DETERMINING MECHANIZATION CAPACITY AND TIME REQUIREMENT FOR FARM OPERATIONS: A CASE OF SMALL-SCALE RICE MECHANIZATION IN RIAU PROVINCE, INDONESIA

U. Paman, S. Inaba, S. Uchida

ABSTRACT. *The successful development of farm mechanization is determined primarily by the transition process from manual tools through animal-drawn implements and finally to the application of mechanical power technologies, which will affect mechanization capacity and time requirement of farm operations. This study attempts to determine the capacity of rice farming mechanization and the time requirement for farm operation practices in Riau province. The study was carried out in two rice centers from two regencies in the province: Kampar and Siak regencies. A total number of 120 sample farmers were selected randomly from both locations and interviewed personally to collect data. As a result, there has been an increasing capacity of rice mechanization in Riau province. The increase was mostly due to increasing availability and utilization of power intensive machines on the farm in the province. In farming practices, the farm operations which involved machine power include only land preparation, threshing, and milling, while other operations are employed entirely by human labor. Under these conditions, the total time required to complete rice farm operations was 851 h·ha^{-1} on average, contributed mostly by transplanting, weeding, and harvesting that still use manual tools. Therefore, it suggests that a mechanized farming scheme should be expanded to a wide range of operations to increase capacity of rice mechanization as well as complete farm work in a timely and short time.*

Keywords. *Farm operations, Mechanization capacity, Small-scale rice mechanization, Time requirement.*

In many developing countries today, agricultural operations are becoming increasingly mechanized through a mechanization development process to modernize operation system and increase production. The mechanization process, by shifting from manual tools and animal-drawn implements to mechanical power technologies, especially in rice farming systems, has been going on during the last few decades. Nevertheless, human labor and animal power still play a vital role in many farming systems in Asia, mainly on smaller and poorer farms (Lawrence and Pearson, 2002). The power input used in rice farming in Indonesia, for example, has still come from human and animal power with an increased use of mechanical power (Salokhe and Hendriadi, 1995). Consequently, the mechanization level which is determined greatly by the successful development process remains low in many countries in the region. Agricultural mechanization, however, has made a significant contribution to agricultural and rural development (Bishop, 1997).

According to Rodulfo et al. (1998), the mechanization application can be characterized by three levels: low (manual power used exceeded 33% of cultivated land), fair (animal power utilization ranges from 34% to 100% of cultivated land), and high (mechanical power utilization ranges from 67% to 100% of cultivated land). In the Asian countries, for example, mechanization development is low progress in which about 30% of total cultivated land is cultivated by human labor, 30% by draught animals, and 40% by tractors (FAO, 2007; 2008). Under low levels of mechanization, the role of human power is very important and significant (Sims and Keinzle, 2006). Therefore, many small rice farms in the countries remain unproductive and inefficient due to lack of mechanical power technologies. Igbeka (1984) stated that farm power shortage has been known as a major constraint to increase agricultural production.

In Indonesia, mechanizing rice farming remains a priority because rice is a main staple food for most of the population. Although being dominated by small-scale farms and subsistent level of production, rice farming is the most important economic activity for the majority of the people living in rural areas, including on-farm activity, processing, and other post-harvest activities related to rice. Singh and Siswasumarto (1988) argued that the agricultural mechanization process in the country was in its early stages of development. Presently, the level of mechanization primarily in rice production system varies from low to high, ranging

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from 10% to 90% of cultivated land depending on the intensity of the farming system and common figure indicates its average level of 30% of cultivated land (Handaka, 2005).

In Riau province, rice farming mechanization is still in progress. Rice is grown predominantly by small farmers under different levels of mechanization and with a shift from traditional hand tools to mechanically-powered machines. Although farm mechanization has increased a rather slow progress in the province, the total number of major farm machines such as tractors, power tillers, water pumps, power threshers, rice milling units, and dryers, increased significantly about 60% to 3,552 units in 2006 from 2,208 units in 2000. Currently, machine power technologies are gradually taking over the labor-intensive farm operations such as land preparation, threshing, lift irrigation, and milling.

A number of methods have been used to evaluate development and situation of farm mechanization in a country/region, such as level, indices, and degree. The mechanization level can be determined in terms of farm power availability per hectare (kW/ha), number of tractors/1000 ha, ha/tractor, mechanical power/total power, and equipment weight/tractor (Ozmerzi, 1998). Such approaches were commonly used and practiced by many researchers (Herdt, 1983; Singh, 1984; Farrington, 1985; Mancebo, 1986; Chamsing and Singh, 2000; Kaneko et al., 2000; Viegas, 2003; Mondal et al., 2008; Sharabiani and Ranjbar, 2008; Karimi et al., 2008). The level of mechanization can also be expressed by an index which represents the percentage of machine work to the sum of manual and machine work, expressed in energy units (Singh and De, 1999; Andrade and Jenkins, 2003; Singh, 2006; Ramirez et al., 2007; Olaoye and Rotimi, 2010). In addition, the degree of farm mechanization is the ratio of mechanized operations to the total operations (Karimi et al., 2008; Sharabiani and Ranjbar, 2008; Ghadiryanfar et al., 2009). The mechanization degree can also be expressed as the average energy input of work provided exclusively by human power (labor) per hectare (Olaoye and Rotimi, 2010).

Most of the above methods did not consider machine capacity in their calculations, so potential of the available farm machines was ignored. It becomes important because a majority of farm machines in developing countries are used under-capacity especially for small-scale farmers (Gifford, 1992). Therefore, a method that considers machine capacity in estimating the situation of farm mechanization is useful to describe potential of farm machine availability in a country/region. Furthermore, the determination of time requirements for farm operations is useful to describe directly how many hours of operation time can be reduced by substituting human labor to machine power, which has frequently been ignored in previous research because the labor saving is a major mechanization issue and a main objective in developing farm mechanization. The purpose of this article is to determine the degree of rice mechanization and the time requirement in rice farm operation practices in Riau province.

Materials and Methods

A field survey was conducted in two rice production centers from two regencies in Riau province, namely Bunga Raya of Siak regency and Bangkinang Seberang of Kampar regency. Both locations were purposively selected to represent an average condition of the most intensive farming system of rice production and the highest level of mechanization adopted in the province. A total sample of 120 farmers was selected randomly, consisting of 60 farmers in each survey area. Interviews were carried out during the 2008 wet cropping season using structured questionnaires for collecting data. The wet season that occurs from September to January is the main cropping season due to the average rainfall that is about 231 mm month^{-1}.

Primary and secondary data were collected and used for analysis purposes. Primary data included farm size, cropping patterns, kind of farm machines, type of tools, and time required for each stage operation of rice production. Furthermore, secondary data were gathered from Annual Reports of Food Crops Service of Riau province, including type and number of farm machines, cultivated area, and rice production during a period of 2000-2006. The quantitative data was processed using simple statistical techniques in Microsoft Excel, such as calculation of percentages and mean, predicting regression parameters, and constructing graphs and figures.

Apart from the previous methods, the approach adopted here is called mechanization capacity. This method refers to a concept that considers the potential of all farm machine availabilities to work per year, which is ignored in previous works. The method also permits the assessment of mechanization capacity for all types of farm operations. The mechanization capacity is the ratio of multiplying available machines by potential working capacity per year to the total operation expressed as a percentage.

$$M_c = \frac{N_m \times W_c}{A_o} \quad (1)$$

where M_c is mechanization capacity (%), N_m is the total number of available farm machines (unit), W_c is the average yearly working capacity for each machine (ha/ton), and A_o is the total operation (ha/ton).

Results and Discussion

Capacity of Rice Farming Mechanization

Rice farming mechanization in Riau province varies widely from hand tools to power intensive machines such as hand tractor (power tiller), water pump, thresher, dryer, and rice milling unit/huller. Animal-drawn implements are rarely used in rice farming system in the province primarily because farm machines have been extensively introduced to rice farmers in the 1990s. Currently, farm operations which require relatively little power are still performed completely by humans such as seeding, transplanting, weeding, harvesting, and drying. On the other hand, farm operations which require high power inputs are mostly performed by machines such as land preparation, threshing, and milling. In addition, very small (<0.2 ha) rice farms are worked completely by human labor with manual tools except for milling operation.

In order to mechanize rice farming, most small farmers resort to custom service organized by individual or group/cooperative farmers for their field operations. Operations, such as land preparation, threshing, drying, and milling, are available through such services. Through the custom services, most of the small farmers are able to handle their farm operations without the need to purchase or own any machine and related equipment. Service charges can be paid in the form of cash or installments after being decided together. The custom hiring for on-farm operations was widely practiced in Riau province particularly in the rice farming system (Paman et al., 2010).

By using equation 1, the rice farming mechanization capacity was calculated and the results are presented in table 1. Although increasing over the seven-year period, the rice mechanization capacity remained very low except for milling and varied on each stage of operation. The average capacity was about 15.3% in 2000 (ranging from 2% for drying to 100% for milling) and this figure slightly increased to 21.1% in 2006 (ranging from 17% to 100% for land preparation and milling, respectively). Comparing nationally mechanization capacity [about 30% according to Handaka (2005)] to our results indicates that rice farming mechanization development in Riau has experienced a lower process with an increasing capacity of about 28% during the period of 2000-2006. In addition, the average of rice mechanization capacity in the province in 2006 is slightly lower compared to the capacity found in Philippines at 21.7% in 2005 (Elepaño et al., 2009).

According to table 1, the low capacity of rice mechanization indicates that the number of farm machines available in Riau province have not been sufficient for rice farming operations. The machinery application in rice farming operations is restricted to land preparation, irrigation, threshing, drying, and milling operations. The shortage of machines available in the province is a major factor causing such restrictive operations.

On the other hand, the increased rice mechanization capacity was generated by increasing the number and use of small tractors, water pumps, threshers, dryers, and rice milling units in the province during the period. A number of farm operations are still performed completely by human labor such as seedling, planting, weeding, pest control, and harvesting. Table 2 shows the number of major farm machines distributed in Riau province from 2000-2006. From the table, most farm machines increased at different rates primary after 2001. The significant increase occurred on dryers to about 115%, and followed by small tractors of about 22% per annum. The trend was not followed by large and medium tractors which decreased to about 9.9% during the same period. Discussion with farmers revealed that the use of medium and large tractors in small-scale farming is not common among small farmers due to under capacity and cost for such farm scale.

Time Requirement in Rice Operation Practices

Under the current level of rice mechanization, total time required for 1 ha of rice farm varied from 717 to 1206 h with an average of 851 h (table 3). This finding is higher compared to the average working hours for rice cultivation under mechanized labor in South Sulawesi of 588.8 h in 1980, excluding drying and milling operations (Maamum et al., 1983). In addition, the average number of working hours in the Riau province is much higher compared to the current national average of working hours for rice cultivation per hectare in Japan to only 350 h under full mechanized system (Sasaki, 2002).

If a working day is assumed to be 7 hours according to the present survey, the total operation hours are equivalent to 122 working-days ha^{-1}. There was variation in total time requirement among farmers as shown by coefficient of variation. The variation may be due to differences in farm size, level of mechanization, field conditions, etc.

Table 2. Population of major farm machines in Riau province from 2000 to 2006.[a]

Type of Machines	2000	2001	2002	2003	2004	2005	2006	Average Growth (%)
Large and medium tractors	225	129	189	170	28	30	37	-9.9
Small tractors[b]	285	516	613	889	799	817	774	22.0
Water pump	343	427	757	900	737	742	795	18.4
Power thresher	764	1037	1105	1246	1180	700	947	7.4
Dryer	20	146	224	128	100	89	164	115.3
Rice milling unit	571	1386	852	970	1078	1081	835	17.8

[a] Source: Food Crops Service of Riau Province, 1998, 2001, 2004, 2007.
[b] Including hand tractor, rotary tiller, and cultivator.

Table 1. Variation of mechanization capacity on rice farming operations in Riau province (%).

Type of operations	2000 Hand Tool[a]	2000 Mechanical Power	2006 Hand Tool	2006 Mechanical Power	Tools and Machines Used and Capacity[b]
Land preparation	92.3	7.7	73.0	27.0	Using hand tractor with capacity = 40 ha yr^{-1}
Seeding and planting	100.0	0	100.0	0	Using traditional tools, such as hand pushed seeders and planting stick
Weeding	100.0	0	100.0	0	Using traditional tools, such as hoe and weeding hoe
Pest control	100.0	0	100.0	0	Using hand sprayer
Irrigation	91.2	8.8	79.2	20.8	Using water pump with capacity = 30 ha yr^{-1}
Harvesting	100.0	0	100.0	0	Using traditional tools, such as sickle and jagged sickle.
Threshing	80.5	19.5	75.2	24.8	Using power thresher with capacity = 30 ha yr^{-1}
Drying	97.9	2.1	82.8	17.2	Using dryer with capacity = 120 ton yr^{-1}
Milling	0	100.0	0	100.0	Huller and rice milling unit = 200 ha yr^{-1}

[a] Including using animal power.
[b] Source: Data were processed from a number of machines in 2000 and 2006.

Table 3. Average time per hectare required for various rice operations in Riau province ($h \cdot ha^{-1}$).

	Human Labor						
	Family Member		Hired Labor				
Type of Operations	Man	Woman	Man	Woman	Machine Power	Total Hours	Coefficient of Variation (%)
Land preparation	0	0	0	0	26	26	29
Seedling	0	35	0	0	0	35	38
Planing	39	112	0	52	0	203	31
Weeding	38	97	0	18	0	153	39
Fertilizing	16	26	7	6	0	55	49
Pest control	29	8	0	0	0	37	41
Harvesting	55	64	7	53	0	179	38
Threshing	0	0	0	0	20	20	23
Cleaning	0	39	0	0	0	39	35
Transportation	44	0	0	0	0	44	62
Drying	24	25	0	0	0	49	48
Milling	0	0	0	0	10	10	21
Total	245	406	14	129	66	851	11
Percentage of total hours	28.8	47.7	1.6	15.2	7.8	100	--

Regression analysis was performed on the time requirement data and revealed a negative relationship between time requirement and farm rice cultivated area as described by the following equation (fig. 1):

$$Y = -97.25X + 931.70 \text{ with } R^2 = 0.19 \quad (2)$$

where Y = time requirement ($h \cdot ha^{-1}$) and X = farm rice cultivated area (ha).

The linear regression gave as good a fit and could explain only 19% of the observed variation in time requirement in hours per hectare. It means that farm cultivated area in hectare alone did not provide an adequate basis for explaining or predicting the time requirements of farm operations. This suggests that other factors, not considered here, are important determinants of time requirement.

Most of the total hours (93.2%) came from human labor and the rest (7.8%) were from machine power. It was observed that farm operations which involve farm machines included only land preparation, threshing, and milling, while other operations were employed entirely by human labor. Human labor was required for planting, weeding, and harvesting operations that consumed about 63% of the total hours for rice production (fig. 2).

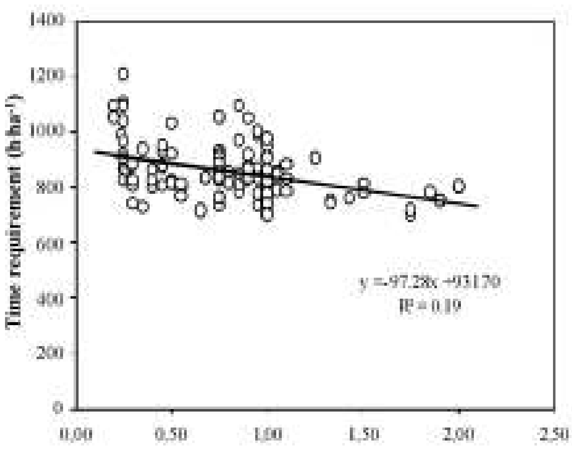

Figure 1. Relationship between farm size and time requirement.

Furthermore, about 76.5% of farm operations were carried out by family labor while the rest were carried out using hired labor. Farm operations which employed hired labor with manual tools were planting, weeding, fertilizing, and harvesting. It was also found that farmers who own farm size more than 0.5 ha frequently used hired labor. This result indicates a relatively low demand for hired labor using manual tools in the survey areas. Farmers confirmed that labor demand decreased gradually with increasing farm machines used in rice farming. Approximately 90% of the hired laborers were female and the rest were male. This may be due to the female laborer was very dominant to perform rice farm operations in the survey areas, contributing about 63.5% compared to 36.5% of male labor. The hired labor was paid IDR 40,000 (US $4.4) and IDR 60,000 (US $6.7) per working day for female and male, respectively.

It is evident that farm operations using mechanical power require shorter time than human and draught animal powers. For instance, land preparation, which is the most power intensive operation for rice farming required time to only 26 $h \cdot ha^{-1}$ or about 6% of the total hours for rice production (fig. 2). Hand tractors equipped with single moldboard plow and circle puddler for plowing and puddling, respectively, were the most common machines used by small farmers. Interviews with farmers (according to farmers' experience before using hand tractor) revealed that

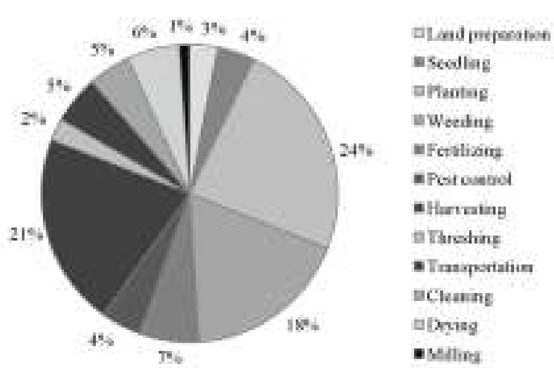

Figure 2. The contribution of each operation time on total time requirements (851 $h \cdot ha^{-1}$) for rice farm operations.

the actual working time required for the same operation was about 588 h·ha^{-1} by human or 82 h·ha^{-1} by draught animal. Besides shorter time, mechanized land preparation with hand tractor, for example, is also favored because its cost is considerably lower than animal and human powers: Rp 800,000 ha^{-1} (US $89) compared to Rp 1,800,000 ha^{-1} (US $200) and Rp 4,500,000 ha^{-1} (US $500) for draught animal and human labor, respectively. It is important to note that the application of machine power in farm operations could relieve pressure on human labor at a critical time of high demand particularly during tillage period.

Apart from reducing a significant operation time and cost, the use of machine power for carrying out various rice operations created a little variation of operation hours between farmers as shown by smaller value of coefficient of variation compared to use manual tools (table 3). Farm operations by machine power such as land preparation (29%), threshing (23%), and milling (21%) had relatively smaller variation compared to other operations (ranging from 31% for planting to 62% for transportation) by human power. The results suggest that the mechanized farming scheme should be expanded not only for land preparation, threshing, and milling at present but also for a wide range of operations such as planting and harvesting. Thus, the level of rice mechanization can increase and farm operations can be done in a timely and shorter time. Mechanization purposes such as improving timeliness for planting and harvesting and reducing human labor demands for peak farm operations can eventually be achieved.

CONCLUSIONS

There has been an increasing trend to improve rice mechanization capacity in Riau province, although the pace is relatively slow. The average level increased from 16% in 2000 to 21% in 2006, contributed by land preparation, irrigation, threshing, drying, and milling. This increase was primarily due to greater availability and use of small tractors (power tiller), irrigation pumps, threshers, dryers, and rice milling units to perform the operations during the same period. In farming practices, the farm operations which involved farm machines include only land preparation, threshing, and milling, while other operations are employed entirely by human labor. Under these conditions, the total time required for rice farm operations was about 851 h·ha^{-1} on average, contributed mostly by planting, weeding, and harvesting which still use hand tools. The total required time is equivalent to 122 person-days·ha^{-1}. The results suggest that mechanized rice farming should be expanded to other intensive labors such as planting and harvesting to mainly increase level of rice mechanization as well as make a lesser working hour and a timely operation of farm works.

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