CHAPTER XI
EXPLORATORY SIMULATIONS WITH THE BAN MAK MAI AGENT-BASED MODEL

According to the sequentiality of the modelling process (see details in chapter VI), after the design phase, simulations are run to make use of the model for knowledge discovery. The exploration of the dynamic behaviour of the model is usually firstly oriented towards a systematic investigation of the sensibility of the models to a set of key parameters. This first step allows pointing out parameters that drastically influence the dynamic behaviour of the model. Ultimately, it may give indications to narrow down the spectrum of scenarios interesting to be explored by simulation.

Scenarios are described as possible future alternatives that take into account the interactions of various heterogeneous components of a complex system (Wagener, Liu et al., 2006). Rather than relying on predictions of such alternatives, scenarios produced in a collaborative modelling process are purported to enable creative thinking to prepare stakeholders to face an uncertain future events (Schwartz, 1996). Scenarios simulated provide a dynamic view of the prospective events by exploring different trajectories of change (Means, Patrick et al., 2005). Two types of scenarios are often referred in the literature: explanatory and anticipatory scenarios. Explanatory scenarios are used to describe the future according to known processes of change and given extrapolations from the past. These are scenarios with no major interventions or paradigm shifts along their progression (McCarthy, Canziani et al., 2001). Explanatory scenarios were usually produced to examine future trends projecting forwards in time using trend experienced over some past period, and imagine upcoming change that significantly varies from the past (Hulse and Gregory, 2001). Anticipatory scenarios are based on different desired or feared visions of the future. They correspond to a specific future that is achievable only if certain events or actions take place (Godet and Roubelat, 1996).

In the context of companion modelling, "scenario" is straightforwardly understood as an operating mode for the simulation model, or more precisely a set of factors which are going to modify its operation: a certain stakeholder behaves differently, certain ecological dynamics are disturbed, certain variable of social or economic clamping is changed. Changes in how interactions are organised is also frequently envisages (new exchange systems, new negotiation protocols).

From a methodological point of view, the sensitivity analysis helps to detect specific characteristics, critical determinants and key parameters that drive the system under study. These elements are considered to formulate scenarios identified by model users. Once the scenarios are run, the detailed quantitative and/or qualitative information would subsequently be analyzed for impact assessment. Scenario analysis focusing on identifying the consequences of interactions among the boundary conditions, driving forces, and system components is a process of evaluating possible future events through the consideration of alternative possible outcomes and their implications (Wagener et al., 2006). Because unanticipated conditions have more chances to occur over a long period of time, long-term scenarios have more uncertainty than short-term scenarios. Besides, to eliminate some constrains, such as demographic change (see details in chapter X), only 5 simulation years were run.

This chapter starts to use the BMM model for of the scenario exploration in field-based simulations and participatory analysis followed by laboratory-based simulations and analysis.

11.1. Field-based Simulations and Participatory Analysis

In general, scenario analysis is primarily a scientific effort, employing a variety of statistical and other analytical techniques to examine the scenarios. In my case, the baseline scenario was first presented to the local farmers. During the same workshop, they proposed alternative scenarios that were run on the spot, leading to extensive and intensive discussion among themselves and with the scientific team.

11.1.1. Scenario Identification

During the participatory simulation workshop organized in May 2008, two scenarios were identified by participating RLR farmers (see details in chapter VIII). The first scenario was characterized by the presence of 30 cheap wage-earners from neighbouring countries (no labour constraint scenario). The second one was featured as no water constraint situation as a result of farm ponds always full of water.

11.1.2. Scenario Exploration and Participatory analysis

In the "no labour constraint" scenario, the simulation showed higher income differentials across farm types compared to the baseline scenario (see details of the baseline scenario in chapter X). Income from rice sales of small farms was not significantly different, but they lost on-farm income received from large farms compared to the baseline scenario. In contrast, without labour constraints and despite higher labour costs, large farming households earned higher incomes from selling high quality paddy thanks to faster harvests. However, participating farmers argued that small farms may not lose on-farm income as much as it was shown by the simulated results. It was also argued that immigrant workers are not likely to be hired because they are not as meticulous as local rice farmers. Furthermore, local farmers prefer to hire labour within their kinship networks.

In the second scenario with guaranteed access to water, two large virtual farms could not complete the transplanting of its entire rice land when heavy rains came late, and by then some rice seedlings were too old to be used. This counterintuitive result (one may expect that water abundance would improve rice-growing performances) occurred because the pumping of water from a pond for transplanting activity was not possible in this model, accordingly to the insights of local farmers. Besides, due to a lack of knowledge regarding conditions where there is no water constraint, none of the participating farmers pointed out the usefulness of full water levels in the pond for transplanting.

Nevertheless, this result discloses an unobvious consequence of the synchronization of rice farming activities: when all local farmers start nursery at the same date (because all of them have access to irrigation water), they are all busy transplanting at the same time and consequently the availability of labour is temporarily lower than under desynchronized rice production, which in the simulation led to the problematic situation described above. Participating farmers did react to such exhibition by the model by arguing that the incomplete transplanting resulting in fallowed paddies is unlikely to happen in reality because rice farmers have practices not related to the use of water to avoid that by either establishing new nurseries, or buying healthy rice seedlings from neighbours. Participants were also aware of the risky decisions based on a water availability that is only made possible by erratic rainfall distribution. To clarify the point regarding extra nurseries, I modified the BMM model to integrate the risk of rice nursery failure (all rice seedlings become unusable, and a second rice nursery has to be established) into the model, and discussed the results with farmers. Once they observed the simulation, they disagreed with the total failure of the first nursery since it has never happened under their real circumstances. They proposed to let only a maximum share of 1/3 of the rice seedlings to die, or become worthless, for transplanting. The algorithm was modified in the model to take their comments into account. Both scenarios illustrate how water dynamics and labour availability are intertwined, resulting in varying amounts of household income, which is a key determinant of migration decision. To deepen the investigations about this mechanistic relationship, further explorations by simulation with the BMM model have been conducted back to the lab (on a scientific side only).

11.2. Laboratory-based Simulation and Analysis

11.2.1. Sensitivity Analysis of the BMM model

Sensitivity analysis is aimed at understanding the conditions under which the model yields the expected results, and estimating uncertainty particularly in integrated modelling studies (Gilbert, 2008). The principle behind is to systematically change the values of the initial conditions, parameters and inputs of the model by a small amount and rerun the simulation, observing differences in the outcomes (Balci, 1998). The purposes of sensitivity analysis are to: (i) test which parameters dominate a certain response to eliminate insensitive parameters to reduce model complexity and calibration burden, (ii) to test how well parameters are defined, or to test where additional effort should be placed to reduce uncertainty, and (iii) to test if parameters are sensitive in period where the processes they represent are assumed to dominate (Wagener et al., 2006). The results of sensitivity analysis are useful to narrow the range of parameters' value by selecting only the interesting ones to input in the BMM model for scenario exploration. This analysis is also often purposed to test "what if" scenarios. Likewise, it can be used to identify those input variables and parameters to the values of which the model behaviour is very sensitive. As a result, model validity can be enhanced by assuring that those values are specified with sufficient accuracy (Balci, 1998).

11.2.1.1. Selection of Parameters for the Sensitivity Analysis of the BMM model

It should be noted that even with only a few parameters, a sensitivity analysis can require an astronomical number of runs and thus to hold a practical strategy is challenging (Gilbert, 2008). As a result, the sensitivity of the BMM model was tested by limiting the range of values at some points where major changes in the simulation's behaviour were expected (e.g. crop establishment). Referring to the baseline scenario, I assumed that the successful rice crop establishment in the BMM simulations was likely to be sensitive mainly to four parameters: (i) the earliest starting date of RLR nursery establishment (not possible to establish a nursery bed prior to that date even when the conditions regarding water requirements are satisfied). In Thailand, the Royal Ploughing Day which is used to justify when the RLR production is supposed to start is, in fact, changed every year. I decided to test several dates in May (month of the Royal Ploughing Day), but also in April to evaluate the strategy "start as soon as possible"; (ii) the initial water level in farm ponds, tested with values 0 (default value used in the baseline scenario), 1, 2 and 3 m (full capacity); (iii) the daily rainfall threshold to enable starting RLR nursery establishment (when irrigation water is unavailable), tested with values 15, 20, 25, 30 (default value), 35 and 40 mm; and (iv) the daily rainfall threshold to start transplanting, tested with values 5, 10, 15, 20 (default value), 25 and 30 mm.

Because the main factor impacting the dynamics of the BMM model is undoubtedly the input of rainfall and PET patterns, the influence of these four parameters has been tested under: (i) 27 independent climatic years (Table 11.1) to investigate how these independent climatic conditions are affecting farm management across farm types, and (ii) 19 sets of successive 5 climatic years (Table 11.2) to investigate the effects on the migration patterns which evolve through time (each household member reconsiders its migration status by the end of every rice cropping season). The spatial and agent settings defined in the baseline scenario were reused (see details in chapter X).

Table 11.1 Summary of 27 climatic years of accumulation of daily water input influencing water level in farm ponds.

Year	All seasons				Rainy season (May-September)
	Quantity at the end of each year (mm)	Average (mm)	Maximum (mm)	Minimum (mm)	Average (mm)
1966	0.00	481.68	1081.70	0.00	625.48
1967	0.00	0.00	68.20	0.00	0.00
1968	0.00	97.62	745.50	0.00	122.69
1969	0.00	0.00	433.20	0.00	113.37
1970	0.00	200.85	738.50	0.00	221.94
1971	0.00	0.00	405.50	0.00	111.01
1972	0.00	222.02	698.50	0.00	184.18
1973	0.00	0.00	315.30	0.00	0.00
1974	0.00	130.20	568.10	0.00	114.00
1975	0.00	98.39	500.70	0.00	39.88
1976	0.00	68.56	425.40	0.00	77.90
1977	0.00	0.00	202.10	0.00	0.00
1978	151.60	449.18	1020.10	0.00	341.75
1979	0.00	194.50	735.90	0.00	273.05
1980	0.00	215.05	598.20	0.00	183.05
1984	355.54	493.19	1087.38	0.00	308.70
1985	0.00	120.17	485.42	0.00	89.65
1986	0.00	137.86	579.85	0.00	47.63
1987	0.00	105.49	544.80	0.00	28.95
1988	0.00	0.00	252.71	0.00	100.51
1989	0.00	7.97	369.67	0.00	38.14
1990	40.24	245.05	641.53	0.00	153.81
1991	0.00	105.83	581.64	0.00	0.00
1992	0.00	199.67	607.47	0.00	141.53
1993	0.00	0.00	171.25	0.00	0.00
1994	235.82	432.97	939.80	0.00	386.15
1995	0.00	0.00	230.00	0.00	73.37

Note: Daily water input is computed on quantity of daily rainfall subtracted by quantity of daily potential evapotranspiration (PET).

To measure the impact of each combination of parameters under each climatic condition listed in tables 11.1 and 11.2, four indicators were defined: (i) number of nursery re-establishment, (ii) number of pumping water to establish nursery, (iii) number of pumping water to alleviate water stress, and (iv) percentage of paddy field without rice transplanted. In fact, as already mentioned, the event depicted by the last indicator never happens in actual circumstances because RLR farmers can buy healthy seedlings from their neighbours, but it was kept as such in the model to clearly display the impact of extreme drought on rice production.

Table 11.2 Summary of 19 sets of 5 successive climatic years of accumulation of daily water input influencing water level in farm ponds.

Years	All seasons				Rainy season (May-September)
	Quantity at the end of the first year (mm)	Average (mm)	Maximum (mm)	Minimum (mm)	Average (mm)
1966-1970	0.00	69.27	1081.70	0.00	171.56
1967-1971	0.00	26.00	745.50	0.00	98.01
1968-1972	0.00	55.77	745.50	0.00	119.16
1969-1973	0.00	61.20	738.50	0.00	117.71
1970-1974	0.00	78.56	738.50	0.00	105.46
1971-1975	0.00	56.51	698.50	0.00	81.45
1972-1976	0.00	30.98	698.50	0.00	34.87
1973-1977	0.00	68.83	1020.10	0.00	61.13
1974-1978	0.00	122.61	1020.10	0.00	113.02
1975-1979	0.00	136.75	1020.10	0.00	124.53
1976-1980	0.00	144.42	1020.10	0.00	141.45
1984-1988	355.54	121.83	1087.38	0.00	87.11
1985-1989	0.00	115.81	939.80	0.00	94.86
1986-1990	0.00	102.75	939.80	0.00	93.23
1987-1991	0.00	98.85	939.80	0.00	98.30
1988-1992	0.00	98.02	939.80	0.00	106.96
1989-1993	0.00	116.95	939.80	0.00	107.89
1990-1994	40.24	135.11	939.80	0.00	119.51
1991-1995	0.00	113.12	939.80	0.00	112.65

Note: Daily water input is computed on quantity of daily rainfall subtracted by quantity of daily potential evapotranspiration (PET).

11.2.1.2. Results of the Sensitivity Analysis of the BMM model

The beginning of RLR nursery establishment

"The beginning of RLR nursery establishment" parameter was set to range from 1st April to 31st May with intermediate values every 5 days: 351 simulations (13 different dates tested under each of the 27 available climatic years) were run. The overall results show that the beginning of RLR nursery establishment set in April triggered more nursery renewals than in May. This is particularly marked in case of households B and C (see Figure 11.1). However, the result was slightly different for households A1 and A2. Since these small holders are not equipped with farm pond in the baseline scenario, they have no opportunity to alleviate water stress by irrigating the nursery. However, fewer number of nursery re-establishment does not necessarily yield better outcome. As shown in Figure 11.2, the percentage of paddies without rice planted was higher when the beginning of RLR nursery establishment was set in May than in April. This could be a result of the shorter time to manage transplanting activity by household B who has labour constraint before reaching the last week for RLR transplanting.

With no water initially in farm ponds (as set in the baseline scenario), only very few simulations had irrigation water used by households B or C (4 occurrences only to establish nursery and 7 occurrences to alleviate water stress). Thus, I decided to run additional simulations to assess the influence of different initial water levels in farm ponds.

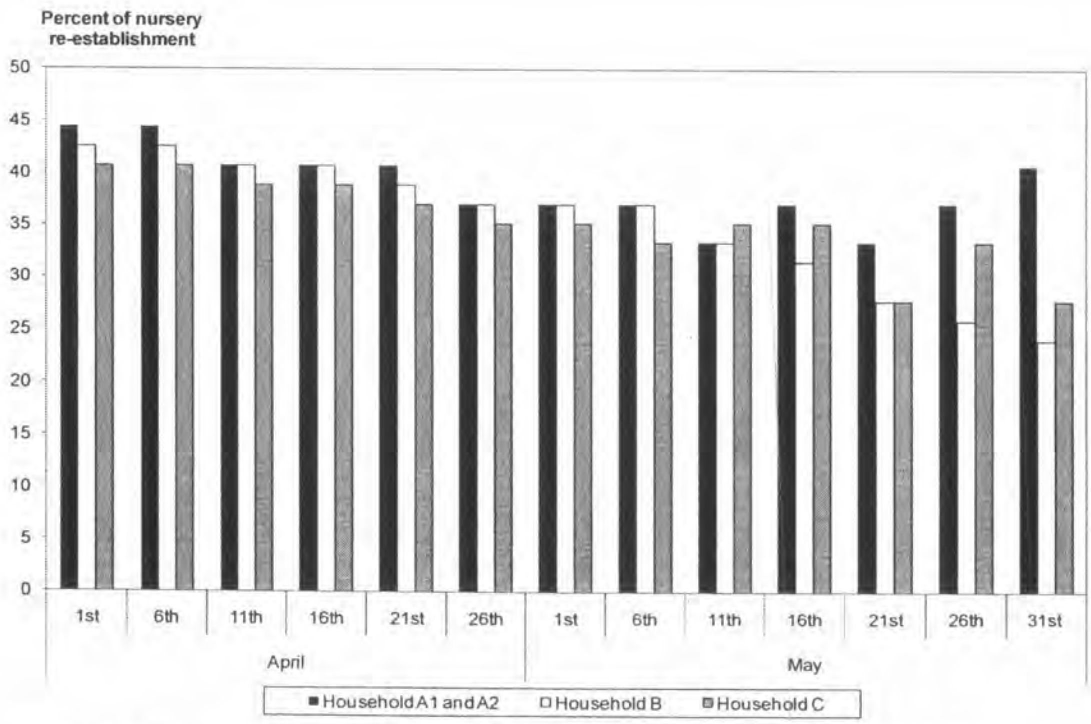
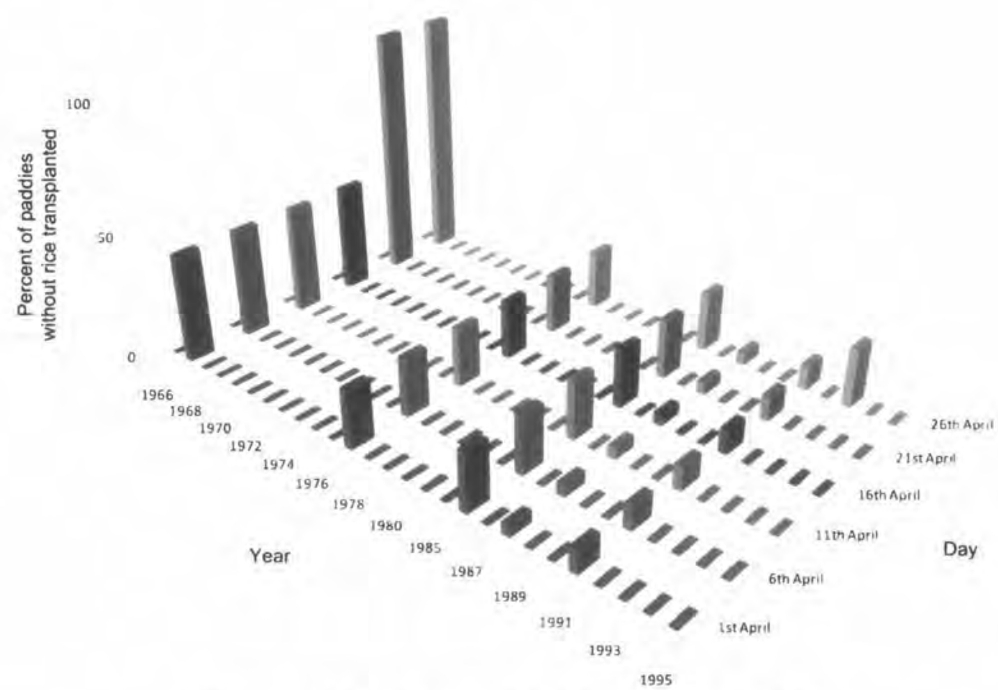


Figure 11.1 Influence of the earliest date to start nursery establishment on the accumulated number of nursery re-establishments

a) Household B: the beginning of RLR establishment set in April



b) Household B: the beginning of RLR establishment set in May

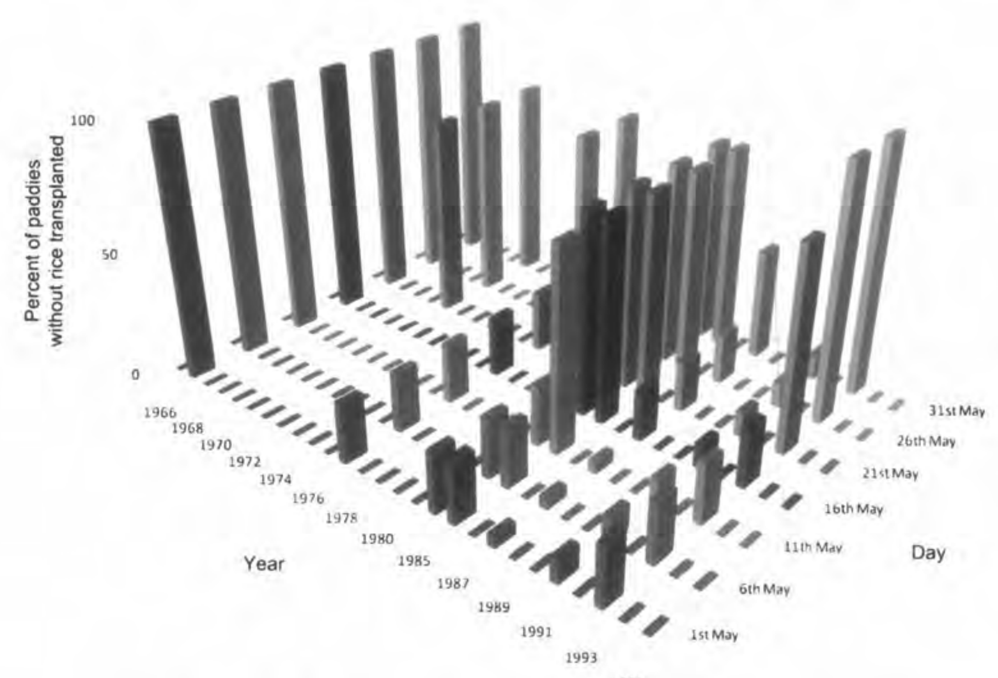


Figure 11.2 Influence of the earliest date to start nursery establishment on the percentage of paddy filed without rice transplanted (household B) under 27 climatic years.

Different initial water levels in farm ponds

Four values (0, 100, 200, and 300 cm) were set for the initial water level in farm ponds. After running 108 simulations to test these values under the 27 available climatic years, the result shows that water was equally more frequently used as soon as the initial water level was higher than 100 cm (see Figure 11.3). Because the farm pond belonging to household B is larger, it could store more water volume leading to more irrigation occurrences. When water is available (initial water level > 100 cm), logically there are fewer nursery re-establishments because water stress can be mitigated (Figure 11.4).

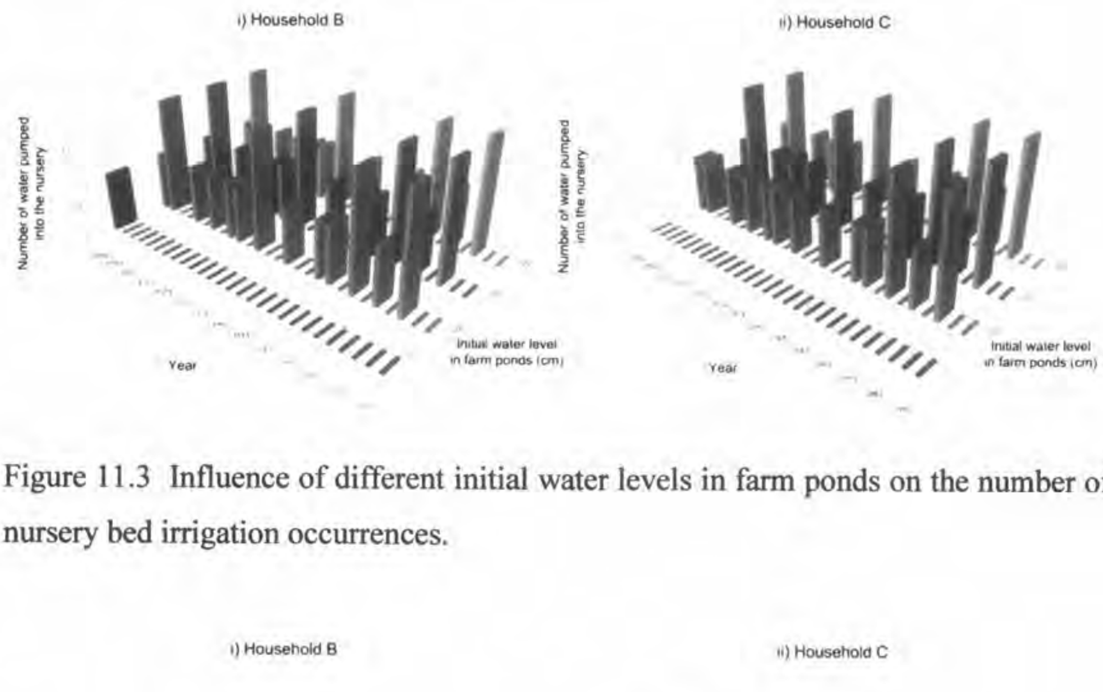


Figure 11.3 Influence of different initial water levels in farm ponds on the number of nursery bed irrigation occurrences.

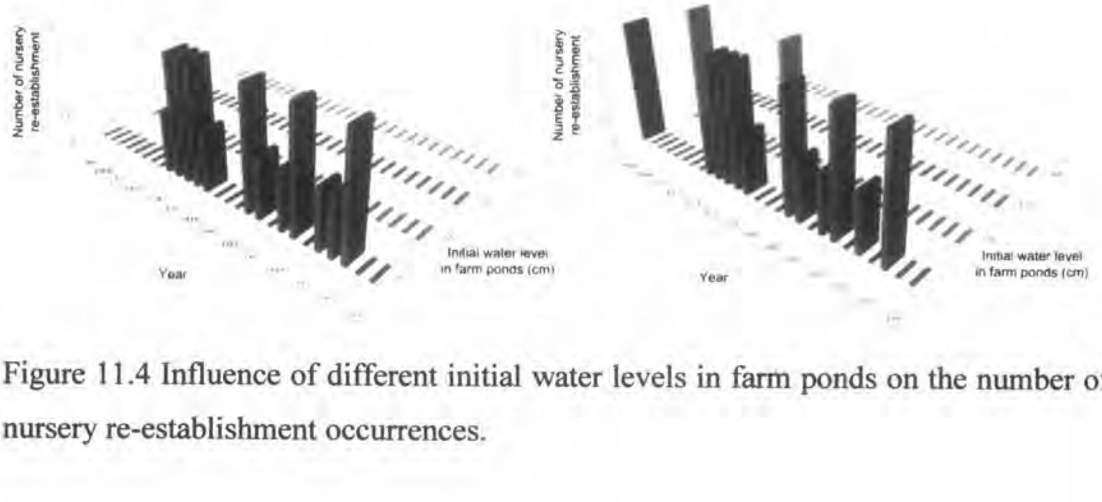


Figure 11.4 Influence of different initial water levels in farm ponds on the number of nursery re-establishment occurrences.

Daily rainfall threshold to initiate RLR nursery establishment

Six values were assigned to the threshold of daily rainfall needed to initiate RLR nursery establishment. The higher value of this parameter is likely to provide the fewer number of nursery re-establishments because sufficient water collected in ponding tanks of paddy fields could prevent the nursery failure caused by water stress (Figure 11.5). However, such important daily rainfalls are unlikely to happen during the early rainy season. This could lead to either the inadequate length of time for rice seedlings to be ready for transplanting, or delay transplanting as a result of the long dry spell. It, therefore, would affect the percentage of paddies with unsuccessful rice transplanted as shown in Figure 11.6.

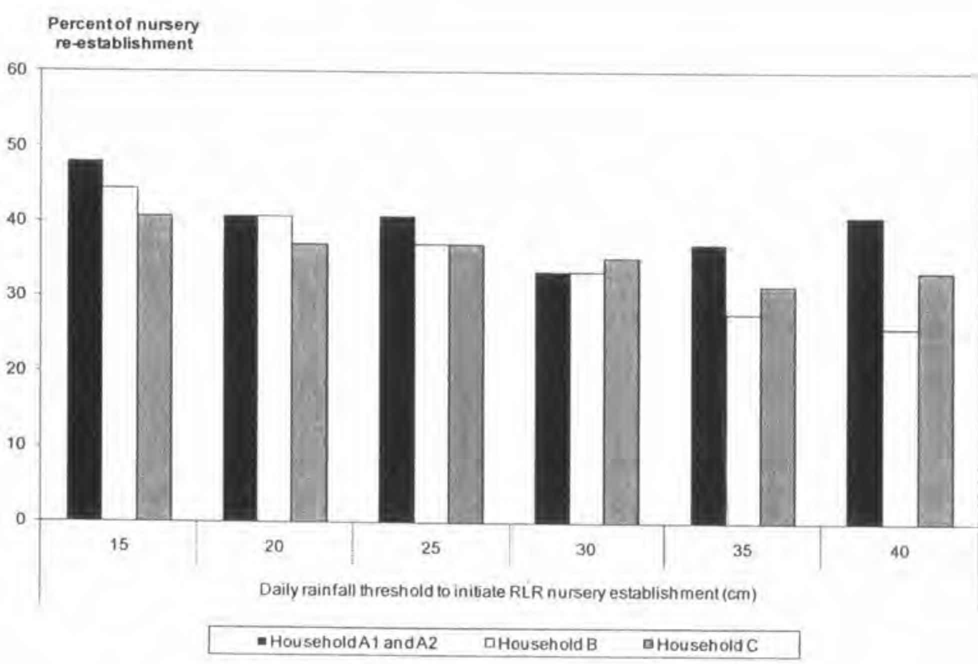


Figure 11.5 Influence of the daily rainfall threshold to initiate RLR nursery establishment on the Cumulated number of nursery re-establishments.

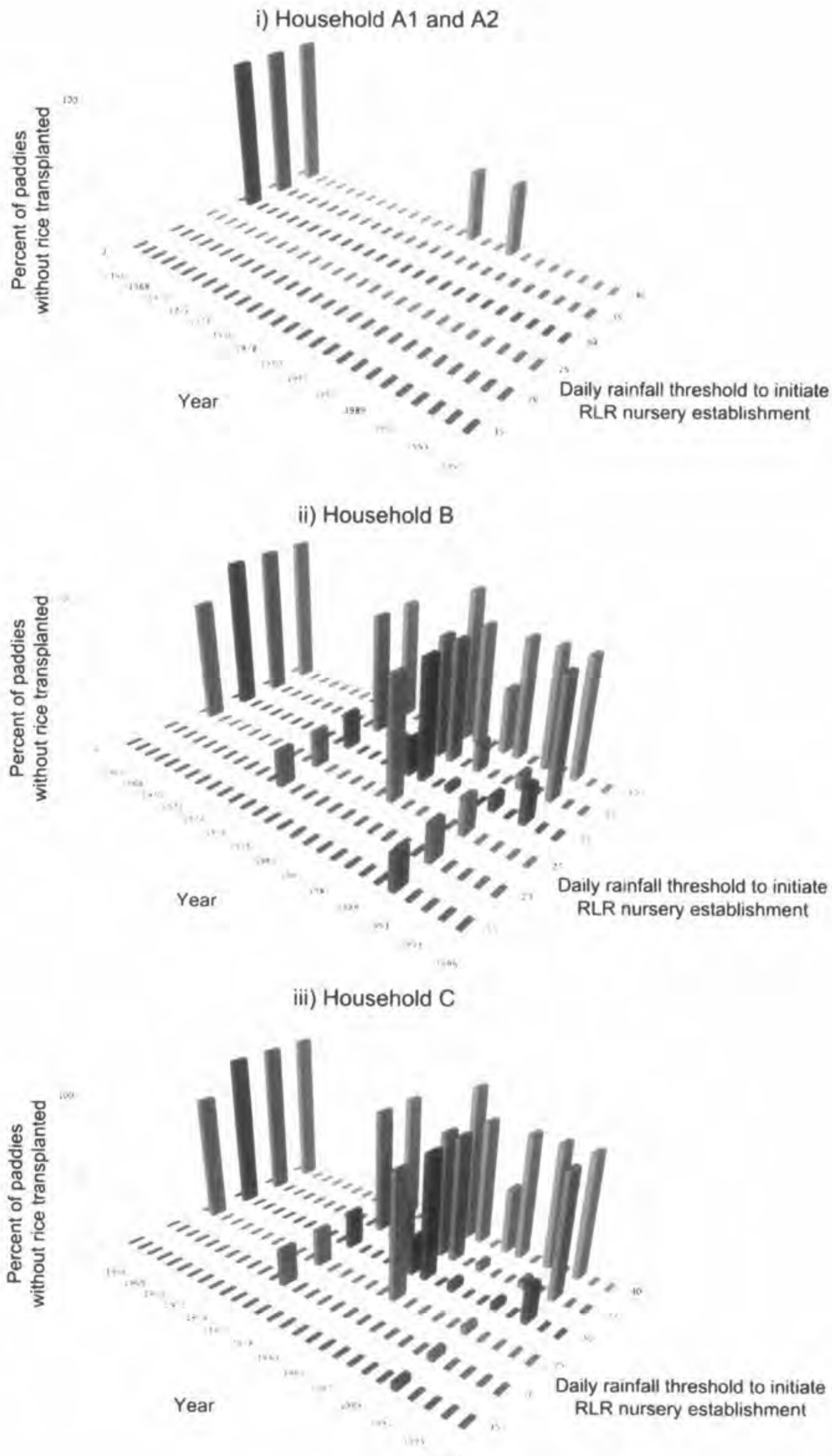


Figure 11.6 Influence of the daily rainfall threshold to initiate RLR nursery on the percentage of paddy filed without rice transplanted under different 27 climatic years.

Daily rainfall threshold to start transplanting

The daily rainfall threshold to start transplanting was varied with six values. Increasing values of this parameter cause little more occurrences of nursery re-establishment (Figure 11.7). This is because the delayed start of transplanting caused by long waiting for the daily rainfall to reach the threshold lead the rice seedlings ready to be transplanted (30 days old) for too long (more than 15 more days) in the nursery. However, this parameter is unable to trigger the complete (for the entire paddy fields) failure of rice transplanting (Figure 11.8).

To explain the slight differences (in years 1988 and 1991) between households B and C in the percentage of paddy without rice transplanted, the availability of farm workers has to be investigated. Because household B is the one with the most labour constraint (only two family members who are farm workers), it suffers more failures to complete transplanting than any other household whose land and labour ratio is lower and therefore is able to complete more transplanted paddies. This result leads us to deepen the exploration of the effects of interactions between water and labour availability on rice production of the households and on the migration patterns of their family members.

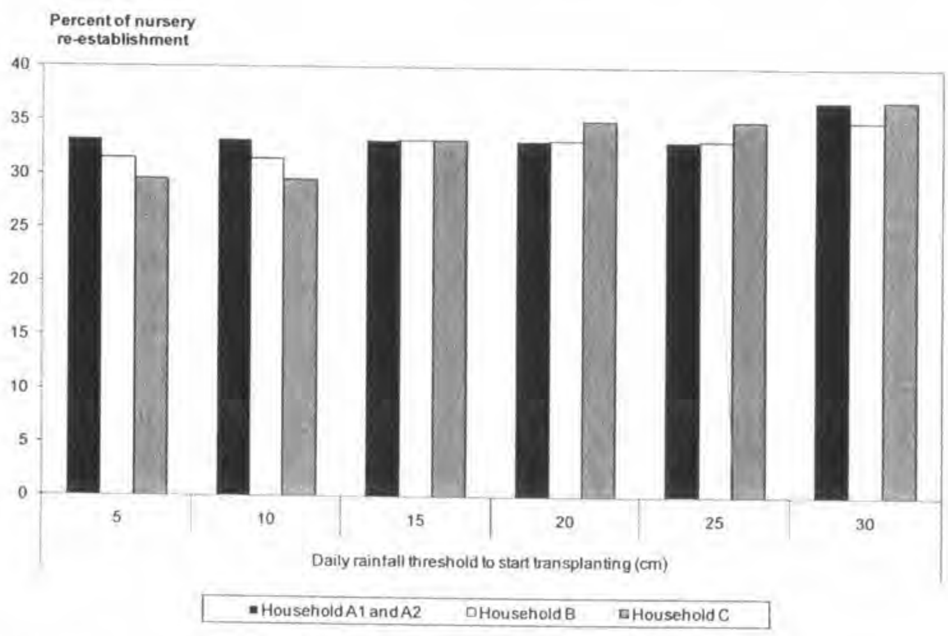


Figure 11.7 Influence of the daily rainfall threshold to start transplanting on the accumulated number of nursery re-establishment.

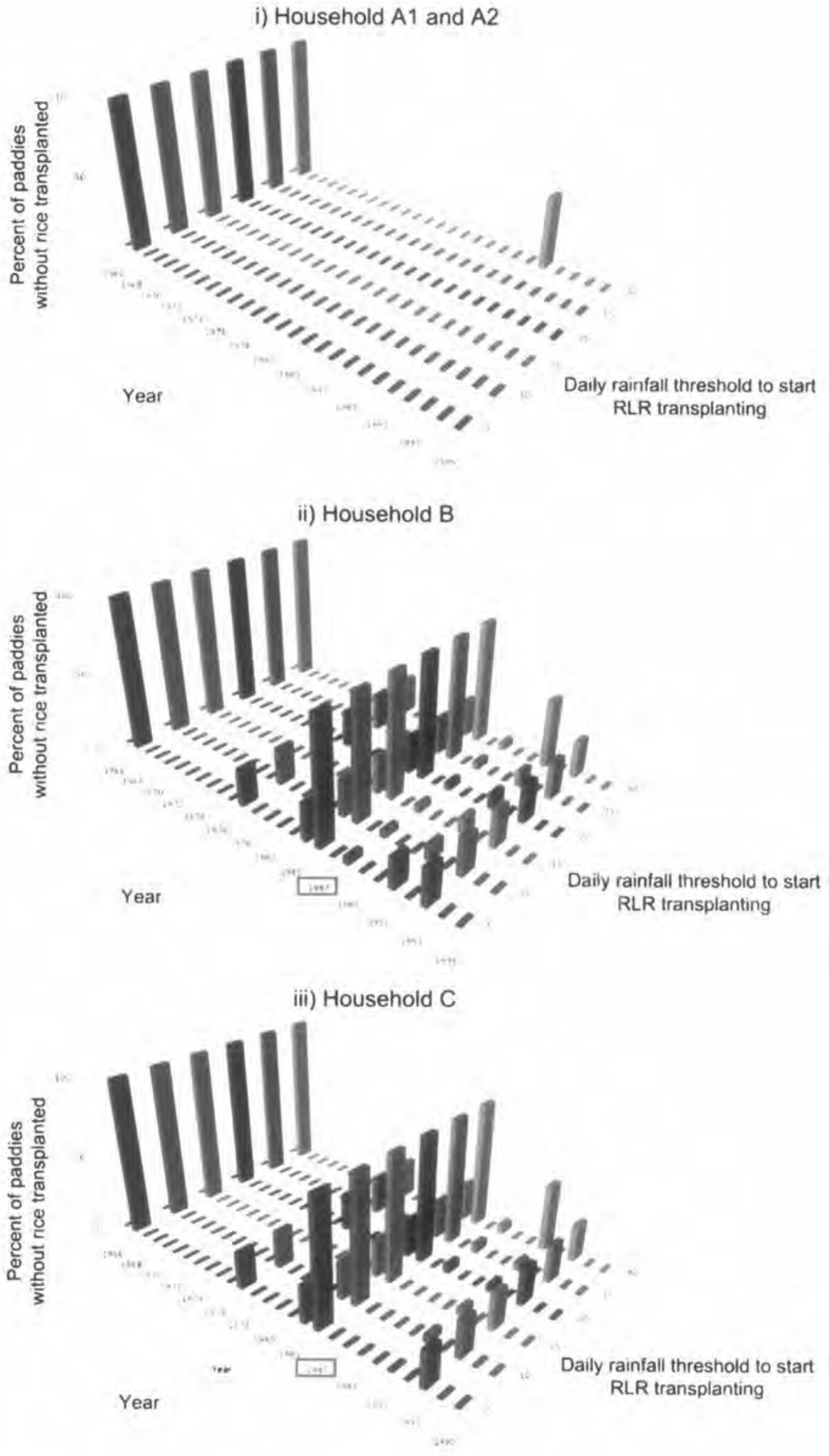


Figure 11.8 Influence of daily rainfall threshold to start transplanting on the percentage of paddy filed without rice transplanted under different 27 climatic years.

11.2.2. Exploration of Scenarios based on Water and Labour Availabilities

11.2.2.1. Scenario Identification

Nine scenarios were proposed to examine interactions between water and labour availability, as shown in Table 11.3.

Table 11.3 Coding of the 9 scenarios defined to explore the interactions between water availability and labour availability.

		Water availability (W)		
		No farm has farm pond (n)	Two large farms (B and C) have farm ponds (i)	All farms have farm ponds (a)
Labour availability (L)	No hired farm workers from outside the village (n)	WnLn	WiLn	WaLn
	10 hired farm workers from outside the village (i)	WnLi	WiLi	WaLi
	20 hired farm workers from outside the village (a)	WnLa	WiLa	WaLa

Three levels of water and labour availability are defined as none (n), intermediate (i) and all (a) available. These 9 scenarios represents intermediate situations from an extreme case of water and labour limitation (WnLn) to an extreme case virtually without limitation of water and labour (WaLa). For water availability, the 2 farm ponds in all three scenarios *Wi* are the one assigned to households B and C in the baseline scenario. However, in all three scenarios *Wa*, a similar pond (0.16 ha with 3 m deep) is assigned to each household. In all scenarios with farm ponds, the initial water level in all farm ponds is set to 200 cm. This value is based on the result of the sensitivity analysis: there is no difference of water use once the initial water level in farm ponds is higher than 100 cm. Here, to ensure that water is adequately available over 5 successive years, 200 cm of initial water level in farm ponds was set.

For all the other parameters, the values are the same than in the baseline scenario (see chapter X for more details). Five indicators defined at the household level will be analyzed: (i) income generated from rice sales, (ii) labour cost to produce rice, (iii) wage received by family members who are hired by other households, (iv) number of seasonal migrants and (v) number of permanent migrants.

The duration of a simulation is set to 5 successive years are used so that the evolution of labour status of households' members can be investigated. To account for the climatic variability, the 19 sets of 5 successive years presented in table 11.2 have been run for all 9 scenarios.

11.2.2.2. Scenario Analysis

Income generated from rice sales

The result shows that the labour availability, in all three sets *Wn*, *Wi* and *Wa* scenarios, influences positively and significantly the household income generated from rice sales (Figure 11.9). This is because more farm workers can accelerate the rice harvest leading to high paddy quality and high price in the market.

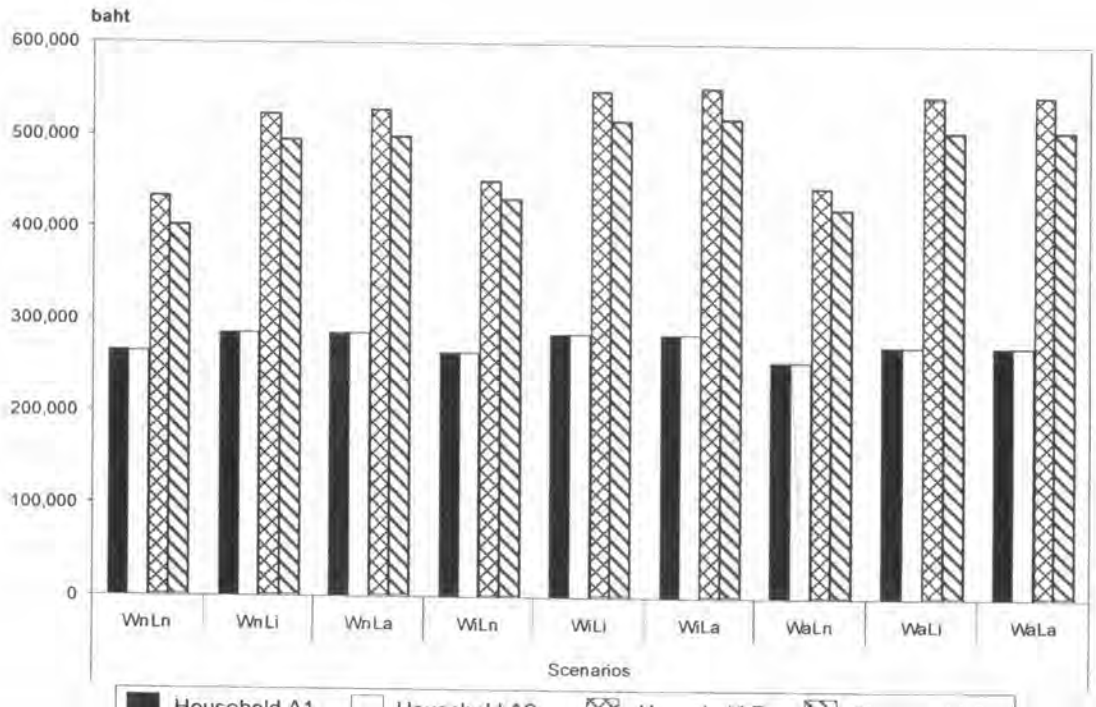


Figure 11.9 Average (over 19 simulations under different climatic conditions) of accumulated (over 5 years) household income from rice sales per household per scenario.

However, the most significant income differentiation is between "no additional labours from outside the village (*Ln*)" and "10 hired workers from outside

(*Li*)". There is no difference between *Li* and "20 hired workers from outside (*La*)" This is indicating that more workers may not provide different outcome once the all paddy was completely harvested before 1st December for high paddy quality. Even if such completeness was reached long before the date threshold, it would not increase the income generated from rice, but on the opposite more cash would be spent for hiring extra workers as shown in Figure 11.10.

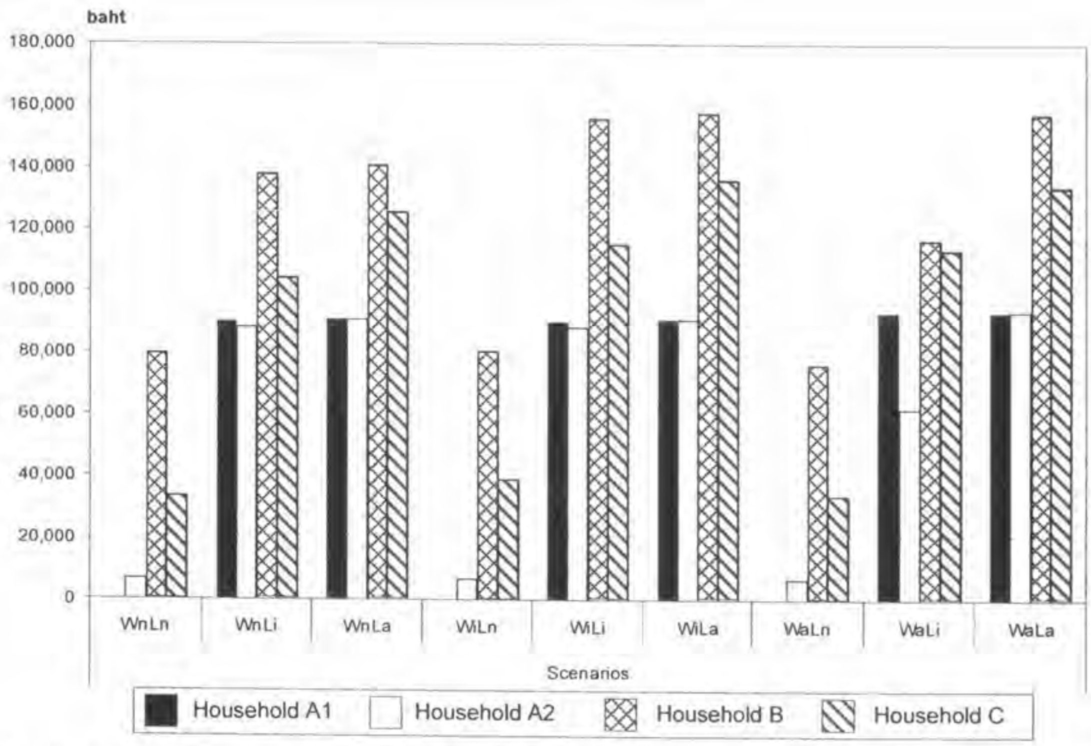


Figure 11.10 Average (over 19 simulations under different climatic conditions) of accumulated (over 5 years) household labour cost per household per scenario.

Hired wage received from on-farm employment to produce rice

In contrast to the household income, the differentiation of hired wage received by small holders A1 and A2 is significantly found between *Li* and *La*: the difference between *Li* and *Ln* appears insignificant (Figure 11.11). Based on Figure 11.9 and 11.11, it seems that the balance between household income and wage earned from on-farm employment needs careful considerations so that the household income from rice can be satisfying while the wage income of small holders is not decreased. Besides, based on this synthesis, such balance seems to be achievable.

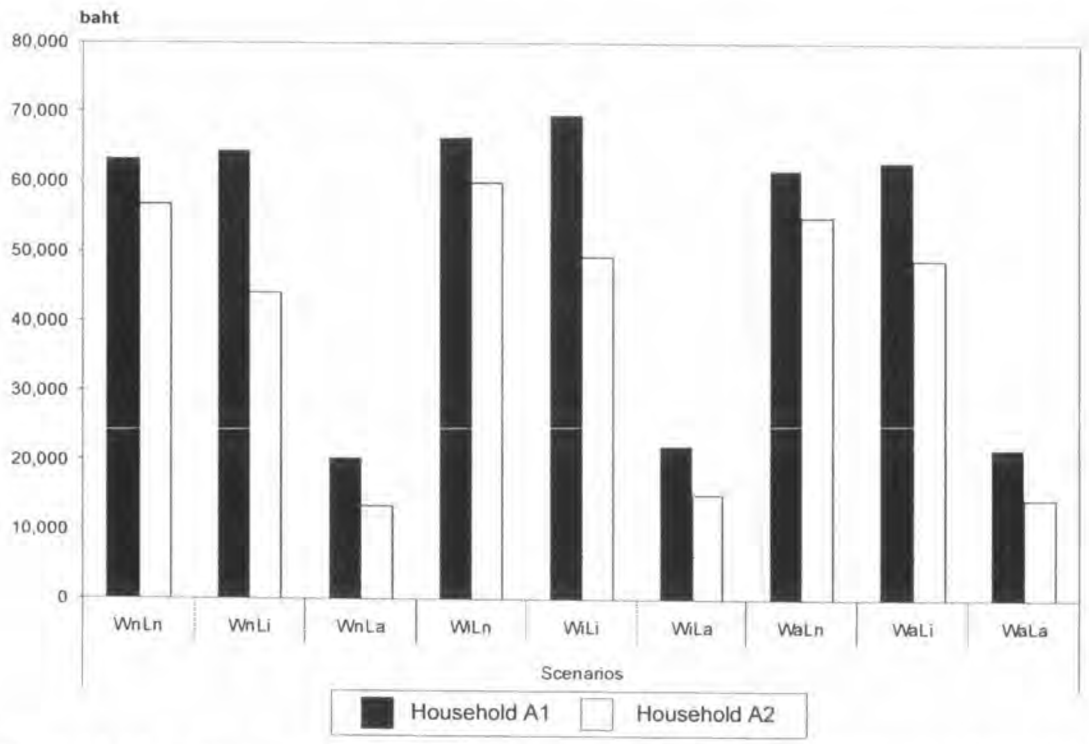


Figure 11.11 Average (over 19 simulations under different climatic conditions) of accumulated (over 5 years) household hired wage employment per household per scenario.

Number of migrants

The number of seasonal migrants is clearly influenced by the availability of hired farm workers from outside the virtual village. As shown in Figure 11.12, when farm workers from outside are unavailable (scenarios with *Ln*), the seasonal migrants is significantly lower than when farm workers from outside are available. This could be caused by an indirect effect of more household income received from wage employment on migratory patterns.

However, the effect of water availability on labour migration is not clear. Only when considering the *Ln* set of 3 scenarios, it can be notice that when assigned with ponds plenty of water (*WaLn*), small holders have more seasonal migrants. Anyway, further investigation is needed to deeply examine the interaction between water availability and labour migration.

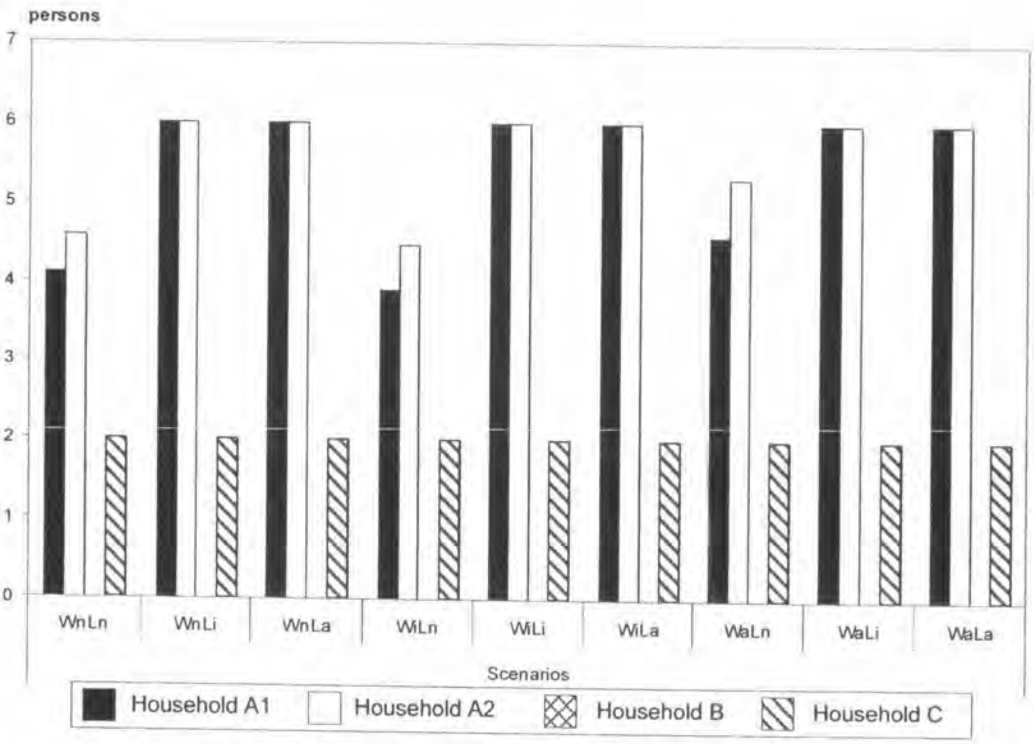


Figure 11.12 Average (over 19 simulations under different climatic conditions) of accumulated (over 5 years) number of seasonal migrants per household per scenario.

The monitoring and evaluation of this ComMod process is presented in the next chapter. It deals with the assessment of the ComMod effects on participants, mainly different types of local rice growers and the analysis of effects across farm types.