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Orawan Srisompun, Thanaporn Athipanyakul, Somporn Isvilanonda

Mahasarakham University, Kasetsart University, Knowledge Network Institute of Thailand

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Thailand Vietnam Socio Economic Panel (TVSEP)
TVSEP Database Centre
Leibniz Universität Hannover
Königsworther Platz 1
30167 Hannover, Germany

Contact: thanh.nguyen@iuw.uni-hannover.de

The Adoption of Mechanization, Labour Productivity and Household Income: Evidence from Rice Production in Thailand

Orawan Srisompun[1], Thanaporn Athipanyakul[2] and Somporn Isvilanonda[3]

Abstract

The planning of mechanization requires the quantitative assessment of a mechanization index and the impact of this index on agricultural yield and economic factors. The purpose of this paper is to investigate the effect of the adoption of agricultural mechanization and scale production on labour productivity and the generation of income for farmers. Cross-sectional data for jasmine rice production by 569 households in 1,003 plots in the north eastern part of Thailand in 2017 were employed. The study found that the average rice planting workforce and labour productivity have an inverse relationship with planted area, while large farms have the highest ratio for machine labour to workforce. The rice yield, labour usage and labour productivity of the farmers varied by mechanization level (ML) and farm size while different levels of Machinery Owned labour (MO) have no effect on rice yield. Therefore, there are three main suggestions: 1) performing land consolidations, since applying a production strategy with large rice paddies may increase labour productivity and the net profit of rice famers; 2) improving the quality of machinery for use in rice production in Thailand, especially the performance of the machinery to prevent losses during harvest; and 3) increasing the mechanization level to 50-75%, which could also increase labour productivity and net returns.

Keywords: Family labour, Farm size, Hired labour, Multivariate analysis-of-variance, Pillai's statistics, Production cost, Rice yield, Small farm

JEL: Q12, Q16, Q18

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[1] Department of Agricultural Technology, Faculty of Technology, Mahasarakham University ,44150 Thailand (corresponding author; E-Mail: orawan.s@msu.ac.th)

[2] Department of Agricultural and Resource Economics, Faculty of Economics, Kasetsart University, 10900, Thailand

[3] Knowledge Network Institute of Thailand, Bangkok 10400, Thailand

Introduction

Agricultural mechanization implies the use of various power sources and improved farm tools and equipment, with a view to reducing the drudgery of human beings and draught animals, enhancing the cropping intensity and the precision, timeliness and efficiency of various crop inputs, and reducing the losses at different stages of crop production. The objective of farm mechanization is to enhance overall productivity and lower the cost of production (Verma, 20106. There are two general types of agricultural labour in developed countries: owner-operator labour (or farm household labour) and hired labour. Mechanization affects both sources of labour, but in slightly different ways. Mechanization tends to expand the reach of owner- operator labour, resulting in larger farms (Schmitze & Moss, 2015).

The agricultural mechanization of rice production in Thailand was one of the consequences of the green revolution in the 1960s that caused the distribution of photoperiod insensitive varieties of rice, so that farmers in irrigated areas who accepted the new rice varieties with a higher cropping intensity caused a higher demand for labour for rice production (Isvilanonda & Wattanutchariya, 1994). Meanwhile, the expansion of industrial and service segments has increased the labour demand for non-agricultural segments, and wages in these segments are higher than agricultural wages. There is therefore a move of labour from agricultural to other segments (OAE, 2016), which is the key push factor that has increased the rate of use of machinery as a replacement for human labour for rice production in Thailand consecutively. Currently, the result is a labour shortage arising from the absorption of labour into the industrial and service segments and aging farmer issue were push factor to adoption of agricultural machinery to replace human beings in the entire rice production process (Soni, 2016). Most farmers use small four-wheeled tractors for ploughing, instead of the labour of draught animals and wheeled ploughs of the past, robotic chemical spraying machines instead of hand sprayers, and combine harvesters instead of the labour of human beings and draught animals to carry out threshing, leading to the nationwide acceptance of combine harvesters (Poapongsakorn, 2011; Napasintuwong, 2017). This has led to the continuing fall in rice production labour, from 470 hours per hectare in 1987 to 275 hours per hectare in 2004 (Butso, 2010).

Many previous study results have implied that the adoption of agricultural mechanization to replace human labour causes a decrease in production labour because of production efficiency, and that would also decrease farmers' production costs and increase their income (Singh, 2006; Ebers *et al*., 2017; Stavytskyy & Prokopenko, 2017). However, some previous studies have shown results that contradict the concept mentioned above; they have found that farmers' production costs increased even though the rate of agricultural mechanization increased (Chowdhury *et al*., 2010). In Thailand, the hours used by machinery for rice production increased from 75 hours per hectare in 1987 to 175 hours per hectare in 2007, while farmers' production costs in 1987 were 17,500 baht per hectare and in 2007 had risen to 32,500 baht per hectare (Butso, 2010). This is partly because of the constantly increasing cost of depreciation of agricultural machinery, especially for small farmers who have smaller planted areas for whom this fixed cost increases by a greater proportion than for large farmers. Meanwhile, farmers who decide to hire machinery for ploughing, chemical spraying, or harvesting increase their variable costs, especially their variable cash costs, and affect their net income. Thus, although the key objective of the adoption of agricultural mechanization focuses on increasing production efficiency and decreasing costs, Thai rice farmers still face continuous increases in production costs even as the agricultural mechanization rate increases.

In past years, the Thai government was aware of the issue of falling rice production efficiency and increasing rice production mechanized labour cost, so there were support measures for farmers including limits on harvesting costs charged by harvester entrepreneurs (Bangkokbiznews, 2016), compensation for harvesting costs for farmers, and also agricultural machinery support for farmers' groups (Naewna, 2017). Although the policies mentioned above focused on lightening the burden of labour costs for rice farmers, and the budgets for these policies were large, their empirical result has still not appeared. Mechanization planning requires the quantitative assessment of a mechanization index and its impact on agricultural production (yield) and economic factors (Singh, 2006; Rasooli Sharabiani & Ranjbar, 2008). A study of the effect of the adoption of agricultural mechanization and changes to the scale of production on labour productivity and the generation of income for farmers would provide key data to support the efficiency of policies to improve the rice production sector in Thailand and rice producing countries in other regions.

Material and method

Level of adoption of agricultural machinery for rice production

The result of agricultural labour shortages and increases in wages affects the replacement of human labour with machinery. However, the acceptance of agricultural machinery for rice production by Thai farmers is limited because the farmers have small planted areas and no budget for investment in machinery, while many machines, such as four-wheeled tractors and combine harvesters, are expensive because they must be imported from other countries (Thepent, 2015). The adoption rate for agricultural machinery for rice production by farmers varies according to the region, the physical properties of the farm and the socio-economic status of the farmer. The measure used for the adoption of agricultural machinery uses the two indicators that are discussed in what follows. The first indicator measures the proportion of machinery used compared to the entire quantity of labour used. This is defined as the mechanization level (ML) of a farm, and is calculated by dividing the hours spent in agricultural operations by farm machinery by the total number of hours of labour, as shown in equation (1) (Zangeneh & Banaeian, 2014).

$$ML = \frac{A_m}{TA} \times 100 \qquad (1)$$

where

ML is the mechanization level;

A_m is the number of mechanized hours for rice production; and

TA is the total number of labour hours for rice production

Acceptance of machinery is important in the explanation of the changes in the mechanization of agriculture, because farmers in different locations have their own types of rice production and cultures, and this affects the adoption of agricultural mechanization. Moreover, social and economic status and the different physical properties of the farm also affect the type of agricultural mechanization. Whether a farmer uses household machinery or hired machinery for rice production activities may affect the farmer's yield productivity, so the second index used in this study is the Owned Machinery ratio (MO), which introduces the mechanized hours of machinery owned by the farmer (Mf) as a proportion of the total labour used for rice production (TL). This index determines the distribution pattern of machinery owned by farmers. Equation (2) shows the MO index:

$$MO = \frac{M_f}{TL} \times 100 \qquad (2)$$

where:

MO is the owned machinery indicator;

M_f is the number of mechanized hours using farmer's own machinery for rice production

TL is the total number of mechanized hours for rice production.

Labour productivity

The level of agricultural machinery usage may increase a farmer's yields if they use specific machinery to avoid the limitations of the farm, and this would increase the farm's profits. The adoption of agricultural mechanization then affects the yields both directly and indirectly: increased yields may result from the better quality of ploughing and the shortened ploughing time, while the indirect effect of the use of agricultural machinery is that a shortened ploughing time may increase the efficiency of the farmer's production factors including the efficiency of the use of fertilizer, chemical substances, and the ability to access irrigation (Singh, 2006). Moreover, the farmers who are able to invest in agricultural machinery for rice production are the same farmers who can purchase fertilizers and other chemical substances, and access irrigation; farmers who are unable to own machinery cannot purchase the other inputs that increase yields (Pingali, 2007). The direct effect of agricultural mechanization is on yields and labour productivity (Agarwal, 1981). The acceptance of agricultural mechanization as technology to save on the labour force increases farmers' labour productivity (Hayami & Ruttant, 1986). Generally, labour productivity can be calculated as the labour used as a share of the for rice production, as shown in equation (3), which displays the labour productivity calculation in this study (Hunt, 2000).

$$P_L = \frac{O}{L} \qquad (3)$$

where

P_L is the total labour productivity for rice (in kilograms per man-day of labour);

O is the output of rice (in kilograms); and

L is the input of labour (in man-days)

Data and analysis of variables

This article studies the effect of agricultural mechanization on labour productivity and household income by using cross-sectional data for jasmine rice production in the north eastern part of Thailand in 2017. The data came from the research project 'Poverty dynamics and sustainable development: A long-term panel project in Thailand and Vietnam, 2015 – 2024 (TVSEP)'. The data base for the 7th wave (2017), which consisted of 569 households and 1,003 plots in Burirum, Nakorn Phanom and Ubon Ratchatani province, was employed, with the variables used in the analysis being as follows:

Table 1 Names and definitions of the variables used in the study

Variable	Definition	Unit/Remark
1. Adoption of mechanization		
ML	Share of mechanization labour to total labour use	(%)
A_m	Number of mechanized hours for rice production	(h)
TA	Total labour hours for rice production	(h)
MO	Share of owned machinery to total machinery labour	(%)
M_f	Number of mechanized hours for rice production using farmer's own machinery	(hour)
TL	Total number of mechanized hours for rice production	(hour)
ML level	Mechanization level	where 1 = low (<=25%); 2 = medium (26-50%); 3 = high (51-75%); 4 = highest (> 75%)
MO level	Owned machinery level	Where 1 = no family machinery; 2 = low (share of mechanized hours using family machinery <=25%); 3 = medium level (share of mechanized hours using family machinery 26-50%); 4 = high (share of mechanized hours using family machinery 51-75%); 5 = highest (share of mechanized hours using family machinery share > 75%)
2. Labour productivity		
P_L	Labour productivity	(kg per man-day of labour)
O	Output of rice	(kg)
L	Input of labour used for rice production	(Man-days)

LP level	Labour productivity level	Where 1 = low (<=50 kg per man-day); 2 = medium low (51-100 kg per man-day); 3 = medium high (101-150 kg per man-day); 4 = high (151-200 kg per man-day) 5= highest (> 200 kg per man-day)

Equality of means and variance of productivity and rice income

In order to analyse the effects of the adoption of machinery on the yield, the productivity and the profitability, it is necessary to prove that there is a statistically significant difference in average profitability and rice yield. We divided the scale of production of the farms in the rice production area into four groups, as follows: (i) marginal farm (area cultivated for rice <= 1 hectare), (ii) small farm (area cultivated for rice 1-2 hectares), (iii) medium farm (area cultivated for rice 2-4 hectares), and (iv) large farm (area cultivated for rice > 4 hectares).

The analysis divides the ML (mechanization level) into four groups, as follows: (i) low level of agricultural machinery usage (ML <= 25%), (ii) medium level of agricultural machinery usage (ML = 26-50%), (iii) high level of agricultural machinery usage (ML = 51-75%), and (iv) highest level of agricultural machinery usage (ML > 75%).

We also divided the type of rice production mechanization according to the MO level into five groups, as follows: (i) used only owned machinery labour or did not use any machinery, (ii) low share of hired machinery (MO <=25%), (iii) medium share of hired machinery (MO = 26-50%), (iv) high share of hired machinery (MO = 51-75%), and (v) highest share of hired machinery (MO > 75%).

Using a MANOVA analysis (multivariate analysis-of-variance), we tested the hypothesis that yields and profits for rice production vary for different levels of ML, MO and farm size. This method allows the equality of the means of a few response variables for various groups to be tested. It is based on the following assumptions (Tabachnick & Fidell, 2011:

- Observations are statistically independent;
- There is a normal distribution of the dependent variable;
- Linear relationships can be seen between all dependent variables and covariates;

- The variance is equal for all the groups of predictors;
- Inter-correlation between the dependent variables is homogenous.

The difference in the productivity and profits for different levels of investment in machinery was tested using Pillai's statistic, which is often considered to be the most reliable way to conduct a MANOVA analysis:

$$\text{Pillai's} = \text{trace}\{(E + H)_{-1} H\} \quad (4)$$

This tests the null hypothesis H0 : $\mu 1 = \mu 2 = \mu 3 = ... = \mu n$, where μi is the mean value of the respective group. The null hypothesis is rejected if E (the error variance) is small enough compared to H (the variance explained by treatments). Consequently, the hypothesis is rejected for high values of Pillai's statistic.

Results and discussion

Adoption of machinery for rice production

Machinery is a key production factor for current Thai rice production. The aging of the population of farmers and the economic growth in non-agricultural sectors have caused a labour shortage, and most farmers have adopted machinery to replace human labour, especially for tillage and harvesting activities. Most farmers use a small four-wheeled tractor for tillage, and a combine harvester to harvest their crops (Srisompun *et al*., 2014). Figure 1 shows that the labour used for rice production averages 112.64 hours per hectare, that the ratio of mechanized hours to the total number of hours of labour for rice production is about 14-17%, and that marginal farms have the highest average number of hours of labour. This result demonstrates that the average amount of labour has an inverse relationship with the size of the planted area (Fig. 1). Large farms use less labour than farms of other sizes, so that the mechanized labour for a large farm is lower than that for a small farm (Fig. 2). The production of marginal farmers focuses on using household labour. Most of the current hiring activities for labourers for rice production in Thailand are contract hires rather than hires with a daily payment (Srisompun *et al.*, 2019). Labourers hired under a contract give a better performance than day labourers, and perform faster than household labourers (Solanke *et al.*, 2016). Moreover, small farmers grow rice for the major purpose of household consumption, so their planting and harvesting

methods mainly focus on the preservation of quality, such as transplanting rice plants, weeding by hand, or using human labour for harvesting. For large-scale farms that focus on planting rice for sale, and restrict the use of household labour, most activities are carried out using machinery, which has a better performance than human labour (Srisompun *et al.*, 2019).

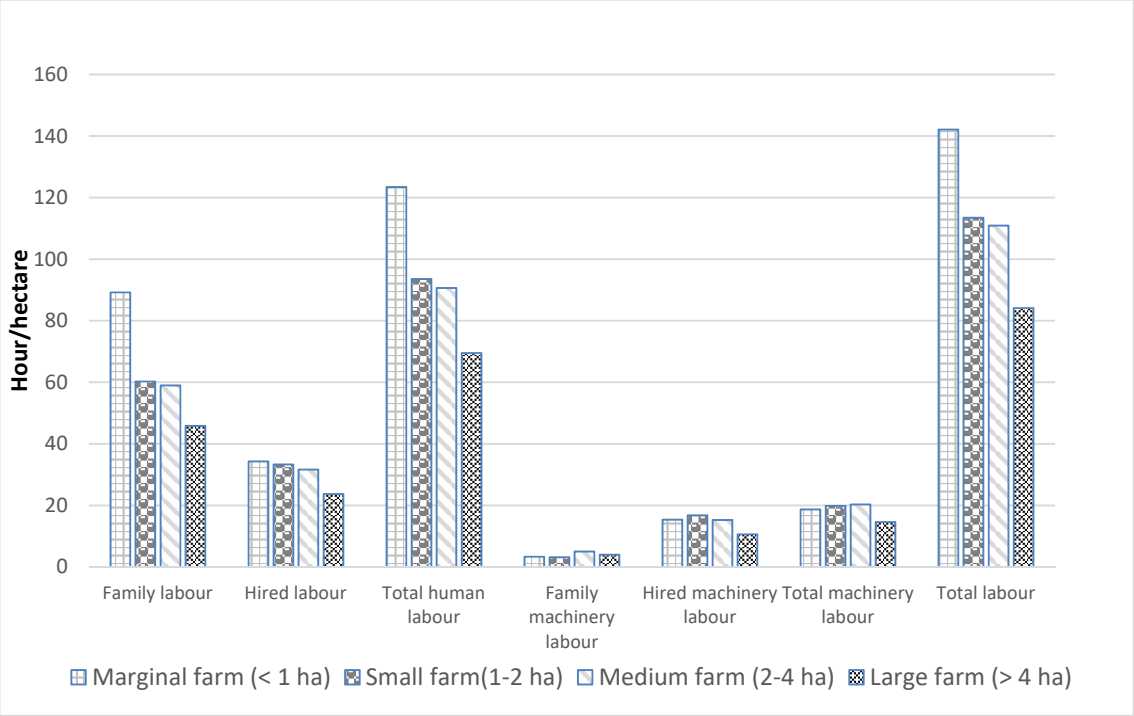

Fig. 1: Labour use for rice production, distribution by farm size

Although the use of machines in rice production could solve the labour shortage in the Thai agricultural sector, the rate of adoption of agricultural mechanization for rice production varies by farm size. Farms with large-scale planted areas have a ratio of machinery owned (MO) of 30%, which is higher than farmers in other farm sizes (Fig. 2). This confirms the trend of changes in rice production technology for farmers in other regions, who have adapted to mechanization to solve labour shortage issues (Biggs & Justice, 2015; Liu *et al.*, 2016). The reason that small-scale farmers show a lower tendency to adopt machinery is that their household labour is sufficient and suits small farms. The ratio of family-owned machinery may affect the labour productivity if the hypothesis of a labour market failure is confirmed. The theory of labour market changes indicates that hiring machinery may increase labour productivity more than using household machinery, because using

hired labour for rice production under contract provides better performance. Moreover, considering the MO ratio, large farms have a higher MO ratio than small farms (Fig. 2) because large farms have a bigger budget or better access to capital than smaller farms (Ehiakpor *et al.*, 2016). In Thailand, especially, agricultural credit systems are constantly being developed and farmers who own land are able to use their land as collateral for an investment loan, in contrast to farmers who do not have their own land (Ebers *et al.*, 2017). Therefore, access to agricultural credit is the key push factor for investment by farmers in machinery, and the ratio between hired and household labour usage may affect the production yield and productivity, as mentioned above. The next section analyses the results of mechanization for rice yield and labour productivity, in order to analyse the proper mechanization level (ML) for each size of farm.

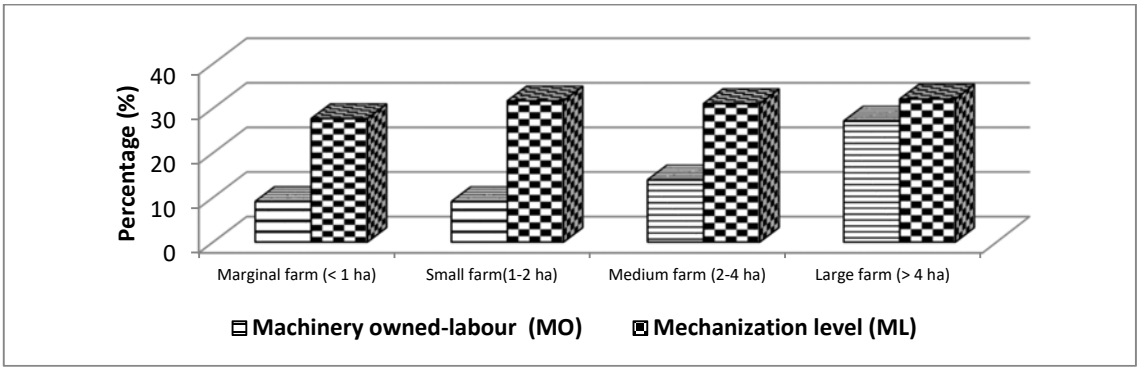

Fig. 2: Machinery owned labour (MO) and mechanization level (ML) by farm size

Effect of adoption of machinery adoption on labour use, rice yield and labour productivity

The results of the MANOVA analysis demonstrate that the estimates for the coefficient values of all the variables are as follows: yield, labour use and labour productivity for different levels of MO, ML, and farm size differ, with statistical significance, at a confidence level of more than 95%, except as regards the MO level where the results are similar for each level. The different result for the ML level means that the levels of rice yield, labour usage, and labour productivity of farmers are different as a result of ML and farm size, while different levels of MO do not affect the rice yield (Table 1).

Farm size is the key variable that affects labour productivity. The highest labour productivity was identified in the big farms (Liu *et al.*, 2016). The main reason could be the wider range of activities

of the big farms, which, besides the primary production, also process the primary products and use their free capacity for other farming activities (Novotná & Volek, 2016). From the results of the study shown in Table 2, farm size is related to labour usage and productivity. We find strong evidence that the inverse relationship between rice productivity and planting area is significantly attenuated. Small farms have the highest labour usage, of 123.45 hour/ha, while large farms have the lowest average labour usage per unit area of 69.51 hour/ha. This also means that they have the highest labour productivity, of 62.55 kg/hour, while marginal farms have the lowest labour productivity. However, comparing in terms of yield, it is found that large farms have the lowest average yield, 2167.76 kg/ha, while marginal farms have the highest yield, 2618.03 kg/ha (Table 2), because marginal farms have small planted areas and focus on growing rice for household consumption, while large farms focus on using hired labour, especially hired machinery, as mentioned in the study result in Figure 1. Therefore, the labour usage causes marginal farms to produce greater yields, and the inverse relationship between farm size and output per hectare is perhaps due to more inputs being used by small farms rather than diseconomies of scale (Thapa, 2007).

Table 1 Effect of machinery adoption on yield, labour use and labour productivity using MANOVA analysis

Variables	Estimates	Approx. F	Pr (>F)	
Farm size				
Yield	0.0320	10.5500	0.0000	***
Labour use	0.0239	7.7800	0.0000	***
Labour productivity	0.0083	2.6300	0.0487	**
ML level				
Yield	0.0088	2.8100	0.0383	* *
Labour use	0.2242	91.6100	0.0000	***
Labour productivity	0.0966	33.8700	0.0000	***
MO level				
Yield	0.0052	1.2500	0.2895	ns
Labour use	0.0998	26.3300	0.0000	***
Labour productivity	0.0175	4.2300	0.0021	***

Note: ** = significant at p<0.05; *** = significant at p<0.01

The main purpose of agricultural mechanization for growing crops is to replace or compensate for the shortage of labour in the agricultural sector. Although using machinery means that planting and harvesting activities are faster, the planted area can be extended, and cropping intensity can even be increased (Verma, 2008), there are concerns that agricultural mechanization may cause the yield to drop in both quality and quantity because of the planting process and the losses during harvesting using a harvester rather than handpicking. Hand harvesting produces 2–6% higher head rice yield than combine harvesting, and the loss of field grain during harvesting is 2–5% higher using a combine harvester than it is when harvesting by hand (Bunna *et al.*, 2018). However, farmers must face not just the loss of rice yields or quality but also the pressure of labour shortages and the aging of the farmer population, which have pushed farmers towards agricultural mechanization for rice crops, including for tillage, rice sowing, chemical spraying, and harvesting crops; this affects farmers' rice production labour usage by ML level. For farmers with the lowest and highest ML, it was also found that the highest rice labour usage is 144.55 hour/ha and the lowest 90.88 hour/ha, while the group with the lowest ML has the lowest rice yield, so that these two groups have the lowest labour productivity (Table 2). This also reflects the low performance of agricultural machinery; agricultural machinery for planting rice still requires improvement to increase rice production.

As regards the relationship between MO level and labour productivity, it is found that the level of labour productivity may increase with the level of MO, which means that farmers with a high level of MO tend to increase their labour productivity as well. However, farmers who mostly use their own machinery have the lowest labour productivity, because this group is not only using the most labour for rice production, but also their rice yield is lower than that of farmers with other levels of MO. However, the result of the statistical analysis of the difference in the average yield for each MO level shows no statistically significant differences.

Table 2 Labour use, rice yield and labour productivity of Thailand rice production categorized by farm size, machinery level (ML) and owned machinery level (MO)

Variables	Labour use		Paddy yield		Labour productivity	
Unit	Mean Hour/ha	S.D.	Mean Kg/ha	S.D.	Mean Kg/hour	S.D.
Farm size						
Marginal farm	141.18	12.73	2599.28	91.55	51.54	4.71
Small farm	112.98	6.94	2436.84	71.12	53.38	3.08
Medium farm	108.60	5.53	2138.82	43.64	54.49	2.65
Large farm	84.10	5.25	2167.76	52.12	65.54	3.81
F-statistic	8.63***		10.67***		2.93**	
Prob. F	0.0000		0.0000		0.0329	
Machinery level (ML)						
Low	144.55	6.11	2215.44	48.39	35.94	2.46
Medium	48.79	2.40	2329.63	40.93	69.52	2.50
High	52.22	5.12	2301.47	100.41	66.66	4.41
Highest	90.88	18.61	1718.83	232.15	35.25	11.11
F-statistic	91.61***		2.81**		33.87***	
Prob. F	0.0000		0.0383		0.0000	
Machinery-owned level (MO)						
No machinery owned	81.78	3.37	2277.44	36.06	55.29	1.80
Low	71.49	13.88	2490.34	154.04	50.16	6.87
Medium	57.69	8.46	2259.65	98.41	61.60	4.70
High	62.46	10.79	2394.55	90.00	75.70	10.18
Highest	181.29	13.68	2113.53	83.89	39.38	7.98
F-statistic	29.3***		1.34^{ns}		5.19***	
Prob. F	0.0000		0.2515		0.0004	

Note: ** = significant at p<0.05; *** = significant at p<0.01

Effect of adoption of machinery on production cost and farm income

The analysis of the relationship of farm size, ML level, and MO level with the production variables and labour productivity gives information that is clearly connected to policy implications. However, a consideration of the advantages of mechanization should focus not only on yield and labour variables: policy analysts should also give priority to related issues and the connections with raising farmers' income. The results of the MANOVA analysis show that the estimated coefficient values for production cost, income, and revenue from the rice production of Thai farmers vary on the basis of

farm size and ML level, while none of the four variables under consideration varies by MO level (Table 3).

Table 3 Effect of adoption of machinery on farmers' income

Variables	Estimates	Approx. F	Pr (>F)	
Farm size				
Cost	0.0198	6.4600	0.0003	***
Rice income	0.0243	7.9700	0.0000	***
Net profit	0.0018	0.5900	0.6257	ns
Profit over cash cost	0.0064	2.0700	0.1031	*
ML level				
Cost	0.0113	2.7500	0.0273	**
Rice income	0.0103	2.4800	0.0422	**
Net profit	0.0113	2.7300	0.0278	**
Profit over cash cost	0.0020	0.4700	0.7548	ns
MO level				
Cost	0.0056	1.3400	0.2515	ns
Rice income	0.0029	0.6800	0.6058	ns
Net profit	0.0017	0.4100	0.8043	ns
Profit over cash cost	0.0076	1.8300	0.1201	ns

Note: * = significant at p<0.10, ** = significant at p<0.05; *** = significant at p<0.01

The rice production cost decreases with planted area. Marginal farms have the highest production cost, 21,142 THB/ha, while major farmers have the lowest production cost, 16,270 THB/ha. The reason that large farms have a low production cost is that agricultural production displays an L-shaped average cost curve, where the costs are lower initially but reach a point where no further gains are achieved. Spreading fixed costs, bulk purchases, and marketing power are cited as reasons for economies of scale (Duffy, 2009). Although large farms have the lowest production cost, their average yield is the lowest, which makes their rice income the lowest as well. From this statement, there is no statistically significant difference between the net profits of each size of farm. However, from the calculation of profit over cash cost, it is found that, with statistical significance, marginal farms have more net profit over cash cost than large farms (Table 4). The rice production of Thai farmers in large planted areas requires more hired labour because there is insufficient household labour; this increases the production cost in cash and decreases the net profit over cash cost as well (Srisompun *et al.*, 2019).

Considering the results for the adoption of agricultural machinery on farmers' income, it is found that rice production cost and net profit from rice production vary according to the different mechanization levels (ML) of the farmers. Farmers with the highest agricultural mechanization level have the lowest production cost, which demonstrates that there is an inverse relationship between the agricultural mechanization rate and the rice production cost for farmers; a farmer using agricultural machinery is able to replace hired labour. The cost of hired labour has been increasing because of increases in wages in the agricultural segment, which are the result of a minimum wage adjustment: the minimum wage was raised across the country to 300 THB per day – an average increase of around 60 per cent in real terms, which was unprecedented in the country (Lathapipat & Poggi, 2016). However, farmers' income from rice production decreases as a result of the increased adoption of agricultural machinery (Table 4); this is because of the lower yield with machinery than with human labour, although mechanization should increase the yield. Higher levels of mechanization are preferred by farmers to ensure timeliness, to increase crop yield, and to reduce the cost of cultivation, provided the farm is large enough to use the machine and sufficient labour at reasonable wages is not available when it is required (Singh, 2006). Decreased yield when the use of mechanization is increased reflects issues with machinery performance, and demonstrates that agricultural machines in the study area still have low performance and are still unable to replace human labour completely.

From the analysis of the relationship between ML level and farmers' revenue, the net profit of rice production increases with ML level: the groups with high and highest ML have greater net profit than the groups with medium and low ML. However, the highest use of rice production machinery caused a decrease in farmers' net profit because of the effect of the decreased averaged yield. The results of the analysis of the relationship for MO show that production cost, rice production income, and net profit are no different by rice production MO (Table 4). Although most hired rice production machinery in Thailand is used for tillage and harvest activities, the machines are mostly hired at a customary rate that reflects the fact that the performance of hired machinery is similar to that of owned machinery in terms of rice income.

Table 4 Cost and return from rice production categorized by farm size, mechanization level (ML) and owned machinery level (MO)

Variables	Production cost		Rice income		Net profit		Profit over cash cost	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Unit	THB/ha		THB/ha		THB/ha		THB/ha	
Farm size								
Marginal farm	21,142	780	20,807	798	-336	969	8,932	838
Small farm	19,787	797	19,206	637	-581	782	8,391	628
Medium farm	17,792	517	17,267	401	-524	586	6,973	479
Large farm	16,270	833	16,908	483	638	893	7,051	662
F-statistic	6.46***		7.97***		0.59		2.07*	
Prob. F	0.00		0.00		0.62		0.10	
Mechanization level								
Low	19,183	539	17,542	411	-1,641	556	7,869	411
Medium	18,003	611	18,475	401	472	647	7,206	516
High	16,311	832	18,358	835	2,048	1,043	7,966	962
Highest	12,265	1,657	13,410	1,932	1,146	2,039	5,590	1,590
F-statistic	2.75**		2.48**		2.73**		0.47	
Prob. F	0.03		0.04		0.03		0.75	
Owned machinery (MO) level								
No machinery owned	18,338	368	18,055	325	-283	409	7,089	347
Low	15,098	2,102	17,289	1,173	2,191	1,959	8,551	965
Medium	16,891	1,554	17,734	837	843	1,483	8,785	877
High	20,636	3,799	19,555	937	-1,082	3,776	7,785	2,526
Highest	17,519	1,149	17,206	751	-313	1,264	9,781	948
F-statistic	1.34		0.68		0.41		1.83	
Prob. F	0.26		0.61		0.80		0.12	

Note: * = significant at p<0.10, ** = significant at p<0.05; *** = significant at p<0.01

Conclusion and policy implications

In rice production, most farmers have tended to adopt mechanization to replace labour to solve labour shortages and high wage issues. On average, the rice planting workforce and labour productivity have an inverse relationship with the planted area, and large farms have the highest rate of using machinery. The rice yield, labour usage, and labour productivity of farmers varies by mechanization level (ML) and farm size, while different levels of the owned machinery to human labour ratio (MO) have no effect on rice yield. Therefore, from the study results, the following suggestions can be made:

1. Labour productivity has a statistically significant relationship with farm size. Performing land consolidations by applying a large paddy rice production strategy may increase labour productivity and the net profit of Thai rice farmers, and this policy is suitable for raising the household income of small-scale farmers in a developing country.

2. A high level of agricultural mechanization by farmers should be encouraged to obtain the highest level of labour productivity, and also the machinery may be effective in terms of quality improvement, loss of yield, and cost reduction. However, using machinery for rice production in Thailand still requires improvements in machinery quality, especially the performance of the machinery in preventing loss during the harvest, in order to allow farmers to maximize the utilization from mechanization that replaces human labour.

3. Using machinery for rice production at a mechanization level of 50-75% of the entire labour usage may encourage farmers to use labour at an appropriate level that could increase labour productivity and net return as well.

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