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Machinery Utilization and Production Cost of Wetland, Direct Seeding Paddy Cultivation in Malaysia

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Abstract

A mean mechanization index of 0.59 and a total machinery energy of 477.78 MJ/ha were recorded for the direct seeding paddy cultivation in Malaysia. Highest mechanization index and machinery energy were obtained in the harvesting operation (0.99 and 336.81 MJ/ha) while the lowest values were in pesticides operations (0.19 and 3.97 MJ/ha). The benefit-cost ratios for an average farmer with and without government support within the block were respectively 1.37 and 1.68 with a mean yield of 7.63 tons/ha and mean total production cost of RM 6658.18/ha.

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Keywords: Mechanization index; machinery energy; paddy production cost; benefit-cost ratio; wetland paddy cultivation

1. Introduction

Rice is a major food crop grown and consumed on every continent of the world because of its adaptive capabilities which enable it to grow in areas having different soil types and climatic conditions (Ferrero and Tinarelli, 2008). Its origin is still surrounded by controversy, with some researchers holding the view that it was first domesticated in Southeast Asia around the bay of Bengal and other researchers claimed that it was first domesticated in China around Yangzi valley since around 7000 BC (Chang, 1983; Hill, 2010). World's production of rice for the year 2012 was estimated to be 719,738,273 tons harvested from 163,199,090 ha of farmlands with

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average yield level of 4.441 tons (FAOSTAT, 2014).

About 692,340 ha of arable land in Malaysia are subjected to paddy cultivation. The farmers in the country cultivate both lowland and upland paddy, and about 72% of the lowland paddy produced comes from eight granary areas practicing double cropping per year (Najim et al., 2007). Despite huge yearly budgetary expenditure dedicated to supporting paddy production, the average national yield of 3.973 tons/ha (FAOSTAT, 2014) is about 10% lower than the world average. The low paddy productivity level in the country has been attributed to a number of factors, with inadequate labour force being of great concern because of its strong influencing effects on production cost and the need for achieving timeliness in completion of critical farm operations in order to avoid undue losses. Presently studies have shown imported white milled rice cost less compared to similar grade of rice produced locally (Najim et al., 2007). One way to reduce production cost is by mechanizing operations with the highest human labour engagement in paddy production. Baruah and Bora (2008) in their study on energy demand forecast for agriculture in rural India demonstrated that the need for human labour reduces with an increase in the level of mechanization.

Mechanization of crop production is important in boosting farmland productivity and using tools, implements, and machineries of appropriate type, size and power ratings, can help to improve the efficiency of human time and labour. Ferrero and Tinarelli (2008) reported that a typical farm worker in Italy manages 40 – 60 ha of rice farm and affirmed the existence of one tractor and one combine harvester on every 12 and 60 ha of farmlands. In less developed countries nearly all paddy production operations are done manually. Therefore, the land area that a farmer manages is quite small often less one hectare per year. Khan et al. (2009) examined energy use pattern and the relationship between energy inputs and yield in Pakistan and found that higher net returns accrued to tractor operated farms compared to bullocks operated farms. Baruah and Dutta (2007) reported the farmers who used tractors and commercial fertilizers on their farms recorded higher yield compared to other farm groups that do not use tractors in India. Singh et al. (2005) reported the significant effect machinery energy expenditure has on yield where additional 1 MJ of machinery energy in wheat production led to increase in yield by 8.167 kg. Asgharipour (2012) claimed that with 1% increase in machinery energy the yield of sugar beet was increased by 0.22% in Iran.

The level of mechanization determines the magnitude of machinery energy used in crop production. Singh and Chancellor (1975) conducted energy input–output analysis in crop production by surveying 26 rice farms under various regimes of mechanization in North Central India. The result showed that farms under management category utilizing tractor in conducting tillage operations and also as means of transport expended more tractor energy to the tune of 240 kWh/ha compared to other farm categories. Pathak and Singh (1978) revealed the usage of higher machinery energy in paddy farms operated by tractors (639 kWh/ha) than those operated by bullocks (391 kWh/ha) for some selected crops in India. Pimentel and Pimentel (1979) showed that rice farmers in California used more machinery energy (1,506.96 MJ/ha) than rice farmers in both Japan (753.48 MJ/ha) and the Philippines (173.40 MJ/ha). Rutger and Grant (1980) showed a close matching in machinery energy expended by rice farmers in Arkansas and Louisiana but the machinery energy expended by rice farmers in the Philippines of 339.07 MJ/ha was found to be about seven times lower than the machinery energy used by rice farmers in Arkansas. Other related studies include Dazhong and Pimentel (1984) in China, Singh and Singh (1992) in India, Hulsbergen et al. (2001) in Germany, Bockari-Gevao et al. (2005) in Malaysia, Khan et al. (2010) in Australia, Pracha and Volk (2011) in Pakistan. Cherati et al. (2011) and Alipour et al. (2012) in Iran.

In this regard, an assessment of farm mechanization status for paddy production system has the potentials to reveal not only the level of energy used but also the critical operations that need to be favored for the introduction of mechanization. With correct farm machineries of appropriate power ratings, correct crop inputs and proper planning paddy cropping intensity per year could be increased, thereby boosting annual production. Currently, there are no documented studies regarding the extent of the machinery involvements in typical direct seeding wetland paddy cultivation systems, in Malaysia. Therefore, the objectives of the present study are to obtain field data on farm machinery utilization covering all the standard operations practiced by paddy farmers, to identify critical operations needing mechanization, and to evaluate the economic viability of paddy production in the country. The results of the study are expected to assist agricultural policy makers in their tasks of making comprehensive farm mechanization plan for wet paddy cultivation in Malaysia, in line with the ongoing rapid modernization and industrialization. Current developments are increasingly making the profession less attractive to the educated youths due to perceived field work drudgeries and the widely acknowledged low income earned by paddy farmers compared to earnings made by segment of the society engaged in other occupations. Becoming an industrial giant without achieving sound and sustainable food security base is not the pride of any nation including Malaysia.

2. Methodology

The data used in this study were collected during the February to July, 2013 paddy cropping season from 40 farm lands at block E5 Parit Lima Timur, Sungai Besar in Sabah Bernam district of Selangor, Malaysia located at $3^0$41'51.60" to $3^0$41'19.01" latitude and $101^0$01'21.09" to $101^0$01'59.51" longitude. The data collection included six wetland paddy production operations which consisted of tillage, seeding, fertilizing, harvesting, slashing and spraying operations. Field measurements were taken to determine the net land area of each farm, for the computation of field capacities and energy expenditures for the machineries used in field operations. Classical mathematical equations and energy conversion factors were used to computes farm machinery energy expenditures and mechanization index for all the operations covered. Effective field capacity, machinery energy, human energy and mechanization index were computed using the following equations:

$$Fc = \frac{A}{T} \tag{1}$$

where Fc is the effective field capacity (ha/h), A is the net farm land area (ha) and T is net field time (h). To compute the energy input of farm machinery, the total useful life and field capacity of the machines were taken into consideration as expressed in Equation 2.

$$ME = \frac{Cf * W}{Fc * L} \tag{2}$$

where ME is machinery energy (MJ/ha), Cf is conversion factor (MJ/kg), W is weight of machinery (kg) and L is useful life of machinery (h). The useful life for the machineries used in the study area was adopted from ASABE Standard (2006) as follows: 2 wheel drive tractor 12000 h, self-propelled combine harvester 3000 h, rotary tiller 1500 h, sprayer 1500 and spreader 1200 h. The energy conversion factors used for the machineries were 96.61, 87.63 and 62.70 MJ/kg respectively for tractor, self-propelled combine harvester and others (Canakci et al., 2005).

$$HE = \frac{H * lc}{A} \tag{3}$$

where HE is human energy (MJ/ha), H is duration of operation (h) and lc is energy conversion factor for human labour (MJ/h) assumed to be 1.96 MJ/h (Gajaseni, 1995).

$$MI = \frac{ME}{ME + HE} \tag{4}$$

where MI is mechanization index, ME and HE are as defined previously.

The total farm machinery energy expenditure in MJ/ha, was determined in each farm lot as the ratio of the summation of machinery energy expenditures for all the operations and the net land area of the respective farm lots. The average farm machinery energy expenditure for the block was obtained as the ratio of the summation of the machinery energy accrued to all the farms/hectare and number of farms in the block. The average mechanization index for paddy cultivation in the block was also obtained in a similar manner.

Regarding economic analysis the cost of all inputs, services paid by the farmers, and price of paddy was based on the prevailing market rates. Operations performed by the farmers themselves or their family members were also evaluated based on the prevailing market rates following approach adopted by Khan et al. (2010). Paddy price, gross margin, benefit-cost ratio, labour productivity, fuel productivity and machinery productivity were computed using the following mathematical relationships:

$$P = Yp \quad (5)$$

where P = price of paddy harvested per unit area (RM/ha), Y = harvested yield per unit area (tons/ha) and p = guaranteed minimum price set by government (RM/ton) current rate is RM 1,200/ton.

$$GM = P - TC \quad (6)$$

where GM = gross margin (RM/ha), TC = total cost of production (RM/ha), it is the summation of rent, transport, labor, fuel, fertilizer, chemicals, seeds and machinery use costs and P is as defined previously.

$$BCR = \frac{P}{TC} \quad (7)$$

where BCR = benefit-cost ratio and P and TC are as defined previously.

$$Lp = \frac{LC}{Y} \quad (8)$$

where Lp = labor productivity (RM/ton), LC = cost of labour (RM/ha) and Y is as defined previously.

$$Fp = \frac{FuC}{Y} \quad (9)$$

where Fp = fuel productivity (RM/ton), FuC = cost of fuel consumed by machineries (RM/ha) and Y is as defined previously.

$$Mp = \frac{MC}{Y} \quad (10)$$

where Mp = machinery productivity (RM/ton), MC = cost of machinery use (RM/ha) and Y is as defined previously.

3. Results and discussion

3.1 Machinery inventory and field performance analysis

Farmers in the study area used medium size two wheel drive (2WD) tractors of different makes and models with engine power ratings ranging from 55 – 70 kW as prime movers in performing the tillage and slashing operations. In performing tillage operations, rotary tillers of different working width ranging from 2.40 to 3.18 m were attached to the tractors while open blade paddy straw cutters with average cutting width of 1.70 m were coupled to the tractors in performing the slashing operation. In seeding operation all the farmers used portable power knapsack blowers to broadcast the pre-germinated rice seeds on the puddle soil. None of the farmers used transplanting machine on their farms nor performed the operation manually. The blowers were carried by farm workers on their backs during the seeding operation and they have an average weight of 12 kg with engine power rating of 3.6 kW. The same blowers were used by the farmers in performing fertilizer application and a similar power knapsack mist blower was used in spraying pesticides. The harvesting operation was done using a 7.5 tons 1545 Clayson New Holland rice combine harvesters with rated engine power of 82 kW at 2500 rpm and reel width of 4.27 m.

Tillage, slashing and harvesting operations are mechanized whereas seeding, fertilizing and spraying operations are not. In developing countries like India, Pakistan, Bangladesh, Thailand, etc. Most of their paddy farmers who are resource-poor and low-scale producers, still perform the task of land preparation using draft animals and or two wheel pedestrian tractors (Khan et al, 2009; Ramachandra and Nagarathna, 2001; Pathak and Singh, 1978; Islam et al., 2001) leading to huge human energy expenditures in terms of total seasonal field time. The use of combination of medium size tractors and portable power blowers by paddy farmers in the study area differs significantly from high powered implements and machineries use by paddy farmers in developed countries. For example in Italy, Ferrero and Tinarelli (2008) reported use of tractors with the power rating above 100 kW, 6 – 10 t/h capacity combines, laser guided levelling blade, spring toothed ploughs and rotary harrows by rice farmers.

Table 1 presented the machinery field capacities recorded in performing the various operations associated with wetland paddy cultivation in the study area. The highest field capacity of 1.325 ha/h was recorded in slashing operation and paddy harvesting had the highest field time (least field capacity) among all the operations covered by the study. In tillage, the least field capacity was in the first run (0.982 ha/h), and the highest in the third run (1.063 ha/h). Farmers in the study area used wider rotary tillers with working width of 3.18 m in performing the third tillage pass. Although both the first and second tillage runs were done using rotary tillers having same working width of 2.4 m, better field performance to the tune of 7.4%, was recorded during the second tillage run over the first tillage run. A cumulative machinery field time of 21.28 h/ha was used by the farmers. Spraying and slashing operations accounted for about 41.12% and 3.48% respectively of the total machinery time.

Table 1. Field capacity and total field time based operation.

Field operation	Field capacity (*ha/h*)	Total field time (*h/ha*)
First tillage	0.982	1.06
Second tillage	1.055	0.97
Third tillage	1.063	0.84
Seeding	0.722	1.56
Fertilizing	1.250	5.82
Spraying	0.901	8.75
Harvesting	0.665	1.54
Slashing	1.325	0.74

Table 2 shows the distribution of field time based actual operation and turning/reversing time in respect of the three mechanized operations. Analysis of the field time distribution, showed that slashing operation had the highest percentage of turning/reversing time of 21% (9.32 min/ha), compared to the other operations with scores of 15, 15, 19 and 13% for first tillage, second tillage, third tillage and harvesting operations respectively. Thereby reflecting the small working width for the class of paddy straw cutters used (1.70 m) compared to the working widths of the rotary tillers used in the first, second and third tillage operations (2.40 – 3.18 m) and the combine harvester's reel width (4.270 m). The highest percentage actual operation time recorded was in the first and second tillage operations, with 85% of net operation time each representing 54.06 and 49.47 min/ha respectively. Both the first and second tillage operations were conducted using rotary tillers of the same working width while the third tillage operation was done using a much wider rotary tiller. Thus turning time in tillage operation for tractor–implement combination increases with an increase in the width of the implement used, perhaps amplified by the fragmented nature of the farmlands in the study area which ranges from 0.255 ha to 1.125 ha, with the average being 0.675 ha. Analysis of the net harvester field time showed that only 66% (60.98 min/ha) of the total harvesting time, was used in performing the actual harvesting activities.

Table 2. Time and motion analysis for mechanized operations.

Field operation	Percent field time		
	Task	Turning/Reversing	Others
First tillage	85	15	-
Second tillage	85	15	-
Third tillage	81	19	-
Harvesting	66	13	21
Slashing	79	21	

3.2 *Analysis of machinery energy expenditure*

A mean total machinery energy expenditure of 477.781 MJ/ha was used by the farmers in conducting all the operations covered by the study, the breakdown of which is given in Table 3. The highest machinery energy expenditure of 336.814 MJ/ha (3.844 kg/ha) representing 70.50% of the total machinery energy was accounted by harvesting operation. Followed by the three tillage runs (first, second and third tillage) in combination accounted for

22.76% or 108.730 MJ/ha (1.454 kg/ha) and slashing operation, with 24.907 MJ/ha or 0.325 kg/ha representing 5.21% of the total average machinery energy expended by the farmers. The least machinery energy was recorded in seeding operation with share of 0.945 MJ/ha (0.012 kg/ha) accounting for 0.20% of the total machinery energy used by the farmers. The higher contribution of machinery energy expenditure due to fertilizer and pesticide applications over seeding operation highlighted on the multiple application frequencies for the two operations. Farmers in the area performed about four rounds of fertilizer applications and six rounds of pesticide applications compared to one seeding operation. Thus on a per application basis, pesticide application contributed the least machinery energy of 0.628 MJ/ha, reflecting the high level of human labour involvements in conducting the operation. Compared to machinery energy used by rice farmers in developed agriculture, paddy farmers in Malaysia use less than one fifth of the reported machinery energy of 38 kg/ha used by rice farmers in USA (Pimentel, 2009).

Table 3. Distribution of machinery energy expenditure based operations.

Field operation	Energy expenditures	
	(kg/ha)	(MJ/ha)
First tillage	0.528	39.620
Second tillage	0.484	36.284
Third tillage	0.442	32.825
Seeding	0.012	0.945
Fertilizing	0.038	2.134
Spraying	0.063	3.972
Harvesting	3.844	336.814
Slashing	0.325	24.907
Total	5.736	477.781

3.3. Comparison of mechanization index among operations

An overall mean mechanization index of 58.57% (Table 4) was recorded for all the farms in the study area. Operation–wise, harvesting operation had the highest mechanization index of 99.11%. Paddy farmers in Malaysia generally use self-propelled combine harvesters in performing harvesting operation. Therefore the energy use in paddy harvesting operation in Malaysia is comparable with those of paddy farms in developed agriculture such as America, Australia and Italy (Ferrero and Tinarelli, 2008; Hulsbergen et al., 2001) but contrast sharply with typical energy use in India and Bangladesh paddy farms where reaping, threshing and cleaning activities are treated as distinctive unit operations (Baruah and Dutta, 2007; Iqbal, 2008) involving huge manual labour. The next operation with high mechanization index is the tillage operation, with a recorded mechanization index of 95.04%. About 4.96% of the energy expended in performing tillage operation was accounted by human labour. The higher contribution for human labour in conducting tillage operation compared to the share contribution for human labour in harvesting operation reflected on multiplicity in the conduct of tillage operation. Tillage operation in wetland paddy farms generally involves many passes (about 2 – 3 runs) before achieving good soil tilt compared with a single pass required for harvesting operation.

Slashing operation which is conducted using tractor mounted paddy straw cutter also has a high mechanization index of up to 94.45%, denoting human labour involvement of 5.55%. In comparison with tillage operation, the human labour in slashing operation is marginally higher to the tune of 0.59%. Compared with the mechanization index of slashing operation, harvesting operation was accomplished with about 4.66% less human labour in proportion to machinery energy. As for the remaining operations (i.e. planting, fertilizing and spraying) their mechanization index was found to be below 50% each thereby suggesting more human labour involvements compared to machinery energy used in performing the operations. The most critical operation requiring mechanization is therefore spraying of chemicals. Its need for mechanization is as high as 80.76%, suggesting that spraying operation as currently done by farmers in the study area is not only laborious and tiring but also poses significant threat to the health of the farmers/farm workers due to their prolong exposure to the chemicals during application. Hence a major drawback to the sustainability of paddy production in Malaysia, in this regard there is an urgent need for mechanizing pesticides application operation in the country.

Table 4. Distribution of mechanization index according to operations.

Operations	Mechanization index (%)	Confidence interval
Tillage	95.037	0.049
Fertilizing	19.900	0.605
Spraying	19.296	0.864
Harvesting	99.113	0.000
Slashing	94.450	8.059
Average	58.570	

3.4 Benefit – cost analysis

The cost analysis presented in Table 5 shows a benefit-cost ratio of 1.37 assuming no government subsidy support package of RM 1,213.56/ha (comprising of RM/ha of 100, 200 and 913.56 for tillage, pesticides and fertilizer respectively) given to paddy farmers in Malaysia. Inclusive of the subsidies the benefit-cost ratio moved up to 1.68 and mean gross margin of RM3705.38/ha. This benefit-cost ratio is still low compared to the benefit-cost ratio of 3.33 obtained by rice farmers in Australia (Khan et al. 2010) even though farmers in Malaysia do not incur any financial cost due to irrigation activities ranked as the most expensive operation for growing rice in Australia. It is therefore evident that cost of inputs are higher in Malaysia and also farmers lacks scale economy to achieve optimum benefit from selective mechanization under the existing conditions of small areas of farmlands which they cultivate. Most of the chemical pesticides and fertilizers use by farmers in Malaysia are imported. Similarly cost of labour is high particularly during peak periods due to limited availability and high demand.

Table 5. Cost analysis for 40 farm lots.

Details	Mean
Yield (tons/ha)	7.63
Paddy price (RM/ton)	1200.00
Value of yield (RM/ha)	9150.00
Break even yield (ton/ha)	5.55
Total cost of inputs (RM/ha)	3905.67
Labor (RM/ha)	614.67
Fuel (RM/ha)	111.07
Machinery (RM/ha)	828.10
Seeds (RM/ha)	483.98
Pesticides (RM/ha)	690.47
Fertilizer (RM/ha)	1177.37
Rent (RM/ha)	2600.00
Transport (RM/ha)	152.51
Total cost of production (RM/ha)	6658.18
Gross margin (RM/ha)	2491.82
Cost efficiency (%)	137.43
Labor cost productivity (RM/ton)	80.61
Machinery cost productivity (RM/ton)	108.60
Fuel cost productivity (RM/ton)	14.57
Total cost productivity (RM/ton)	873.20

Land rent and operating expenses (labour and fuel) accounted for about 39.05% and 10.90% respectively of the total cost of production. Excluding rent the benefit-cost ratio will be 2.25, modest enough for investment lasting four months. It has been shown that fragmented farmlands increases production costs and reduces the advantages that could be derived from scale economies (Kentaro, 2010). Olaoye and Rotimi (2010) cited Muchow et al. (2002) statement that profit of reasonable scale in mechanized systems of production is achieved through cultivation of large farm areas. The reasons are that fixed cost decreases considerably by distributing it over large areas in addition to improvements in the field capacities of heavy duty machineries such as the self-propelled combine harvesters in use by paddy farmers in Malaysia.

The highest cost of inputs was in fertilizer procurements (Table 5). It accounted for 30.15% of the cost of inputs used or 17.68% of the total cost of production. Fuel cost accounted for about 2.84% of the total cost of inputs used by the farmers. Smith (1993) reported fuel expenditures in the production of cotton and soya beans of 3.5 and 8% respectively in USA. The cost of producing 1 ton of paddy in the study area was RM 873.20 making break-even yield to be 5.55 tons/ha which is about 28.41% higher than the national average. Labour, machinery and fuel cost productivities were RM 80.61, 108.60 and 14.57/ton respectively. This analysis is of particular importance to agricultural policy makers since it highlighted on the implications of policy change e.g. removal of government subsidies, rise in labour cost due to stringent immigration policies and hike in custom charge due to rising costs of tractors and spare parts on the cost of paddy production and profit margin to farmers. It is pertinent to point out that current government incentive support packages contributes about 32.75% of the total profit made by the farmers. Removing subsidies without commensurate increase in the price of paddy (which is heavily regulated by government) will put the farmers in bad economic spot. This is likely to cause further abandonments of paddy cultivation by farmers to more lucrative occupations, hence a threat to sustainable production.

4. Conclusions

In this study mechanization status and benefit-cost ratio for direct seeding wetland paddy cultivation in Malaysia were evaluated. From the results of the study the following conclusions are drawn:

About 41.43% of the work associated with direct seeding wetland paddy cultivation in the country is manually executed. The most critical operation requiring mechanization is the spraying operation with demand for mechanization of up to 80.76%. It should be prioritized in any future government plan for mechanizing paddy cultivation in the country. It accounted for about 41.14% of the entire cultivation time, implying that farmers/workers faces high risk of over exposure to the chemicals. Mechanizing spraying operation would help to safeguard the farmers/workers health, help achieve timeliness in operation and better management in using pesticides.

The mean yield of 7.63 tons/ha recorded in the study area nearly doubles the national average, indicating the possibility for boosting national paddy productivity level if farmers in other irrigation schemes follow the practices of farmers in the study area.

Fertilizer procurements had the highest cost and it accounted for 30.15% of the costs of inputs used or 17.68% of the total costs of production. The cost of producing 1 ton of paddy is RM 873.20 making break-even yield to be 5.55 tons/ha which is about 28.41% higher than the national average.

In the absence of government support packages paddy farmers in the country will be in bad economic position due to low benefit-cost ratio of 1.37 as found in the present study. This is likely to cause further abandonments of paddy cultivation by the farmers to more lucrative occupations.

The low gross margin earned by the paddy farmers in the country is partly due to small cultivated farm area making both fixed and operating expenses to be high on per hectare basis. The high rent paid to land owners is another major expense that significantly makes profit low. Generally for mechanization in paddy production to be cost effective, farm areas must be large enough (above 1 ha) to lower both the high cost of owning and operating expenses for the machineries used.

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