

# Effect of Population Dynamics and Mechanization on Agricultural Land Use: Evidence from Nang Rong, Thailand

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*This study examines the effects of population dynamics and the role of agricultural machinery on agricultural land use in Nang Rong district, Thailand between 1994 and 2000. The unit of analysis is the household, using data from a sample of 5,255 households. The results show that population dynamics continuously influenced agricultural land use. Migration was the most influencing factor among population dynamic indicators; it had negative effects on land use for rice and field crops, but positive effects on multiple and rotation crops. Death events had some negative effects on land use for field crops, while in-migration had positive effects on rice growing. Agricultural machinery factors produced a great influence on land use changes both in terms of number and size of plots, and play an essential role in the enhancement of agricultural practices. In conclusion it is important to recognize that the effect of population dynamics and the use of agricultural machinery are key indicators that result in crucial influences on land use.*

**Keywords:** *population dynamics, mechanization, agricultural land use, Nang Rong*

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## Introduction

Population size is one of the key factors that can have an effect on agricultural land use. Changes in demographic patterns, such as increased fertility, decreased mortality, and increased migration can have an important effect on land utilization. With high rates of population growth, for example, land areas allocated for housing, agricultural cultivation, infrastructure and industry will inevitably increase to meet the demand of the population (Idrisi, 2005). In the long term, there is a need for agriculture to be more intensive and to produce sufficient food. In most cases, agricultural intensification involves not only greater use of human labor but also improved technologies (Boserup, 1965). This process of agricultural intensification eventually impacts upon land use in many dimensions.

In Thailand, as in many developing countries, land utilization has changed primarily from forest to agricultural uses (Charupatt, 1998). This process of change can be seen in reductions of forest land areas while agricultural land areas have increased over the past several decades. For example, during the period from 1950 to 1974, forest areas declined from 273,600 to 131,520 square kilometers (Office of Agricultural Economics, 2000). With the decline of forest land, the area used for agricultural purposes increased from 37% in 1980 to about 42% in 1995 (Ministry of Agriculture and Co-operatives, 2003). This change took place over a significant period of time and occurred alongside changes in demographic dimensions.

However, in recent decades, expansion in agricultural land has been restricted, due to both limited land area available and the need to maintain forest land for ecological purposes. Yet, increases in food production are necessary not only for consumption purposes but also for generating income (Entwisle & Chamrathirong, 1998). This, combined with the process of social and economic change, has led to changes in agricultural practices characterized by increasing use of technologies.

This paper aims to understand changes in agricultural land use in the context of a rural setting in Thailand in the late 20<sup>th</sup> century. The analysis addresses the key question of how such change can be understood in light of population dynamics and changes in the use of agricultural technologies. For analytical purposes, agricultural land use will be measured in terms of the number and size of land parcels for each crop at the household level.

## Changes in agricultural land use: What do we know?

The causal linkage between population and land use has long been a subject of interest among scholars in different fields. Interest in the connection between population and food production may be traced back to the work of Thomas R. Malthus (1766-1834) widely known in the late 18<sup>th</sup> to early 19<sup>th</sup> century (Malthus, 1798). According to Malthus, a population will increase faster than food production. Therefore in the long term, population growth will be checked not directly by “limited availability of food”, but largely by social and cultural processes that have been influenced by concern about the imbalance of growth between food and population. Such processes may be expressed in terms of positive and preventive checks on population growth. Positive checks involve phenomena that have a direct effect on population size such as famine and war, while preventive checks have to do with cultural practices that slow down population growth such as delayed marriage and birth control (Malthus, 1798). In Malthus’ perspective, food production has a direct effect on population changes.

Ester Boserup (1965), a Danish economist, viewed this in a different perspective. According to Boserup, it is population that influences food production, particularly in terms of agricultural practices. Boserup’s theory begins with the issue of a population increase that puts pressure on food production. This leads to agricultural intensification in three aspects. First, agricultural land may be expanded by different means. Agricultural practices based on land expansion are generally known under the concepts of the slash and burn technique commonly practiced in many parts of the developing world. By nature, this practice is land intensive. But in many cases, land is limited and people have to put more labor into agricultural production in order to maintain the level of food supply. Such labor intensive techniques can produce sufficient food provided that population pressure does not increase too rapidly. However, with rapid population growth in most societies during the 20<sup>th</sup> century, food production has become more mechanized to produce sufficient food for the increasing population. As such, population pressure is an important factor behind the agricultural evolution from land-intensive to labor intensive and finally to technological intensive (Boserup, 1981).

Boserup’s theory is supported by several studies. For example, research in South Africa found that excessive population pressure has led to the utilization of marginal land, short fallow periods, and conversion of pasture and natural forest lands into cropland with an increasing number of crops (May, 1995). Another study

in Java found similar results. There, population pressure, especially in the lowland areas, led to more intensive agricultural practices (Verburg, Veldkamp, & Bouma, 1999).

Although population size is an important factor in agricultural land use change, other factors are also involved. These include ecological, geographical, market, and policy-level factors. A study in Indonesia by Clifford Geertz (1963) found that influence of population factors occurred alongside ecological and geographical factors. Geertz defined such changes under the concept of “agricultural involution” which is more or less similar to the concept of agricultural intensification (Geertz, 1963). A literature review on this subject by Wongsachue, Sawangedee, and Rindfuss (2008) found that many factors additional to the ones reported above have an effect on agricultural land use. These include market demands, price of products, biomass, and the physical characteristics of the land (Wongsachue, Sawangedee, & Rindfuss, 2008).

According to the previous studies, even if there are several factors affecting land use, it is population and machinery that nowadays mainly influence agricultural practices. Hence, the main analytical framework of this study draws on the concept that population affects agricultural production. At the household level, agricultural practices may become intensified in the form of land intensification, labor intensification, and/or technology intensification as stated in Boserup’s theory.

## Research Setting

This paper is based on research carried out in Nang Rong District of Buri Ram Province, in the northeast region of Thailand. Nang Rong is located in the southern part of the Korat Plateau. The soil is generally highly weathered and leached, with deficiencies in nutrients, low water-holding capacity, and low organic matter content. Agriculture in this area, like in other parts of the region, is dominated by growing of wet rice and upland cash crops; all rely almost entirely on rainfall (Entwisle & Chamrathirong, 1998).

During the previous decades Nang Rong experienced many demographic, social and economic changes that had a significant effect on land use. Although rice remains an important crop, other market crops have also been introduced, especially cassava, sugar cane, maize and perennial trees such as rubber, eucalyptus, and fruit trees

(Rattanawarang, 2002). As a result, some paddy fields were changed to areas where field crops were grown in response to international market demands. Also, some land parcels were transformed to buildings in accordance with development trends. In terms of infrastructure development, improvement of roads, electricity, water supply, bus services, machines, and communication tools has also taken place. Several kinds of agricultural technologies were imported to support the new planting processes (Office of Agricultural Economics, 2000; Rindfuss et al., 2003).

Besides rapid social change, demographic change is the phenomenon that has seen the greatest change. Natural increase in the population of Nang Rong continued to grow, but with a lower rate from the 1990s until the present. The high rate of out-migration during these years occurred among young adults and the working age population. This resulted in a labor shortage, and laborers from neighboring countries such as Cambodia, Lao and Vietnam were imported to substitute for the out-migrants (Entwisle, Walsh, & Rindfuss, 1997). For this reason, the setting of Nang Rong, with a number of variants in population dynamics, rapid social change, greater use of agriculture machinery and other factors, provides an interesting and appropriate place to investigate these interrelationships.

## Data and Methods

This analysis used panel data from the research project, “Demographic Responses to a Changing Environment in Nang Rong”, conducted in 1994 and 2000 by the Institute for Population and Social Research (IPSR), Mahidol University in collaboration with Carolina Population Center (CPC), University of North Carolina at Chapel Hill. The unit of observation for this study is households, with 5,255 households in the sample.

The advantage of using this particular dataset is that it provides not only rich information on population dynamics measured by the household roster, the life history calendar and variables such as socio-economic status, assets and tools, fertility, mortality, migration processes, land use patterns and agricultural equipment of the household. These variables provide an opportunity for uncovering the interrelationships among people and their environment. Systematic probability random sampling was applied in the sample areas at the sub-district level and village level. Finally, a complete census of all households in the sample villages was collected.

Data analysis begins with a description of key household demographic characteristics, use of machinery and land use. Multiple Regression Analysis was performed to identify the effect of population dynamics and the role of machinery utilization. Independent variables comprise two sets of household data (i) data on population dynamics which includes births, deaths and migration; and (ii) data on the use of agricultural machinery or essential farming tools such as large tractors, harvesting machines, water pumps, and pickup trucks. The dependent variable was land use, measured by two aspects of land use changes: (i) the number of land parcels by type of crops grown, and (ii) the size of land parcels. Crops commonly grown in the Nang Rong area are classified into three major types: (i) rice, (ii) field crops and other single crops, such as cassava, sugarcane, maize, vegetables, fruit trees and rubber trees, and (iii) rotational and multiple crops.

The construction of variables for the analysis was built upon the causes and consequences perspective. Population dynamics variables were constructed from the life history calendar data via the retrospective method. Increase and decrease in the number of household members were the result of the net calculation of population events -births, deaths and migration. While birth and deaths are calculated directly, migration is measured in a different way. This is due to the dynamics of migration, which could occur multiple times for the same individual. However, in this analysis movement of individual members of the household, when it occurs, is counted as a single event regardless of the number of times the individual moves. Two types of movement are considered: i) moving out of the household, and ii) moving into the household. The immediate consequence of such migration is a change in the number of household members. The variables on use of machinery are measured in terms of the actual utilization of modern farm equipment by the household in 1994 and 2000.

A variable on agricultural land use was created to measure two aspects of change. The number of land parcel changes for each type of crop was built by matching the data of each individual land parcel. Type of use for each land parcel was observed, and the number of each type of crop was counted separately. Three variables of agricultural land use were created 1) rice growing, 2) field crops and other crops, and 3) multiple and rotational crops, as described above. The change in size of land parcels was constructed by accumulating the agricultural area of each household. The purpose of this variable is to measure the magnitude of use.

For the analysis, the variables are specified by two statistical models to address different research objectives. Model 1 is designed to examine the effects of population dynamics and use of machinery on land use changes, measured in terms of changes in the number of land parcels by the three major crop types. It is separated into three statistical equations based on the dependent variables, consisting of rice growing, field crops and other crops, and multiple and rotational crops. Model 2 examines the effects of population dynamics and use of machinery on the size of individual land parcels.

## Results

### a) General situation of the population, machinery used, and agricultural land

Table 1 presents descriptive statistics on population events that occurred in the sample households during the study period of 1994 to 2000. During the 7-year period, households that experienced birth were of greater number (and proportion) than those that experienced death. Among those that experienced birth and death, the majority had only one such event. Altogether, about one-third of the sample households (33.6%) experienced birth while 28.1% experienced death. Household experience with regard to migration is different. As will be seen in Table 1, migration experienced by the sample households was overwhelmingly out-migration. Those that experienced in-migration were of a small number/ proportion. However, as in the case of birth and death events, the majority of the households with this migration experience had only one such event.

Summary statistics of the households experiencing changes in household members is given in Table 2. As observed in this table, more than half of the households (53.5%) experienced no change in the number of members during the period from 1994-2000, while about one-fourth experienced an increase and slightly more than one-fifth experienced a decrease in the number of household members.

**Table 1:** Number and percentage of sample households with demographic events, by number of experienced events, 1994 to 2000.

Number of events experienced by HH		Demographic Events			
		Births	Deaths	In-Migr.	Out-Migr.
None	n	3,486	3,779	4,948	2,748
	%	66.3	71.9	94.2	52.3
1	n	1,379	1,128	39	2,065
	%	26.2	21.5	0.7	39.3
2 or more	n	390	348	268	442
	%	7.4	6.6	5.1	8.4
Total	n	5,255	5,255	5,255	5,255
	%	100.0	100.0	100.0	100.0

**Table 2:** Number and percentage of sample households experiencing change in the number of household members, 1994-2000

Change in household members	N	%	$\bar{x}$ *	S.D.
Increase	1,299	24.7	1.22	0.45
Decrease	1,148	21.8	-1.56	1.61
Unchanged	2,808	53.5	0.00	0.00
Total	5,255	100.0		

\* Refers to mean change in the number of household members.

During the study period (1994-2000) the use of machinery in agriculture includes mainly large tractors and harvest machines. The use of such machines has sharply increased from 71% in 1994 to 91% in 2000. It is also found that the use of vehicles for transportation increased two-fold from 37% in 1994 to 74% in 2000, while the percentage of use of water pumps increased gradually from 32% to 36% during the 7 year-period (Table 3).

**Table 3:** Number and percentage of households using machinery, 1994 to 2000

Use of machinery in agriculture		1994			2000		
		Use	Not Use	Total	Use	Not Use	Total
Large tractor and harvest machine	n	3,728	1,527	5,255	4,761	494	5,255
	%	70.9	29.1	100.0	90.6	9.4	100.0
Water pump	n	1,663	3,592	5,255	1,892	3,363	5,255
	%	31.6	68.4	100.0	36.0	64.0	100.0
Vehicles of transportation	N	1,948	3,307	5,255	3,904	1,351	5,255
	%	37.1	62.9	100.0	74.3	25.7	100.0

Table 4 presents data on agricultural land use of the study households in order to describe the general situation of land use and its changes during 1994 to 2000 in Nang Rong. It is found that rice dominates agricultural land use of the households. The rice crop increased insignificantly from 80% in 1994 to 83% in 2000, with an average of 1.43 parcels and 1.52 parcels per household respectively. Land use for field crops and other cultivation experienced a decrease from 16%, (= 0.28) to only 7%, (= 0.12) during this period. Interestingly, land parcels that grow multiple and rotational crops doubled both in terms of percentage from 4% to 10% as well as the average number of land parcels from 0.07 to 0.19. It is thus noted that a proportion of land use for field crops and other crops probably have changed to multiple or rotational crops.

**Table 4:** Change in number and percentage of households using agricultural land for different crops and mean size of land parcels (in *rai*\*), 1994 to 2000.

Agricultural land used for different crops	Number and percentage of households and mean size of land parcel											
	1994				2000				2000-1994 Changes			
	n	%	$\bar{x}$ **	S.D.	n	%	$\bar{x}$ **	S.D.	n	%	$\bar{x}$ **	S.D.
Rice	4,221	80.3	1.43	0.95	4,356	82.9	1.52	1.03	135	2.6	0.09	1.17
Field crops and Others	814	15.5	0.28	0.55	352	6.7	0.12	0.45	-462	-8.8	-0.15	0.59
Multiple/Rotation crops	221	4.2	0.07	0.28	547	10.4	0.19	0.49	326	6.2	0.12	0.57
Total	5,255	100.0	1.79	1.74	5,255	100.0	1.84	1.96	923	17.6	0.05	2.31
Size of land parcel			23.18	24.46			20.95	23.55			-2.24	29.83

\* 1 *rai* = 1600 sqm<sup>2</sup>

\*\* Refers to mean size of land parcel used for planting different crops

## b) Effects of population dynamics and mechanization on agricultural land use

Table 5 presents results of the first statistical model which examines the effects of population dynamics and mechanization on agricultural land use changes during the study period. The dependent variable here was the change in number of land parcels planted by different types of crops: rice, field crops, and rotational/multiple crops. The independent variable included two sets of factors: population dynamics and the role of machinery. The coefficients from Table 5 show that the net increase and decrease in household members had no significant effect on any cultivation changes. The number of land parcels used to plant rice significantly increased when households experienced a member migrating in ( $\beta = .055^*$ ). Likewise, there is no effect on other types of cultivation. Conversely, the out-migration event significantly reduced number of land for rice and field crops ( $\beta = -.050^{**}$  and  $-.018^*$  respectively), but it slightly increased the use of rotational and multiple crops ( $\beta = .016^*$ ). The death of a member had a negative effect on land parcels planted with field crops ( $\beta = -.049^*$ ).

As for the effect of machinery use, results in Table 5 clearly indicate that the use of large tractors and harvest machines significantly increased the number of land parcels used for planting rice by approximately 1 parcel ( $\beta = .950^{***}$ ). But, it significantly decreased the number of parcels for upland crops, and multiple and rotational crops ( $\beta = -.468^{***}$  and  $-.192^*$ ). Use of water pumps had a positive effect on the number of land parcels planted with rice ( $\beta = .130^{***}$ ). Contrastingly, it did not have any relationship with the number of land parcels planted with other crops. Besides, the use of motor vehicles for transportation had a significant positive effect on the number of land parcels used for planting rice, and rotational and multiple crops ( $\beta = .125^{**}$  and  $.037^*$ ).

**Table 5:** Effects of population dynamics and use of machinery on land use changes from 1994 to 2000

Variables	Change in number of land parcels for different crops		
	Rice	Field crops and others	Rotational and Multiple crops
	$\beta$ (s.e.)	$\beta$ (s.e.)	$\beta$ (s.e.)
<b>Population dynamics</b>			
Increase in HH members during 1994 – 2000	-.025 (.072)	-.036 (.036)	.021 (.035)
Decrease in HH members during 1994 – 2000	-.059 (.070)	.052 (.035)	.046 (.034)
Births 1994 – 2000	.033 (.050)	.027 (.035)	.002 (.024)
Deaths 1994 – 2000	-.047 (.048)	-.049* (.024)	-.006 (.023)
In-migration 1994 – 2000	.055* (.022)	.013 (.011)	-.018 (.011)
Out-migration 1994-2000	-.050** (.017)	-.018* (.009)	.016* (.009)
<b>The use of machinery</b>			
Use of large tractors 1994-2000	.950*** (.198)	-.468*** (.100)	-.192* (.097)
Use of water pumps in 1994-2000	.130*** (.034)	.005 (.017)	-.024 (.016)
Use of vehicles for transportation in 1994-2000	.125** (.038)	-.018 (.019)	.037* (.019)
Constant	-.882*** (.198)	.330** (.100)	.284** (.097)
df. (Total)	5254	5254	5254
F	8.211***	3.580***	2.290*
R <sup>2</sup>	.014	.006	.004

\* Significant at level 0.05, \*\* Significant at level 0.01, \*\*\* Significant at level 0.001

For convenience in understanding the effects of population dynamics and mechanization on changes in land parcels used for rice in the first model, the coefficients of important factors such as in-migration, out-migration and the combined effect of the use of machinery were simulated in the probability of changes in the number of land parcels used for rice cultivation between the two observations, as shown in Figure 1.

The average number of land parcels used for growing rice reduced from 1.43 parcels per household in 1994 to about 0.55 parcels in 2000 when all other factors have been controlled. Interestingly, the number of land parcels for rice cultivation increased slightly to 0.60 parcels when household members migrated in. By contrast, the number of land parcels used for rice cultivation reduced slightly (0.50) when out-migration occurred in the family. As expected, the use of machinery created a significant effect on the changes in the number of land parcels used for rice cultivation. That is, the number of land parcels used for growing rice increased by 1.75 parcels per household when agricultural machinery was used.

**Figure1:** Simulated probability of changes in number of land parcels for rice cultivation due to the effect of important selected factors, Nang Rong, 1994-2000

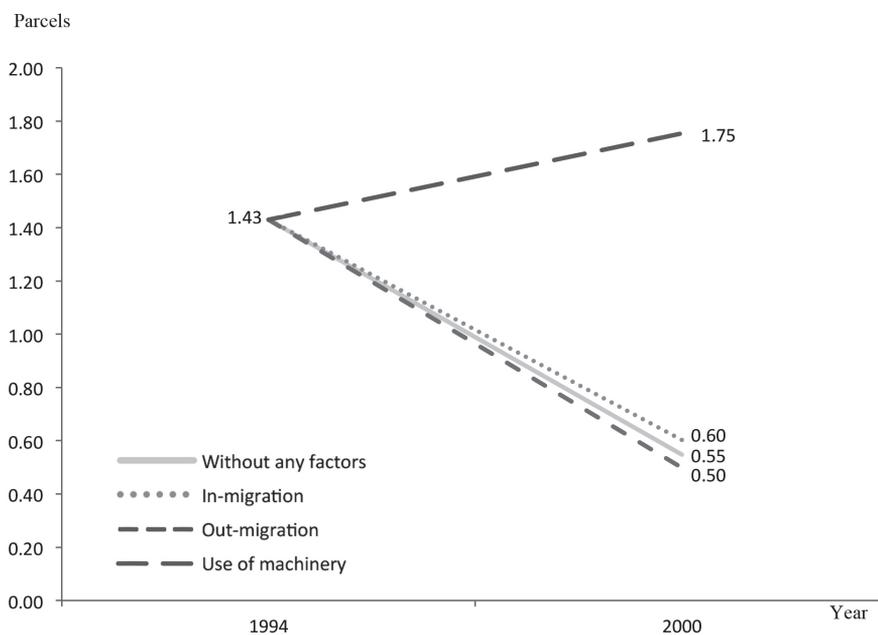


Table 6 presents the results of the second model which examines the effects of population dynamics and use of machinery on the cumulative change in size of agricultural land parcels. The dependent variable in this model was measured in terms of the change in size of combined agricultural land parcels of the household. The independent variables were population dynamics and use of machinery, similar to the first model. Results in Table 6 shows that a decrease in the number of household members strongly influenced the changes in the size of land parcels used for agriculture. For example, the size of land parcels would be reduced by approximately 5 *rai* ( $\beta = -4.567^{**}$ ) when the decrease of a household member occurred. The in-migration event of a member increased the size of a land parcel by approximately 1 *rai* ( $\beta = 1.195^*$ ). Out-migration decreased the size of land parcels by about 1 *rai* as well ( $\beta = -.992^*$ ). By the same token, use of large tractors or harvesting machines was found to greatly increase the size of land parcels for agriculture by about 12 *rai* ( $\beta = 11.814^*$ ).

**Table 6:** Effects of population dynamics and use of machinery on changes in the size of land parcels 1994-2000

Variables	Size of land parcel changes ( <i>rai</i> )
	$\beta$ (s.e.)
<b><u>Population dynamics</u></b>	
Increase in HH members 1994 – 2000	1.177 (1.837)
Decrease in HH members 1994 – 2000	-4.567** (1.837)
Births 1994 – 2000	-1.328 (1.276)
Deaths 1994 – 2000	0.777 (1.223)
In-migration 1994 – 2000	1.195* (.574)

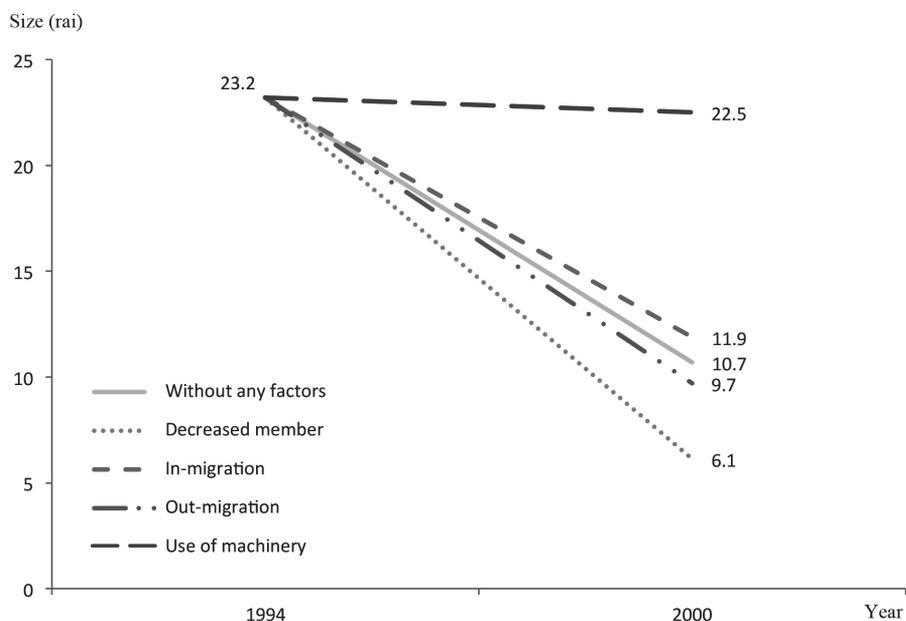
**Table 6** (cont.)

Variables	Size of land parcel changes ( <i>rai</i> )
Out-migration 1994-2000	-.992* (.446)
<b><u>The use of machinery</u></b>	
Use of large tractors 1994-2000	11.814* (5.054)
Use of water pumps 1994-2000	.404 (.861)
Vehicle for transportation 1994-2000	-.524 (.971)
Constant	-12.508* (5.067)
df. (Total)	5254
F	3.394***
R <sup>2</sup>	.006

\* Significant at level 0.05, \*\* Significant at level 0.01, \*\*\* Significant at level 0.001

To gain greater understanding of these interrelationships, Figure 2 shows the simulated probability of changes in the size of agricultural land parcels of households during the observation period. The average size of land parcels decreased from 23.2 *rai* in 1994 to 10.7 *rai* in 2000 when all factors were considered. Similarly, the size of land parcels further reduced to 6.1 *rai* and 9.7 *rai* when a decrease in the number of household members or outmigration occurred. In-migration events maintained the change in the size of agricultural land parcels at 11.9 *rai*, while use of large tractors and harvesting machines had the effect of strongly maintaining the size of agricultural land parcels at 22.5 *rai* per household in 2000.

**Figure 2:** Simulated probability of change in size of land parcels due to the effect of important selected factors, Nang Rong, 1994-2000



## Conclusion and Discussion

Empirical findings from this study indicate that population dynamics and mechanization play a significant role in changing agricultural land use at the household level in Nang Rong district. Migration is the strongest factor among population dynamics influencing change in land use patterns. For instance, in-migration had a positive effect on the number of rice paddy fields and their size. On the contrary, out-migration had a negative effect on both rice and field crop cultivation, while having a positive effect on rotational and multiple crops. Births and deaths of household members did not have a strong effect either on changes in size or and number of land parcels. Besides this, decreases in the number of household members produced negative effects on the size of land parcels used for agricultural cultivation.

The use of agricultural machinery, however, comes to play a more important role in the enhancement of agricultural production, particularly land use for rice cultivation. Machinery, including large tractors, water pumps, and vehicles, are used to substitute

for human labor in many processes of agricultural practice. They are able to transform the undulating land into paddy fields by using large tractors, irrigating with water pumps, and accessing inhospitable land by trucks or walking tractors. That is to say, obstacles to incorporating the best strategies for land management can be overcome by use of technological advances (Van der Eng, 1993; Moncharoen, Vearasilp & Eswaran, 2001). Thus, it is reasonable to conclude that population dynamics and mechanization are important factors that directly affect agricultural land use. The pressure from population events was replaced by labor and technology intensification. The negative effect of high growth rates and out-migration is not a danger to agricultural land use as thought previously. The demand for human labor can be effectively substituted by agricultural machinery in several processes of production.

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