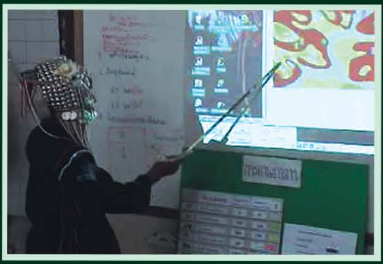
Companion Modeling and Multi-Agent Systems for Integrated Natural Resource Management in Asia



Edited by F. Bousquet, G. Trébuil, and Bill Hardy

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Participatory modeling for managing rainfed lowland rice variety and seed systems in lower northeast Thailand: methodology and preliminary findings

C. Vejpas, F. Bousquet, W. Naivinit, G. Trébuil, and N. Srisombat

Rainfed lowland rice varietal and seed management involves a complex system dealing with problems such as variety adoption, biodiversity, and the supply of good-quality seed. Participatory modeling of rainfed lowland rice varietal and seed management in lower northeast Thailand has been carried out to better understand the seed system and identify problems. Conceptual modeling was done through interinstitutional research team meetings, stakeholder analysis, surveying stratified random sampling of farmers and seed supply agents in Ubon Ratchathani Province, and conducting role-playing games (RPGs). The seed system was divided into three subsystems: farmers' decision-making related to rice varieties, farmers' management of seeds, and the whole existing seed supply system. A first RPG representing the first two subsystems was used at two different locations with 25 farmers. The initial findings from the RPG helped to validate and improve the conceptual model and provide a common understanding of farmers' rice varietal and seed management. Problems of limited access to or sharing of information about varieties and seed, the need for early-maturing varieties, and the scarcity of good-quality seeds were identified. A second RPG will deal with the whole seed supply system. A more comprehensive analysis of the RPG results with those of the farm survey will be done to improve the conceptual models, together with developing a multi-agent model representing the whole rainfed lowland rice seed system.

This paper aims to present and discuss the research framework, research methods, and initial results of investigating the systems for rice varietal and seed management through systems modeling with a participatory approach under a collaborative research project between IRRI-CIRAD and the Office of Agricultural Research and Development (OARD) IV and Rice Research Institute (RRI) under the Thai Department of Agriculture (DOA) and Ubon Ratchathani University (UBU) that started in November 2002 within a selected region of lower northeast Thailand, a major rainfed lowland rice (RLR) area in Thailand.

The lower northeast Thailand subregion contains nine provinces covering 8.4 million ha, with 17,357 villages and 11.5 million people. About 70% of the agricultural land belongs to the rainfed lowland rice ecosystem (DOA 2001). According to a survey done by the Rice Research Institute during 1982-86, more than 1,500 rice varieties were grown in northeast Thailand (Chaidee and Thongpitak 1992). The government has been making a high investment for a long time to release better varieties (according to rice scientists' criteria) as recommended varieties and produce and supply seeds to farmers. Fourteen recommended varieties have been distributed by the DOA to farmers in northeast Thailand since 1956 (Pantuwan and Jongdee 2003). Rice varieties in this region can be separated into glutinous and nonglutinous ones. Glutinous rice is mainly for family consumption in the majority of households in the region and the nonglutinous paddy is mainly for sale. Recent surveys reported that the glutinous rice varieties were more diverse than the nonglutinous ones (OAE 2000, Polthani et al 2002). RD6, the glutinous variety released in 1977, is the dominant one in this group. The nonglutinous one mainly grown for sale is "Hom Mali rice," which officially includes the two recommended RLR varieties, KDML105 and RD15 (Ministry of Commerce 1997). KDML105 was released in 1959 and is much more dominant than RD15, an early-maturing mutant of KDML105 released in 1978. About 77% of the farmers in the northeast have adopted these three recommended varieties (OAE 2000). In Thailand, Shinawatra and Woottikarn (1994), CBDC (2002), and Gypmantasiri et al (2003) have studied farmers' adoption and preference of rice varieties. The DOA has tried to find out why farmers have not adopted the most recently released varieties (Pantuwan and Jongdee 2003). Little work has been done to comprehensively analyze farmers' variety adoption and especially to study the linkage between farmers' requirements for varieties and seeds and the government and commercial seed service systems.

It has been reported that most farmers in the northeast are still using their own rice seed, but more farmers tend to buy seeds and also to change seeds more frequently (OAE 2000). However, the production capacity of the government for rice seed is only 3–5% of the demand (DOCP 2001). Meanwhile, more and more organizations and projects are becoming involved in the rice seed supply system nationally besides the Seed Centers (SCs) under the Department of Agricultural Extension (DOAE), which used to be the only ones responsible for this task in the country since 1976. These emerging agents are supported by either the government or the private sector. The deficiency in rice seeds required by farmers is a problem that also occurs in countries such as Indonesia, Vietnam, and Malaysia (CBDC 2001a,b). In Thailand, few technical documents have explained the rice seed production and supply system, except for some statistical reports and comments in the annual reports of each institute, such as the DOA, DOAE, or Department of Cooperative Promotion (DOCP). A need to improve rice seed production systems of the DOAE has been recently documented in Siriwattananukul et al (2003), studying the adoption of the DOAE's rice seed production program in the southern region. No comprehensive information on rice seed supply systems of different agents and their linkage with the varietal and seed management system at the farm level has been reported. The situation of seed systems in Thailand agrees with what Tripp (2001) had identified as the three main generic problems of seed systems: problems with variety release procedures, which were a monopoly of the public sector subject to bureaucratic delays; the inadequacy of information available to farmers; and weaknesses in commercial seed markets.

Similar to what occurs in many other rice-growing countries, the impact of the adoption of a few dominant recommended varieties has led to genetic erosion concerns

(IRRI 1998), resulting in more attempts to establish rice biodiversity conservation projects (Bellon et al 1998, DOA 2002, CBDC 2002, Zhu et al 2003), with research and development trends turning to the farmer participatory approach (CBDC 2002). Bellon (2004) has argued that the crop diversity maintained by farming households results from the interplay between a demand of farmers and a supply of seed. Now, there is no common platform for stakeholders to communicate about this topic, particularly for farmers, who should have their required varieties match their consumption needs and field conditions and should have good-quality seed for agronomic and marketing aspects, while the public institutions conserve rice biodiversity as valuable genetic sources and as alternative varieties.

To understand the complexity of the system, an interactive participatory modeling approach is proposed for better knowledge integration and communication of different perceptions. The rice varietal and seed management system is modeled to encompass farmers' behavior regarding RLR variety and seed source selection in such a heterogeneous ecosystem in relation to seed supply systems. The modeling process requires the participation of farmers and other stakeholders to share their actual needs and roles in the common communication platform. A main purpose is to provide a better understanding of the system's behavior, to identify its key constraints and current weaknesses, and to help find acceptable ways to improve its current functioning to better meet farmers' seed requirements. This can lead to establishing a coordination and negotiation support system for serving farmers' needs in RLR production and to harmonize stakeholders' roles and objectives as well as conserving biodiversity under dynamic and multilevel circumstances.

This paper explains the research problems, the model conceptualization, its theoretical background, and methodology used. The participatory research procedure starting from establishment of the interinstitutional research team with information and concept sharing is emphasized. The paper also presents the preliminary major activities of conceptual modeling and an analysis of stakeholder and farm surveys together with the conducting of a role-playing game (RPG) as a part of participatory modeling. Also mentioned are some proposed aspects for the next phase.

Assumptions and hypotheses

The study of a system is dynamic and complex, spatially diverse, and multilevel and concerns many stakeholders. A system is based on several assumptions drawn from existing knowledge about it. Rice biodiversity in the region tends to decrease because of the high adoption of major rice varieties under market demand and their fitting with farmers' preferences. Also, farmers are more commercially dependent on a seed supply from different external sources with seed scarcity and quality concerns. However, many farmers (more than a third of them in our study area) are still using other varieties beyond the recommended ones. Those varieties fit their needs, resources, and environments, but are not looked after by government agencies involved in the seed system. One assumption examined in this research is the contrast in objectives among the government or international agencies themselves—promoting a few recommended varieties, but also willing to conserve biodiversity for global sustainability.

Hence, our central hypothesis to be examined with the mentioned assumptions is that, in the system of rice varietal and seed management, what the farmers decide and need does not match with what policymakers decide and implement because of the lack of system understanding, and improper connections and poor communication from farmers to policymakers and researchers. In addition, some significant weak points in the existing system need to be identified and improved.

The participatory modeling approach we selected should provide a clear and holistic explanation of the system and can be applied to other similar problems related to the management of scarce renewable resources. Consequently, the model and knowledge produced should be able to produce a best-bet alternative for farmers and other stakeholders to put in place a sustainable seed supply system for suitable varieties while conserving rice biodiversity.

Theoretical background and state of the art

The management of RLR varieties and the seed system deals with various varieties having different purposes of use, different sources and suppliers, different farmers with different resources, and different institutes and agents, with systems changing over time and location, depending on many levels of decision-making—from the plot level to international concerns. Understanding this complexity can be attempted by a systems approach and simulation modeling. Several methods of simulation modeling have been developed for social sciences for decades. For example, system dynamics based on differential equations with the stock-and-flow concept describes the system under study as a single entity or object and aims to use simulation for prediction. Forrester (1972) illustrated some examples of system dynamics models for simulating the supply of products from a factory to its customers. Low (1980) applied this system dynamics modeling principle to improve the Samuelson-Hicks multiplier-accelerator model of a business cycle that can identify causal structures that underlie actual decision-making and clarify the direction of causality. However, these types of model also depend heavily on quantitative assumptions that are weak points of simulation based on social science that we are more concerned with understanding and explaining (Gilbert and Troitzsch 1999).

Multi-agent models able to simulate autonomous individuals and their interactions developed from nonlinear dynamics and artificial intelligence research could be applied to the simulation of human societies. They rely on computer programs to facilitate an increase in knowledge and procedural skills by learning from experience. Models with the ability to learn are very useful both for simulating cognitive processes of individuals and for modeling the society adapting to circumstances over time.

The participatory modeling approach based on multi-agent systems (MAS) associated with RPGs is proposed as our chosen method. In this approach, field work and system modeling are two complementary activities that are closely linked in an iterative way to produce a shared representation of the system. Recent field experiences have demonstrated the effectiveness of the use of such models to support on-farm, interdisciplinary, and action-oriented research in various contexts (D'Aquino et al 2002). MAS are the computational systems originated from distributed artificial intelligence (DAI) and they rely on the technology of cellular automata (Bousquet et al 2004, Trébuil et al 2002a) that are increasingly used in various fields of natural resource management research. This MAS modeling process can be associated with RPGs, another interactive tool frequently used in the companion modeling approach. The use of RPGs derived from more complex models through simplifications is a dialogue-facilitating tool for the collective and interactive learning process among multiple stakeholders (Bousquet et al 2004). RPGs are used to validate and criticize the preliminary conceptual model and our existing knowledge of the system, and to enrich it through an interactive process among players. Another advantage of RPGs over interviews is that people may feel more comfortable in answering "what if" questions because these are closer to the reality than thinking of a way to answer a more difficult and abstract question. Moreover, the game playing is orderly when played in a sequence reflecting the step of decision-making actually used in real circumstances. Working on the 3-D model board helps the players visualize together and make decisions under the spatial arrangement (Bousquet et al 2004, Trébuil et al 2002b).

Since this study involves both the decision-making of individual farmers and the management of the seed supply system of institutions, several economic theories can be employed. The theory of decision-making in product choice explained by the conceptual model of consumer behavior called the Consumat approach using MAS proposed by Jager and Janssen (2003) is aimed for inclusion in modeling. This interesting approach integrates several decision-making theories and explains the different behaviors in choosing products as repetition, imitation, social comparison, and deliberation regarding the two dimensions of uncertainty and need satisfaction level. These can be applied to the selection behaviors for rice varieties and seed sources of farmers, which seem to be diverse and influenced by the uncertainty of physical and social variables of the RLR production system.

The analysis and modeling of a seed production and supply system at the institutional level can be done under the approach of supply chain modeling that crystallizes the concepts of integrated business planning with the functional integration of purchasing inputs, manufacturing, transporting, and warehousing, and the spatial integration of these activities across vendors, facilities, and markets, with support from a geographic information system (GIS) to become a decision support system (Hoffman 1997). Moreover, modeling the process of seed distribution from different institutions to farmers can be compared and shared with model-based analysis and simulating the diffusion of "green" (organic) products with co-evolution between firms and consumers under the abovementioned Consumat approach (Janssen and Jager 2002).

Construction of a conceptual model and data gathering

At the initial stage of the research project, the system was first analyzed within the boundary of RLR in Ubon Ratchathani Province, a major province in the region with key agricultural research and extension institutes. The participatory approach was employed to carry out several meetings of different relevant institutes in Ubon Ratchathani to gradually establish the research team and develop a conceptual model of RLR varietal and seed management. The interdisciplinary team is composed of an agricultural systems specialist and a MAS modeler from IRRI-CIRAD, a breeder and a seed production specialist from the Ubon Ratchathani Rice Research Center (URRC), a farming systems research and development team from the OARD-IV, and a systems agronomist, as well as a landscape agronomist and a rural sociologist from Ubon Ratchathani University.

The unified modeling language (UML) for building the conceptual model has been introduced to provide a diagrammatic representation of the research team's understanding of the rice varietal and seed management system before looking for more information from farmers and other stakeholders. The whole system was initially split into two models: farmers' varietal management model and seed supply model.

The first model was formed as a decision flow diagram explaining farmers' decision-making on varieties. The farmer decision-making model was initially based on relevant secondary data and experiences from the team. The other model was constructed to represent the structure of seed supply systems concerning the relevant institutes or agents. Stakeholders were defined by the research team and questions were asked concerning their objectives, roles, and functions in the system (Table 1). These have been done with iterative processes from simple to more complex models during several meetings, along with information gathered from field work and available data. Successive half-day-long meetings gradually improved the models by sharing experiences, information, and perceptions of each researcher, especially the ones from OARD-IV and URRC, who have much experience working with rice farmers and agricultural institutes in this region. This helped to create a common picture of the system to be managed and generated follow-up questions. Then, information was gathered for improving our understanding for the next meeting, meaning more updating of information and a better conceptual model each time a meeting took place.

Another model about farmers' choice of seed sources was added to a link between the first two models mentioned above. This model is another decision flow diagram that explains how farmers manage their seeds and decide to buy new ones from a certain supplier. Data from the farm survey and the RPG helped to construct this model.

Relevant documents were reviewed and secondary data were analyzed in parallel with the field survey. The complementary field work included interviews with key informants from different stakeholders such as the DOA, DOAE, DOCP, agricultural cooperatives (ACs), seed traders, and contract farmers (Table 1). A survey of farmers' use of rice varieties in the 2002 wet season was carried out by stratified sampling of 258 farmers from all 25 districts in Ubon Ratchathani from December 2002 to May 2003. This aimed to collect, analyze, and integrate current information to document farmers' decision-making rules regarding rice varieties and seed supply. Results were also compared with previous rice variety studies in northeast Thailand by Chaidee and Thongpitak (1992) and Gypmantasiri et al (2003) to assess rice biodiversity dynamics as well as its spatial distribution. These gradually improved conceptual models are presented below.

Construction of the role-playing games (RPGs)

We decided to build two separate RPGs on the basis of different focused objectives based on the knowledge acquired during the model conceptualization phase and the

Table 1. Stakeholders of the RLR rice seed system in northeast Thailand, 2002.

Stakeholder	Role/function/linkage in the system
Farmers	Producing paddy rice for home consumption and sale. Using variety and seeds as inputs, collect own seed if not changing, exchange seed with other farmers.
Seed production contract farmers of each agency (SC, cooperatives, or CP)	Doing as other farmers do, and also producing stock or certified seed to sell to their contract agencies.
Rice Research Centers (RRCs)/ Rice Research Institute (RRI)/under the Dept. of Agriculture (DOA)	Breeding for new varieties. Maintaining quality of the recommended cultivars. Producing foundation seed for the requested seed multiplication agents and selling the surplus. Conserving rice genetic pool.
Seed Centers (SCs)/under the Dept. of Agricultural Extension (DOAE)	Managing contract farmer system to produce stock and certified seed, seed improvement and selling seed at the center or through agents and DAO, or providing seed for special projects. Certifying seed. Certifying seed traders.
Agricultural Cooperatives (ACs) (supported by Dept. of Cooperative Promotion, DOCP)	Seed-producing cooperatives (5 in Ubon Ratchathani) producing stock or certified seed through contract farmers and implementing other AC activities such as seed trading, paddy trading, and providing loans to members.
District Agricultural Office (DAO, under the Dept. of Agricultural Extension, DOAE)	Assisting community rice Seed Centers and distributing seed to farmers at the district level. Collecting data on farmers, providing seed and technical information. Getting stock seed from SC through DAO to produce certified seed through members and distributing seed for the community by exchanging or selling.
Charoen Phokpand (CP) Seed Company	Running seed production business. Multiplying foundation seed to produce stock seed and sell seed.
Bank for Agriculture and Cooperatives (BAC)	Giving loans to farmer members, including distributing seed from the ACM.
Agricultural Cooperative for Marketing (ACM)	Trading seed and other agricultural inputs and products.
Rice mills	Trading rough rice and producing milled rice, grading rice production quality when buying. Sometimes selling seed.
Agricultural store/traders	Trading seed and paddy. Distributing stock or certified seed to farmers.

results of the farm survey. The first RPG simulates farmers' decision-making on rice varieties and seed sources and the second one simulates the decision-making of different stakeholders in the seed supply system. Each game is used in sessions organized at different geographical locations (an area close to seed production agencies and a more remote one) to avoid the management of too many players and activities at the same time.

Before designing these RPGs, the research team from Ubon Ratchathani had visited two other teams and projects using this tool with MAS modeling in other regions of Thailand. One was about understanding the interaction between agricultural diversification and the risk of soil erosion in a highland watershed of Chiang Rai Province (Trébuil et al 2002b) and the other one was about the dynamics of the transition from paddy land to sugarcane plantations in Khon Kaen Province (see Suphanchaimart et al, this volume). At these two sites, our team learned how to design an RPG and to implement a gaming session followed by individual farmer interviews and collective discussions.

In the first game, the room is spatially arranged into two zones according to different factors such as distance to major seed suppliers and degree of rice biodiversity found during the farm survey. The 3-D board (60 cm × 60 cm) representing the paddy landscape made up of three main types of fields is prepared to represent the lower, middle, and upper paddy terraces (Fig. 1). The selection of RLR varieties or seed sources is represented by sticker tapes of different colors and patterns applied by players to each field with the help of several assistants. For practical convenience, two boards representing two different areas are played simultaneously in the same room. Six farmers play at each board, with two players representing each main type of farm (small, medium, and large ones) in the same zone. The number of paddy fields assigned to each player changes with his/her farm size, as shown in Figure 1.

Farmers are selected from the surveyed villages but not among the ones we interviewed. The selection of farmers aims at a diversity in farm size, rice variety, and seed suppliers, with a balance between the number of male and female players. At the beginning of the game, the suitable types and number of rice fields are allocated to each farmer on the 3-D board according to the actual characteristics of their own farms. Each farmer receives a certain amount of money for buying seeds. Each "year," farmers are asked to select the varieties grown on each plot, the planting method (transplanting or direct seeding), and the source of seeds for each selected variety. Then, farmers pay for the purchase of their seeds if applicable. After all players complete these activities, they are asked to harvest their rice crops and to decide, for each variety, how much paddy they want to retain for seeds, family consumption, and sale. They

Fig. 1. Players allocating their rice varieties to their different types of paddy fields on the RPG board.

receive payment for the sale of their paddy and wait to play the following "year" of the gaming session. Farmers are reminded not to be too much concerned about cash flow and earnings in the game but to decide according to their actual practices under the given conditions.

This first game explores the decision-making behaviors that include the choice of rice variety and the choice of seed source, the allocation of each variety to different types of paddy fields, and the decision to collect or discard RLR seed from their own fields. The feedback of players' decisions that may affect the decision of the next step can be shown as the quality and/or price of rice sold depending on seed quality, variety grown, and amount of money left after buying seed. A key concept is to keep the game interactive and flexible. Some game conditions or rules may be modified according to the players, for example, changing the landholding size, number of family members, farm labor, seed price, and rough rice price, or a new variety can be introduced to see its contribution to the next decision-making.

After playing for two simulated "years," we discussed with farmers their feelings and opinions about the game in relation to reality. Farmers were asked whether they wanted to change the rules or resources allocated; however, no farmer suggested significant changes. We discussed rice practices, such as planting methods, variety choice, seed prices, and seed supplier availability across villages and zones. Farmer-players were interviewed the day after the gaming session about their decision-making during the game, their real circumstances, and their opinions about the usefulness of the RPG tool. Analysis through the game gave us some more details on what farmers do and how they decide at each step of a round of play. The farmers are observed to see how they relate their actions in the RPG to reality, and how they experiment and imagine new things during the game. We also try to study the different kinds of reasoning behind farmers' decision-making processes on varietal management according to the abovementioned Consumat approach of Jager and Janssen (2003).

The first gaming session was played on 29 September 2003 at the Ubon Ratchathani Agricultural and Technology College with 12 farmer-players from three specific zones: one close to the RRC, another one close to the city, and a last one in a partially irrigated area. The second session was played on 26 January 2004 in the more remote areas of Ban Bua Ngarm village of Det Udom District, 80 km south of Ubon Ratchathani. This time, 13 farmer-players took part. They belonged to different ethnic groups: Khmer farmers from a village near the Cambodian border growing only nonglutinous rice, Lao farmers from Ban Bua Ngarm growing diverse glutinous rice varieties, and Lao villagers engaged in a special rice production for a niche market in Pibun Mungsaharn District. Seed-producing farmers from the Community Seed Centers (CSCs) in each village also took part in this second session. The initial results of these first gaming sessions are presented below.

The second RPG deals with the whole seed supply system and is designed according to the conceptual model on seed supply. Players will mainly belong to the seed production and supply institutes or will be contract farmers producing seeds (Table 1). This time, each player can use different system boundaries or scales according to their respective mandates and responsibilities. The CSC may play at the village scale, while the cooperatives could play at the District scale, and the RRC or SC at the provincial scale. This setup should assist in the collective learning of each stakeholders' objectives, functions, and interactions, or lack of them, in different RLR-growing areas. The decision-making, planning, and implementing process of each seed-producing agent to get and supply the amount of seed of each variety required by seed purchasers each year and at different locations could be learned from this second RPG.

Preliminary results and discussion

Farmers' choices and management of varieties

Modeling the farmers' choices of varieties was based on our initial understanding that ethnicity is a determinant of the type of rice to grow for home consumption as reported by Chaidee and Thongpitak (1992) and Polthani et al (2002). Lao farmers, who are the majority of people in the northeast, usually eat glutinous rice, whereas the Khmers, living in the lower part of the region, as well as other Thais, eat mainly nonglutinous rice. The decision flow model shown in Figure 1 simply states that Lao farmers have to grow glutinous rice for food security and they grow nonglutinous rice (Hom Mali rice) for cash income since it usually fetches a higher farm-gate price. However, we found that some nonglutinous rice is also consumed (around one in ten meals) by most Lao households. In our survey, the 3.5% who did not grow glutinous rice are Khmers, living in the southernmost part of the province along the Cambodian border. However, several Khmer households included in our survey in Ubon Ratchathani Province and who took part in the first RPG also grow and consume glutinous rice, probably because of the proximity and influence of the majority of Lao ethnic farmers.

The survey and the first RPG indicated that Lao farmers prioritize growing glutinous rice in agroecological zones and fields to be able to produce enough yield to ensure food security (Fig. 2). From our survey data, we found that the average glutinous rice area required per family member is about 0.16–0.32 ha, or 1.6 ha per household. Some 11.5% of the households grow only glutinous rice, with an average farm size of 2 ha and average family of five members, with not much variation (Table 2). In the RPG, when increases in household members and labor units were announced, most farmers then grew more glutinous rice. This confirms the priority of glutinous rice for food security and as a preference. One farmer who grew only glutinous rice asked us to sell some, though breaking our initial game rule. We found that few farmers grow glutinous rice for sale except when they have a surplus.

KDML105, RD15, and RD6 are the major RLR varieties confirmed by our field survey (Table 3) and the first RPG. Many different reasons for choosing glutinous varieties are found, such as taste preference, maturity, yield, etc. Growing only RD6 for glutinous rice is most popular (61%), but other glutinous varieties are still used by 17.4% of the farmers, while 18.1% grow a combination of RD6 and other glutinous varieties (Table 3). All the farmers seem to be familiar with RD6, but some have rejected it for different reasons. Many claim that RD6 has a hard cooking texture if its seeds are not changed frequently (1–3 years). Some prefer to grow early-maturing or nonphotoperiod-sensitive glutinous varieties to avoid drought or to be able to grow postrice crops earlier, especially for upper paddy conditions.

Choosing early-maturing glutinous varieties can be related to the decision to grow nonglutinous KDML105 or RD15 rice because of the mutual help practice still

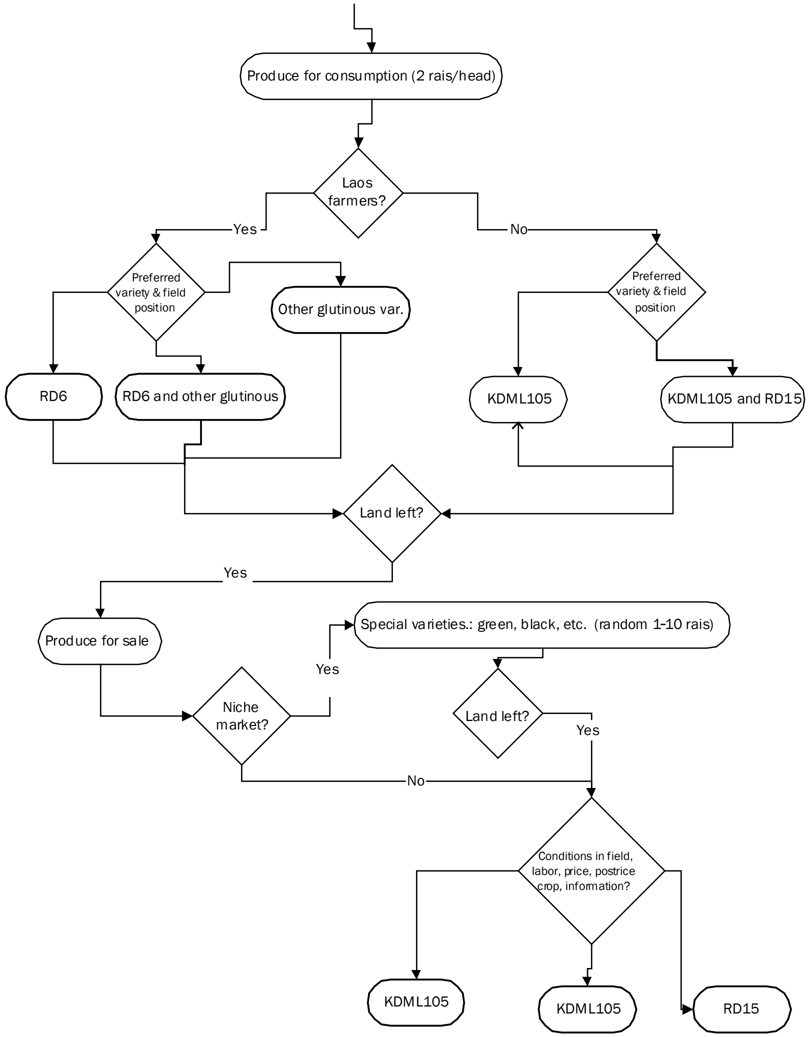

Fig. 2. Decision model for a farmer's choice of rice varieties, focusing on main varieties, lower northeast Thailand, 2002. Percentages are the proportion of farmers found in the survey in Ubon Ratchathani, 2002.

in use at harvesting. Some farmers who grow KDML105 prefer to grow early-maturing glutinous rice to be harvested first. Farmers also grow more than one glutinous variety when they want to stagger the rice harvest. A labor constraint at rice harvest is common as the average farm labor is only 2–3 persons (Table 2). Some 35 variety names of glutinous rice were found in this survey and almost all of them seem to be early-maturing varieties bearing the same names as local varieties listed in Chaidee and Thongpitak (1992) such as Daw Boonma, Daw Khao, Daw Ko Diew, etc. Some of them used to be recommended, such as Niew Sanpatong, RD8, and Hang Yi cultivars. Some surveyed farmers grow RD10, a nonphotoperiod-sensitive variety that is currently recommended for irrigated rice during the dry season. It is considered as an early-maturing variety because it is usually planted early in the season and then harvested first. The E-norn glutinous upland rice variety is also planted by a farmer who took part in the RPG. Frequent changes in these glutinous rice varieties are observed but access to information about them is sometimes limited, even in the same community. New varieties may be introduced from other provinces, often thanks to relatives living there. Variety names used by farmers are sometimes confusing, as reported by Bellon (2004).

Growing rice for cash as a second priority can have two alternatives (Fig. 2). If farmers have potential access (skill and a market) to produce special types of rice or rice for a niche market such as glutinous green rice (immature rice), black glutinous rice, or yellow nonglutinous rice for dessert and red Mali rice that seems to earn more income than Hom Mali rice, they should grow those varieties, but on a small area of 0.16 to 1.6 ha because of the limited production capacity and limited market. Only 2.7% of the farmers represent this case from our survey. A late harvest of RD6 or any glutinous rice can be used to make green rice.

The nonglutinous rice varieties such as Khao Chao Daeng used for producing Thai noodle starch existed 10 years ago in many areas of Ubon Ratchathani Province as reported by Chaidee and Thongpitak (1992) but they were not found at all in our recent survey. The Thai noodle factories buy milled nonglutinous rice from other provinces, such as Nakhon Ratchasima, for this purpose instead. One farmer selected to play in the second gaming session grew a deepwater nonglutinous rice variety called Leb Mue Nang to avoid flooding damage and could sell it to the local rice mill.

Generally, growing nonglutinous rice is limited to KDML105 or RD15 since they

Table 2. Rice type grown by farmers with different ethnic groups and main purposes and frequency (%), with average farm household and amount of farm labor and mean, standard deviation, and range of farm size (surveyed in Ubon Ratchathani, 2002 wet season).

Farmer group by rice type grown	Farmer ethnic group	Rice production type	% of farmers growing	Mean no. of household members	Mean household labor	Rice-growing area (rai) (1 rai = 0.16 ha)			
						Mean	Standard deviation	Min.	Max.
Only glutinous	Lao	Subsistence	11.5	5	3	12	8	4	33
Only nonglutinous	Khmer, Thai	Partly commercial	3.5	5	2	22	11	10	46
Both glutinous and nonglutinous	Lao	Partly commercial	85.0	5	2	20	16	3	130

are the only varieties accepted as Hom Mali rice and are accepted on most of the non-glutinous rice markets in the region, where they are 10% to 50% more expensive than the other common rice varieties. According to our survey, 65% of the local farmers are planting only KDML105, 12% grow only RD15, and 15% produce both cultivars (Table 3 and Fig. 2). This kind of choice depends on several factors. RD15 matures in late October or early November, 2–3 weeks earlier than KDML105, and this early harvest leads to a higher farm-gate price. RD15 is suitable for well-drained fields that tend to be more extended. RD15 also provides more time for labor sharing at harvest if farmers also grow RD6. However, limitations of RD15 are its early harvesting period, sometimes in wet conditions, which damage the quality of the paddy; the scarcity of good-quality seeds; and the lack of information about this cultivar. However, our survey found that RD15 is becoming more popular in many areas of the province.

The need for early-maturing varieties was confirmed in the RPG. When a new glutinous nonphotoperiod-sensitive variety with 120 days' maturity was introduced, some farmers selected it, especially those from areas with a higher diversity of cultivars. This also indicates different characteristics among farmers and areas regarding variety adoption. The preliminary findings from both the field survey and RPG indicated that the extent of rice biodiversity or number of varieties found is related to spatial patterns in the province. In the districts close to URRC and the SC and near Ubon Ratchathani City, only three recommended varieties were found. Areas with high rice biodiversity (9–16 varieties) were found in the southern and eastern districts, with influence from irrigated rice varieties and border exchanges with Laos and Cambodia.

The allocation of certain varieties to specific types of fields is decided for various reasons. For example, priority staple glutinous rice is grown in more favorable conditions, mostly in the well-watered lower paddies, whereas early-maturing rice is grown in the upper paddies for water-regime reasons or close to the farm hut or the road for convenient rice threshing and paddy transportation. These familiar choices are well represented on the playing board of our RPG (Fig. 1).

In summary, many factors have been claimed by farmers to influence the choice of variety, such as yield, landscape, market demand, price, seed availability and accessibility, information accessibility, labor availability at harvest, farm size, cooking quality, aroma, preference, maturity, disease or pest susceptibility, degree of lodging, flood or drought tolerance, grain fitting the milling machine, or use for specific rice products, or even health problems.

Farmers' management of seed sources

Our initial understanding regarding farmers' choice of seed sources is shown in Figure 3. This conceptual model has been developed from the survey information and was validated and improved through the RPGs. This model is linked to the previous one presented in Figure 2 displaying how farmers select the RLR varieties to be used. If farmers do not plan to change a variety, the decision they have to make is between collecting seeds from their fields or changing to new seeds from outside their farm. Our survey found that 50–60% of the farmers changed the seed of the three recommended varieties every 1–3 years, whereas 10% never changed it (Table 4). A similar picture emerged from the game results.

Table 3. Choice of varieties used and frequency (%) of farmers growing them, with average farm household and amount of farm labor and mean, standard deviation, and range of farm size (surveyed in Ubon Ratchathani, 2002 wet season).

Choice of rice varieties	% of farmers growing (n = 258)	Mean no. of household members	Mean household labor	Rice-growing area (rai) (1 rai = 0.16 ha)			
				Mean	Standard deviation	Min.	Max.
Glutinous							
RD6 and other glutinous	18.1	5	3	28	23	8	130
RD6 but not other glutinous	61.0	5	3	20	12	3	65
Other glutinous but not RD6	17.4	5	3	20	17	4	94
Nonglutinous							
KDML105 and RD15	14.8	5	3	27	22	5	130
KDML105 but not RD15	64.7	5	3	22	15	3	94
RD15 but not KDML105	12.4	5	3	22	11	4	50
Special varieties for niche market	2.7	6	3	26	18	11	58

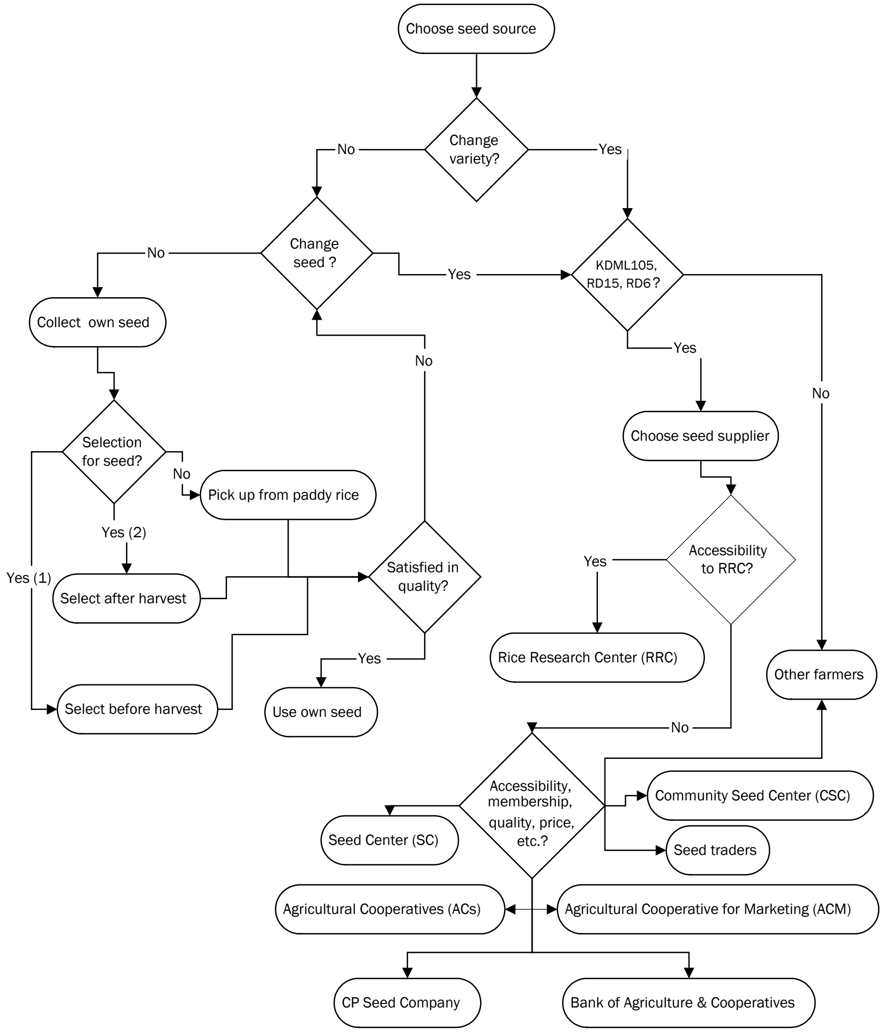

Fig. 3. Decision model for a farmer's choice of seed sources and suppliers, Ubon Ratchathani, lower northeast Thailand, 2002.

A major reason for changing glutinous rice seed is cooking quality, as the grain becomes harder with time. For nonglutinous KDML105 and RD15, a change of seed is necessary when more off-type plants appear, resulting in a lower paddy price. The seed suppliers of the above three recommended varieties could be several agencies: URRC, Seed Center (SC), Community Seed Centers (CSCs), the Agricultural Cooperatives (ACs), and the Charoen Pokphand Seed Company (CP). The SC's seed can be obtained through the District Agricultural Offices (DAOs) or from their network of certified stores and rice mills, whereas CP seeds are sold by the Agricultural Cooperative for Marketing (ACM) organization with support from the Bank for Agriculture and Cooperatives (BAC), or at several stores (Fig. 3 and Table 4).

Based on information from both the farm survey and the RPG, many farmers are very unclear and confused about seed sources. Most farmers may know a direct supplier but not the actual original source of the seed. Some suppliers sell seed from more than one source. The diversity of places from which farmers buy seed is high (Fig. 3 and Table 4). However, the survey findings show that seed of the three dominating recommended varieties is mainly purchased from two sources—the SC through DAOs and traders (14–20%) and ACs (18–21%). The price of seed from ACs was lower (260–320 baht 25 kg^{-1}) and varied more than at the SC (320 baht 25 kg^{-1} or 12 baht kg^{-1}). CSCs had a small share probably because of poor quality, poor packaging, and limited distribution to the local community. A higher proportion of CP rice seed was observed in 2003 though its high price (360 baht 20 kg^{-1} or 18 baht kg^{-1}) limited access, but it had the best packaging and good quality.

Most farmers cannot explain clearly why they choose such seed suppliers or do not choose any at all. Poor accessibility to seed information was confirmed in the survey and RPG. Most farmers had not realized that so many suppliers were available. However, several reasons for their choice of suppliers can be listed, such as distance to selling places, access to relevant information, seed quality, brand name, community influence, membership in an organization, seed price, etc. URRC seems to be the first choice because of its production of high-quality foundation seed and its reputation for a relatively cheap price (10 baht kg^{-1}) thanks to government subsidies. But seed availability and access limit its role as a first-choice supplier. In the seed supply model (Fig. 3), we considered that seed quality should be the first priority when making a choice among suppliers and concluded that URRC is the most preferred, if it is accessible. Proximity or accessibility—physical or social—to seed suppliers was found to be a major determinant of supplier choice. Seed price does not seem to trouble most farmers compared with fertilizer or labor costs. In the RPG, when we let every supplier sell the major recommended varieties at the same low price (10 baht kg^{-1}), this did not change farmers' decision-making. For some farmers, seed investment in the game was somewhat higher than in reality. In fact, some farmers did not purchase enough seed for all their fields, especially farmers using the broadcasting method with a higher seeding rate.

For other RLR varieties that are not currently recommended, farmers have to exchange seed among themselves. Seed of the recommended varieties is also being exchanged among farmers (14–20% of the total) and some seed trading among farmers is observed. Switching to other glutinous rice varieties seems to be common in areas with a higher diversity of varieties. The model shown in Figure 3 illustrates the different ways farmers manage to collect seed: selection from the part of the field with the best crop stand, selection of bunches of panicles during threshing, or random selection from the rice grain pool. This behavior and the seed quality seem to be related to the choice of threshing technique—manual or mechanized. Farmers may finally decide whether to grow a variety by using the seed they collected only after seeing the aspect of the milled rice or after tasting cooked rice from that field. This part of the model was improved by information obtained from the RPG and the follow-up interviews. We were able to specify how farmers collect seed, how they decide to exchange seed with certain farmers, how they buy seed, or how much they keep from their harvests before selling rice. This improved understanding of the farmers' decision-making

Table 4. Frequency of farmers (%) choosing rice seed suppliers of each variety from the survey of 258 farmers in Ubon Ratchathani, 2002 wet season.

Seed supplier	Seed production source[a]	Seed quality class[a]	% of farmers			
			KDML105	RD15	RD6	Other varieties
Ubon Rice Research Center (URRC)	RRC	FS	4	3	4	3
Seed Center (SC)	SC	SS	2	2	0	0
District Agricultural Office (DAO)	SC	SS	19	13	14	9
Seed traders	SC, RRC	SS, FS	5	5	2	0
Rice mills	SC, RRC	SS, FS	2	2	1	1
Agricultural Cooperative (AC)	AC, RRC, SC	SS	25	23	22	7
Bank for Agriculture & Cooperatives	CP Company, SC	SS	4	2	3	1
Community Seed Center (CSC)	CSC	CS	1	2	1	0
Others organizations/projects, e.g., NGOs	na	na	2	0	1	0
Farmers (exchange)	Farmers	–	18	27	28	47
Farmers' self-production	Farmers	–	17	22	25	32
Total			100	100	100	100

[a]FS = foundation seed (produced from breeder seed inside URRC), SS = stock seed (produced from foundation seed), CS = certified seed (produced from stock seed). na = not available.

processes led to improved conceptual models and a better design of the second RPG focusing on the seed supply model.

Seed supply system

The UML diagram shown in Figure 3 displays the structure of the existing seed supply system as understood by our interinstitutional research group and based on the survey results. This conceptual model and other relevant information were used for designing the second RPG.

Officially, every year, the URRC is the only producer of foundation seed of the main recommended varieties (KDML105, RD15, and RD6) on its station. The foundation seed is then distributed annually to other seed production agencies to produce the stock seed to be sold commercially. URRC tries to produce the amount of seed of certain varieties requested in advance (before the growing season, one year before the seed is needed) by the key seed stock producers (SC) and other entities. Any remaining amount can be sold to farmers.

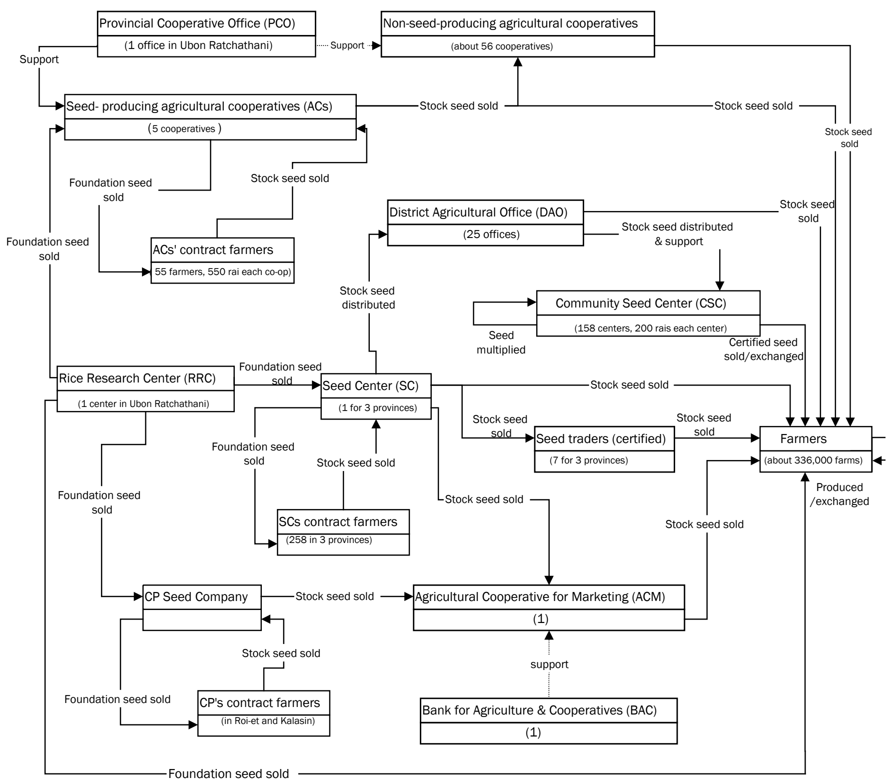

Fig. 4. Structural diagram of the seed supply system in Ubon Ratchathani, lower northeast Thailand, 2002. Seed flow among institutions is mainly KDML105, RD6, and RD15; the others mostly belong to farmer-to-farmer systems only. Numbers below each agent indicate number of places or persons of each agent in Ubon Ratchathani, except for SC and CP seed company subsystems.

The SCs have been the major rice seed producer for as long as their mandate has existed to produce stock seed at the amount planned at the national level for selling to farmers and for special projects. The total combined amount of seed production of RD6, KDML105, and RD15 was about 1,500 t in 2001.

The ACs—privatized agencies with technical and institutional assistance from the Provincial Office of Cooperatives (POC) under the DOCP—have run their rice seed project since 1998 and they also use a system of contract farmers. In 2002, five ACs were producing seed in five districts of Ubon Ratchathani Province. Each AC manages its seed production separately. The ACs producing seed, or those that don't produce seed, can be seed, paddy, or milled rice traders. The amount of stock seed (mostly KDML105) produced by these five cooperatives amounted to about 700 t in 2002 from 16 t of foundation seed.

We also investigated the contract farmers with seed production agencies. The basic seed production systems used by ACs and the SCs are similar. These institutions select farmers, sign a contract, purchase foundation seed from URRC, and sell it to the contract farmers at no profit. Contract farmers produce seed that will be certified and sold back to the contracting agency at a price about 10–20% above the paddy price, depending on the quality of the seed and sometimes on the institutional budget and rules. Some contract farmers become unhappy with the system because of the lower selling price of the seed compared with their expectations, labor limitations, and lack of technical support. This is in agreement with the observations reported by Siriwattananukul et al (2003). Informally, some contract farmers sell some seeds to other farmers. In 2002, 258 contract farmers were under SCs in seven districts belonging to three provinces, including Ubon Ratchathani. In the same year, about 250 contract farmers worked under the five seed-producing ACs in Ubon Ratchathani.

The only rice seed company, CP, locally established in 2001, also purchases foundation seed from URRC under the DOA and produces seed through its own network of contract farmers. The seed factory and contract farmers are located in neighboring Roi-et and Kalasin provinces, about 200 km northwest of Ubon Ratchathani. The contract system used by CP has not yet been investigated. In Ubon Ratchathani, CP seed is sold at the Agricultural Cooperative for Marketing (ACM) and at some agricultural stores.

The CSCs, established in 2000, are part of a nationwide project supported by the DOAE to distribute seed at the tambon (subdistrict) level. Some 158 CSCs existed in Ubon Ratchathani Province in 2002 and they use a different system for producing seed. Each center is made up of a group of 20 farmers. They obtain stock seed from the SC through the DOAE office at the district level to produce certified seed to be exchanged or sold in their community. During our farm survey, labor limitations for field checks, poor seed processing, and the lack of adequate government support were mentioned by some farmers belonging to CSCs. DOAE officials emphasized problems of quality control.

Formal seed traders need to be certified each year for selling seed purchased from the SC. They can receive a price deduction of 20% if the seed is sold at the price usually used for SC seed (320 baht 25 kg^{-1}). Seven seed traders (four of them located in Ubon Ratchathani Province) were registered under the Ubon Ratchathani SC in 2000. Some millers who buy rough rice also sell rice seed purchased from the

URRC or the SC to the farmers. Many informal seed traders are observed, including seed-producing contract farmers or unregistered farmers.

It should be noted that the rice seed supply system of URRC (under the DOA), the SC (under the DOAE), and CP is actually operating at the national level. The recommended varieties and their seeds can also be supplied to other parts of the country. Decisions concerning variety release, recommendations, and seed supply are being made at their headquarters in Bangkok. Therefore, this research project's initial regional boundary, lower northeast Thailand, can be used for modeling farmer decision-making, but it is not broad enough for the whole seed supply system. This problem is strongly related to the centralized phase of planning for the seed supply system at each seed-producing agency. Moreover, recent administrative changes concerning DOA, OARD, RRI, and RRC make things unclear. This aspect will be further investigated in the coming gaming sessions using the second RPG representing the RLR seed supply system, to be followed by MAS modeling of the RLR seed system for Ubon Ratchathani Province.

Conclusions and perspectives

Participatory modeling of this RLR varietal and seed management system using UML diagrams and role-playing games, associated with a farm survey, revealed the complexity of its different facets. Diversity of varietal uses, farmers' choices of seed sources, and linkage or competition of seed suppliers and producers are interrelated with several social (household differentiation) and physical (types of paddy fields) factors among rice-growing farms and communities. Integration of various research tools and activities is needed to well understand this complexity.

Forming the interinstitutional research team with several successive meetings was essential to this research project, while the UML diagram of conceptual modeling is effective for interactive construction by integrating and sharing information among our research team, as a basic framework for stakeholder analysis, survey activities, and RPG, and also for the presentation of such a complex system.

Interviews of selected representatives of each stakeholder and of a stratified sample of farmers during the farm survey, combined with observations on the farm environment and activities related to RLR varieties and the seed system, provided a lot of updated quantitative and qualitative data for helping to improve the conceptual models and RPG design.

The first RPG with a 3-D board improved communication among researchers and farmers toward a common understanding of the system to model. The first gaming sessions elucidated the successive decision-making steps related to the allocation of a combination of RLR varieties to different types of paddy fields, the procedures for seed collection, exchanges across farms, or acquisition from seed-producing agencies. This created an artificial community to observe the pattern and intensity (or lack) of information exchange among players. Testing the farmers' behavior responses to given conditions (such as the introduction of a new variety) was also possible with the RPG. A second RPG focusing on interactions among seed production and supply agencies and growers is being conceived to model the regional RLR seed production and supply system.

Preliminary findings generally confirm our previous understanding of farmers' choice of RLR variety, such as the high rate of adoption of three recommended cultivars in relation to the decreasing regional biodiversity in rice. A better understanding of the whole system and particularly of the roles of each stakeholder was reached. Problems of farmers' limited access to information about seed suppliers, the need for early-maturing varieties, the scarcity of good-quality seed, on-farm seed production constraints, and the difficult adoption of CSC's seeds were identified as key entry points for improving the current situation. These findings also confirm that more dynamic and interactive information sharing about the RLR seed system should be encouraged as part of the new official or community-based seed projects. To be more useful, both agronomic and economic studies on rice varietal and seed management should also take institutional aspects into account. Particularly, the contradiction between the biodiversity conservation goal and the promotion of only a few varieties deserves a more in-depth analysis of the current situation and possible future scenarios. GIS (geographic information systems) can be applied to integrate and analyze spatial information on RLR varieties and seed suppliers across agroecosystems, administrative units, and society.

The current understanding of the seed system proposed in the UML diagrams is being tested and validated with all key concerned stakeholders through the second RPG. After this step, MAS modeling will be used to build a single agent-based model of the whole RLR seed system. It will be verified and validated with the stakeholders who took part in the RPGs because they will be able to recognize the system's features and be in a better position for following what computer simulations are doing in a few minutes (compared with half a day for a gaming session). Finally, we intend to use the MAS model to simulate different scenarios of changes proposed by the stakeholders and to discuss the simulation results collectively to facilitate a common agreement on acceptable ways to improve the current seed system.

By studying such complex systems, we have confirmed that appropriate approaches and tools need to be developed for making use of the information to obtain a better understanding and to correctly identify the problems before implementing any strategies. This suggests the prospect of applying participatory modeling to the evaluation methods for such development-oriented research activities. Obtaining participation of various stakeholders may need much effort, skill, and time but should be worthwhile for providing a common and collective understanding of reality and more acceptable and practical policies.

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Notes

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