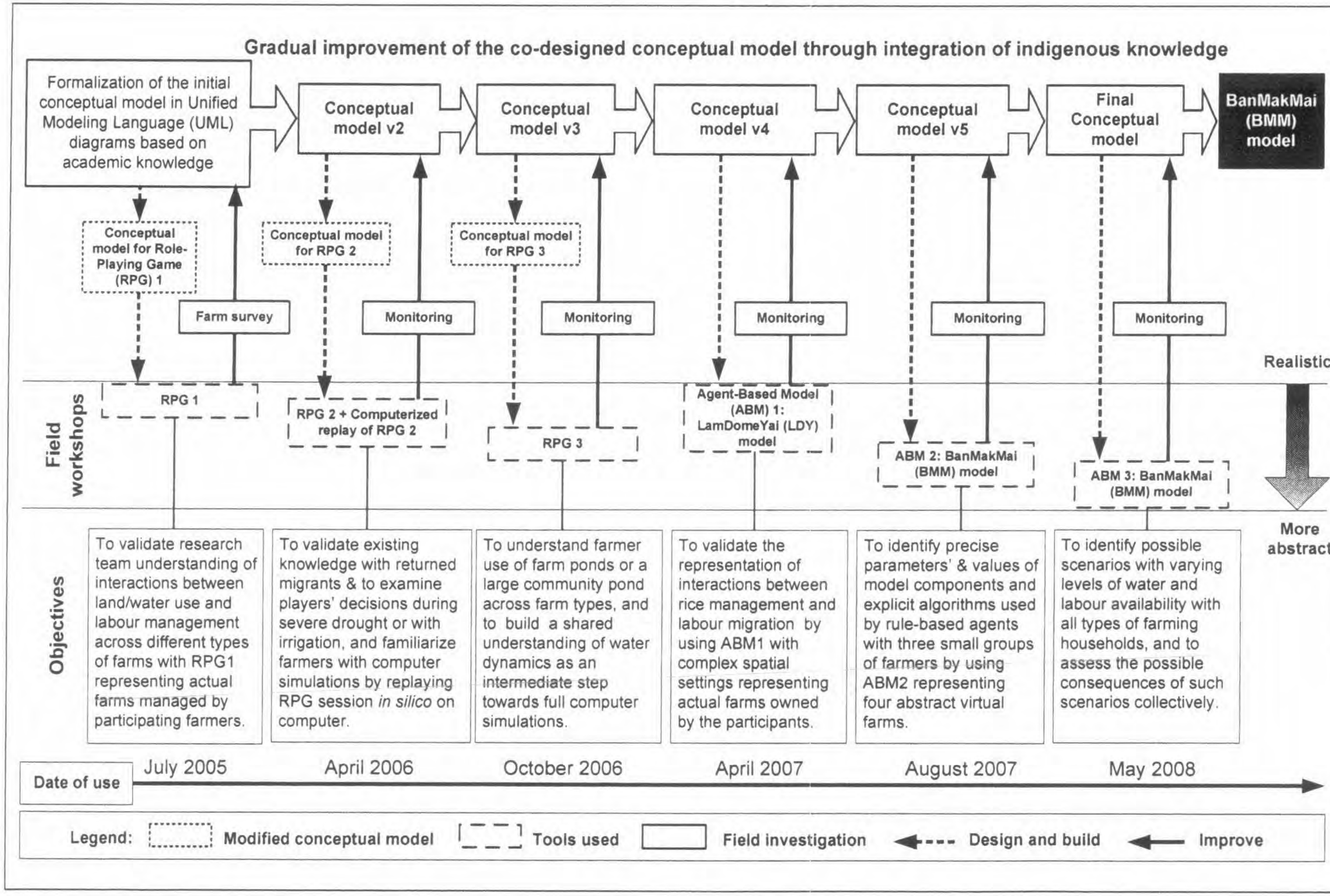

Figure 8.1 Description of the ComMod process implemented in the Lam Dome Yai watershed showing the evolution of co-constructed models, the specific objectives of successive workshops and the tools used 2005-2008.

In this ComMod case study, throughout the cyclic process, different modelling tools, rooted in the same underlying conceptual model, were used with different complementary objectives. RPG and ABM used in association support each other in the system analysis and gradual improvement of the common underlying conceptual model (d'Aquino, Barreteau et al., 2002). The initial conceptual model, with key interacting components and the sequential operations of key activities in this RLR ecosystem, was depicted in complementary UML Class, Sequence and Activity diagrams. The design and implementation of the RPGs and ABMs will be fully described in the following RPGs and Ban Mak Mai Agent-Based Model chapters respectively. The four sequences of ComMod activities implemented in this process are presented below.

8.2.1. First Sequence: Researchers' Knowledge Validation by Local Farmers

This sequence started once the UML diagrams were completed in early 2005 and ended in July 2005.

8.2.1.1. Objective

The aim of this sequence was to validate the research team's initial understanding of the interactions between land/water use and labour management across the farm types in the local RLR ecosystem. Another purpose was also to train a team of assistants to prepare and operate ComMod field activities.

8.2.1.2. Method and Tools

To be able to validate the research team's understanding of the system of interactions under study through local farmers' actions, the UML diagrams were simplified to implement a first RPG (Figure 8.1). This simplified UML omitted scientific hydrological processes, and depicted only RLR growing activities and labour migration practices. The yearly climatic cards were used to simply represent different rainfall conditions. This RPG was used with farmers in a first participatory modelling field workshop on 9-10 July, 2005. The research team used new information derived from local farmers' decision-making processes during the gaming session to enrich the initial conceptual model. The underlying theoretical assumption was that with the transparent structure and rules of the RPG made available to stakeholders, this tool would support the validation of the underlying conceptual model and its improvement through the acquisition of new knowledge on the system, while facilitating exchanges and collective learning among stakeholders.

The two-day workshop was made up of two main sessions (Box 8.1), starting with a gaming session in the first day. The gaming sequence was based on the main rice-growing phases: nursery establishment, transplanting, harvesting, and the post-harvesting period, including labour migration. Yearly climatic conditions (wet, dry, and very dry years) were drawn by a player. The players' decisions were driven by rice-growing phases associated with specific rainfall conditions, and their related actions were displayed on a 2D game board (Figure 8.2). Four rounds, equivalent to four successive crop years, were played. On the second day, a plenary discussion and individual interviews were held to compare what happened in the gaming session with actual circumstances, and to clarify the players' actions during the gaming session. In addition, the interviews were used to identify concrete water, land and labour management strategies actually employed on the farm. The findings of follow-up individual interviews were used to enrich the initial conceptual model and to design and build an improved second RPG. The players were divided into two groups during the individual interviews. Each group consisted of six players and one researcher. One research assistant interviewed a member of each household with the help of a semi-structured guideline document.

Box 8.1 The first participatory modelling workshop and its artefacts.

The first participatory modelling workshop using RPG1

Date: 9-10 July 2005

Meeting place: Ban Mak Mai School.

Participants:
Seven researchers, one NGO representative, one extension worker, seven research assistants and eighteen local farmers from eleven households; eight households came in pairs (husband and wife), and three households were represented by only one member.

Objectives:
To validate the research team's understanding of land / water use and labour management on the different types of farms, and to train and engage villagers in the action research process. Moreover, to initiate a collective learning process on land, water and labour management.

Main issue:
Focus on rice-growing steps and labour management as influenced by internal factors such as age, education, and household income, and by rainfall variability.

Gaming sessions:
(1) First day: the research team leader introduced the project in the first session. Then the RPG session started, moving through rice-growing phases that affect the players' decision making regarding land, water and labour use. The main phases in the game focussed on key rice growing stages: nurseries, crop establishment by transplanting, harvesting, and the post-harvesting period, including dry season activities. Four rounds were played to simulate four crop years over five hours. The players had different roles: farmers, migrants, and hired labourers.
(2) Second day: ninety minutes were spent on individual interviews of players, followed by two hours of plenary discussion with the participants to discuss the results of the previous day's gaming session and possible next steps.

Equipment and materials:
Thailand map; tokens; fake money, role cards; dice; computer software (Excel package); flipchart; post-it notes; camera; video camera and recorder.

Artefacts:
Game boards; game cards; writing pads to record players decisions.

Figure 8.2 First participatory modelling workshop based on a role-playing game in Ban Mak Mai village on 9-10 July 2005, **Top left:** players allocating rice-growing areas; **Top right:** players located where their migrant workers were working on a map of Thailand. **Bottom left:** a player selling his rice at the 'market'; **Bottom right**: plenary discussion after the gaming session.

8.2.1.3. Main Results

The first field workshop held in Ban Mak Mai village demonstrated the feasibility of using such key ComMod collaborative modelling and simulation activities with 22 local farmers and two development officers. The research team (the process designer and his seven assistants) gained precious experience on how to facilitate such events to be used in the following sequences. The research team's understanding of the interaction between land & water use and labour management & migrations was validated, and our initial conceptual model was enriched,particularly, decision-making to hire extra farm workers and changes of migratory patterns across farm types when encountering different rainfall conditions. Differences in means of production available, especially farm size and family size and composition, played a crucial role in determining the availability of hired labour in the gaming session. The introduction of very dry annual conditions pushed farmers to migrate because inadequate water availability for farming caused unemployment. The risk linked to unpredictable wage levels introduced in the game, through the drawing of a "received wage" chance card when a player decided to migrate, did not influence the players' migration decisions.

Diverse farming households played different roles in the local labour market since different farm types have different cropping calendars and farm sizes, resulting in different labour needs. These differences also make some farmers, in particular less farm size farmers being available for hiring. When players hired labour, it was found that they based their decisions in the game on their actual practices. Due to their small farm sizes, type A farmers generally spent a shorter time completing rice-growing activities and were then hired in this game by larger farmers during the high peak labour demand periods of transplanting and harvest. In simulated drought years, farmers who produced rice only (small farm type A) tended to provide more out-migrants.

Although the spatial setting of the gaming board was rather abstract (Figure 8.2) and the rules quite simple, farmers considered that the game provided situations similar to their reality. A friendly relationship between the research team and the other participants was also reinforced throughout this highly interactive activity. The participants realized that a RPG was not only for kids but could also be useful for knowledge sharing, in particular when unpredictable rainfall conditions and wage levels were introduced in the game.

Meanwhile, the participating farmers underlined that returned migrants should also be able to participate in such gaming workshops because they wanted to share their perceptions of the issue at stake with these migrant workers. Therefore, they suggested holding another similar workshop just after mid-April when the migrants return home to celebrate the Thai New Year.

8.2.2. Second Sequence: Elicitation of Farmers' Decision-making Processes Regarding Migration in Relation to Water Availability

The second sequence was implemented similarly to the previous one. A revision of the conceptual model was produced to integrate the findings during the first participatory modelling workshop, and the second farm survey carried out at the beginning of this sequence.

8.2.2.1. Objective

This second ComMod sequence aimed at validating existing knowledge with participating migrant workers. Another objective was to observe and investigate changes in the players' farm and labour management decisions under different rainfall conditions, in particular prolonged drought and newly introduced irrigation canal scenarios.

8.2.2.2. Methods and Tools

Three methods were implemented in this second sequence. A specific farm survey was carried out in August 2005 after the exceptionally long drought of the 2004-2005 crop year. This survey aimed to understand farmers' decisions regarding the impact of drought on farm management including labour migration practices in order to integrate these decision-making processes into the initial conceptual model.

A second improved RPG, designed according to the revised conceptual model, was implemented in early 2006 and used with farmers just after the Thai New Year, at the end of the dry season when many migrants visited the village. The organization of this participatory modelling workshop was similar to the previous one (Box 8.2). The first day was devoted to an RPG session with features, rules, and materials similar to the first RPG. But in this workshop, the impact of water availability (scarcity or abundance) on farmers' decisions was particularly examined through the creation of two successive drought years and the introduction of an irrigation canal in the game. Six rounds (corresponding to six simulated crop years) were played. In addition, this time a computer simulator was introduced to replay the gaming session *in silico* in front of the players on the second day to facilitate exchanges and discussions about their actions in a plenary session (Figure 8.3).

Box 8.2 The second participatory modelling workshop and its artefacts.

The second participatory modelling workshop using RPG2 and a computer model

Date: 20-21 April 2006.

Meeting place: Ban Mak Mai School.

Participants:
19 people, only one of them being a returned migrant, from 11 farming households. Nine households were represented by pairs and two sent a single member. Seven people were members of the research team. One extension worker and four research assistants participated in the workshop.

Objectives:
(1) To validate existing knowledge with the new migrant player, a member of a family who had participated in the first gaming sessions;
(2) To investigate the players' decision-making processes regarding farm and labour management under prolonged drought and irrigation canal scenarios;
(3) To train the research team in the action research process;
(4) To introduce replays of the gaming session by the computer as a collective learning support tool and to validate the model.

Main issue:
Farm management with returned migrants, and under severe drought and irrigation canal scenarios.

Gaming sessions:
The gaming sessions were carried out over two days:
(1) On the first day, the RPG was used to simulate scenarios with and without irrigation canals, taking five hours to complete six rounds (crop years): four crop years under rainfed conditions and the last two crop years with an irrigation canal. During the gaming session, traditional songs (Mo Lum) were sung by female players to entertain the other players. The wage chance cards were removed after the morning session because of the lack of players' interest in them; this helped to speed the game up.
(2) The second day started with a three hour plenary discussion about the proceedings on the previous day's gaming session and the replayed computer simulation was projected on the screen to help local farmers understand what the ABM was doing and what was happening during the simulation. Later on, individual interviews with 11 households were conducted by four research assistants.

Equipment and materials:
Thailand map; tokens; fake money, role cards; dice; computer software (Excel package); flipchart; post-it notes; camera; video camera and recorder.

Artefacts:
A game board and Excel package were used with the same objectives than in the first sequence.

Figure 8.3 Second participatory modelling workshop based on a role-playing game and computer simulation replaying the gaming session on 20-21 April 2006, **Left:** players receiving income from migrant workers. **Right:** plenary discussion about the players' actions in the gaming session, with a projected replay of the computer simulation.

Follow-up individual interviews were conducted by four research assistants at the end of the field workshop, and more interviews were conducted by RPG designers one month after the workshop. The follow up interviews aimed at gaining a more in-depth understanding of farm and labour management decisions made under the prolonged drought and abundant water scenarios simulated during the gaming session, and to compare those decisions to reality.

8.2.2.3. Main Results

The players' decisions to deal with prolonged drought were not different from what was observed during a very dry year in the first RPG session. Under the irrigation canal scenario, type A small land holders were more adaptive in take advantage of better access to water. They planted more cash crops in the dry season and there were fewer migrants on their farms. The returned migrant players did not participate in the first RPG, but their decisions on on-farm and off-farm employment for their household labour were not different from those of the participants in the first RPG session. The fact that the decision regarding labour migration is a collective agreement among household members was confirmed.

This second RPG also helped the farmers to understand the rules and sequence of operations of a computer simulation thanks to the replaying of the gaming session. This helped them to better understand their own situation compared to others, and to examine the causes of actions made by other players. All the participants were eager to share their knowledge during the replay session. Linking the RPG session to this computerized replay helped participants become familiar with a computer simulation.

The irrigation canal scenario was useful in stimulating the player's thinking about what additional farm goods should be produced after rice production, but this kind of infrastructure is not readily available in reality due to the high investment required. According to the players' comments, a common pool resource, such as ponds, should be added as a new feature in the next workshop. Farmers' representation of water dynamics in relation to rainfall conditions was still needed to validate the hydrological processes and irrigation function in the model. This specific topic was taken into account when designing the third RPG that was to be used in the next ComMod sequence.

8.2.3. Third Sequence: a Shared Representation of Water Dynamics Interacting with Labour and RLR Management

This longest sequence was implemented between May 2006 and March 2008 and its key events were three participatory workshops held in the village.

8.2.3.1. Objective

The activities aimed to gain a more in-depth understanding of the players' decisions regarding the management of individual farm and community ponds, in relation to labour and RLR management. The RPG used in this sequence was designed to provide the participating farmers with further initiation in the use of learning through simulations of scenarios before the introduction of fully computerised simulations.

8.2.3.2. Methods and Tools

The third RPG

Box 8.3 describes the third field workshop held in Ban Mak Mai village on 10-11 October 2006. During the first day, participants played an RPG designed to acquire their perceptions about water dynamics in paddies and individual farm ponds in relation to weekly rainfall conditions. The weekly rainfall conditions were announced, and their related pictograms were pasted on a public calendar bulletin. Then, the players were asked to draw the water levels of paddies and ponds on decision sheets prepared by the game designer. On the second day, simple graphs and tables comparing the players' decisions during the first day's gaming session were presented and collectively analysed. Similar patterns within the rice-growing calendar and dates of water pumping from individual farm ponds were grouped and discussed to verify if the successive water levels indicated by the players in the gaming session were correct.

To create a singular situation, all participants also had to build a shared perception of water levels when using water from a community pond. Because only one assistant participated in this workshop, a short questionnaire was used instead of individual interviews. The objective was to check participants' understanding of the features and dynamics of the gaming session and the differences from the two previous workshops was distributed to all players. The plenary discussion was carried out after the gaming session to collectively define water availability of the community pond in relation to weekly rainfall conditions used in the game. The collective agreement derived from this plenary discussion was used to validate the water level in the ABM. Figure 8.4 shows the activities and materials used in the gaming session.

Even if the water use practices were better understood across the farm types, the water level of individual farm ponds and paddies was still difficult to be assessed quantitatively to sufficiently validate the hydrological processes of the ABM. This ABM integrated the water module of a previous ABM built to represent the hydrological processes in this RLR ecosystem (Lacombe and Naivinit, 2005). It became necessary to present it to the players for them to validate the water dynamics of ponds and paddies. Therefore, I decided to introduce this first ABM, named "LamDomeYai (LDY) model" after the local river, to the participating farmers in the following ComMod activities.

Box 8.3 The third participatory modelling workshop and its artefacts.

The third participatory modelling workshop using RPG 3

Date: 10-11 October 2006.

Meeting place: Community building in Ban Mak Mai Moo 17.

Participants:
21 local residents participated; three of them were new participants from three households. Nine research team members were involved in the implementation of the activities.

Objectives:
(1) To acquire knowledge on players' water use and labour migration strategy across farm types when encountering different water availability;
(2) To improve agents' water-use rules in the LDY model;
(3) To provide the players with a supporting tool for learning about simulations and scenarios through a new RPG before introducing an ABM simulation.

Main issue:
Agreement on a common representation of water dynamics.

Gaming sessions:
(1) First day: three key phases of the rice growing cycle (crop establishment, harvest and dry season activities) were built into the game. Rainfall pictograms were used by the facilitator to visualize the amount of rainfall on a weekly basis. Players were assigned to produce rice under two predefined scenarios with individual small ponds or a larger community one. Six rounds of play were implemented for each of them;
(2) Second day: simple illustrations to compare the decisions among players were prepared and presented to them for participatory analysis. Similar patterns within the rice-growing calendar and dates of water pumping in individual farm ponds were grouped and presented to the players for collective discussion. A short questionnaire on their understanding of the features, contents of the game, and its differences with the ones used in the two previous workshops was given to all players.

Equipment and materials:
Post-it notes; camera; video camera and recorder.

Artefacts:
Players' decision sheets to record their decisions, weekly rainfall condition bulletin board, pond and paddy field water level boards.

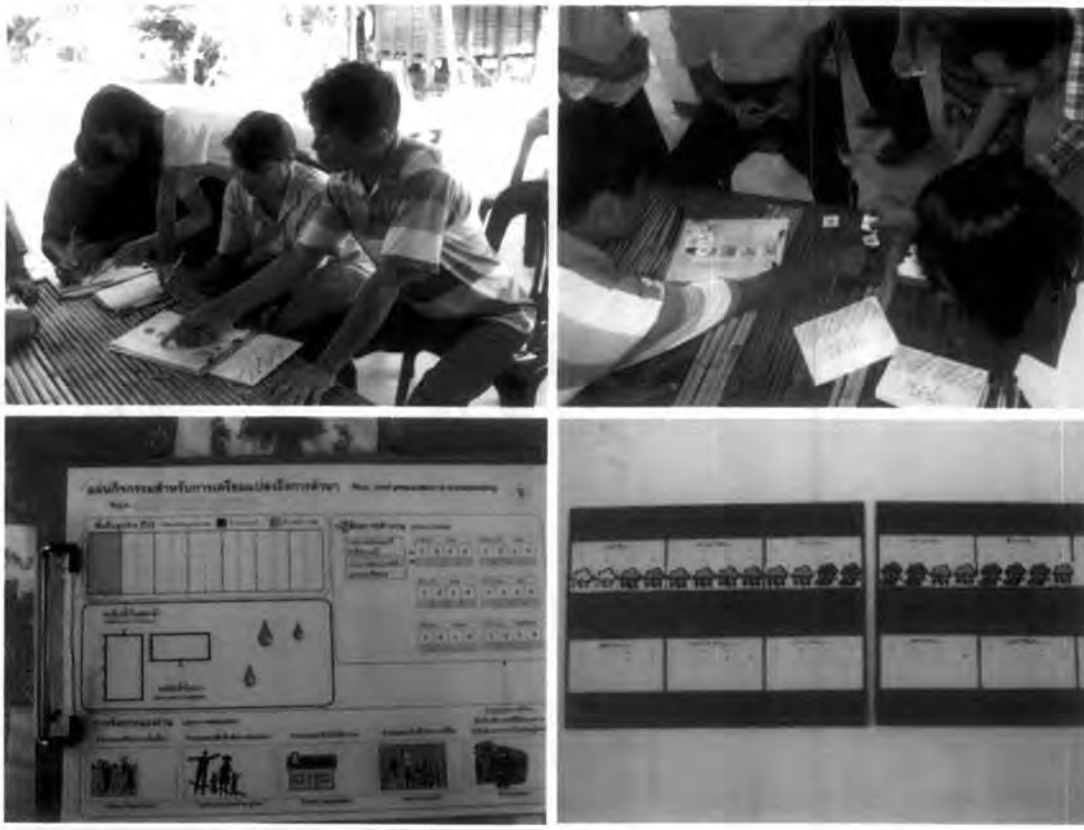

Figure 8.4 Third participatory modelling workshop based on a role-playing game in Ban Mak Mai village on 10-11 October 2006, **Top left:** a couple discussing before drawing the water level in their paddies and pond on the decision sheet; **Top right:** players deciding the amount of rice produced before pasting bag pictograms on their decision-sheet. **Bottom left:** decision sheets completed by a couple of players from the same household; **Bottom right**: pictograms on a public bulletin board showing the weekly rainfall conditions during the rice crop cycle.

Participatory simulation workshop using the Lam Dome Yai (LDY) ABM

The LDY model was implemented to validate the knowledge and representation of interactions between water dynamics and labour migration through the use of computer simulations. Three major steps in the LDY simulations were rice establishment, rice harvest and dry-season activities (Box 8.4). To learn how the simulation worked, the participants were guided from looking at simpler (model configuration with two virtual farms only) to more complex (model configuration with eleven virtual farms) simulations.

The two virtual farms were introduced in the morning session on 24 April 2007. The hydrological module with homogeneous rule-based agents was presented to validate the representation of water dynamics in relation with RLR production practices. Two different paddy fields were displayed, with or without access to a pond. Players were 'rice-growing consultants' who delivered comments and suggestions to moderators acting as inexperienced rice farmers. After looking at the weekly rainfall conditions, the participants were asked to guess the outputs of simulated water levels in the paddy fields and the farm pond. This was the chosen way to validate this water module of the ABM with local 'RLR experts'. This simple setting was also used to refresh participants' memories of the LDY co-designed activities implemented during the previous workshop in October 2006. In the afternoon session, a more complex simulation with eleven virtual farms representing the actual holdings belonging to participants was introduced (Figure 8.5). The simulation displaying heterogeneous groups of rule-based agents representing diverse farm types was run to validate the interaction between water dynamics and labour migration with these expert farmers.

It was found that the simple configuration with two virtual farms was more effective in stimulating collective exchanges and learning than the more complex one. I also had difficulty conducting model validation steps with highly heterogeneous participating farmers. Therefore, to enhance participants' communication, I decided to organize smaller participatory simulation meetings with homogeneous groups of farmers belonging to the same type of farm to improve the model calibration and validation.

Box 8.4 The participatory simulation workshop using the LDY model.

Participatory simulation workshop using the LDY model

Date: 24 April 2007.

Meeting place: Community building of Ban Mak Mai Moo 17.

Participants:
21 local residents; three of them were new participants from three households. Nine research team members were involved in the implementation of the activities.

Objectives:
(1) To validate the understanding of interactions between on-farm or community pond use and labour management;
(2) To calibrate the hydrological module of the LdyModel, representing the water dynamics according to rainfall and players' decisions;
(3) To discuss the on-farm and community pond scenarios with the players, and to define other future ***scenarios*** to be explored by using ABM simulations.

Main issue:
Community and on-farm pond water use and interactions with labour management.

Simulation sessions:
Three major steps of the LDY model simulations were rice crop establishment, rice harvest and dry-season activities. The sessions were organized in two parts:
(1) An initial part introduced a simple scenario with only two different paddy fields: one with a pond and the other without. Players were acting like consultants, giving recommendations for rice transplanting to the moderator who acted as an inexperienced farmer;
(2) A more complex configuration showing eleven actual farms was introduced in the last gaming session. The moderator asked the participants questions concerning the decisions farmers made with regard to rice-growing practices and water pumping, household by household across all farm types.

Equipment and materials:
Camera; video camera and recorder.

Artefacts: Players' decision sheets to record their decisions, weekly rainfall condition bulletin board, pond and paddy field water level boards, and ABM simulation.

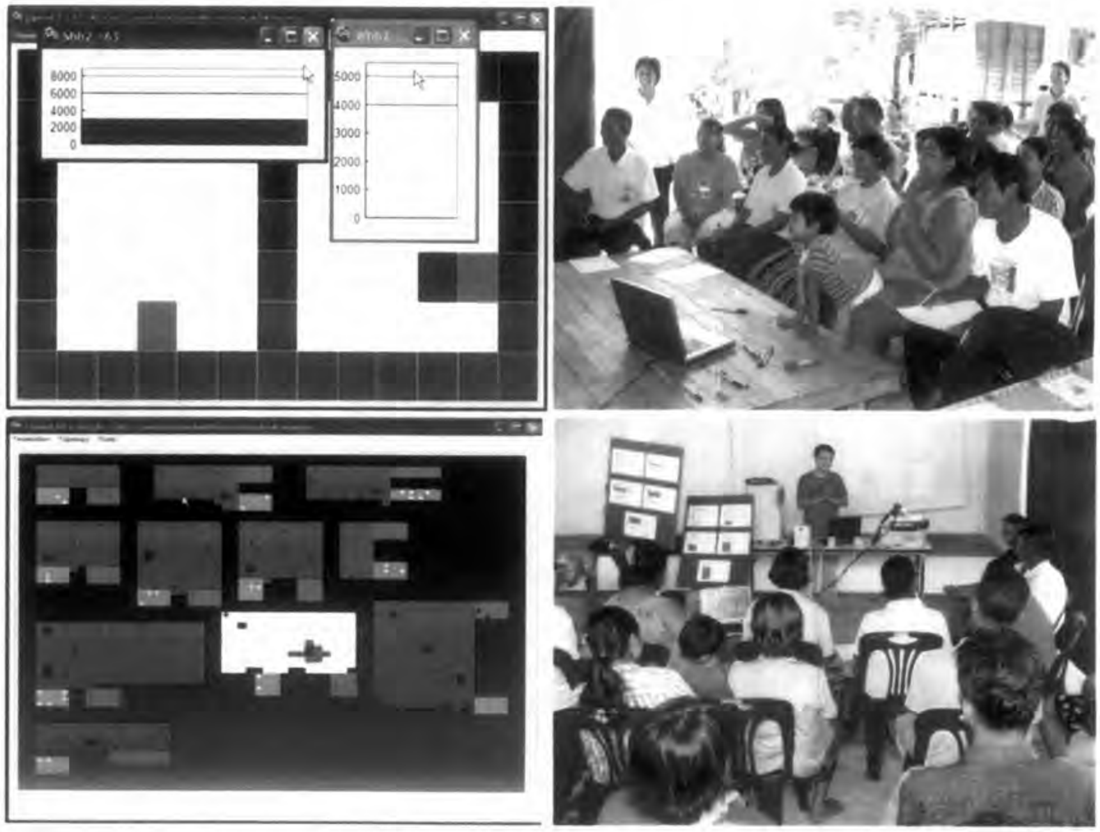

Figure 8.5 Participatory simulation workshop using LDY model on 24 April 2007, **Top left:** simple interface with two virtual farms and water levels in paddies and pond introduced in the morning session; **Top right:** local farmers looking at a LDY simulation. **Bottom left:** interface with eleven farms used in the afternoon session; **Bottom right**: exchanges among participants during a simulation run.

Fine-tuning the Ban Mak Mai (BMM) model with small and homogeneous groups of farmers

The name of the ABM was changed from Lam Dome Yai (LDY) to Ban Mak Mai (BMM) to truly represent the decision-making processes of field collaborators, and to give them a higher sense of ownership of this new model representing the local rice farming conditions in Ban Mak Mai village. Three visits were made between August 2007 and March 2008 to refine the first version of the ABM, with three small homogeneous groups of farmers belonging to the same farm type participating.

Two different artefacts, a set of simple drawings and successive versions of the BMM model itself, were used. In August 2007, three group discussions on the model algorithms of rule-based agents were organized by using drawings (Figure 8.6). The underlying assumption was that while the ABM simulation was spatially explicit enough to display changes in land use as a result of interactions between the computer agents and their virtual environment, the algorithms used to operate the computer agents and their dynamics had to be made explicit by using simple drawings. Furthermore, this was also a preparation stage for participants before exposing them to fully computerised BMM simulations.

The proceedings included: (i) the presentation of algorithms that were built in UML diagrams and later used to implement the ABM. They were translated into simple drawings projected on transparencies and dealt with algorithms of agents' decisions during RLR crop establishment, RLR harvest and post-harvest period; (ii) the participants were divided into three small groups: two groups of four type A householders (eight people) and three households (six people) of farm types B and C in the last group.

Among the two scenarios used, the first one was based on the current actual situations faced by farmers; one situation offered the use of a pond, while the other situation did not. The second scenario simulated severe drought conditions, and 'what if' questions were asked to stimulate the participants to think beyond their actual circumstances. This second scenario also aimed at identifying other 'what if' situations that would lead to new relevant scenarios to be simulated with the players. The workshop was implemented at the house of a TAO representative for this village on August 5, 6 and 10, 2007. The meeting place for the workshop needed to be quieter and darker than previous locations. Among the 22 local farmers who participated this time, one was a returned migrant and another one was an observer. Two researchers and one research assistant were also present.

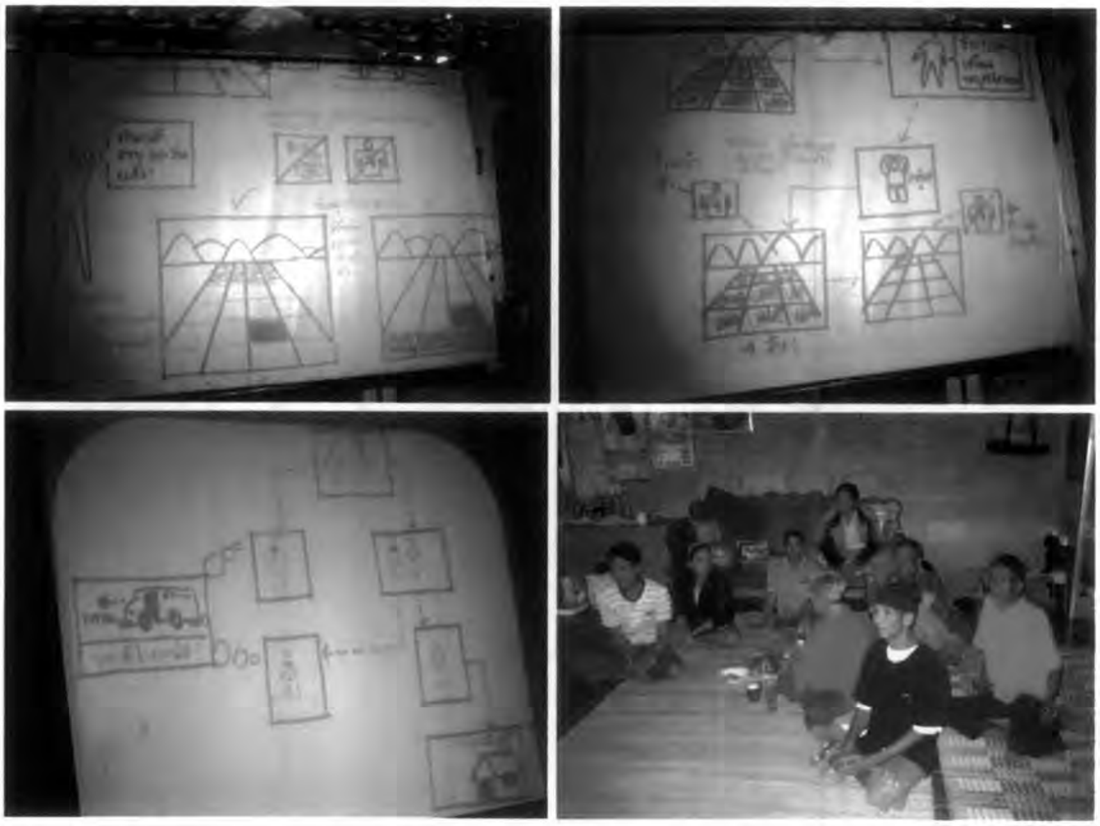

Figure 8.6 Participatory modelling workshop using drawings on 5-6 and 10 August 2007, **Top left:** a drawing showing initial location of transplanting activity and indicating no water use for this practice; **Top right:** a drawing to discuss the hiring of additional farm workers to harvest rice. **Bottom left:** a drawing to discuss migration practices; **Bottom right:** small groups of participating type A farmers.

Similar sessions were implemented a second time, at the same place, on 5-6 February, 2008. A smaller group of participants was invited, based on their capacity to follow simulations and their degree of involvement in the discussions during the previous workshop. This time, the BMM model was directly used with participants without more explanations given on drawings (Figure 8.7). The aim was to validate the model with a focus on identifying precise values of several key parameters and variables, as well as useful indicators to be observed during simulations and to be included in the BMM model. During the run of the BMM model, the moderators operated the simulation slowly to allow the participants to observe, discuss and propose changes in the dynamics visualized on the screen. The decision process on hiring labour during RLR transplanting and harvest periods could not be successfully validated because of the lack of diverse farm types in the room. Larger farms (type B and C) often hire additional farm workers from small farming households (type A) during RLR transplanting and harvest periods. Therefore, a last field work of this sequence focusing on this topic was organized in March 2008 with four selected households covering the three main farm types.

Figure 8.7 Participatory simulation workshop using the BMM model on 5-6 February and 19 March 2008, **Top left:** moderator operating the simulations; **Top right:** interface of the BMM model showing four different farms. **Bottom left**: a participant describing the features displayed on the BMM interface; **Bottom right:** a small group of participating type B and C farmers.

8.2.3.3. Main Results

Results from the third RPG session

For very small land holders, water is conserved to be used in cases of long dry spells that affect rice seedlings' growth, while other farm types also use water to establish nurseries. However, this decision is also dependent on the location of the farmer's paddy fields. Farmers who grow rice on lower paddies, where water is naturally adequate, usually use water to establish nurseries no matter how large their paddy fields are. In the gaming session, the difference in water use between wet and very dry years was in the frequency of water pumping. In the community pond scenario, improvement in water availability effectively provoked an increase in farm intensification on very small holdings but not for other farm types facing labour constraints. As a result, the number of migrants from very small holdings decreased when water availability was improved, while the number of migrants from the other two types of farms did not change.

The display of weekly rainfall conditions provided more precise information to the participants who felt more confident when deciding what water-related activities in RLR production practices should be undertaken. From the participants' point of view, the pumping of water from ponds for RLR production introduced in this game made it closer to reality. The collective pond was effective in stimulating knowledge sharing. Different water use strategies, depending on water availability, across the farm types lead to different cropping calendars for rice crop establishment and regulation of the availability of hired labour during RLR transplanting in this village.

Results of participatory simulations using the LDY model

The LDY model allowed the moderator to introduce virtual farms, and all participants were able to collectively criticize the actions of rule-based agents and suggest modifications. Since the LDY model was constructed based on the same conceptual model than the previous RPG, the participants had no difficulty in understanding its structure and operating rules. The two virtual farm versions successfully encouraged communication among participants. Water levels in the paddies and pond were displayed on screen on a weekly basis and used for rice-growing activities. Participating 'experts' helped the moderators, who were acting as inexperienced rice farmers, handle the changing situation. As a result, I quantified these water level changes and used that data to verify and calibrate the hydrological processes represented in the LDY model.

The version that simulated eleven realistic farms did not stimulate a collective discussion about the interactions between water dynamics and labour migrations; instead, the participants focused on correcting what they perceived as 'mistakes' made by the model displayed on the screen, rather than sharing opinions on the proposed representation of the interactions between water dynamics and migratory behaviours, and discussing desirable scenarios to be examined later. As a result, these interactions were not sufficiently validated at this stage and no scenarios to be explored were identified. The lessons learned from this experiment helped the researchers think about better spatial settings to stimulate knowledge sharing and learning.

Results from participatory simulation to fine-tune the BMM model

Drawings of the rule-based algorithms helped participants to get a clear picture of the cause-effect relationship of the actions operated by agents. Several parameter values were precisely identified during the BMM model fine-tuning activity (See details of this model in the description of the Ban Mak Mai model chapter below). At the end of this ComMod sequence, the BMM model was validated by small groups of participating farmers, but it was not yet used to identify interesting future scenarios to be simulated and assessed collectively. However, the players better understood the principles of ABM simulations and this enabled the research team to use simulated scenarios exploring 'what-if' conditions. Based on these results and to achieve the objective of knowledge discovery, the fined-tuned BMM model was selected as the key artefact to be used in the final sequence of this ComMod process.

8.2.4. Fourth Sequence: The Final BMM Model and Its Use with Local Farmers

8.2.4.1. Objective

This last sequence of the ComMod process used participatory ABM simulations to validate the BMM model with all participants, and to identify and explore scenarios of interest proposed by local farmers.

8.2.4.2. Method and Tools

A last participatory simulation field workshop was organized on 13-14 May 2008 and was made up of two sessions (Box 8.5). The first session aimed to validate the model and identify possible scenarios of interest with participating farmers, and the second one used simulations to explore these scenarios. The BMM model was improved based on the results of the previous ComMod sequences and was here used to facilitate discussion among participants (Figure 8.8). The spatial characteristics of the baseline scenario represent land use types (paddies, pond, and human settlements: house, village, city). Four farming households with different number of members in each household were rule-based agents. There were two small farms (3.3 ha) and two large ones (6.5 ha) with different pond sizes.

A 'Household' is made of heterogeneous 'Member' agents having different demographic characteristics (age, gender, and marital status). The 'Household' is a key decision-maker responsible for assigning specific roles (farmer, seasonal migrant, more permanent migrant or dependent) to its members. Once RLR is planted, it grows from seedling stage to maturity. Three main decision-making processes are: (i) decisions during nursery establishment and transplanting, (ii) decisions at harvest, and (iii) decisions after rice harvesting, including migration (See details on the BMM model description in Ban Mak Mai model chapter below).

Box 8.5 The final participatory simulation workshop using the BMM model.

Participatory simulation workshop using the BMM model

Date: 13 -14 May 2008.

Meeting place: Ban Mak Mai School.

Participants:
21 participants: 15 people from eight households and 6 members of the research team.

Objectives:
(1) To validate the final version of the BMM model and;
(2) To explore to scenarios with varying availability of water and hired labour.

Main issue:
The gradually co-constructed BMM model to be validated by local expert farmers.

BanMakMai model: The BMM model included:
(1) A spatial configuration consisting of two small farms (21 rai or 3.36 ha) called farm A and B, and two large farms (41 rai or 6.56 ha) called farm C and D, and different farm pond sizes;
(2) Farm A had 3 labourers and 3 dependents, farm B had 4 labourers and 2 dependents, farm C had 2 labourers and 1 dependent, and farm D had 3 labourers and 4 dependents;
(3) Different rainfall distribution patterns, whereby daily and weekly rainfall were fed into the simulation and displayed by explicit pictograms on the projected main interface.

Simulation sessions: The steps of the sessions were:
(1) Introductory VDO presentation about the previous workshops to refresh the players' memories;
(2) Running the BMM model slowly, step by step, and allowing the players to identify all its features and sequential operations in the simulation to discuss them and to propose possible scenarios to be simulated (for example: 4 farms with no individual ponds and 4 farms with individual ponds, hiring labour among the represented farms, and hiring labour from outside the village);
(3) A final plenary discussion about the scenarios to be simulated proposed by participating farmers.

Equipment and materials:
Camera; video camera and recorder.

Artefact: the BMM model.

8.2.4.3. Main Results

The BMM model running the baseline scenario was validated by the local farmers who accepted that this model sufficiently represented the system under study. Participating farmers used the BMM model to identify interesting scenarios to be simulated. They were interested in examining the effects of: (i) a recent increase in the number of cheap foreign labourers from Lao PDR and Cambodia who can be hired during RLR transplanting and harvest periods, and (ii) adequate water availability, thanks for instance to an irrigation canal, on the system dynamics. The simulations were used to explore the consequences of the interactions between the model components on the emerging behaviour of the simulated system under the specific conditions (see details in chapter XI).

Figure 8.8 Participatory simulation workshop using the BMM model in Ban Mak Mai village on 13-14 May 2008, **Left:** moderator operating the simulations and discussing with participants. **Right:** the main interface of the BMM model growing four rice farms.

8.2.4.4. BMM Model Presentations to Scientists by Local Farmers

The BMM model constructed with local farmers for knowledge sharing and discovery was put to use in two special meetings between local farmers and scientists. On 11 June 2008, four representatives of the participating farmers used the BMM model to exchange knowledge with a delegation of international scientists working for the PN 25's 'Companion modelling for resilient water management' project of the CGIAR Challenge Program on Water and Food (CPWF). In addition, a special seminar was organized at the Faculty of Agriculture of Ubon Rajathanee University on 18 October 2008 to give nine of Ban Mak Mai collaborators the opportunity to present the BMM model in front of researchers and 70 master students studying in the Information Technology for Agricultural and Rural Development (ITAR) program (Figure 8.9).

Figure 8.9 Local farmers using the BMM model to exchange their knowledge with scientists and master students in two special meetings, **Top:** Four representatives of the participating farmers explaining the model features to visiting scientists by using the BMM model. **Bottom:** Nine representatives of participating farmers using the BMM model for discussions with lecturers and master students at the local university.

8.3. Recapitulation of the Evolution of the Co-constructed Model along the ComMod Process

Based on the typology of relationships between RPGs and computerized models proposed by Barreteau (2003b), in this case study, the three RPGs and two ABMs used in succession were based on the same underlying, gradually improved and shared conceptual model. In addition, the three different modes of gaming to support the co-construction of the ABMs were: (i) games used for mutual knowledge acquisition and model design, (ii) games used as a communication tool between a model and real circumstances, and (iii) games used as a medium to explain the contents of a computer model; in this case the game was a simplified version of the computer model. Even if RPGs were proved necessary to support the implementation of an ABM they have been time-consuming and costly. To overcome such RPG limitations, an ABM was introduced to participating farmers once I was confident that they were able to understand and follow computer simulations. Using an ABM enhanced collaborative support in design and analysis of the conceptual model because such ABM entails the repetition of rapid, prevents repetitive and time consuming RPG sessions, and provides results of simulated experiments for collective assessment (Barreteau, 2003b). The first prototype BMM model (the LDY model) was implemented and completely replaced the use of RPGs in April 2007. Since then, all the remaining co-designing activities were carried out by using BMM computer simulations.

The attempt to integrate a map of the study site into the spatial interface of the first ABM was found in the LDY-GIS model. This was proposed to represent the realistic spatial entity of the study site and develop it with local farmers. However, the map scale was too large to be used to observe changes at the micro level, which was reserach focus. Later, I downsized to look at farm level with a model representing the eleven actual participating farming households. Therefore, the model named "LDY-RPG model" was introduced to the participating farmers during the second participatory modelling workshop after the RPG session had been played (Table 8.2). During the gaming session, data regarding decisions made by participating farmers were recorded in the Excel spreadsheets. The simulation was only operated and displayed based on these data. Thus, this computer simulation can be considered as just a replay of the gaming session and not an autonomous ABM simulation. This replay by the computer was used to stimulate knowledge exchange and discussion of individual actions taken during the gaming session. This exercise was also a learning step toward helping participating farmers to relate the RPG to computer simulations.

The first prototype ABM (the LDY model) was used in the participatory simulation workshop organized in April 2007. The visualization was implemented to represent elevens farms resembling the actual farm sizes, farm components and farm locations (upper, middle and lower paddies) belonging to each participating household. Another modification was made to the timing: from a weekly basis used in the LDY-RPG model to a daily basis in the LDY ABM, thus corresponding to daily decisions made by local farmers.

As the complex and too realistic spatial configuration used in the LDY model did not provide good results, I decided to simplify it to represent only four virtual farms with differences in size, and water resources (Figure 8.9). These abstract landscape settings were designed to enhance discussion by shifting the participants' focus from sticking to their own actual situations to being 'experts' on the management of virtual RLR farms and providing comments on their agents' actions observed during simulations. However, the main principle of the landscape configuration in this simplified BMM model (toposequence and land use types) was not different from the complex one. The BMM model was finalized after the workshop on 13-14 May 2008 and was used for scenario identification and exploration with farmers, and in the laboratory. (See table 8.2 for characteristics of these two models).

Table 8.2 Characteristics of the family of agent-based models constructed during the ComMod process in the Lam Dome Yai case study.

Model name		LDY-GIS	LDY-RPG	LDY	BMM
Objective		To represent the whole study area based on field survey	To replay players' actions during gaming session for discussion in plenary session	To assist model validation through participatory simulations	To fine tune the validation of the ABM and explore scenarios
Source of spatial configuration		Study area (GIS map)	11 farms like the game board	11 farms & abstract spatial setting	4 farms & abstract spatial setting
Representation of diverse farms		Created randomly based on demography and farm types	11 households with their actual characteristics		4 archetypes of farm types A, B and C
Cell size		400x400m (16 ha = 100 rai)	20x20m (0.04 ha = 0.25 rai)		
Area displayed on interface (sq km)		1680	1.92	1.44	0.45
Land use types		5 (paddies, other crops, forest, water, settlement)	3 (paddies, water bodies and human settlement)		
Hydrological features and processes	*Tank size (sq.m.)*	160,000	None	400	2,800- 9,600 (at random)
	Ponding tank proces	Infiltration - evapotranspiration - run-off	None	Infiltration - evapotranspiration - run-off	Plant-soil system water outflow & run-off
	Water storage tank	Evaporation & run-off	None	Evaporation & run-off	
	Root zone tank	Percolation	None	Percolation	None
	Subsoil tank	Discharge	None	Discharge	None
Time step (days)		1	7	1	
Strengths		Covers all main land use types with actual location in the study area	Easy to understand as all settings are same than in the game	Fully autonomous agents & representation of space, calendar, water levels similar than in the game	Enough to represent the system and stimulate discussion to identify scenarios & to explore them.
Weaknesses		Cell size too large to represent land use at farm level. Slow simulations.	Cannot accomodate changes as data directly fed from the game to the simulator	Participants focus on specific situation of their own farm displayed on screen and do not discuss the simulations	Most abstract spatial settings with simple water balance assessment.
Use in simulation workshops (date)		No	20-21 April 2006	24 April 2007	13-14 May 2008

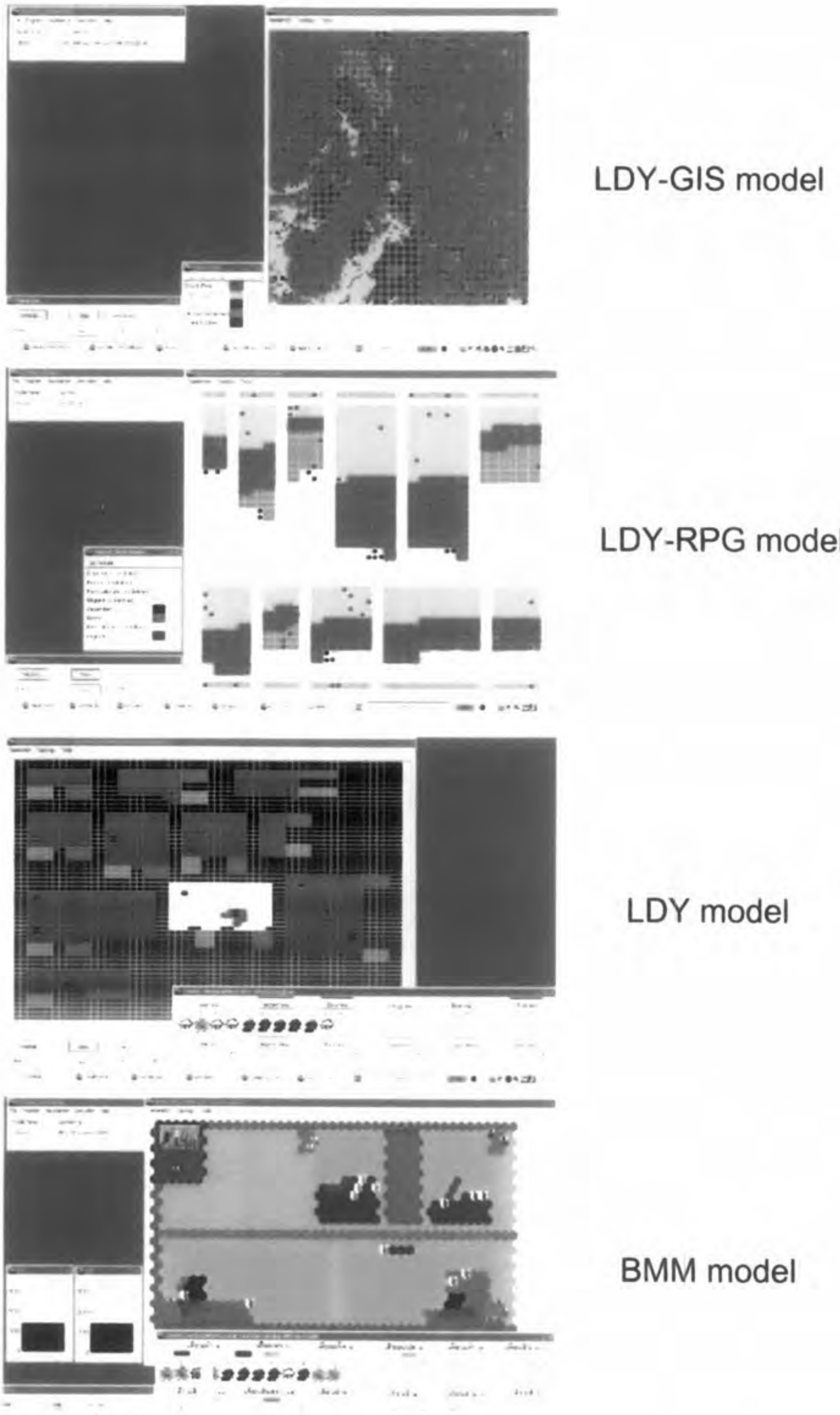

Figure 8.10 Evolution of the spatial configurations of the main interface of the successive computer models in the Lam Dome Yai case study: from singularity to abstraction.

Another major difference between the first ABM and the final BMM model was the adoption of a simpler hydrological module. The representation of complex hydrological processes related to the water balance in soil, such as evapotransipation, infiltration, percolation, and diffusion that were developed to precisely simulate the availability of water in paddy fields and ponds in an initial model were finally discarded. I took this decision to keep the BMM model as simple as possible. I also had difficulty in making these hydrological processes transparent to participating farmers in the co-designed modelling process. Moreover, during this long collaborative modelling process, it was found that farmers decide what action should be taken mainly by observing the daily rainfall conditions. As a result, this complex hydrological module was replaced by a unique parameter to remove 10 mm of water as daily outflow from a paddy field (See details in the description of the BMM model in chapter X). However, I retained two virtual hydrological surface tanks (ponding tank in paddies and water storage tank in pond) to operate the run-off and evaporation processes. Another important outcome of this collaborative modelling experiment was the various types of effects generated by the ComMod activities on this sample of participating farmers and their social network. Their knowledge acquisition, and changes in perceptions, decision-making, behaviours, and actions, were monitored and evaluated under the ComMod monitoring and evaluation activities. The details of all results generated by this specific ComMod process are provided below in a specific chapter on the assessment of ComMod's effects.