Interactions between water use and labour migration in lower northeast Thailand. Context and use of a companion modelling methodology

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A. Richard,, P. Caron, J.Y. Jamin, T. Ruf (éditeurs scientifiques), 2006. Coordinations hydrauliques et justices sociales. Actes du séminaire PCSI, novembre 2004, Montpellier, France. Cirad, Montpellier France, Colloque

Interactions between water use and labour migration in lower northeast Thailand

Context and use of a companion modelling methodology

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Abstract — Interactions between water use and labour migration in lower northeast Thailand. Context and use of a companion modelling methodology. Erratic rainfall distribution and coarse textured soils create harsh biophysical conditions in lower northeast Thailand. Agricultural productivity is low and the region is the poorest of the kingdom. Small-scale rainfed lowland rice production is dominating land use and millions of farmers face water management problems during frequent drought and floods. Farmers use various strategies to mitigate ecological and economic risk. Labour migration could be seen as either a solution or a constraint depending on ones' point of view. Multi-agent systems (MAS) are used to explore interactions between ecological and social dynamics in complex systems by creating virtual societies sharing an environment and its resources. We will use MAS in a "companion modelling" (ComMod) approach to better understand and model stakeholders' decision-making processes regarding the management of land and water resources at the field, farm, and community sub-watershed levels. The communication presents the original agricultural features and dynamics of the Lam Dome Yai community in Ubon Ratchathani Province. Key farmers' decision-making processes regarding land & water use and labour migration are explained. Farm surveys and GIS are used to analyze spatial and temporal changes, and to define a suitable spatial interface for the future MAS model. The elicitation of decision-making processes at the household level is used to define agents' social behaviour to be represented in the model. The preliminary diagnostic survey shows that the impact of labour migrations on renewable resource management is more obvious than (limited) land use changes over the last decade.

Résumé — Interactions entre usages de l'eau et migrations des travailleurs dans les basses terres du nord-est de la Thaïlande : contexte et utilisation d'une méthode de modélisation d'accompagnement. Dans les basses terres du nord-est de la Thaïlande, les conditions bioclimatiques sont particulièrement difficiles : répartition irrégulière des précipitations, sols à texture grossière. La productivité agricole y est faible et la région est la plus pauvre du pays. Les parcelles de riz de bas-fond occupent l'essentiel des terres agricoles et les millions de paysans de la région doivent faire face à des problèmes de gestion de l'eau lors des fréquentes sécheresses ou inondations. Pour réduire les risques à la fois écologiques et économiques, les paysans mettent en œuvre diverses stratégies. La migration est, dans ce cadre, considérée selon les points de vue comme une solution ou une contrainte. Les systèmes Multi-agent (MAS) sont utilisés pour explorer des interactions entre les dynamiques écologiques et sociales dans des systèmes complexes en créant des sociétés virtuelles partageant un même environnement et ses ressources. Nous emploierons un MAS dans une approche de modélisation d'accompagnement (ComMod) afin de mieux comprendre et de modéliser les processus de décision des exploitants concernant la gestion des ressources (terre et eau) au niveau de la parcelle, de l'exploitation, et de la répartition des eaux communautaires. Cette communication présente les caractéristiques originales et la dynamique de l'agriculture de la communauté de Lam Dome Yai dans la province d'Ubon Ratchathani. Les principaux processus de décision des exploitants vis-à-vis de l'utilisation de la terre, de l'eau ou de la migration sont expliqués. Des enquêtes d'exploitation et des Gis sont utilisés pour analyser les changements spatiaux et temporels, et définir une interface spatiale adaptée pour le futur modèle MAS. La mise en évidence des processus de décision au niveau de ménage sert à définir le comportement social des agents représentés dans le modèle. L'analyse diagnostique préliminaire montre que l'impact des migrations de travail sur la gestion des ressources renouvelables est plus évident que les changements (limités) intervenus dans l'usage de la terre au cours de la dernière décennie.

Introduction

Agriculture is the largest form of land use in Thailand. A big share of the agricultural land is allocated to rice production which requires a high quantity of water. As the result, water resources are vital in the development of Thailand. However, only some 20% of the total farmland is irrigated nationwide and even in rice production the non-irrigated rainfed lowland rice (RLR) ecosystem still dominates. This is particularly the case in the northeastern region of the kingdom where more than 6 million ha of RLR are planted every year to glutinous or non-glutinous aromatic jasmine rice. Though the region has an annual average rainfall comparable to other parts of the country, there is a severe shortage of water during dry season (December – May) and the rainfall pattern is the least reliable of all regions. Moreover, coarse textured of low chemical fertility soils make harsher biophysical conditions for agricultural production.

In the lower northeastern sub-region, RLR covers more than 80% of the farmland. Because of very constraining ecological conditions (see details below), paddy yields are low with a regional average of some 2 t ha^{-1}. The better farm gate price of aromatic "hom mali" ("jasmine scented") rice does not fully compensate for this low physical productivity and northeast Thailand remains the poorest region of the kingdom. But it is a strategic region where a third of the total population of the country (62 millions) lives. It occupies a large part of the right bank of the medium course of the Mekong River along the border with Laos. The regional population is dominated by a large majority of Lao ethnic rural dwellers, while a significant minority of Khmer people lives in the southern part of the region, along the border with Cambodia. During the past decades, characterized by political tensions in Indochina, the successive Thai governments implemented different policies, particularly in the field of water resource management, to avoid increased social tensions, a higher degree of inequity, and the economic marginalization of this "Isan" country that was completely bypassed the green evolution in rice during the 70s and the 80s. But many existing irrigation schemes are not fully used to provide full time employment to farm workers all the year round. Well-known labour migrations from the agricultural to the industrial & services sectors of the economy have been an effective adaptation for northeastern people to increase their incomes and to fight rural unemployment.

This is partly due to an important and complex interaction between people mobility (i.e. different types of labour migrations) and the expansion and (more recently) intensification of agricultural production in this region. This is a key interaction the Thai state has to manage carefully when considering new policies and investments, particularly costly rural infrastructures and employment schemes. However, as stated by Nancarrow and Syme (2002) people decision-making emerges from the complex system of interactions occurring in real life. It is therefore crucial to understand how such interactions are working to be able to insert a social fairness dimension when discussing and planning new water resource development projects in this part of the country. The aim of this communication is to:

– characterize the agro-ecological context and the socioeconomic status of the lower northeast Thailand sub-region;

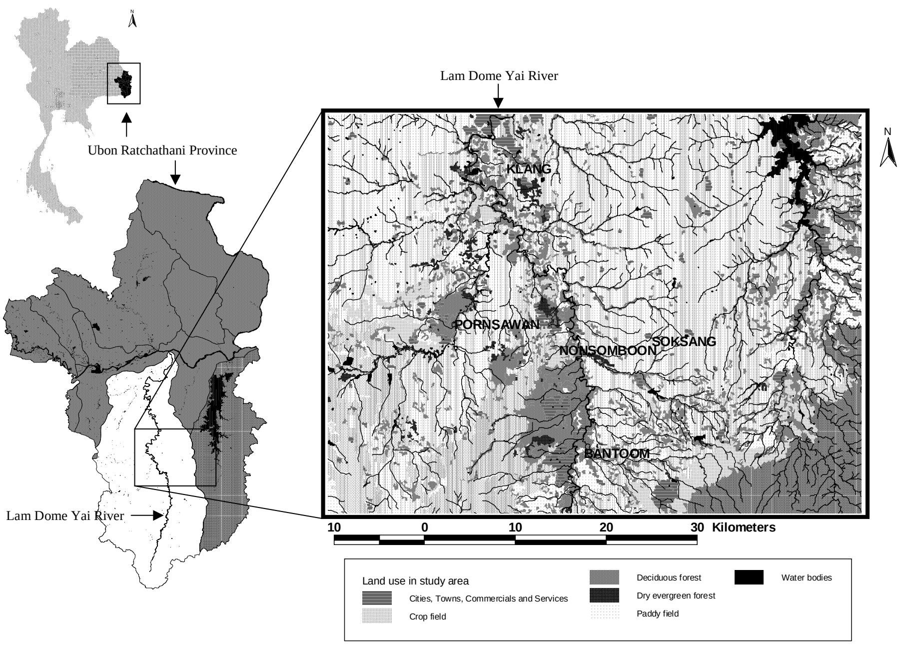
– document the recent evolution of policies and transfers of capital from the center to this more peripheral region to develop water resources and to decrease the rate of poverty;

– emphasize the linkage between labour migrations and water availability at the farm level among different types of farmers adopting different strategies to manage their varying amounts of productive resources;

– propose an approach and methodology to improve the current status of this key interaction.

Agroecological and socioeconomic characteristics of lower northeast Thailand

Ubon Ratchathani Province is crossed by the Mun River that flows eastward to the Mekong River. The study area is located along a major tributary of the Mun River, the Lam Dome Yai Watershed south of Ubon Ratchathani (figure 1). The area is about 45 000 ha characterized by erratic rainfall and poor soils.

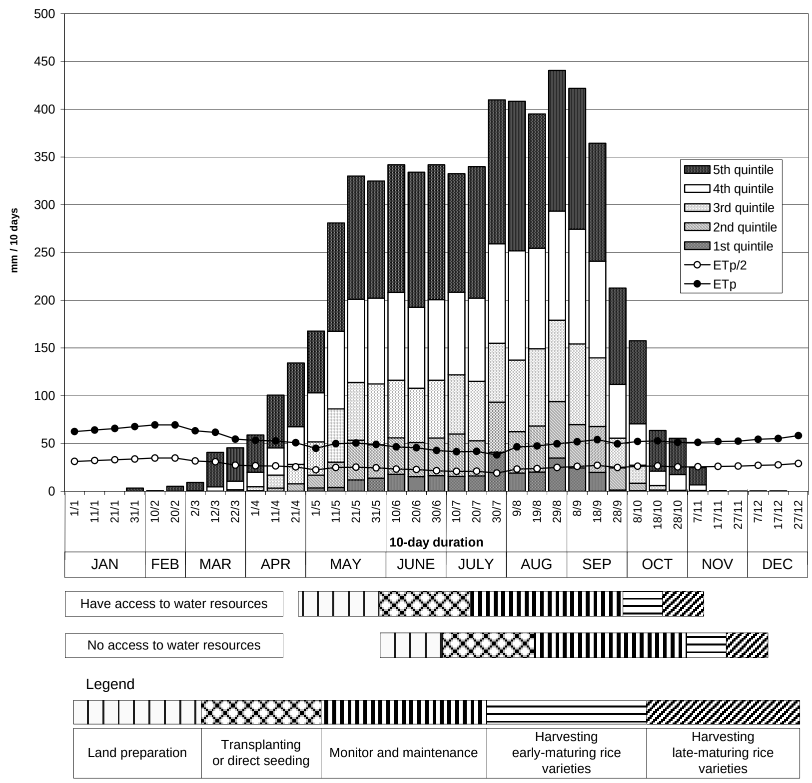


Source: Land Development Department 1991, Ministry of Agriculture and Cooperative.

Figure 1. Location of the study site in the Lam Dome Yai Watershed, Ubon Ratchathani Province, lower northeast Thailand.

More than 80% of the farm land in the lower northeastern sub-region is used to grow rainfed lowland rice (OAE 2001). Because the amount of irrigation water available is very limited, rainwater volume and its distribution still play a crucial role in determining the level of agricultural yields, especially in RLR. But rainfall distribution in this area is very erratic and farmers have to adapt their cropping calendar to current field conditions such as soil moisture and water resource accessibility (figure 2).

Another unfavourable feature for farming is the general poor quality of local soils mainly derived from sandstone (Fukai 1993). They are usually very sandy with low nutrient content and low water-holding capacity (table 1). As the result of these harsh local agroecological characteristics, paddy yields are very low (2 t ha^{-1}) and contribute to a relatively extensive economic poverty (Somrith 1997). The average monthly household income amounts to about 178 euros and is inadequate to meet both basic human needs and agricultural production requirements (table 2). The relatively high in-kind component (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 crop productivity cause such very low per capita income and make the northeast region the poorest and least developed one in the country. A common response to this situation is labour migration, particularly in the form of seasonal (non-agricultural) moves to urban areas (mainly Bangkok) when rice-farming activities end (De Jong 1997).



Source: Daily rainfall and ETP data from Northeast Meteorological Center, Ubon Ratchathani.

Figure 2. Effects of the variability of rainfall and access to water on cropping patterns in rainfed lowland rice in Lam Dome Yai watershed, Ubon Ratchathani Province.

Table 1. Properties of soil belonging to the Nam Phong series in Det Udom District, Ubon Ratchathani Province, 1993 wet season.

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.

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

	Whole Kingdom		Regions									
			Greater Bangkok[1]		Central		North		Northeast		South	
	Euros	%	Euros	%	Euros	%	Euros	%	Euros	%	Euros	%
Percent of households	**100.0**		**17.4**		**19.1**		**19.4**		**31.6**		**12.5**	
Average household size (person)	**3.5**		**3.3**		**3.4**		**3.2**		**3.7**		**3.8**	
Total income	264	100.0	543	100.0	272	100.0	183	100.0	178	100.0	240	100.0
Wages and salaries	111	42.0	299	55.0	115	42.2	63	34.6	55	30.7	83	34.6
Profit (non-farm)	51	19.1	117	21.5	51	18.6	33	18.0	30	16.6	46	19.1
Profit (farm)	28	10.5	2	0.4	41	15.1	28	15.3	24	13.2	49	20.6
Property income	4	1.6	13	2.4	4	1.4	3	1.5	2	1.0	3	1.1
Current transfers[2]	24	9.2	39	7.1	18	6.7	21	11.2	26	14.8	16	6.6
Income-in-kind[3]	42	15.9	71	13.1	40	14.6	31	16.8	38	21.1	37	15.5
Other money receipts	4	1.7	3	0.6	4	1.5	5	2.5	4	2.5	6	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.

Evolution of policies dealing with the development of water resources

Before the 1960s, all the major irrigation projects in Thailand were located in the central or the northern regions. The Chi-Mun river basin situated in the northeast and flowing into the Mekong river, was neglected until the systematic development of irrigation systems began with the first National Economic Development Plan (1961-66). The first large-scale irrigation project implemented in the northeast was the Ubolrattana Dam located in Khon Kaen Province, upper northeast Thailand, which was completed in 1965. Following this project, the Chi-Mun river basin saw the construction of the Sirinthorn and Chulabhorn hydropower dams and reservoirs, and a number of irrigation dams and weirs, including the Lam Pao, Lam Phra Phloeng, and Lam Takhong dams. In 1978, a water policy for the northeastern region was designed in a National Master Plan. It followed a two-pronged approach: (i) the effective distribution of available water resources from large reservoirs and reliable rivers to the people adjacent to these sources, and (ii) the development of small water resource projects to meet basic water requirements of the local communities living away from large reservoirs and reliable rivers (WCD, 2000). As a result, more medium-sized irrigation projects were constructed in the northeastern region. Some of them were located in Ubon Ratchathani Province (table 3). However, the capital transfer through such water resource improvement was very low. For instance, in 1999, the national budget expenditures for the agricultural sector amounted to 1 180 million euros, but only 0,07% of this budget was allocated to improve water resources in this Ubon Ratchathani Province. In the 1980s and early 1990s, the emphasis shifted to medium-scale irrigation schemes, dominated by the weir system. The Pak Mun Dam in Ubon Ratchathani Province started to operate in 1994 and is one among these medium-scaled multi-purposed irrigation projects.

Because the topography and water systems of the northeast are not well suited to large-scale irrigation projects, the current water resources development plan in the Chi-Mun river basin confirms a strategy centred on the development of small-scale water resources (KKU, 1994). In addition, the so-called “New Theory” of farming pattern for northeastern farmers, initialized by His Majesty the King of Thailand and emphasizing the self-reliance of their farming units, was introduced to poor farmers possessing small land holding with scarce water resources. The basic principle of this theory is the effective allocation of land to serve the different needs of farm households. The “New Theory” aims to provide food security and decent quality of life at the farming household level in non-irrigated areas still poorly integrated in the cash cropping economy. The “New Theory” kind of agricultural production systems (or “integrated systems”) are now being promoted and extended throughout the country, especially in the northeastern region where poverty and water shortage are still serious problems (Jitsanguan, 2001).

Table 3. Large and medium size irrigation projects in Ubon Ratchathani Province.

Year	Project name	Type	Location		Storage capacity (10^6 x m^3)	Expected irrigated area (ha)	Actual irrigated area (ha)	Actual/Expected irrigated area (%)
			Sub-district	District				
1951	Nong Lao Hin	Medium reservoir	Sank Hao	Khung Nai	2.3	160	107	67.1
1953	Hua Wang Deang	Medium reservoir	Pho Sai	Phibunmungsaharn	0.7	88	88	100.0
1953	Nong Chang Yai	Medium reservoir	Hua Raue	Muang	7.7	720	689	95.8
1953	Sa Ming	Medium reservoir	Nong Bok	Lao Sua Kok	1.0	120	23	19.1
1969	Lam Dome Noi	Large reservoir	Non Klang	Phibunmungsaharn	1,996.5	24,000	N/A	N/A
1983	Hua Chaluai	Medium resevior	Na Chaluai	Na Chaluai	1.1	N/A	192	N/A
1983	Hua Pun	Medium resevior	Ban Tum	Na Chaluai	1.3	N/A	32	N/A
1984	Hua Tum Kae	Medium reservoir	Kum Chareon	Trakarn Phutphon	13.7	1,863	1,863	100.0
1986	Lam Dome Yai	Weir	Muang Det	Det Udom	1.6	240	N/A	N/A
1987	Hua Jun La	Medium reservoir	Klom Pradit	Num Yun	16.9	2,000	2,000	100.0
1988	Lower Hua Phalan Sua	Medium reservoir	Klom Pradit	Num Yun	27.7	932	932	100.0
1988	Hua Pun	Medium resevior	Non Som Boon	Na Chaluai	1.0	N/A	32	N/A
1994	Hua Wang Yai	Medium reservoir	Klom Pradit	Num Yun	8.0	576	N/A	N/A
1994	Hue Kra Jeen	Weir	Na Tan	Khem Marat	1.0	160	N/A	N/A
1999	Hua Bang Koy	Weir	Kam Pom	Khem Marat	1.0	320	N/A	N/A
					2,081.5			

N/A: Not Available

Source: Irrigation Office, Region 7, Ubon Ratchathani, 2004.

In Det Udom and Na Chaluay Districts (location of study area) of south Ubon Ratchathani Province, small-scale irrigated infrastructures at the community level have been constructed since 1981 (table 4). At the farm level, the development of individual water resources based on tens of thousands of small farm ponds (storing a maximum of some 1,200 m^3 of water) has been well-adopted by farmers during the past decade. The evolution of irrigation project management in the northeast is likely to evolve from a state-controlled and centralized type of management (large dams) to a more decentralized, often individual type of management in the case of small farm ponds and on-farm reservoirs.

Table 4. Small irrigation projects in Det Udom and Na Chaluay Districts of Ubon Ratchathani Province.

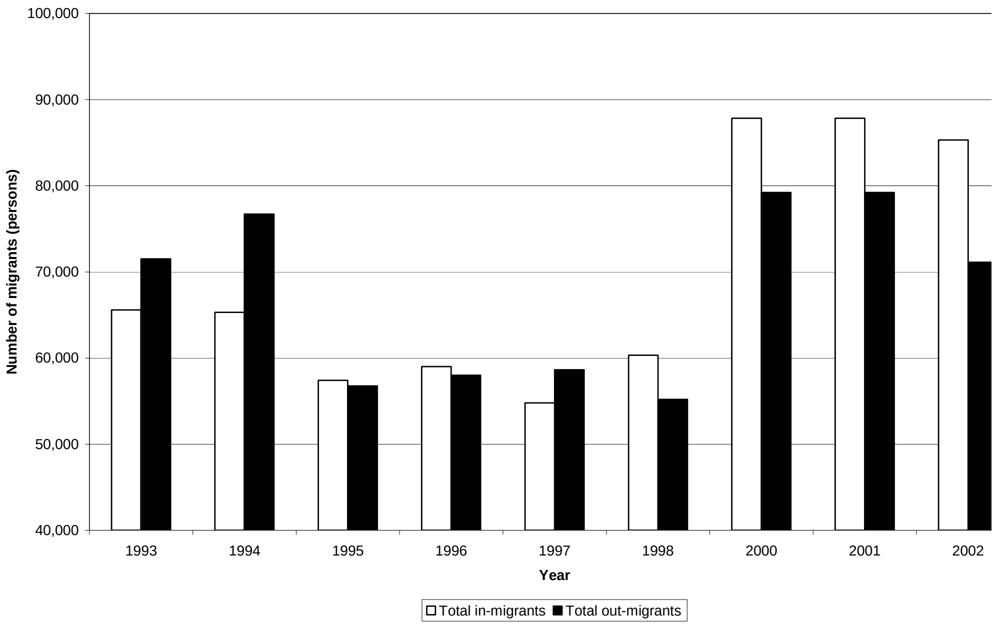
Year	Project name	Type	Location		Storage capacity (m^3)	Number of households affected	Irrigated area (ha)	Cost (million Euros)
			Sub-district	District				
1981	Hua Hin Siew	Weir	Kam Krang	Det Udom	108,360	280	32	0.06
1981	Hua La Long	Weir	Kam Krang	Det Udom	63,000	650	24	0.03
1981	Hua Oum	Small resevior	Na Chaluai	Na Chaluai	380,000	40	32	0.04
1981	Hua Sun	Small resevior	Na Chaluai	Na Chaluai	800,000	2,400	48	0.05
1982	Hua Ar Rong	Weir	Som Sa Ard	Det Udom	60,000	534	80	0.03
1982	Hua Can	Weir	Na Suang	Det Udom	60,000	664	16	0.04
1982	Hua Lok	Small resevior	Na Chaluai	Na Chaluai	350,000	240	3	0.05
1983	Hua Bua	Weir	Klang	Det Udom	80,000	120	19	0.04
1983	Hua Can	Weir	Na Suang	Det Udom	61,000	170	16	0.04
1983	Hua Hin Siew	Weir	Phon Ngam	Det Udom	85,000	250	32	0.05
1984	Hua Chorm	Weir	Kreng	Det Udom	108,000	400	32	0.11
1984	Hua Pun	Small resevior	Na Chaluai	Na Chaluai	130,600	160	56	0.04
1984	Kud Ngo	Small resevior	Phon Ngam	Det Udom	427,280	250	8	0.04
1985	Hua Bua	Weir	Klang	Det Udom	100,100	120	19	0.08
1988	Hua Chaluai	Small resevior	Ban Tum	Na Chaluai	401,615	500	32	0.07
1990	Hua Tiam	Weir	Non Som Boon	Na Chaluai	870,500	190	32	0.11
1992	Hua Bua Tiam	Weir	Klang	Det Udom	150,500	400	80	0.17
1992	Hua Ta Kod	Weir	Ban Tum	Na Chaluai	950,100	492	32	0.16
1995	Hua Karm	Weir	Meung Det	Det Udom	90,000	251	128	0.12
					5,276,055	8,111	722	1.31

Source: Irrigation Office, Region 7, Ubon Ratchathani, 2004.

Labour migrations, water availability, and agricultural production

The Thai villagers living in this area belong to the lao-issan and khmer ethnic groups. Their culture and means of subsistence are strongly linked to rice and its production, even if it is generally not an economically profitable crop. In general, they spend approximately 6 months per year growing rice on the greater share of their farm land. Since rice production requires the presence of the family labour during only 6 months, a lot of the villagers are unemployed or under-employed after harvesting rice due to the lack of local employment opportunities and the difficulty to practice other agricultural activities throughout the long dry season. Although the government has tried to alleviate the harsh environment by improving water resources, which led to pockets of intensive agricultural production with increased labour needs, the success of these small-scale irrigation projects is not very satisfactory.

Labour migration is closely interlinked to the economic balance between rural and urban labour force, and, for many decades, mobility has been an important strategy for farmers to increase their households' incomes. Figure 3 shows that the early 1990s was a period of high labour migration flowing from agricultural sectors to industrial sectors when the Thai economic was booming with a double digit rate of annual growth. And following the economic crisis of the late 1990s, the flow of migrants increased again in the recent years. Even though the Thai government attempted to promote regional growth centres to reduce the pattern of migrations to Bangkok, it has not been successful because the rural-urban disparities in employment opportunities and wage levels are too large to be reduced by such rural development efforts (Matsumura *et al.,* 2003). On the contrary, in early 1997, Thailand's economic bust caused a sudden increase in unemployment and the new labourers could not enter the market. The crisis also affected people in rural areas because most of the households depended more and more on off-farm incomes. The economic crisis also caused thousands of migrants to return to their rural homes after loosing their jobs, and many reverse migrants returned to the northeastern region (Subhadhira *et al.,* 2000).



Source: Department of Local Administration, Ministry of Interior.

Figure 3. Evolution of the number of migrants in Ubon Ratchathani Province, 1993-2002.

The local migration pattern is categorized into seasonal (temporary) and more permanent migrations. Though the pattern of migration is widely known, the decision-making process involved is still not very well-known. Guest (1998) showed that migration among rural households in northeast Thailand helps to reduce cross-province inequality in household incomes. The flow of remittances from rich to poor provinces is one channel to redistribute incomes through labour migration. Ironically, the policy of the Thai government has been to curb migration flows to Bangkok, although without much success (Yang 2003). The change of profession from agricultural employment to wage-earners in urban areas has increased (Nakwiboonwaong 1990). While more than 80% of the national labour force was employed in the agricultural sector in the early 1980s, this share is currently estimated at 55%. In parallel, a higher farming area per labour ratio requires farmers to adapt their land and water use strategies. However, the decision-making process to effect such a change is still not well-understood.

Socioeconomic and demographic data have rarely been linked with other biophysical data in landscape studies (Wang and Zhang, 2001). Many researchers have built models of labour migration in relation to the economy only (De Jong, 1997; Yang, 2003) and there is very little research investigating the interactions between water use and labour management. Furthermore, none of them used MAS simulations to explore such relationship, while recent research has shown that MAS could be used to understand dynamically the interactions between biophysical and socioeconomic dynamics. A model implemented for 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 examine the use of innovation to compensate for labour loss in the Melado River, Chile. Laine and Busemeyer (2004) used agent-based learning model to understand what kind of spatial patterns (land use) emerge from different agent characteristics and learning mechanisms for making decision about farming activities or looking for off-farm employment. Agents calculate the payoff between farming and off-farm employment and the decision is based on which one provides a higher payoff. These models are site specific and not applicable for situations such as the Lam Dome Yai watershed. However, they contribute to provide a better understanding of the relationship between natural resource use and labour migration and provide useful ideas to conceive our own model.

The land use maps at different dates and the analysis of secondary data from two previous agricultural system studies indicate that land use patterns have not been significantly altered since 1994. However, new data from in-depth interviews with a range diverse types of farmers show that many of them have to adapt their strategies regarding both farm and non-farm activities to satisfy their personal objectives and preferences. Labour 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 remittances from migrants are normally used for investments such as the construction of a house and children education. The decision to migrate out of the village is influenced by the prospects of increasing income through employment in cities. The migrant networks based on family members and friends, as well as previous migration experiences, are other important supportive reasons in the villagers' decision to migrate.

At the beginning of the rice growing season, landless villagers are generally hired locally by their more well-off neighbours. Water accessibility plays an important role in farmers' decision-making for agricultural practices especially in rice production. The traditional rainfed 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 the type of rice varieties being grown. However, the cropping calendar has been changed because of the availability of water resources such as reservoirs, weirs, ponds, and irrigation canals. With capital support from the Agricultural Land Reform Office (ALRO, a government agency), farm ponds have become an affordable source of water for local farmers. However, farmers consider not only the financial investment but also their farm area. Farmers whose land is small are likely to refuse to have a pond dug on their land because they do not want to loose any farmland. Farmers with on-farm water resources start their rice production sooner, at the end of April, in order to take an advantage of selling rice with a higher price at the very beginning of the harvesting season in October. Moreover, it is also easier for them to hire labourers in this initial phase of rice harvesting.

Table 5 displays the extent of the diversity of the situation among local households regarding farmers' annual net income and their farm land per labour ratio (F_L). It shows the demand for hired labour from each type of farm to manage rice production, especially at transplanting and harvesting stages.

Table 5. Need for labour in rainfed lowland rice production depending on farm land per labour ration and income levels in Lam Dome Yai area of Ubon Ratchathani Province.

			Annual net income		
			high greater than 1,770 euros	moderate between 440 euros and 1,770 euros	low lower than 440 euros
FL 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

FL ratio = Farming area (ha) per labor

Usually, seasonal migrants return to help on their family farms during these peaks of labour demand periods, while the 3-month long duration of crop maintenance in paddy fields requires little labour. Thus, some family-members might decide to migrate during this period depending on two factors: the family food security situation in relation with the labour demand, and the level of cash income offered by employers in the cities. At least, the family needs to have enough members to manage rice production and resources to hire extra labourers if necessary. If the food production is secured at the household level, some family members are likely to migrate and might not return if the income they receive is high. In this case, they send cash to their family to hire local labourers. More permanent migrants usually remit a share of their wages to their families to allow them to compensate for the loss of family labour by hiring labourers.

Proposed research approach: the companion modelling methodology

The participatory approach to renewable resource management is context dependent. The specificities of this context should be known as early as possible by anyone intending to facilitate resource use through negotiation among stakeholders (Röling and Wagmaker, 1998). The participatory approach aims at letting people identify and understand their problems and not outsiders who assume what their problems are (Campo, 2003). The stakeholders work as a team towards shared objectives, with each contributing its own expertise and point of view. A key advantage includes the exposure of every participant to bodies of knowledge that would otherwise be unknown or 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). Bousquet *et al.* (1999) proposed a participatory modelling approach called Companion Modeling (ComMod), which uses Multi-Agent Systems (MAS) simulation together with other mediation tools such as Role-Playing Games (RPG) and spatial modelling for better understanding and sharing of stakeholders decision-making processes and collective management of renewable resources. ComMod requires a continuous, evolving, and iterative confrontation between modelling activities and the analysis and observation of 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 a given complex system (Barreteau, 2003). The process involves interdisciplinary methodologies that seek to facilitate dialogue 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 the 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 the 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 RPGs. 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). MAS modelling and simulation is based on the idea that it is possible to represent the behaviour of entities in computerized form, which are active in the world, 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 behavioural rules and is able to act locally in response to stimuli from its environment or communication with other agents (Bousquet, 2002).

Geographic Information Systems (GIS) are supporting tools for modelling, especially spatial data management, analysis, and visualization. GIS applications can be fully integrated or linked with models through data exchange 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 modelling in both their asynchronous updating of cellular data and implicit cellular nature (Gilbert *et al.,* 2002). Integrating GIS with MAS simulation could bring the fourth dimension, time, and human behaviour (decision-making processes) into a comprehensive model.

In a recent paper, Nancarrow and Syme (2003) stated that when looking at the problem of water allocation among various users, different sets of agents will form their fairness rules in different ways. They see a role for the researcher to investigate these rules and contribute to gaining community consensus. They also suggest that Agent-Based Modelling (ABM) may be a useful way for assisting in this. ComMod principles and approach truly support this statement due to the importance given to stakeholders' decision-making processes. ComMod emphasizes the stakeholders' involvement throughout the process. The simulated results are verified and validated by stakeholders with the assistance of the modeller. Moreover, this approach intends to improve stakeholders' knowledge related to their current situation via participatory methods and tools and a general process of collective learning. Our research, will use the ComMod approach due to its characteristics (participatory, evolving and iterative) that are well-adapted to our research topic and our aim at acquiring and sharing situational knowledge among stakeholders about the interaction between land/water use and labour migration in the study area.

Research perspectives and work plan

The structure of a conceptual model to look into the interaction between land & water use and labour migration is being conceived in the form of Unified Modelling Language (UML) class and sequence diagrams. Farmers' decision-making processes will be modelled as UML activity diagrams for their use in the representation of the social behaviour of rule-based agents. The conceptual model will be translated into a first RPG to be played with different kinds of villagers from the Lam Dome Yai watershed to get feedback from the stakeholders on the representation of the issue at stake proposed by the research team. We expect that following the gaming session, the initial conceptual model will have to be improved thanks to the comments and criticisms made by the players during the game, the following collective debate, as well as during individual interviews. Special attention will be paid to the interactions among the different kinds of players (different types of farmers, job broker, etc.) during the gaming sessions.

The computer software Common-pool Resource and Multi-Agent Systems (CORMAS, Le Page *et al.,* 2001), which was specifically tailored to simulate collective resource management problems, will be used to build a first MAS model. The participatory methodology will be principally used to better understand the diversity of stakeholders' perceptions about the issue and to build comprehension among them (including between farmers and researchers) through interviews, focused group discussions, gaming sessions, and participatory simulations during short workshops held in the villages. The simulated results will be verified and validated by presenting and discussing them with stakeholders. At each step of the process, new information gathered with farmers-players will lead to improved or more relevant versions of the model, as well as their validation by the stakeholders.

Conclusion

The system under study is complex due to the spatial, biophysical, economic, and social interactions between water use and labour migration among heterogeneous stakeholders living in the Lam Dome Yai watershed. To understand and model such complex interactions, an innovative methodology is required. We made the choice to examine it in a bottom-up way, starting from the analysis and understanding of the different kinds of behaviours among the heterogeneous individual agents at the farm and rural community level. The final output of this research could be an adapted tool for local coordination of stakeholders regarding the management of water resources and for better communication between field level stakeholders and decision-makers at the provincial, sub-regional, or even national level.

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