Participatory Modeling for Watershed Management: The Use Role-playing Game and MAS Model

Panomsak Promburom
Multiple Cropping Center, Chiang Mai University, Thailand 50200. panomsak@chiangmai.ac.th

Abstract. Scarce farm land and water resources in the highland watersheds of northern Thailand coupled with multiple users have led to conflicts among stakeholders who play important roles in the system dynamics. Integrating companion modeling and multi-agent systems (MAS) can facilitate adaptive learning processes to result in a decentralized collective management strategy that meets the balanced needs of all parties. However, this requires innovative methods and tools, and coordination from all stakeholders involved in the process. This paper presents the use of role-playing games (RPG) with local stakeholders using simplified rules and environment to facilitate dialog among the party and to understand stakeholder behavior in using and managing land and forest resources. Knowledge obtained from the game and following interviews was used to develop MAS model to reproduce the context of the games. The model will be used in further participatory MAS modeling processes.

1. Introduction

The human-/agroecosystem of upper northern Thailand is characterized by mountainous tropical forest ecosystem, where various ethnic groups are practicing agriculture for staple food and cash crops. Since the 1950s, drastic changes have occurred in land use patterns, resulting from political and marketing factors, coupled with an increase in population density. This has had a substantial effect on natural resource viability and the integrity of watershed systems.

This compelled the Thai government to impose land use constraint laws and policies to preserve forest area in the highlands. Thus, it has produced conflict among multiple stakeholders who differ in goals and strategies, and play important roles in the use and management of forest, land and water resources in the watershed area.

Most recent research and development projects concerning natural resource management in northern Thailand have been moving toward decentralization and adoption of integrated participatory approaches while government reform efforts have led to a new national constitution and strengthening of local governance institutions. There is now a stimulating challenge to step forward and integrate new tools and approaches to support and encourage participatory and collective management of natural resources at the watershed level in northern Thailand. MAS is one of the
promising concepts that has been adopted and applied to deal with natural resource management in many aspects.

Number of integrated natural resource management projects was implemented in watershed area of northern Thailand using dynamic and multi-agent system (MAS) model. However most of the model conceptualization, design, development, and validation phases were implemented by the researchers [1], and roles of local and government institutions were merely included in the model [2]. Furthermore, an important issue need to be explored is formalizing the participatory modeling method and supporting tools appropriate for applying with or/and among stakeholders in different level of interest system.

This study targets the following objectives:
1. To employ participatory modeling approach to promote mutual and adaptive learning of researcher and stakeholders to understand roles, and consequences that may arise from individual action and interaction among them.
2. To incorporate political and local institutions in the MAS model to be used as scenario experimental tool by stakeholders.
3. To assess the method of applying different complexity MAS models with different stakeholders.

The paper describes the use of RPG followed by field interviews to verify the researcher’s knowledge, to acquire knowledge on stakeholder behavior, and to enhance co-learning processes among stakeholders of a highland watershed system in northern Thailand, where complex resource managements issue are settled. Apart from game and lessons learned, we illustrate the MAS prototype derived from the result of the game and provide perspectives on the further development and the use of this participatory MAS model.

2. Companion Modeling for Natural Resource Management

“The tragedy of the common” was firstly denoted by Hardin [3], he explained the dependency of environmental problems where the conflict between individual and collective interests took place. The issue has been further captured and elaborated widely in many disciplines trying to understand and explain how individual behavior contributes to collective or social outcome, and what factors influence such behavior and phenomena. The answer tended to be not trying to control behavior of natural resources service clients but rather to support and enhance the self-governed solution or “social norm” to emerge and succeed [4],[5],[6],[7].

In the field of common-pool resource management, many studies have focused on strengthening the adaptive capacity of involved stakeholders to deal with complex situations, with the assumption that better mutual understanding brings about better coordination and greater collective ability [8],[9]. Some of the key issues that contribute to the failure and success of sustainable resource management are: a.) knowledge and understanding of the key stakeholders and the factors governing their resource allocation procedures, b.) methodology and framework for analysis situations and incorporating stakeholder and institutional concerns, c.) tools and
methods to facilitate the design and experiment on possible intervention schemes. [10],[11],[12].

The multi-agent systems (MAS) approach and computational modeling techniques have been progressively developed to explore and understand individual behavior and interaction among agents and the environment that represent the complexity of the whole system [13]. They have been increasingly used to deal with ecological and socioeconomic issues arising from the management of scarce resources by multiple users. Integrating MAS with other biophysical or economic models and spatial database tools can enhance the adaptive learning capability of all stakeholders regarding their roles and effects on ecological system dynamics. This has tremendous potential for assisting decision-makers in understanding and managing landscapes [14].

Recent integration of companion modeling with participatory approaches aims at empowering interested stakeholders through the acquisition of a clear understanding and a long-term vision of their system dynamics. Thus, this allows them to cooperate and manage their natural resources collectively [15]. Coupling role-playing game (RPG) with MAS modeling has been applied to improve understanding of complex phenomena and to develop, modify, and validate MAS models. This can facilitate negotiation and collective decision-making among stakeholders [16],[17].

3. Pre-perception of the System

3.1 Overview of Maehae Watershed

The Maehae watershed comprises two sub-watershed areas in northern Thailand. It is located 80 km southwest of Chiang Mai, one of the major forest-covered areas in the upper Chao Phraya River system Thailand. This highland slope complex area is about 3,288 ha with 70% of pine mixed with evergreen and dry-dipterocarp forests. There are 14 villages and 550 households, scatter over three districts. The two major ethnic groups, the Karen and Hmong, are practicing agricultural activities in both traditional and high-value cash crops and fruit orchards, which have been actively introduced and supported by the Royal Project Foundation (RPF) development center [18].

The highland watershed areas in the north have been generally perceived as a fragile, vulnerable, susceptible national asset and subject to protection and management by government. Highland dwellers and agricultural activities in this area have contributed to highland land and water resources degradation. Meanwhile, the new Thai constitution in 1997 provided a range of new policies to empower stakeholders and local institutions to participate in managing their own local resources in a sustainable way. The Maehae watershed also falls into this category where common resources are located within the multiple political layers of resource management.

As in other communities in this region, the heterogeneity of highland people arises from ethnicity, in which social and cultural institutions, goals, and attitudes toward doing agriculture, household resource availability, and views of their relationship
toward the environment are different [19]. In addition, political intervention also significantly influences the diversity of co-dynamic processes between social and environmental systems that make natural resource management situations more complex and uncertain. It is not easy to perceive and understand the effect of government agencies’ roles and their interactions with social and environmental systems on the overall catchment system.

Thus, the context of environmental components and key stakeholders with their differing perceptions should be analyzed to bring about a better understanding of how individuals behave and interact with the environment and how this may affect the dynamics of the system.

3.2 Stakeholder analysis

In mid-2003, the research team examined the characteristic of natural resources management of Maehae watershed. The data were collected using secondary information from previous studies done by local research institutes. Semi-structured interviews with various local key informants and government agencies were also conducted to complement conceptualization of the Maehae system. The analysis process covered identifying principal stakeholders, investigating their interests, characteristics and circumstances. The patterns and contexts of interaction, and potential conflict between stakeholders were captured. Pre-system analysis resulted in a list of key stakeholders and their important roles in using and managing forest, land, and water resources in this watershed area.

Based on pre-analysis steps, key stakeholders and theirs roles were identified. The farmers are likely facing insecure ownership of their lands. Because most of the cultivated lands are under the national forest reserved boundary. Hence, they are claimed as legally protected areas. The “tragedy of the commons” in Maehae is not confounded within the communities that use resource directly and indirectly. It extends the effect to external beneficiaries such as downstream and urban communities. This second dilemma thus induced external intervention to re-design the rule of forest resource governance, for instance forest-reserved law. However, due to the difficulty in enforcing and monitoring the forest exploitation, thus provide the flaw for local users to be able to over extract this resource.

The RPF, Land Development Department officer (LDD), and Royal Forestry Department officer (RFD) are key government agencies working in the area. RPF development center is actively introducing and supporting cash crops and fruit cultivation to increase farmers’ income. LDD and RFD are responsible for natural resource conservation. The LDD promotes soil conservation practices to reduce soil erosion. Thus, trade-off situation occurs where farmer cultivates crop in slope farmland that are prone to erosion. The RFD promotes forest resource rehabilitation through the collaboration of local people. Occasionally, the conflicts over resources uses have occurred. For examples, there were some farmers encroached and cultivated in restricted forest area, and disagreement on water sharing.

This pre-perception on environmental components, stakeholders, their actions and associations that influence the Maehae system dynamics was transformed and developed into a prototype MAS model using Unified Modeling Language (UML)
static class and simple sequence diagrams. The preliminary design of the “world” representing the Maehae watershed system consists of three major components, corresponding to the stakeholders, their ecological environment, and the local institutions. Stakeholders share and intervene in common resources with different objectives and perceptions. Local institutions are formal and informal groups or organizations representing stakeholders who share similar interests [20]. Figure 1 illustrates a simplified conceptualization of the Maehae watershed system. The solid arrow line represents either one- or two-way association between stakeholders, while dash line and its gradient shows the perception and understanding level toward an interested context.

![Diagram of Maehae watershed system](image)

**Fig. 1.** Pre-perception of the Maehae watershed system.

After stakeholder analysis step, the main issue we focused was how land and forest resource are being accessed and managed under different interests, trade-off and conflict situations. The information obtained from personal interviewing with some local key informant, local RFD and RPF officers could not provide clear explanation on how this situation emerged and exist. To acquire better understanding on this unclear behavior of local resource user and manager, the role-playing game was design to play with local stakeholders.

### 4. RPG and Collective Learning

We designed the game by simplifying our pre-perception of Maehae watershed system into role-play games. Two main objectives of conducting the games are: a.) to verify and improve our knowledge, b.) to initiate collective learning of stakeholders on system components and dynamic processes. Furthermore, this will lead to the trust and friendship building between stakeholders and us. This is considered as an important key when deal with the sensitive common dilemma issue like forest and law enforcement which link to the security and right in owning and accessing the land.
Two games were designed and played with local farmers and other stakeholders. In the first game, two participants were assigned to perform as government agencies and the rest acted as local farmers. In the second game, a real local RFD officer was invited to play according to his real task.

In the evening and the day after the game sessions, we interviewed players individually at home. The interview issues covered comparison of the player’s real life with the game, reasons for the role that the player performed during the game, perception, and experience of other key stakeholders’ roles, and general context of the Maehae watershed.

4.1 The First Role-Playing Game

In late 2003, the first game was designed as a simplified version of our previous complex conceptualized model. Simplifications were made regarding the heterogeneity of the landscape and stakeholders. Some common rules and constraints in access and management of the land were flexibly defined but most social rules were left to the player themselves due to the different level of household resource availability and farming strategy. The game pre-tested was conducted with graduate students whose background are agricultural economic and agronomy to validate parameters and equipments used in the game before conducting with stakeholders in the field.

Preparation of the Game. The first game was conducted with 12 participants from both Hmong and Karen communities. Ten of them represented three different types of farmer corresponded to economical status in their real life, which are rich (type A), middle income (type B), and poor farmers (type C). There were 3 type A (2 Mhongs, 1 Karens), 5 type B (3 Mhongs, 2 Karens) and 2 types C (Mhongs) respectively. [We planed and expected the equal number of players from two ethnic groups in each farmer categories, but some were not come due to their urgent activity, thus there were three new players recruited on the game session day]. The name card labeled with player’s name and status symbol was distributed and tagged to help communicating between game facilitators and players.

The 3-D block model was used to represent a simplified typical highland watershed with various slope classes. The model was painted to represent three categories of landscapes corresponding to foothill, mid hill and top hill areas. Game facilitator showed and explained characteristics of block model to the players but did not explicitly point on the board to show the player where is the flat, low, moderate and steep slope area. This is to assess the ability of player in relating the 3D board to the highland landscape.

The other two participants who are well educated and often access to updated information were assigned to perform the roles of RFD and LDD. The reason of swapping the RFD and LDD roles played by local people is to make the other players feel free to perform the given roles particularly for their first role-playing game. Roles of RFD and LDD were explained to players who will perform the tasks. The RFD player was assigned a task to maintain forest area above threshold level of 40%. Likewise, the LDD player should try to promote soil conservation practices in the vulnerable area to reduce soil erosion. The knowledge on the relation of land
steepness, cultivated crop, and erosion vulnerability was discussed with and confirmed among players.

At the pre-game stage, each farmer received a different amount of cultivated plots allocated on varying slopes. Number of given plots and its location of each player were designed corresponded to the reality. For example, rich and medium status farmers will possess some paddy land, which is not available for poor farmer. Each farmer received different amount of initial cash to invest in cultivation according to the given status. There were four types of crop farmer may choose to cultivate in their plots. There were paddy, vegetables and flower, fruit orchard and upland rice. Investment costs for different crops were post on the board.

**Steps of the Game.** Each yearly time step, the individual farmer can freely allocate different crops to the given lands. Each farmer is allowed to open new plots according to the respective strategies. RFD player has the right to withdraw any new opened plot in the next time step, but only two at each time step according to imperfection in monitoring the responsible forest area as commonly occur in the reality. The aim of this is to see coordination and negotiation that may occur during the game among individual farmers or farmer group and RFD players. This game design allow farmers the free-riding condition that there is no penalty in extra-extracting forest resource. We would like to observe behavior and bring to individual interview to understand why and how they decide to perform in such a way.

During the game, LDD will monitor the plots that are prone to erosion and try to convince the plot owner to accept soil conservation practice. If the owner agrees to do so, there will be trade-off on the 25% lost in crop production of that plot.

At the end of each time step, the random climate condition was announced. This will affect production and soil erosion of crop plots. Then, the crop allocations on the 3-D block model were collected and used for calculating farmers’ household income balance. The farmers who had income balance less than the amount needed for investment in next game step were allowed to continue as if they were able to access to credit sources. This tried to avoid complexity of the game. Lastly, the moderator aggregated and announced the amount of erosion and remaining forest area to all players. This aimed at encouraging RFD and LDD players to actively play their roles for the next gaming session. During the game process, facilitators and the moderator observed some interesting actions and interactions among players.

**After the Game.** There were four time steps conducted in the morning session. Players and game facilitators had lunch together, this allowed informal and open talk among us, some useful information was obtained during this activity. There were some changes in the afternoon session. Farmers had no limitation in opening new plot, while RFD was allowed to withdraw unlimited number of plots. This expected some changes in behavior of the players.

Right after the game, we conducted informal group discussion. All players felt familiar with the game, more comfortable to talk and express their idea. Most of them could recognize and relate 3D model with their real landscape. Type of crops and invest costs are close to reality, but the product prices are supposed to fluctuate year by year. They also suggested that chance to have the dry year is much more than the wet year. This led to some rules adjustment applied in the second game.
4.2 Lessons from the First RPG and the Interviews

It can be observed that two poor farmers decided to open new plots at the time step 1 and 2. This significantly decreased forest area, thus encouraging RFD to play the forest protection role actively. In the next step, the RFD took out the new opened plots of the two poor farmers. This process made communication and negotiation between the RFD and poor farmers emerged. The result was that the RFD took a new plot from each poor farmer and allowed the rest to remain until the end of the game.

The LDD player tried to convince farmers to adopt soil conservation practices after two time steps, as he was concerned by the increased amount of soil erosion announced on the public board. He either went out to the 3D block model and communicated with farmers, or assimilates information within farmers’ group with same ethnicity. This was clarified during follow-up interviews conducted after finishing the game that they rarely communicated and negotiated across communities and even less between two ethnic groups.

A collective manner of trying to compromise with RFD and LDD was shown. Forest area and soil erosion increased during the beginning steps and then declined to a steady stage toward the end of the game [Figure 2]. This contradicted to our pre-perception and the result of the pre-test game conducted with students. It was expected that the one who plays the role of the poor farmer would exploit forest resource to claim more land to increase production that fulfills household needs. Moreover, under free-riding condition without penalty and negative feedback, it was reinforce the self-interest orientation or maximizing individual value behavior to emerge.

The interviews confirm that 15 villages have been coordinating this should encourage the forest conservation network for more than 10 years to manage and protect forest areas. Rules and regulations on forest resource accesses were set up and agreed upon for all members. This is to lower the degree of forest law enforcement, since most of the agricultural area fall into forest reserved area. This is the co-initiative networking among communities with closely support from the local RFD officer. Thus, it made the players reflected upon the cooperation action in the game.

Furthermore, most of the players did not directly know the role of the LDD but they experienced some of the soil conservation practices implemented through RPF. However, collective decision-making on suppressing soil erosion has emerged during the game. During the discussion right after the game, some of players indicated that the increase in soil erosion urged them to cooperate with LDD. Both the LDD and the farmer players expressed the new knowledge gained about the soil conservation roles of the LDD.

There was no strong evidence to support the real change in this behaviour. However the field observation and the interview confirm that farmers are concerning about soil fertility by preparing the cultivated-bed-plot against slope to prevent “good soil lost”.
4.3 The Second Role-playing Game

The second game was conducted one month after the first game. This aimed at clarifying the understanding on how farmers adapt when faced with limited land resources and forest protection policy. Moreover, this tried to reproduce the history of changes in agricultural pattern. There were eight farmer players, four of whom had participated in the first game, and the rest came from different villages.

At this time, the local forest officer was invited to perform this role corresponding to his own duty. One player was assigned to perform the LDD role because the real LDD agent has rarely contacted or communicated directly with farmers. Some rules were changed according to the stated objectives and the comments from players in the first game to make the game closer to common phenomena. These are;

- a.) Chance of climate condition for good: normal: drought is 1:1:3;
- b.) There are no high value cash crops and fruit orchards during time step 1 and 2;
- c.) Product price ranked by good, medium, and low, will be randomly chosen. This will affect the household’s account balance calculation.
- d.) Increased consumption cost.

Moreover, this was designed to put more constraint and pressure on player to achieve household well being, due to the increase in crop production by climate conditions and price fluctuation. This may induce the self-interest behavior of the players.

Group discussion was conducted after the session ended in the afternoon to obtain collective idea on some specific issue emerged from observation of the game. Individual interview as conducted in the evening and the day after to follow up decision and behavior made during the game.

4.4 Lessons from the Second RPG

During the game, poor farmer players tried to get more land for cultivation in time step 1, 2, and 3. When forest area declined to 40%, which was the alarm level for RFD (the task given to RFD was described to all players before starting the game). This revealed the information flow within the group and instantly made collective self-management emerge without any forced action from RFD player. This described the players’ point of view toward the forest resource situation and management. The regulation is so embedded in the minds of the players that the regulator does not need
to force them to take action. The performance toward soil erosion showed similar coordination, which was closely consistent with the first game [Figure 3].

![Fig. 3. Forest area and soil erosion changes during the second role-play game.](image)

Fig. 3. Forest area and soil erosion changes during the second role-play game.

During the interview, most of players expressed that the first two time steps were similar to the situation in the past. Before RFD was established in 1978, agricultural productivity was low. Thus, people needed more land than nowadays to produce crops and generate income. The discussion after the game supported this historical scene. Furthermore, younger, more educated generations had more employment opportunity. The dependency of household income on agriculture has been gradually decreased.

5. Results from the Role-playing games

The rules, steps, and atmosphere of the game can provoke players to react to situations individually and collectively. This allows them to extend their vision and understanding beyond their existing scopes. The game makes them perceive that there are multiple stakeholders taking action in the same system context with differing objectives. Furthermore, this also provides views on interaction between system components and consequences of inter-scale linkage between farm and watershed levels.

The second game imitated the historical scenes of the Maehae watershed and then continued with present situations. This replayed agrarian transformation processes, involved stakeholders, influence factors, and causes and consequences to the players. It can be seen that these two RPG facilitated collective learning processes of players and provided the understanding on complex space-and-time dynamic processes through a simple exercise.

On the researcher’s side, RPG can help verifying previous perceptions by allowing players to react toward given rules and environments. Individual decision-making in the game was clarified during the interview, thus added to the researcher’s knowledge. One of the important outcomes from RPG was the emergence of a collective manner which stemmed from individual decision-making to tackle common problems; for instance, players tried to suppress soil erosion and maintain a given forest area threshold.
Information and lessons learned from RPG and the follow-up interviews were analyzed altogether with additional key informant interviews, and then compared with the pre-perception. The post-perception diagram in Figure 4 illustrates the new outlook toward the Maehae watershed system. Major changes are perceptions of stakeholders toward resources, associations and flow of information among stakeholders, another additional stakeholder, and external factors that may influence system changes in the future. All perceptions and degree of association, which varied from pre-perception, are represented using gray lines.

Most players were directly familiar with RPF and local RFD officers, so-called RFD1 in Figure 4. The Forest network is a social group that strongly influences local forest management among communities in Maehae (as emerged during RPG). Therefore, from the players’ point of view, forest degradation is not a problem for Maehae community.

The LDD officer became a stakeholder outside the system boundary. In fact, the regional LDD will propose a plan and budget to restrain soil erosion in highland area. Then, this will be implemented and promoted through collaboration with the RPF staffs.

The RFD2 is a new stakeholder representing forest officers from the forest protection division. He takes charge in protecting and arresting the one who illegally acts against national forest reserve law, which is stricter than the RFD1. The RFD2 communicates indirectly with farmers but through the social group. The forest protection division is now proposing the national park expansion plan to cover Maehae watershed area. This would lead to more forest law enforcement and restrictions.
6. From the games to Multi-agent System Model

The two role-playing games conducted with local stakeholders can effectively provide knowledge behavior and decision rules in using and managing land and forest resources of the players. These are only part of system properties and characteristics and inadequate to represent all complexity of the Maehae system. Nevertheless, this improves learning capacity of players to understand the links between individual action and consequences that impact the watershed system dynamics. Thus, they are prepared for the further participatory MAS modeling processes.

The structure and rules applied in the games and result from the games and interviewing were transformed into conceptual model in the form of UML diagram. This UML diagram will be further used as a means of facilitating communication among us, researchers from different disciplines. The UML is widely used to enhance the process of identifying agents (stakeholders) and their behavioral characteristics, functions, and relations to other agents. UML can be extended to develop events and sequences of models, which thus supports processes of programming, verifying, and redesigning models [21]. This seamlessly becomes a standard protocol among researchers belonging to different disciplines and having various experiences in developing computerized MAS models [22].

![UML diagram](image)

**Fig. 5.** The UML diagram transformed from role-playing game.

The UML static diagram in figure 5 illustrates the structure of multi-agent system model, which was transformed from the role-playing games. *Farmer, ForestOfficer*
and LandManager agents in the model represent farmer, RFD and LDD players in the games respectively. FarmerA, FarmerB and FarmerC are three sub categories of farmers. LandusePlot, Farm, and Watershed represent plot, farm and watershed areas. Lines linked between these agents and other components mean possible associations and relationships among them.

A multi-agent system model is being developed based on this conceptualized diagram using Cormas platform [23] to reproduce the role-playing games. The current version of this model can simulate and reflect some phenomena occurred in the games such as choice and allocation of crops, fluctuation of climate condition and products prices, dynamics of soil erosion and forest area. Most of dynamics in the model are based on the simple rules and parameters used in the game, which was not designed to cover the deep detail of this aspect. Therefore, at the current stage, it may not well represent the real complex dynamic of Maehae system. The decision rules of exploiting forest for new plot derived from the games and interviews are still in consistence. However, the model will be presented to stakeholders to verified and investigate on these decision rules and parameters.

7. Conclusion and Perspectives

This preliminary work corresponds to the first iterative steps using a companion modeling approach [Barreteau , 2003a] to support and encourage participatory and collective management of natural resources at the watershed level in northern Thailand. The RPG can bring a better understanding on how individuals behave and interact with the environment and how this may affect the dynamics of the systems. This provides room for putting together the missing parts and the dynamics of the Maehae system that improve the knowledge of both the researcher and other interested parties. Moreover, shared representation, which cannot obtain from individual interview, can emerge through RPG.

Role-playing game may not provide complete understanding on individual behavior due to the complex of interest issue. Nevertheless, this important take-off step provides the mean for facilitating the further participatory activities. The model will be further verified and validated with stakeholders, thus encourage and incorporate them into model development process. As soon as stakeholders familiar and feel comfortable with this evolving stage, and the model can satisfactory reflect stakeholders behavior and perceptions, it would be interesting to experiment the alternatives desirable scenarios of resource management suggested by stakeholders, with stakeholders.

However, it can be foreseen that the perception of stakeholders are different by nature, experience and discipline. One particular model may or may not reflect across these variations. A framework for implementing effective participatory modeling may vary among interest stakeholders. Thus, our challenge for further research steps is to develop and assess the combination of method, supporting tool and MAS model to facilitate the collective resource management in the highland watershed of Northern Thailand.
References


