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COMPANION MODELING TO UNDERSTAND INTERACTIONS BETWEEN LAND AND WATER USE, AND LABOR MIGRATION IN LOWER NORTHEAST THAILAND: CONTEXT METHODOLOGY AND PRELIMINARY FINDINGS

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ABSTRACT

The Lam Dome Yai watershed in Ubon Ratchathani Province is an important tributary of the Mun River. The complexity of this area results from the interactions between local ecological (agricultural practices, water and climate) and socioeconomic dynamics (labor migration, diversity of farmers' economic strategies). A comprehensive knowledge of interactions between biophysical and socioeconomic dynamics could help to design efficient investments. Therefore, my research is carried out to better understand such interactions between land and water use and labor migration regarding to allocation of workforce of local farms. Multi-Agent Systems (MAS) and simulation are used to explore interactions in complex systems by creating virtual societies sharing an environment and its resources. I will use MAS simulation in a "companion modeling" approach (ComMod) to better understand and model stakeholders' decision-making processes and their management of renewable resources. The Lam Dome Yai watershed is investigated to comprehend the dynamics of its agricultural system and farmers' decision-making processes regarding to land and water use and labor migration. A preliminary survey and analysis showed that impacts of labor migration on land-use and water-use management are more obvious than land-use changes. Unified Modeling Language (UML) diagrams displaying the stakeholders' decision-making procedures and the structure of the model are presented.

1 INTRODUCTION

Land and water resource are vital assets in the development of Thailand. In lower northeast region, they play a crucial role in supplying rainfed shallow, drought and submerge-prone to the country (Zeigler and Puckridge, 1995). Though the region has an annual average rainfall comparable to other part of the kingdom, there is a severe shortage of water during a long dry season and the rainfall distribution pattern is the least reliable of all regions (Fukai et al., 2000). Moreover, coarse textured soils with low fertility make biophysical conditions in this region harsher.

In Ubon Ratchathani, 80% of land is dominated by agricultural uses especially the rainfed lowland rice production (OAE, 2000). The Lam Dome Yai watershed located in south Ubon Ratchathani Province is an important tributary of the Mun River. The watershed area is about 450,500 ha containing 71 villages. The complexity of this area results from the interactions between local ecological (agricultural practices, water and climate) and socioeconomic dynamics (labor migration, diversity of farmers' economic strategies). Many 20-35 year old people move to search more profitable off-farm employment in cities. At the same time, the government has been investing in small-scale irrigation projects to promote farm intensification. However, the state water management has limitations in achieving its goal. Direct rainwater is still the most important determining high or low annual agricultural yield.

A comprehensive understanding of the interaction between biophysical and socioeconomic dynamics could help to design more efficient investments. Therefore, our research is carried out to understand such interactions between land and water use and labor migration in relation to allocation of work force so that the efficiency of such investments and the use of natural resources could be improved. To achieve our research goal, an innovative approach, "Companion Modeling (ComMod)" based on Multi-Agent System (MAS) simulation, role-playing game (RPG) and Geographic Information System (GIS), will be applied. In this paper, the followings are presented:

- Local biophysical and socioeconomic context emphasizing agricultural production system in relation to labor migration,
- Theoretical background of proposed approach and methodology for improving the existing knowledge of this key interaction,
- The relationship between a diverse number of family laborers and household income inducing

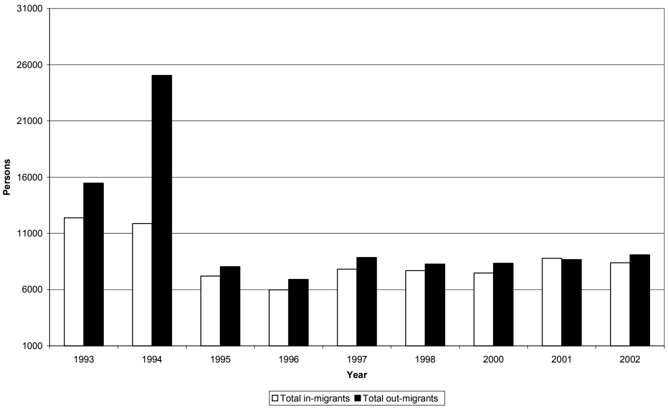
different farmer’s strategies to manage their rice production,

- The structure of conceptual model in form of Unified Modeling Language (UML): Class diagram.

2 BIOPHYSICAL AND SOCIOECONOMIC CONTEXT OF LOWER NORTHEAST THAILAND

In Thailand, migration is an increasingly important issue as structural changes in the economy causing many social and technical changes in the traditional agricultural sector (Shinawatra and Pitackwong, 1996). Labor migration is closely interlinked with the economic balance between rural and urban labor force, and mobility has been an important strategy for farmers to increase their households’ income. Figure 1 shows that the early 1990s, was a period of high labor migration flowing from agricultural sectors to industrial sectors when the Thai economic was booming. Even though the Thai government attempted to promote regional growth centers as a way to reduce migration to Bangkok, it has not been successful because the rural-urban disparities in income and economic opportunity are too large to be reduced by such rural development efforts (Matsumura et al., 2003). On contrary, in early 1997, Thailand’s economic bust caused an increase in unemployment and the new labor forces could not enter the labor market. It was believed that the crisis would also affect people in rural areas because most of the households depended more and more on off-farm income. The economic crisis also caused migrants to return to their rural home, and many reverse migrants who returned to northeastern region (Subhadhira et al., 2000).

Northeast Thailand is the largest region of the kingdom and is characterized by poor soil and erratic rainfall. The soil, mainly derived from sandstone (Fukai et al., 2000), is sandy, with low nutrient content and low water-holding capacity (Table 1). Greater than 80% of the farming area in northeast region is used to grow rainfed lowland rice (OAE, 2001). The rice yield is very low (1.8 t ha^{-1}), causing relative economic poverty (Somrith, 1997). The average monthly household income of about 9,279 baht (232 US dollar) is inadequate to meet both basic human needs and agricultural production requirement (Table 2). The highest income-in-kind (21.1%) indicates that the northeast region is less integrated in the export-oriented market economy than other regions. Likewise, the region benefits more than other regions from currency transfer (14.8%) and has relatively low share of total income from farming (13.2 % only). The harsh biophysical features and related poor productivity caused very low per capita income, making the northeast region the poorest and least developed in the country. A common response to this situation is migration, particularly in the form of seasonal



Source: Department of Local Administration. Ministry of Interior

Figure 1: Evolution of the number of migrants in Ubon Ratchathani Province

Table 1: Property of soil belonging to the Nam Phong series in Det Udom District, Ubon Ratchathani Province

Soil parameter	Range	Mean
Particle size distribution : 0-30/35 cm (%)		
Sand	88.2-94.6	90.9
Silt	3.6-9.4	6.5
Clay	1.7-3.6	2.6
Particle size distribution : 30/35-60/70 cm (%)		
Sand	88.0-95.4	91.2
Silt	3.1-10.3	6.7
Clay	1.4-4.5	2.1
pH (1:1)	3.9 – 5.2	4.2
Organic matter content (%)	0.39 – 1.79	0.85
Total N (%)	0.02 – 0.08	0.04
Extractable P (Bray II, ppm)	6.1 – 19.0	9.8
Extractable K (ammonium acetate, pH7, ppm)	5.0 – 12.6	8.6
CEC (meq100g^{-1})	0.32 – 1.28	0.83

Source: Harnpichitvitaya D., Trebuil G., Pantuwang G., Craig I., Tuong T.P., Wade L.J. and Suriya-Aruroj D, 2000. Identifying soil suitability for subsoil compaction to improve water- and nutrient-use efficiency in rainfed lowland rice.

(nonagricultural) moves to urban area when rice-farming activities end (DeJong, 1997).

The migration pattern is categorized into seasonal (temporary) and more permanent classes. Though the pattern of migration is widely known, the decision-making process involved at the household level is still not clear. Guest (1998) showed that migration among rural households in northeast Thailand helped to reduce cross-province inequality in household incomes, and the remittances flow from rich provinces to poor provinces was one main channel to redistribute the income gain from migration. Ironically, the migration policy of the Thai government has been to curb migration flows to Bangkok, although without much success (Yang, 2003). According to such different point of views, migration is still controversial whether it is a solution or problem. The career change from agriculture to wage earner has increased , especially in village scale (Nakwiboonwaong, 1990). Once labor in the agricultural sector decreases (thereby causing higher farming area per labor ratio), farmers have to adapt their land and water use strategies to compensate for this loss. However, the decision-making process to effect such a change in lower northeast Thailand conditions is still not well understood.

Table 2: Average monthly household income by sources of income and regions in 2002

	Whole Kingdom		Regions									
			Greater Bangkok[1]		Central		North		Northeast		South	
	$	%	$	%	$	%	$	%	$	%	$	%
Percent of households	**100.0**		**17.4**		**19.1**		**19.4**		**31.6**		**12.5**	
Average household size	**3.5**		**3.3**		**3.4**		**3.2**		**3.7**		**3.8**	
Total income	343	100.0	706	100.0	353	100.0	238	100.0	232	100.0	312	100.0
Wages and salaries	144	42.0	388	55.0	149	42.2	83	34.6	71	30.7	108	34.6
Non-farm income	66	19.1	152	21.5	66	18.6	43	18.0	39	16.6	60	19.1
Farm income	36	10.5	3	0.4	53	15.1	36	15.3	31	13.2	64	20.6
Property income	5	1.6	17	2.4	5	1.4	4	1.5	2	1.0	3	1.1
Current transfers2	32	9.2	50	7.1	24	6.7	27	11.2	34	14.8	21	6.6
Income-in-kind3	55	15.9	93	13.1	52	14.6	40	16.8	49	21.1	48	15.5
Other money receipts	6	1.7	4	0.6	5	1.5	6	2.5	6	2.5	8	2.5

[1] Bangkok metropolis, Nonthaburi, Pathum Thani and Samut Prakan

[2] Includes assistance payments, pensions and annuities, terminal pay

[3] Includes imputed rental value of owned dwelling

Source: The 2002 Household socioeconomic survey, National Statistical Office

3. THE THEORETICAL BACKGROUND AND METHODOLOGY

Socioeconomic and demographic data have rarely been linked with other biophysical data in landscape studies (Wang and Zhang, 2001). Many researchers have modeled labor migration in relation to the economy only; De Jong 1997; Yang 2003; Spilimbergo and Ubeda 2004; Matshe and Young 2004, but few investigated interactions between land and water use and labor migration. Furthermore, none of them used MAS simulations to explore such relationship. A model implemented in a Chilean case study by Berger (forthcoming) applied MAS and mathematical programming to investigate the decision making of rural households who regularly make use of migration and innovation to cope with environmental hazards. The model aimed to explore suitable policy options and to forecast out-migration and natural resource changes as well as to examine the use of innovation to compensate for labor loss in the Melado River. The simulation experiments indicated that interpersonal communication slow down the diffusion of innovation significantly and thereby accelerate out-migration. Laine and Busemeyer (2004) used agent-based learning model to understand the kind of spatial patterns (land use) that emerge from different agent characteristics and learning mechanisms for making decision about doing farming activities, indicated by agriculture and forestry or migration to find off-farm employment, indicated by abandoned land. Agents calculate the payoff between farming activities and off-farm employment. The decision is based on which one provides higher payoff. The two learning models have different adaptation mechanisms. The local adjustment learning agent considers the payoff received from one time step before and makes small adjustments to labor allocation in the next time step. The experience-based agent has a perfect memory, so instead of making a small adjustment to the previous labor allocation, it samples its memory of allocations and chooses the one that produced the highest payoff. The simulated result shown that the local adjustment model predicts an increase in the percentage of forest cover relatively accurately, while the experience-based model fails to account for the significant increase in the beginning of the modeled period. These models are site specific and not applicable for the situations such as in Lam Dome Yai watershed. However, they contribute to provide a better understanding of relationship between natural resource use and labor migration.

Bousquet et al. (1999) developed a participatory modeling approach called the Companion Modeling (ComMod), which uses Multi-Agent Systems (MAS) simulation together with other mediation tools such Role-Playing Games (RPG) and spatial modeling for better understanding and sharing stakeholders' decision-making processes and its use in the collective management of renewable resources. The ComMod requires a continuous, evolving and iterative confrontation between theories and field circumstances. Therefore, it is based on repetitive back and forth steps between the model and the field situation to comprehend interactions between ecological and social dynamic in complex systems (Barreteau, 2003). The advantages of this particular approach include exposure to bodies of knowledge that would otherwise be inaccessible. Most important is that there is greater likelihood that the stakeholders will have sufficient motivation and 'ownership' of the results to apply them for 'real' decision-making (Gilbert et al., 2002). The process of ComMod involves interdisciplinary methodologies that seek to facilitate dialog among multiple legitimate perspectives and make use of systematic and structured learning processes. This approach refers to a dynamic perception of the decision-making process in which the scientific and technical perception is only one among others, and not the pre-supposed right perception toward which the decision should be attracted (Barreteau, 2003). The process starts with the construction of a first preliminary conceptual model to explicit theoretical as well as field-based pre-conceptions of the research team. The research team can then verify its hypotheses and validate this first model by directly presenting it to stakeholders or, more frequently, by using complementary mediation tools during field work with stakeholders.

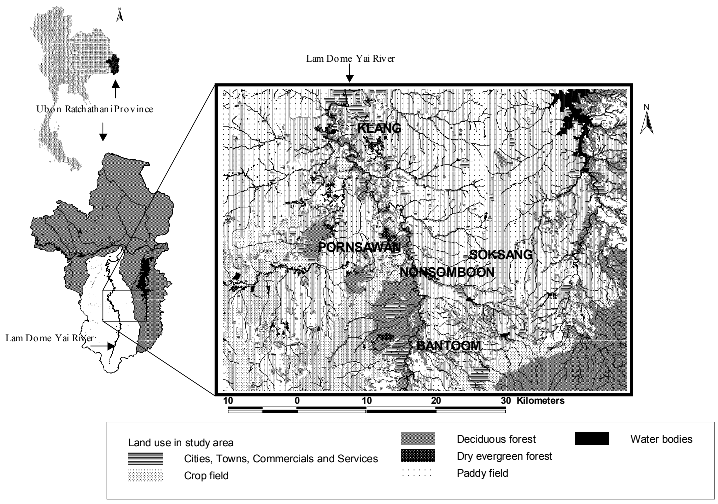
The most often used combined tools in ComMod are MAS simulation models and role-playing game. Building a model is a well-recognized way of understanding the world (Gilbert and Troitzsch, 1999). Innovative methodology such as MAS simulation can create virtual societies sharing an environment and its resources and it offers researchers a tool to better understand the nature of complex systems (Lim et al., 2002). The MAS simulation is based on the idea that it is possible to represent the behavior of entities active in the world in a computerized form, and that it is possible to represent a phenomenon as the outcome of the interactions among an assembly of agents with their own operational autonomy (Ferber, 1999). In MAS, the interactions among agents and between agents and their environment are compulsorily investigated. An agent is characterized by specific attributes and set of behavioral rules and is able to act locally in response to stimuli from its environment or communication with other agents (Bousquet, 2002).

Geographic Information System (GIS) provides supporting tools for modeling, especially spatial data management, analysis and visualization and it can be fully integrated or linked with models through data and interface (Mitasova and Mitas, 1998). GIS applications have moved forwards developing dynamic maps to answer the criticism about GIS only presenting a "snapshot" of a situation at certain moment in time (Campo, 2003). Because GIS are inherently static processes, they are limited for use in dynamic modeling in both their asynchronous updating of cellular data and implicit cellular nature (Gimblett, 2002). Integrating GIS with MAS simulation could bring the fourth dimension, time, and human behaviors (decision-making processes) into the model.

The system under study is complex due to its spatial, economic and social interactions between land and water use and labor migration derived from heterogeneous stakeholders. To understand the processes of real phenomena occurring in this area relating our interesting points, it requires iterative, participatory and interdisciplinary research. The ComMod based on MAS simulation coupling with GIS is the promising approach used for this research.

4 MATERIALS AND METHODS

The study area is located inside Lam Dome Yai watershed comprising of 5 sub-districts (Figure 2). The area is about 45,000 ha. A specific on-farm field survey was conducted to acquire missing information emphasizing relationship between agricultural production system and labor migration. The guidelines of an in-depth interviews of diverse types of farmers was constructed based on previous agricultural system analyses implemented in this area in 1994 and 2001. Furthermore, the theory of planned behavior from social psychology and micro-level empirical migration research (Ajzen, 1988) was integrated into the guideline. This theory explains the labor demand-supply mechanism that drives people to migrate. The same farmers who were interviewed in 1994 and 2001 were revisited to understand the evolution of their production system by investigating the changes occurring between 1994 and 2004. Primary data and secondary data were pooled and summarized to display important aspects relating interactions between land use and water use, and labor migration.



Source: Land Development Department 1991, Ministry of Agriculture and Cooperative

Figure 2: Location of the study site in the Lam Dome Yai watershed, Ubon Ratchathani Province

The information received from the in-depth interviews with 20 farmers were revised in form of functioning diagrams of their household-based farming system so that the relationship between the selection of a production combination and labor migration was more explicit. The farm functioning diagrams display farmers' strategic and tactical decisions made by the farmer and his family, taken in a given set of constraints and potentialities to achieve their own objectives governing the production processes carried out on their farm. Migration was defined as moving out of the community of origin for more than one month. The migration pattern varies from seasonal to more permanent migration. The more permanent migrants refer to migrants who do not return to help their families to produce rice. On the other hand, the seasonal migrants refer to the migrants who generally return to help their families to grow rice. Based on analytical knowledge, the decision-making processes in relation to farm and non-farm activities including labor migration were disclosed and transformed into decision-making diagrams. Figure 3 displays the sate transition of migrant to other states when the event and conditions change. Later, these processes will be applied to our agents' social behaviors in the MAS model.

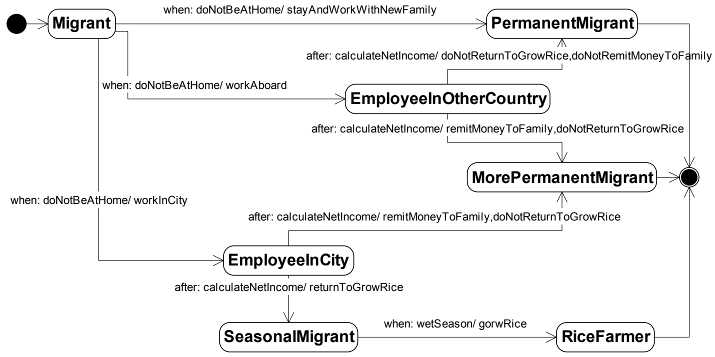


Figure 3: Sate transition of decision-making processes of migrant

GIS maps and series of aerial photographs taken in 1973, 1984 and 1996 were used to reveal sequent spatial changes emphasizing a number of water resources. Because of inadequate irrigated system, most of the farming activities have to rely on direct rainwater. Thus, water resources such as ponds (in paddy field) become an important influence on the crop calendar and strategies for farm and non-farm activities. A frequential analysis of rainfall based on the 50-year meteorological data was implemented to investigate the relationship between rice-growing practices and climatic variability.

5 PRELIMINARY FINDINGS

The villagers in this area are Thai and Lao ethics. Their culture and mean of subsistence are strongly attached to rice, which is generally not a profitable crop. In general, they spend approximately 6 months a year to grow rice. To secure satisfactory rice yield and price, the villagers, on their own initiative or with the help of a variety of rural development agencies, have constructed a large number of small impoundments to store water but water storing in such impoundments is inadequate for agricultural activities in the dry season. Since rice production requires labor force for only 6 months, the villagers normally are unemployed after the rice harvest due to a lack of alternative employment and environmental imitations to continue other agricultural practices in the dry season.

The secondary data from two previous agricultural system analyses indicate that land use patterns have not been significantly altered since 1994. However, our new data from in-depth interviews with a range of diverse farmers show that farmers have had to adapt their strategies for both farm and non-farm activities to satisfy their personal objectives and preferences. Labor migration seems to be an effective and desirable strategy triggered by poverty and less profitable employment or even unemployment in villages. While income received from agricultural products is mainly used for daily expenses, the remittance from migrants is normally used for investments such as building a house and children education. The decision to migrate out of the villagers is influenced by the prospects of increasing income through employment in cities. The family and friend migrant networks, as well as previous migration experiences are other important positive influences.

At the beginning of rice season, landless farmers generally work in the industrial sector such as in rice mills become laborers to be hired by their more well-off neighbors. Land possession is the first factor that determines the current state of villagers. Water accessibility also plays an important role in farmers' decision-making for agricultural practices especially in rice production. Generally, water resources are used to complementarily supply rainwater. The traditional rainfed lowland rice production normally begins at the end of May or beginning of June and stops when finishing harvesting in November or in December depending on rice varieties. However, the calendar has been changed because of the availability of water resources such as reservoirs, weirs, ponds and irrigated canals. With capital support from the governmental agency, Office of Agricultural Land Reform, farm ponds (1,260 m^3) have become an affordable water resource for farmers. However, farmers must consider not only the financial investment to install a farm pond but also their farm area. Farmers whose land is small are likely to refuse to have a water resource in their land because they do not want to loose farm land. As the result, farmers who have access to water resources start their rice production sooner at the end of April in order to take advantage of selling rice earlier (October) when the prices are higher. Moreover, they can hire laborers at lower rate when harvesting.

Two matrices were implemented to display the relationship between farmer's annual net income and the farming area (ha) per one labor force (F_L ratio). The first one presents the labor demand to manage rice production (Table 3). Transplanting and harvesting are the highest labor demand in rice production. Seasonal migrants normally return to help their family to grow rice at these periods. 3 month of monitoring and maintenance need little labor. Thus, some family-members might decide to migrate out at this period depending on two factors; family's food security relating labor demand, and income offered by employers in cities. If the food production is secured, some members are likely to migrate to work in cities and may not return if the off-farm income they receive is high and they will send money to their family to hire laborers. More permanent migrants usually remit a capital so that their families can compensate the loss of family-labor by hiring

Table 3: Need for laborer in rainfed lowland rice production depending on land per labor ration and income levels in Lam Dome Yai area of Ubon Ratchathani Province

			Annual net income		
			high greater than 1,800 US dollar	moderate between 450 and 1,800 US dollar	low lower than 450 US dollar
F_L ratio	low	less than 1.6 ha	Transplanting, Harvesting	Harvesting	None
	medium	between 1.6 ha and 3.2 ha	Transplanting, Harvesting	Transplanting, Harvesting	Harvesting
	high	greater than 3.2 ha	Transplanting, Harvesting	Transplanting, Harvesting	Harvesting

F_L ratio = Farming area (ha) per one labor

Table 4: Diversity of farmer's strategies in relation with their amount of land resources and levels of annual net income

			Annual net income		
			high greater than 1,800 US dollar	moderate between 450 and 1,800 US dollar	low lower than 450 US dollar
F_L ratio	low	less than 1.6 ha	Rent more land (rice production) Hire labors (rice production) Use agricultural machine (hand tractor, pump) Intensify agricultural activities to maximize labor productivity	Rent more land (rice production) Hire labors (rice production) Use agricultural machine (hand tractor, pump) Diversify agricultural activities (integrated farm)	Do not hire labors. Do all activities by themselves Become waged labor for some time in rice reason
	medium	between 1.6 ha and 3.2 ha	Rent more land (rice production) Hire labors (rice production) Use agricultural machine (hand tractor, pump) Intensify agricultural activities to maximize labor productivity Direct seeding rice.	Hire labors (rice production) Use agricultural machine (hand tractor, pump) Diversify agricultural activities (integrated farm)	Hire labors (rice production) Use agricultural machine (hand tractor, pump)
	high	greater than 3.2 ha	Become landlord or investmentor Hire labors Diversify agricultural activities Use agricultural machine (hand tractor, pump)	Hire labors (rice production) Use agricultural machine (hand tractor, pump) Have someone rent part of land	Have someone rent part of land Leave land fallow

F_L ratio = Farming area (ha) per one labor

laborers. However, if the labor shortage is really critical, farmers are likely to have somebody rent their land. The second matrix (Table 4) shows the diversity of farmer's strategies to deal with different constraints and potentialities in relation with their amount of land resources and levels of annual net income. In rice season, hiring labors is considered a common strategy for most farmers except for the farmers who have low annual net income and low F_L ratio as well as the farmers who have low annual net income and high F_L ratio.

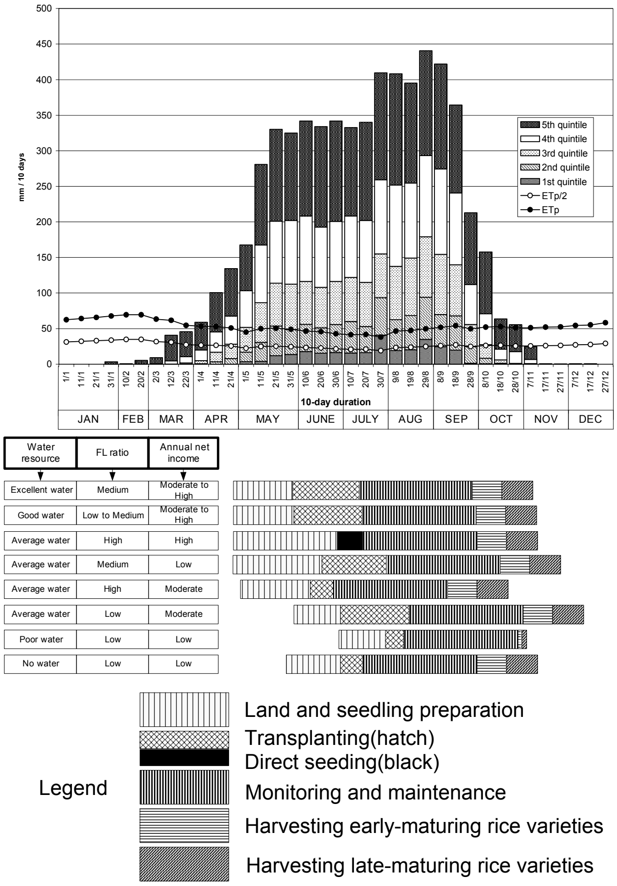


Figure 4: Effect of the variability of rainfall, access to water, land per labor ration and income level on cropping patterns in rainfed lowland rice in Lam Dome Yai watershed, Ubon Ratchathani Province

Based on these two matrices and the analytical diagrams, Figure 4 displays the relationship between climatic variability, water availability, F_L ratio, annual net income and rice production. Although direct rainwater cannot fulfill suitable moisture to paddy fields in late April, farmers who have access to water resources can start their land and seedling preparation. However, they have to rely on rainfall when approaching to transplanting period in late May because the water from other resources are inadequate or too expensive to pump into large paddy fields. The level of farmers' net income and F_L ratio are also playing an important role in deciding which steps of rice production need to hire laborers. To solve the labor shortage problem, two farmers adopted the direct seeding technique even if they had to invest more cash and time to prepare their land. Labor availability becomes more crucial when harvesting the main commercial rice variety, KDML 105. Farmers have to complete harvesting within 15 days to guarantee good rice grain quality and farm gate price. Most farmers hire laborer at this period. The harvesting time is more flexible for the late maturing glutinous varieties because commonly, they are produced for family consumption. After harvesting, farmers generally have two alternatives whether to work at home or migrate to work outside depending on dependants in family, available employment and wage satisfaction.

To simplify this complex system, the structure of conceptual model was implemented in form of the Unified Modeling Language (UML). Figure 6 displays the UML class diagram of this study area. Since an individual can play different role, the player-role pattern was used to describe the change of individual's role. Four roles (Migrant, Laborer, Retired and Farmer) were defined. The other elements composing in the system were also defined as reactive entities (WaterResource and Farmland) and as passive entities (Climate, Market and EmploymentInCity).

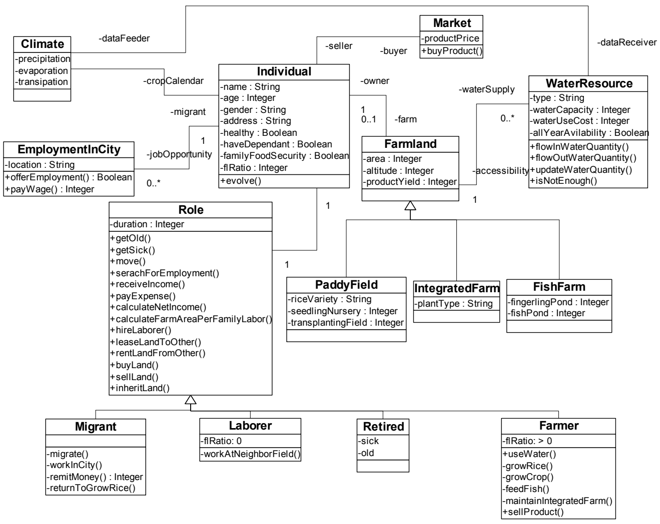


Figure 5: UML class diagram of the structure of conceptual model

6 CONCLUSION

The interaction between land and water use and labor migration derived from heterogeneous stakeholders in this study area is very complex. To understand such a complex interaction, it requires an innovative methodology. Bottom-up way starting from the analysis and understanding of diverse behaviors of heterogeneous stakeholders at the farm and rural community level was selected. Ultimate outcome could be a tool for local coordination of stakeholders regarding the management of natural resources and for a better communication between field level stakeholders and decision-makers at provincial or national level.

7 RESEARCH PERSPECTIVES AND WORK PLAN

The next step of this research is to implement the MAS model based on the structure of conceptual model (UML class diagram) of this study area. The decision-making processes will be applied for social behaviors of rule-based agents. The specific computer software, Common-pool Resource and Multi-Agent Systems (CORMAS), will be used to build the simulation. CORMAS is designed to model natural resources management consisting complex interactions. In parallel, the same conceptual model will be transformed into role-playing games (RPG). RPG will be played by farmers in order to stimulate their participation and share knowledge among them. Furthermore, farmers will be acquainted to the structure and concept of the model. Then, when presenting the MAS simulation to them, it will be easier for them to understand. Simultaneously, new information gathered during the RPG and follow-up discussions with farmers-players will be added into the model as part of its validation by the stakeholders.

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