Participatory Multi-agent Systems Modeling for Collective Watershed Management: The Use of Role Playing Game.

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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 results of a preliminary study on conducting role-playing games (RPG) in order to verify the researcher's perceptions of an interested highland watershed, where a human-/agroecosystem is located within the multi-layered politics of resource management. Two RPG's were conducted with interested stakeholders using simplified rules and environment. Performing the role allowed players to improve knowledge and understanding of both space-and-time-dynamic processes of the whole system. Information obtained from the games supplemented with interviews mutually improved earlier knowledge of researcher and resulted in the "post-perception" which will be used in further participatory MAS modeling processes.

Keywords: multi-agent systems modeling; watershed; collective decision-making; companion modeling; role-playing game.

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 land and water resources in the watershed area.

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 [Letcher et al. 2002], and roles of local and government institutions were merely included in the model [Becu et al., 2003b].

This study aims at coupling role-playing games (RPG) with computer MAS models to tackle natural resource management problems in a watershed area. It involves multiple political layers and stakeholders e.g., forester and forest policy, land developer and soil conservation policy, and local forest resource management organization.

The paper describes the use of RPG and field interviews to verify the researcher's pre-conceptualization, and enhance co-learning processes among stakeholders of a highland watershed system in northern Thailand, where complex resource managements issue are settled.

2. COMPANION MODELING FOR NATURAL RESOURCE MANAGEMENT

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 [Gilbert and Troitzsch, 1999].

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 [Gimblett, 2002].

In the field of complex common-pool resource management, many studies have focused on strengthening the adaptive capacity of involved stakeholders. Some of the key issues that contribute to the failure and success of sustainable resource management are dialogue among multi stakeholders, multi-layered institutions, tools and methods that facilitate experiment, knowledge improving, and co-management process [Dietz et al., 2003; Borrini-Feyerabend et al., 2000].

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 [Barreteau, 2003a]. Coupling 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 [Barreteau, 2003b; D'Aquino et al., 2002].

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 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.

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.

3.2 Pre-conceptualization

In mid-2003, 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. Pre-system analysis resulted in a list of key stakeholders and their important roles in using and managing 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 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. The RFD promotes forest resource rehabilitation through the collaboration of local people. Occasionally, the conflicts over resources uses have occurred. For examples, encroaching the restricted forest area, 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 [Promburom et al., 2004]. 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.

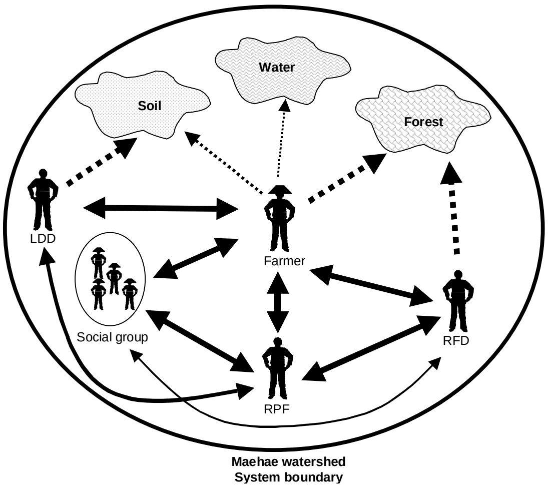

Figure 1. Pre-perception of the Maehae watershed system.

4. RPG AND COLLECTIVE LEARNING

Before developing the model, the researcher's pre-perception was tested in the field using the simplified role-play games. Two main objectives of conducting the games are: a.) To verify and improve the researcher's knowledge, b.) To initiate collective learning of stakeholders on system components and dynamic processes.

Two games were designed and played with local farmers. 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, the research team 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 a complex previously conceptualized model. Simplifications were made regarding the heterogeneity of the landscape and stakeholders. Some common rules 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 first game was conducted with 12 participants, eight of them represent three different types of farmer, rich (type A), middle income (type B), and poor farmers (type C). There were 3 type A, 5 type B and 2 type C respectively. The other two participants were assigned to perform the roles of RFD and LDD.

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.

At the beginning of the game, each farmer received a different amount of cultivated plots allocated on varying slopes and initial cash to invest in cultivation. Each yearly time step, the individual farmer can freely allocate different crops to the given lands. Each farmer was allowed to open new plots according to the respective strategies. The RFD player was assigned a task to maintain forest area above threshold level of 40%. Thus, RFD has the right to withdraw any new opened plot. Likewise, the LDD player should try to promote soil conservation practices to reduce soil erosion. The reason of swapping the RFD and LDD roles is to make the farmers feel free to perform the given roles.

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.

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. 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.

4.2 Lessons from the first RPG

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 the pre-perception, in which it was expected that the one who plays the role of the poor farmer will encroach on forest area to claim more land to increase production that fulfills household needs. The interviews confirm that 15 villages have been coordinating 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 collaborative 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 is 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".

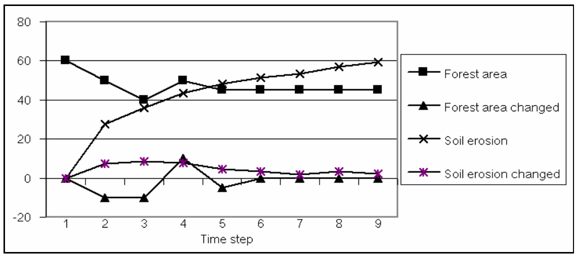

Figure 2. Forest area and soil erosion changes during the first RPG.

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.

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 (this was the given task for RFD 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 revealed 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].

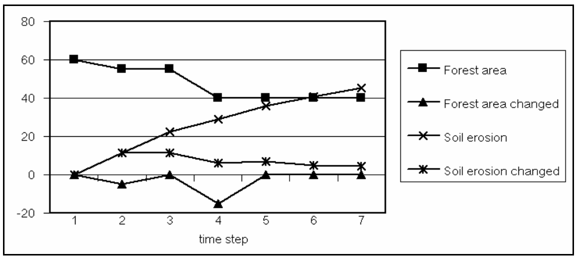

Figure 3. Forest area and soil erosion changes during the second role-play game.

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 study of Ekasingh et al. [Ekasingh et al., 2001] confirms this land use change. 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 Post-perception after Role-play Game

The rules, flow, 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, 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.

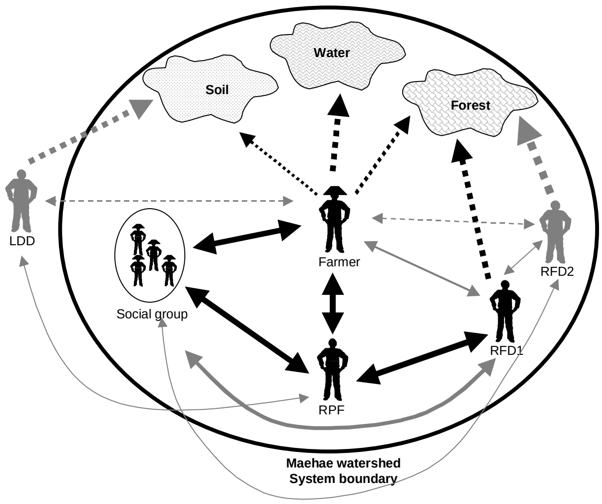

Figure 4. Post-perception diagram of Maehae watershed system.

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. 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.

The further research steps are developing MAS model combining biophysical and social dynamic components. This model will be run and tested with stakeholders for validation and verification purposes. Furthermore, participatory scenario elicitation will be conducted. It would be interesting to use another RPG to test these possible scenarios suggested by stakeholders.

Although the RPG can enhance collective learning process among researcher and stakeholders, but it is limited by cost, time, and players arrangements. Therefore, this RPG will be further coupled with the computer MAS model to be used as a shared representation among stakeholders to iteratively simulate land use and resources dynamics under alternatives desirable scenarios of resource management.

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