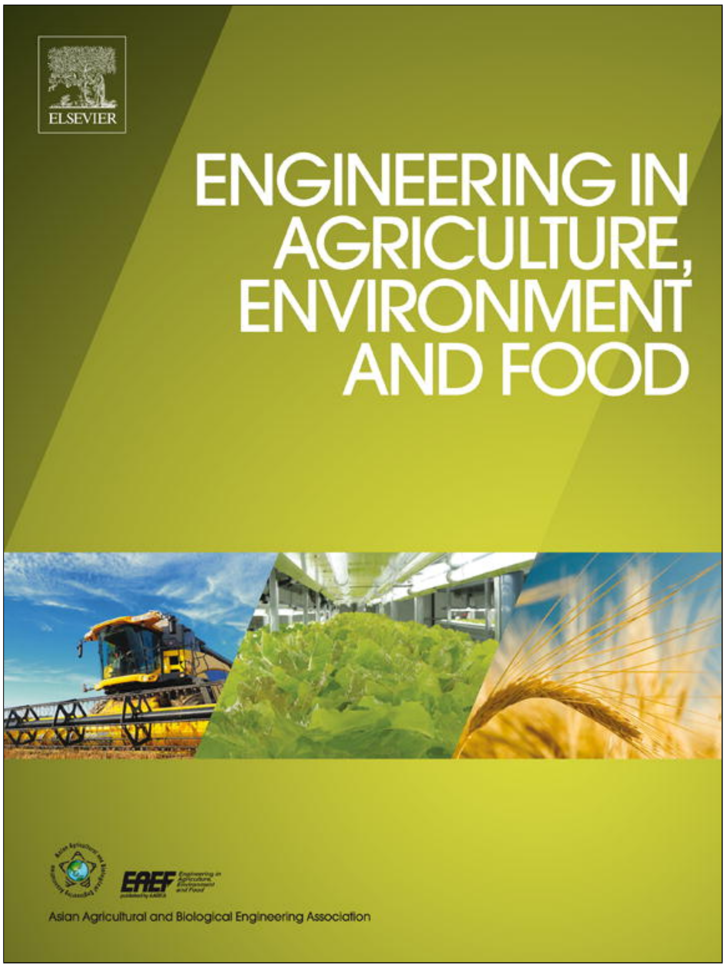
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Research paper

The mechanization of small-scale rice farming: Labor requirements and costs

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A B S T R A C T

This research examines the availability of mechanical power and estimates the labor requirements and costs for small-scale rice farming operations in Riau Province, Indonesia. In 2010, we interviewed 120 farmers from the Siak and Kampar Regencies to collect data. We found that farming operations are predominantly performed by human labor because of the lack of farm machines. Between 2001 and 2010, the average availability of mechanical power was just 0.31 hp/ha and this only increased by 0.75% annually. Therefore, annual rice farming operations required 83.26 man-days/ha compared with 7 machine-days/ha. The total cost per hectare for these operations was IDR 7,895,830 (US $877), contributed mostly by labor costs. Farmers should thus adopt more machines to save labor, time, and cost.

1. Introduction

Many countries aim to increase their power for performing various farming operations because farm power is a crucial input for meeting agricultural production targets (Gifford, 1992). A lack of farm power can be a major constraint to develop an agricultural system. The three principal sources of such power are humans, draught animals, and engine-driven machinery (Bishop, 1997). Compared with mechanized developed countries (Tabatabaeefar and Omid, 2005), human labor and animal power remain important in traditional farming systems, especially those in developing countries (Dunn et al., 1983). Nevertheless, farm machines are becoming the most important power source in agricultural operations today (Ghadiryanfar et al., 2009), particularly for reducing the labor hours required to cultivate agricultural products (Jacobs and Harrell, 1983) in order to ensure timely completion and improve operational efficiency.

In Riau Province, Indonesia, the mechanization of rice farming remains the primary concern of the provincial government because of the importance of rice as a source of livelihood in terms of providing staple food, employment, and income. The use of farm machines in rice farming is increasingly taking over from human labor, especially for power-intensive operations such as land preparation, irrigation, threshing, and milling. For example, the number of major farm machines such as four-wheeled tractors, hand tractors, water pumps, power threshers, and rice milling units (RMUs) grew at an annual average of 10% during 2001–2010 (Food Crops Service of Riau Province, 2011). Nevertheless, the number of machines available remains insufficient to completely mechanize rice farming operations in the province. In the case of land preparation, for example, almost two-thirds of the work is still carried out by hand (Paman et al., 2012).

Further, rice farming in Riau Province, which is dominated by small-scale operations and subsistence-level production, has been facing various issues. Limited cultivated area and low yields are ongoing problems, the latter of which is attributed primarily to untimely field operations, a lack of irrigation (80% of the area remains reliant on rain-fed water sources), and low technological progress. Between 2001 and 2010, both cultivated area and rice production remained almost stagnant (annual growth of 1.4% and 2.9%, respectively), while the provincial population grew by 4.2% annually (Figs. 1 and 2). Consequently, Riau Province produces only approximately half as much rice as it needs (590.5 thousand tons in 2010), and this rice shortage is typically compensated by supplies from neighboring provinces that produce a surplus.

In order to increase cultivated area and rice yields, farming operations must be performed accurately and timely (Jain, 1979) by improving the use of farm power, especially mechanical power. Adequate and appropriate farm power is a key element to

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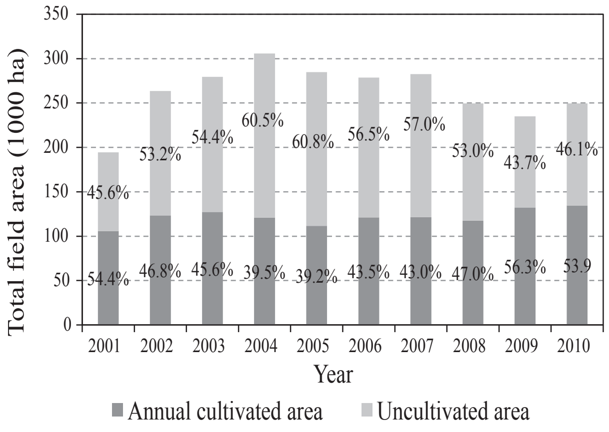

Fig. 1. Total paddy field area in Riau Province during 2001–2010.
Source: Food Crops Service of Riau Province (2011).

increasing agricultural output and labor productivity (Rijk, 1986) as well as an important input to achieve self-sufficiency in food production (Mondal et al., 2008). Based on the foregoing, this study determines the availability of mechanical power in Riau Province and examines the labor requirements and costs for small-scale rice farming operations.

2. Materials and methods

This study was carried out in two villages: Bunga Raya in the Siak Regency and Bangkinang Seberang in the Kampar Regency of Riau Province. These villages, which are rice centers in the province, were selected purposively to represent the most intensive rice production and highest mechanized farming in the province. Our field survey was conducted during the rainy season (October to March) in 2010/11 (the main season for rice growing in Riau Province). Rice growing can occupy 90–100% of paddy areas in the growing season, while farm machinery and equipment can work effectively because of the adequate water supply.

A total of 120 farmers were randomly sampled from the two selected villages (60 individuals in each). Primary data were collected through personal interviews with farmers by using structured questionnaires. The data collected included farm size, machine and equipment types, labor use and sources, labor wages, machinery and equipment rental charges, and the hours required for farming operations. Secondary data were derived from official publications, mainly the Food Crops Service and Statistical Bureau of Riau Province, and they included the number and types of farm machines, cultivated area and rice yields, and the population of Riau Province during 2001–2010. These data were tabulated and analyzed by using traditional descriptive statistical measures. In addition, the procedures for calculating the labor and power requirements and costs were described.

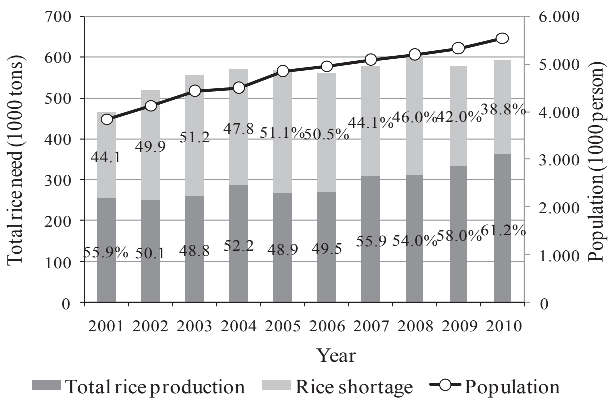

Fig. 2. Total rice demand and population in Riau Province during 2001–2010.
Source: Food Crops Service of Riau Province (2011).

3. Results and discussion

3.1. Mechanical power availability

The most common types of farm machines used on rice farms in Riau Province are four-wheeled tractors, hand tractors (including rotary tillers, power tillers, hydro tillers, and cultivators), power threshers, water pumps, dryers, and RMUs. Most of these pieces of equipment have been supplied through governmental aid under agricultural mechanization development programs rather than by the private sector. In particular, these machines have been given to farmers and organized into groups in order to provide rental services. Therefore, the number of farm machines available rests heavily on the government's budgetary fund. It is noteworthy that the increased availability of farm machinery has gradually contributed to raising farm power over the past 10 years to the point that draught animals are no longer used for rice farming operations in Riau Province.

As shown in Table 1, the availability of mechanical power in terms of horsepower per hectare ranged from 0.25 to 0.38 hp/ha with an average of 0.31 hp/ha annually during 2001–2010. This power level is very low compared with that attained by the Philippines (1.36 hp/ha; Elepaño et al., 2009) and India (1.81 hp/ha; Singh et al., 2010).

The rate of mechanical power also showed rather slow progress, growing by approximately 0.75% annually, with cultivated area increasing at a rate of 3% per annum. However, the simple regression analysis showed that the relationship between mechanical power and cultivated area had no statistically significance at the 95% confidence level.

Moreover, the regression model could explain only 14% of the observed variation in cultivated area ($R^2 = 0.1377$, $Slope = 0.1153$, $p = 0.5188$), suggesting that mechanical power has not yet been provided sufficiently to increase this variable.

Further, Table 1 also shows the density of the available farm machines during 2001–2010 in Riau Province. According to Herdt (1983), the density of machines such as hand tractors can determine the stage of the mechanization process. During 2001–2010, the number of hand tractors ranged from 4.63 to 9.79 units/1000 ha with an average growth of 8.51% annually. This finding indicates that the mechanization process remains low in Riau Province, between the early stage (2.5 units/1000 ha) and take-off stage (20 units/1000 ha). Hence, rice farming operations, especially land preparation, are difficult to mechanize completely in Riau Province owing to the insufficient availability of the necessary farm machines.

From 2001 to 2010, the number of four-wheeled tractors, power threshers, dryers, and RMUs decreased annually, whereas water pumps increased by an annual average of 28.7%. Our interviews revealed that water pumps have become important for increasing the annual cropping rate from 100% (i.e., only in the rainy season) to 200% (i.e., in both the rainy and the dry seasons). In other words, because water pumps transport water from wells or rivers to paddy fields, which lack water during the dry season, so farmers can grow rice in both seasons.

Although farm machines have advanced slowly over the past 10 years, rice farmers have become increasingly dependent on mechanization to perform both tractive and stationary operations.

Table 1
Mechanical power, cultivated area, and the density of farm machines in Riau Province during 2001–2010.

Year	Mechanical power (hp/ha)	Cultivated area (1000 ha)	Density (unit/1000 ha)					
			Four-wheeled tractors	Hand tractors	Water pumps	Power threshers	Dryers	RMUs
2001	0.33	105.68	1.17	4.63	3.89	9.44	1.33	12.62
2002	0.32	123.26	1.73	5.63	6.95	10.14	2.06	7.82
2003	0.34	127.36	1.47	7.64	7.73	10.70	1.10	8.33
2004	0.28	120.77	0.23	6.51	5.93	9.55	0.81	8.73
2005	0.29	111.68	0.32	7.18	6.51	7.99	1.44	9.48
2006	0.25	121.21	0.45	6.36	6.56	7.43	0.62	6.89
2007	0.28	121.37	0.39	6.13	13.41	6.15	0.49	7.87
2008	0.29	117.37	0.42	6.27	13.96	6.36	0.50	8.14
2009	0.38	132.37	0.36	9.79	25.52	8.31	0.48	6.72
2010	0.32	134.47	0.23	8.05	22.90	5.94	0.33	5.68
Average	0.31	121.55	0.37	6.83	16.47	8.84	0.49	7.06
Annual growth (%)	0.75	3.00	−2.90	8.51	28.71	−3.65	−5.58	−6.74

Source: Food Crops Service of Riau Province (2011)

Fig. 3 describes the demand and shortage for five types of farm machines in Riau Province. The greatest demand is for power threshers (8320 units) and the least is for dryers and RMUs (4160 units each). In addition, dryers suffer from the largest shortage (98%) compared with water pumps (50%), suggesting that the supply of all five types of farm machines is only half the level of demand at the very least.

The mechanical power available in Riau Province remains below that required to increase rice yields and achieve an efficient level of farm production. Fig. 4 illustrates that rice yields have increased over the past 10 years in line with the slow development of mechanical power. This finding implies that the growth in rice yields has been influenced by factors other than the available mechanical power, such as improved seeds, fertilizer use, pest and disease control, and better irrigation.

3.2. *Labor requirements and costs*

The machines used by rice farmers in Riau Province are small power types (range 5–23 hp) such as rotary tillers, power tillers, hydro tillers, power threshers, water pumps, and RMUs. In fact, the limited number of available machines has restricted the operations that can be mechanized.

While power-intensive operations such as land preparation, threshing, water pumping, and milling are now mechanized, seeding, planting, weeding, fertilizing, pest control, harvesting, cleaning, transportation, and drying are still performed by human labor. According to Takeshima and Salau (2010), in the early stage of agricultural mechanization, the use of mechanical power is limited to power-intensive operations that require little control.

As shown in Table 2, labor requirements per hectare for mechanized operations are only 7 machine-days compared with 83.26 man-days for manual operations. These labor requirements were calculated from the ratio of the total hours required for certain operations relative to the average number of working hours per day (e.g., eight). This finding shows that rice farming operations still predominantly depend on human power using traditional hand tools.

However, labor requirements vary considerably according to the type and size of farming operations. Land preparation, the most labor-intensive and costly rice cultivation operation, is performed by machine power at the beginning of the growing season. Rotary and power tillers are the most popular machines for performing such activities, although some farmers use hydro tillers if the water supply is sufficient. As shown in Table 2, land preparation takes approximately 3.25 machine-days per hectare and costs IDR 1200 thousand (US $133) based on local wage rates, representing approximately 15% of the total operation costs (Fig. 5).

Manual threshing and milling operations have been replaced by power threshers and RMUs, respectively. These activities now take 2.50 and 1.25 machine-days/ha for threshing and milling,

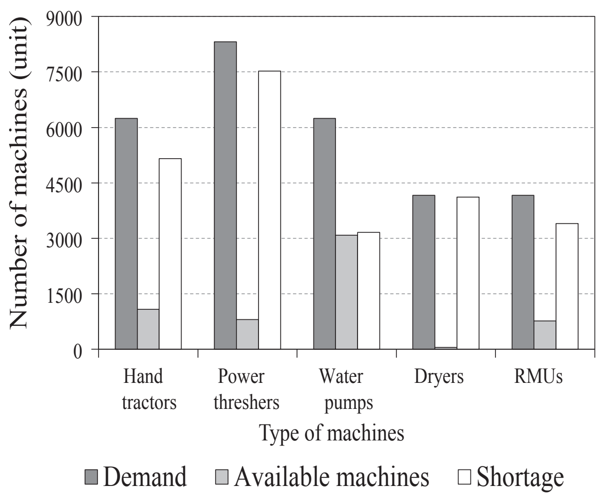

Fig. 3. Demand, availability, and shortage of farm machinery in Riau Province in 2010.
Source: Food Crops Service of Riau Province (2011).

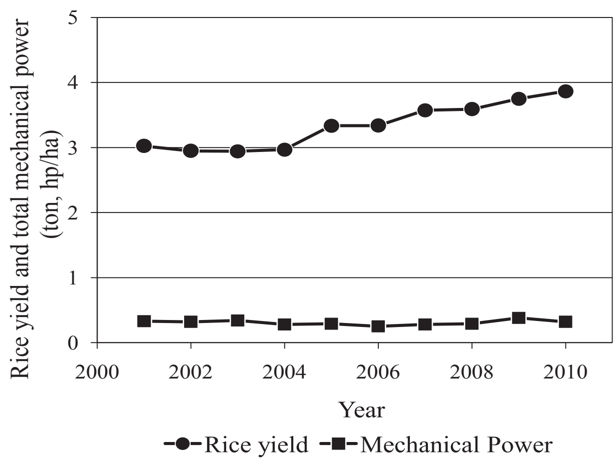

Fig. 4. Rice yields and mechanical power availability in Riau Province.
Source: Food Crops Service of Riau Province (2011).

Table 2
Labor requirements and the cost of rice farming operations.

Type of operation	Man-days/ha	Machine-days/ha	Equivalent to hp/ha	Equivalent to kW/ha	Cost/ha (IDR)	Cost/kW (IDR)
Land preparation	–	3.25	221.00	164.80	1,200,000	7282
Seeding	3.50	–	2.80	2.10	210,000	100,000
Planting	21.25	–	17.00	12.75	1,275,000	100,000
Weeding	16.25	–	13.00	9.75	975,000	100,000
Fertilizing	4.75	–	3.80	2.85	285,000	100,000
Pest control	4.38	–	3.50	2.63	262,800	100,000
Harvesting	19.25	–	15.40	11.55	1,155,000	100,000
Threshing	–	2.50	110.00	82.00	793,430	9676
Cleaning	3.88	–	3.10	2.33	232,800	100,000
Transportation	5.50	–	4.40	3.30	330,000	100,000
Drying	4.50	–	3.60	2.70	270,000	100,000
Milling	–	1.25	150.00	111.90	906,800	8104
Total	83.26	7.00	547.60	408.66	7,895,830	–

Note: An adult man is assumed to be equivalent to 0.1 hp.
One-day working equals 8 h with IDR 60,000 the human labor wage.
Average rice production was 4534 kg/ha.

respectively, and cost IDR 793 thousand (US $88) and IDR 907 thousand (US $101) per hectare, accounting for 10% and 12% of the total operation costs. These costs were calculated by multiplying total rice production per hectare by cost per kilogram (i.e., IDR 175 (US $0.019) for threshing and IDR 200 (US $0.022) for milling). Our discussions with farmers revealed that using mechanical power for these operations helps reduce labor and costs considerably, thereby minimizing yield losses, especially during threshing. Similarly, Sison et al. (1985) argued that the major effect of adopting machine power is the significant reduction in labor requirements for land preparation and mechanical threshers for postproduction operations.

Planting and harvesting are also highly labor-intensive rice farming activities. Srivastava et al. (2006) claimed that completing certain farming operations such as planting and harvesting in a timely manner increases yields and improves profitability. Delayed harvesting for one week after maturity, for instance, can lead to yield losses of 3.35–8.64% (Sunanto et al., 2011). Manual planting and harvesting is laborious and costly. Approximately 21.25 and 19.25 man-days/ha are required to plant seedlings and harvest rice by using a serrated sickle, respectively. Thus, planting incurs the largest cost per hectare (IDR 1275 thousand; US $142) followed by harvesting (IDR 1155; US $128). These costs were computed by multiplying the number of man-days by the labor wage per day (IDR 60,000; US $6.67). Planting and harvesting costs thus account for 16% and 15% of the total operation costs, respectively (Fig. 5).

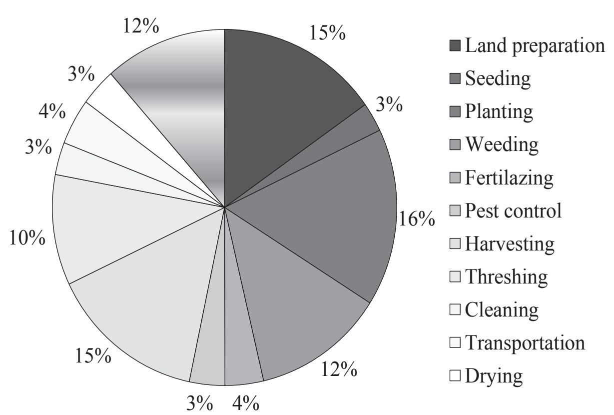

Fig. 5. Contribution of cost components relative to the total cost of rice farming operations.

Seeding, weeding, fertilizing, pest control, cleaning, transportation, and drying are also still manual practices. There are no significant differences in labor requirements for each of these operations, except for weeding, which depends greatly on the weed-growing conditions and thus the frequency of weed control. Generally, the first weeding is carried out 10–12 days after plantation and subsequent weeding is performed every 10 days depending on the growing conditions. Approximately 16.25 man-days/ha are required to perform manual weeding, and this costs IDR 975 thousand (US $108) or approximately 12% of the total cost of rice operations. Overall, it was estimated that the total cost of rice farming operations is IDR 7895.83 thousand (US $877), consisting of human labor (58%) and mechanical power (42%).

Further, the total power required to perform rice farming operations was 547.60 hp/ha, with farm machines accounting for 481 hp/ha (88%) of the total power required compared with human labor (12%). Mechanical power was estimated by multiplying the number of working hours by the average nominal horsepower of one machine, while human power was estimated by multiplying the number of working hours by average human power output.

According to Odigboh (1999) and Sahay (2004), an adult man can produce on average approximately 0.1 hp (0.075 kW) of power output. The total power requirement above is thus approximately 408.66 kW/ha, consisting of 358.7 kW/ha from machines and 49.96 kW/ha from human labor. This figure was calculated by multiplying total horsepower by a conversion factor of 0.75.

The power requirement varies considerably depending on the power source used and type of operation performed. Mechanized farming operations are less time-consuming and incur a lower cost per kW. By dividing the cost per hectare by the required energy, we can show that land preparation, for instance, costs only IDR 7.28 thousand (US $0.81) per kW compared with IDR 100 thousand (US $11.11) per kW for each manual operation. This result indicates that the use of farm machinery lowers operation costs. Therefore, farmers should be encouraged to adopt mechanical power in order to shorten the time needed to perform farming activities, reduce cost, and thus increase operational efficiency.

4. Conclusions

The average mechanical power available to rice farmers in Riau Province is very low (0.31 hp/ha) and it only increased by 0.75% annually during 2001–2010. Consequently, human labor remains the dominant input for performing rice farming operations in this region of Indonesia. The labor required to complete rice farming operations is 83.26 man-days/ha (equivalent to 49.96 kW/ha), whereas the mechanical power necessary is only approximately 7 machine-days/ha (equivalent to 358.7 kW/ha). Therefore, the use of mechanical power is limited only to power-intensive operations such as land preparation, threshing, and milling. Under such conditions, the total cost of rice farming operations was shown in this study to be IDR 7895.83 thousand (US $877). This overall cost is relatively high because of the larger cost of human power (IDR 100,000/kW; US $11.1) compared with IDR 8354/kW (US $0.93) on average for mechanical power.

However, it should be noted that although farm machines produce more power, they also reduce the cost per kW significantly. The results presented herein suggest a need to increase the mechanical power available by providing more farm machines to local rice farmers. Providing an adequate number of farm machines would accelerate the process of replacing human labor in order to save labor, time, and cost and ultimately improve farming efficiency.

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