インドネシアカンパー区の小規模米作農業における三種の耕うん機の経済的・機能的評価

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Working Performance and Economic Comparison of Three Power Tiller Types for Small-Scale Rice Farming in the Kampar Region of Indonesia

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Abstract

A field survey was conducted to compare the working performance and cost of three types of power tillers for tillage operations in the Kampar Region of Riau Province in Indonesia. A total of 22 rotary tillers, 11 moldboard plows, and 27 hydro tillers were purposively selected from seven districts in the region. The managers, custom operators, and mechanics of these machines were interviewed in 2012 and 2013 to collect data. The results showed that hydro tillers were the best in terms of their working performance, operational cost savings, and profitability. These machines must be employed for only 3.07 ha/season for operators to break even. For these reasons, it is suggested that farmers would benefit most by choosing hydro tillers for tillage operations.

[Keywords] working performance, economic comparison, power tillers, small-scale rice farming

I Introduction

In rice cultivation systems, land preparation is one of the most labor-intensive and high-cost operations. The success of such farming operations, especially those involving tillage operations, depends greatly on the type of implements and farm machines used (e.g., tractors). Wanjun (1983) has found that for farm machines to appeal to farmers, they must be suited to specific conditions, easy to operate and maintain, reliable, durable, and inexpensive. Specific local conditions that may also affect the machines' features include natural conditions, farming systems, scales of production, and economic and technical contexts.

In small-scale farming practice, small farm tractors are most commonly used as the power source for land preparation, because they are both affordable and accessible. The availability of these machines allows farmers to improve land productivity and reduce time-consuming manual labor (Reid, et al. 2003). Al-Suhaibani, et al. (2006) explain that the proper selection and matching of farm machines is essential for reducing farms' costs of ownership and operation. Accordingly, selecting the best size and type of equipment for each application and matching machinery components in a complete system are important in the efficient management of machines (Kepner, et al. 2005) and in determining the profitability of a given farming system (Dash and Sirohi, 2008).

One type of small tractor that is most popular with small-scale rice farmers is the power tiller. Power tillers are called a variety of names in different countries, including two-wheel tractors, single axle tractors, hand tractors, and walking tractors. In this paper, they are consistently referred to as "power tillers" for consistency and ease of understanding. These machines are commonly used for land preparation in developing countries in both dry and wet land conditions, because they are particularly well-suited to small fields (Tewari, et al. 2004). The small size and low weight of power tillers make them ideal for use in small-scale paddy fields. In terms of past studies of these machines, the causes and consequences of their utilization have been reported by Jabbar, et al. (1983) and their impact on farm productivity and employment has been explored by Sarker and Barton (2006).

As multi-purpose hand-tractors, power tillers are designed primarily for rotary tilling and other operations on small farms (Salokhe and Hendriadi, 1995; Ademiluyi and Oladele, 2008; Ademiluyi, et al. 2008; Ademiluyi, et al. 2009; Adamu, et al. 2014). In Indonesia, power tillers are

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mostly used for land preparation in agricultural fields containing food crops, and rarely for other farm operations (Salokhe and Hendriadi, 1995). Different types of power tillers have different effects on working performance and operation costs. The working performance in this research is defined as the number of hectare that a power tiller can complete per hour, day or season of operation.

In Riau Province, power tillers are widely used in paddy field areas, and mostly by small farmers for paddy field tillage operations. The three types of power tiller that are most popular among small farmers are rotary tillers, moldboard plows, and hydro tillers. Both rotary tillers and moldboard plows are Japanese made (Yanmar), whereas the hydro tiller is an Indonesian machine type that resembles the floating tiller or turtle tiller of the Philippines (Villaruz, 1985; Tadeo, et al. 1993) and is appropriate for use in water-logged areas. Hydro tiller in Riau Province are made by local workshops (non-fabricated machines) using Honda automobile engines as driving engines.

Power tillers are commonly owned and hired out by groups to perform tillage operations through a customized system under farmer group management. This is one method of mechanization development at the farm level that is suited to small farmers in Riau Province today. The objective of this study is to compare the working performance and economic features of three types of power tillers commonly used in small-scale rice farming in Riau. This information can be useful for farmers in selecting the best type of power tillers for effective use and efficient operation.

II Materials and methods

For this study, a survey was conducted in seven districts of the Kampar Region of Riau Province, during the rainy seasons from September 2012 to January 2013. The rainy season is the main growing season in this region, as rice crop agriculture is feasible on 100% of the available land area. During this season, paddy field areas have ample access to water. Districts in which machinery hiring service groups operate were purposively selected for the survey. Data on 22 rotary tillers, 27 hydro tillers, and 11 moldboard plows were collected using purposive sampling methods. This means that the selected power tillers were operated by custom operators, used for tillage works under similar field conditions, and aged within a predetermined range of economic life (≤5 years) with a good machine condition.

This research used primary data collected using a pre-structured questionnaire to personally interview machinery hiring service group managers, machine operators, and mechanics. The primary data gathered by the interviewers included information on machine make, type, age, purchase price and interest rates; seasonal working areas and days; daily working hours: custom rates; fuel, oil, and lubricant costs; spare part and repair costs; and shelter costs.

The collected data were analyzed using simple statistical techniques, such as percentage, mean, and variance analysis. Analysis of variance (ANOVA) was used to test the significance of the differences in working performance and economic parameters across the three types of power tillers. Furthermore, a simple cost accounting method was employed to analyze the economics of the machinery costs with a focus on analysis of the depreciation, interest, cost, revenue, profit, and break-even point. The values were then expressed in Indonesian Rupiahs (IDR) and United State Dollars (USD).

Cost estimation : Estimating the cost of machinery operation can be done on either an hourly basis or a hectare basis (Fashola et al., 2007), and the hectare basis was used in this study. Costs associated with owning and operating machines were estimated to include fixed and variable costs. Depreciation and interest expenses were considered fixed costs. Other fixed costs, such as tax, insurance, and shelter costs were ignored as irrelevant for a variety of reasons, e.g., none of the machines were housed in appropriate shelters. The most realistic and simplest method for estimating depreciation is the straight-line method (Butterworth and Nix, 1983 ; Kepner, et al. 2005). Depreciation was calculated as straight-line depreciation over 5 years of useful life. The most common equation to calculate the annual depreciation as used by Cicek (2011); Kamboj, et al. (2012) ; Rahman, et al. (2013) is expressed as

$$D=\frac{P-S}{L} \tag{1}$$

where, D is the depreciation (IDR/yr); P is the purchase price of the power tillers (IDR), S is the salvage value of the power tillers (IDR) (assumed to be 10% of the purchase price), and L is the life of the power tillers (y).

Furthermore, the annual interest on the investment of the power tillers was calculated as

$$I=\frac{P+S}{2}\times i \tag{2}$$

where I is the interest on the investment of the the power tillers and i is the annual interest rate (assuming the prevailing interest rate in the survey area is 6%).

Variable costs included all expenditures for fuel, oil, lubricant, repair, maintenance, and operator wages. Repair costs included both the materials and labor required to carry out repairs (Fairbanks, et al. 1971). Operator wages in the survey area were computed as one half of the total revenue minus the total costs. The total costs (*TC*) were expressed on a hectare basis and calculated as

$$TC = FC + VC \tag{3}$$

where *FC* is the fixed cost (IDR/ha) and *VC* is the variable cost (IDR/ha)

Revenue and profit determination: The revenue (IDR/ha) obtained from power tiller operation is equal to the custom rates, i.e., the prices that are paid by the users for custom-provided machinery services. According to Owombo et al. (2012), the profit (π) for each power tiller is computed as

$$\pi = R - TC \tag{4}$$

where R is the total revenue. Farm machinery operation makes a profit when the total revenue exceeds the costs (Riggs, et al. 1998).

Break-evenpoint. The break-even point (*BEP*) is the point at which the total revenue is exactly equal to the total costs. At this point no profit is made and no losses are incurred (Kamboj, et al. 2012). With BEP data, it is possible to compute the average area that must be covered per season to break even over a tractor's life. According to Butterworth and Nix (1983); Paman, et al. (2010) and Kamboj, et al. (2012), the BEP area can be calculated as

$$BEP\,(\text{ha}) = \frac{FC}{CR - AVC} \tag{5}$$

where: *CR* is the custom rate (IDR/ha) and *AVC* is the average variable cost (IDR/ha)

III Results and discussion

1. Power tiller characteristics and performance

As previously mentioned, the three types of power tillers commonly used by rice farmers in the survey area are rotary tillers, moldboard plows, and hydro tillers (Fig. 1). The main differences between these types are their wheels, their attached implements, and the forms of their bodies. Both moldboard plows and rotary tillers are equipped with pairs of iron wheels to prevent them from becoming stuck in deep mud, whereas hydro tillers use pairs of tires that are detached when the machines are operated in a field. Together with different tillage implements, these tillers can accomplish a variety of land preparation activities, including plowing, puddling, and leveling.

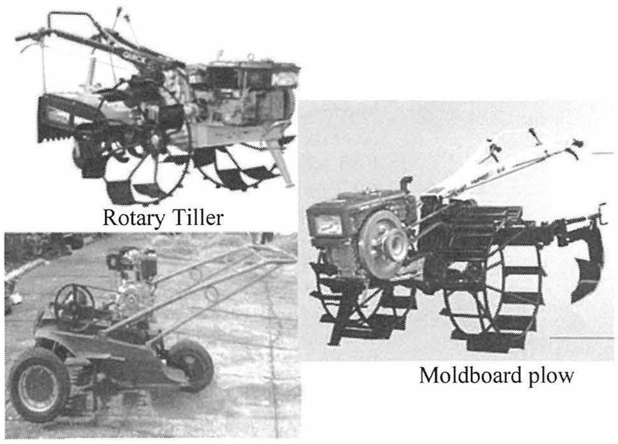

Fig. 1 Three types of power tillers

The moldboard plows commonly use two implement types, i.e., a single moldboard, and puddler (leveler) as reported by (Paman et al., 2007). With a single moldboard attached, the moldboard plow can be used for plowing (primary tillage). The machine is mounted with a puddler implement so that it can be used for puddling and leveling operation (secondary tillage). Plowing and puddling are conducted on soft ground and in flooded conditions, respectively. Rotary tillers and hydro tillers are equipped with rotavator implements to enable them to perform puddling operations in flooded conditions without changing to another implement. With these tillers, tillage work is conducted through a single operation, which is usually repeated one to three times to achieve the desired puddling quality for paddy growing.

According to Table 1, the engine power of the power tillers examined in this study ranged from 8.5–10.5 hp (6.4–7.8 kW) for rotary tillers, 6.5–8.5 hp (4.9–6.4 kW) for moldboard plows, and 5.5–9.0 hp (4.1–6.8 kW) for hydro tillers. The most common engine power for both rotary tillers and moldboard plows was 8.5 hp (6.4 kW), whereas that of hydro tillers was 9 hp (6.7 kWh). The average ages of the power tillers were below the typical economic life of five years, averaging 3.2 years for rotary tillers, 3.7 years for moldboard plows, and 2.8 years for hydro tillers.

The average fuel consumption varied slightly across the power tillers. Moldboard plows had the highest levels of fuel consumption per hectare plowed (17.75 l/ha), followed by hydro tillers (16.98 l/ha), and rotary tillers (15.88 l/ha). The differences in fuel consumption were caused by plow type, plowing depth and speed, and soil moisture level, as has been found in other studies (Sirhan,

Table 1 Characteristics and working performance of three types of power tillers

Items	Rotary tiller	Moldboard plow	Hydro tiller
Characteristics			
Maximum power (PS)	8.5-10.5	6.5-8.5	5.5-9.0
Average age (y)	3.2	3.7	2.8
Fuel consumption (L/ha)	15.88	17.75	16.98
Oil consumption (L/ha)*	0.77	0.93	0.67
Performance			
Working days per season (day/season)	22.82	20.45	19.67
Working hours per hectare (h//ha)	20.95 (8)	23.26 (16)	18.86 (14)
Hectares per working day (ha/day)	0.36	0.32	0.40
Working days per hectare (day/ha)	2.77	3.13	2.49
Working area per season (ha/season)	10.14	8.32	8.63

*Note: Values in parentheses show maximum performance achieved by each machine

et al. 2002; Adewoyin and Ajav, 2013). These factors had an interactive effect on fuel consumption. Adewoyin and Ajav (2013) added that there were other parameters that affected tractors' fuel consumption during ploughing, such as the compression ratio, plant residue, size of the tractor, and variation in tractor engine configurations.

Based on ANOVA, however, there was no significant difference in fuel consumption across the power tiller types ($p > 0.05$). This result is in agreement with the finding of Ahaneku, et al. (2009) who reported that fuel consumption parameters showed no significant differences when tillers were operated under the same conditions. However, in this study, the average oil consumptions of 0.7, 0.93, and 0.67 l/ha for rotary tillers, moldboard plows, and hydro tillers, respectively, showed a significant difference ($p \leq 0.05$). This result indicates that moldboard plows tend to consume more oil than rotary tillers or hydro tillers.

The amount of time available to perform land preparation in the survey area is roughly one month per season. The limited land preparation time is due to the delayed start of the growing season as farmers wait for rainfall. It is important to note that climate change has made it increasingly difficult to accurately predict the beginning of the rainy season. However, it was found that the seasonal working days of power tillers amounted to less than one month on average and varied slightly among tillers. Table 1 shows that the longest average number of working day per season among the different tillers was 22.82 days for rotary tillers, and the shortest was 19.67 day for hydro tillers.

Table 1 also indicates that the hydro tiller performs best in terms of working hours per hectare (18.86 h/ha), hectares per working day (0.40 ha/day) and working days per hectare (2.49 days/ha). The rotary tiller is the second-best performer in terms of working hours per hectare (20.96 h/ha), hectares per working day (0.36 ha/day), and working days per hectare (2.77 days/ha). The lowest performer is the moldboard plow, with 23.26 working hours per hectare, 0.32 hectares per working day, and 3.13 working days per hectare. For all three types of tiller, the working hours per hectare were under the maximum capacity, i.e., 8 h/ha for the rotary tiller, 16 h/ha for the moldboard plow, and 14 h/ha for the hydro tiller. The average working time per hectare for the moldboard plows in this study was longer than that found by Paman, et al. (2007) in the Siak Regency (22.5 h/ha). The ANOVA results indicate that both working days per season and working hours per hectare did not significantly differ across power tillers ($p > 0.05$). In addition to field conditions and inherent machine features, the working performance of a power tiller may depend on the operator (Binisam, et al. 2007)

Furthermore, rotary tillers had the largest seasonal working area, covering an average of 10.14 ha, followed by hydro tillers (8.63 ha), and moldboard plows (8.32 ha). In addition to being affected by these variations in tiller performance, seasonal working areas were also influenced by the number of work contracts, available time of custom operators, machinery breakdowns, and paddy field conditions. Interviews with custom operators revealed that paddy field conditions, such as water supply and weed growth, greatly affected not only seasonal working areas, but also the types of power tillers that could be used. However, seasonal working areas did not significantly differ across power tillers ($p > 0.05$).

2. Machine operation costs

Both fixed and variable costs were determined on a per-hectare basis. To determine the fixed cost per hectare, the fixed costs computed from Equation 1 were divided by the number of hectares in which one machine can be operated during a season. The estimated average fixed costs per hectare were found to vary across power tillers. As shown in Table 2, the highest fixed costs was

Table 2 Cost, revenue, profit, and break-even point for three types of power tillers

Item	Rotary tiller		Moldboard plow		Hydro tiller	
	IDR (Thousands)	%	IDR (Thousands)	%	IDR (Thousands)	%
Costs*	839.46	75	858.97	78	701.26	67
Fixed costs	433.28		446.33		220.19	
Var. costs*	406.18		412.64		481.07	
Revenue	1,122.73		1,104.55		1,050.00	
Profit	283.27	25	245.58	22	348.74	33
BEP (ha)	5.14		4.29		3.07	

Note: US $1 is equivalent to roughly IDR11,000, according to the average exchange rate for 2013. BEP=break-even point. %=percentage of revenue.
*Significantly different at the 5% probability level.

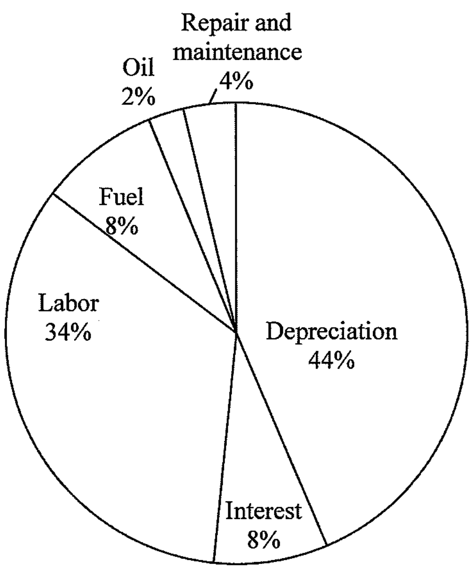

Fig. 2 Relative importance of all cost items for rotary tiller

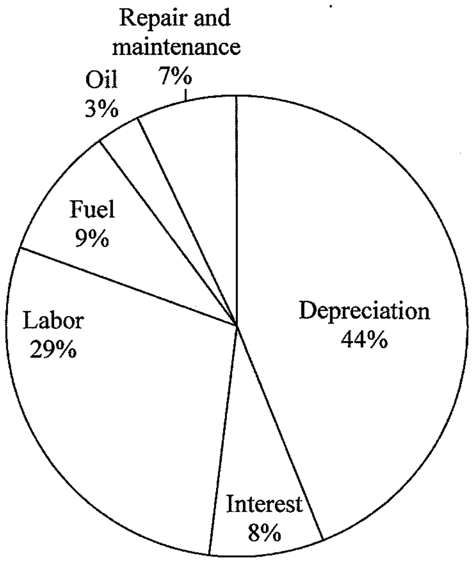

Fig. 3 Relative importance of all cost items for moldboard plow

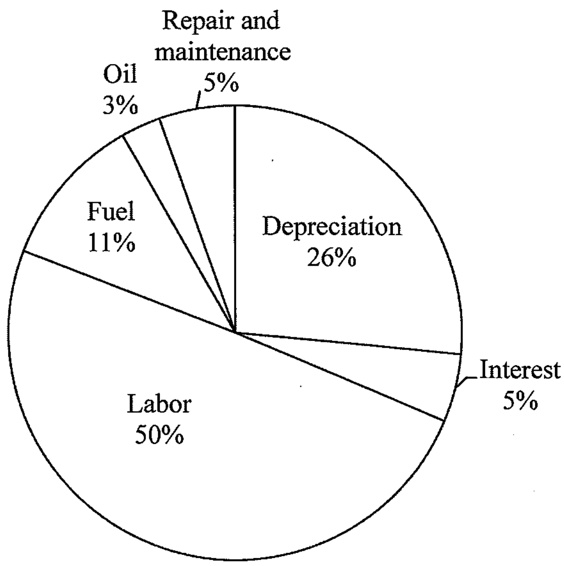

Fig. 4 Relative importance of all cost items for hydro tiller

found to be IDR 446.33 thousand/ha (US $40.58/ha) for moldboard plows, followed by IDR 433.28 thousand/ha (US $39.39/ha) for rotary tillers, and IDR 220.19 thousand/ha (US $20.02/ha) for hydro tillers. The lower fixed costs for hydro tillers were due to their lower purchase prices.

Variation also occurred in average variable costs. Hydro tiller operation had the highest variable costs, at IDR 481.07 thousand/ha (US $43.73/ha), followed by moldboard plows, at IDR 412.64 thousand/ha (US $37.51/ha), and rotary tillers, at IDR 406.18 thousand/ha (US $36.93). In general, fixed costs decrease as the seasonal or annual use of machines increases, and conversely, variable costs increase in proportion to seasonal or annual use (Butterworth and Nix, 1983).

The average total costs varied across power tillers, as did their percentage of total revenue, which ranged from 67% for hydro tillers to 78% for moldboard plows. The highest average total costs were for moldboard plows, at IDR 858.97 thousand/ha (US $78.09/ha), followed by rotary tillers, at IDR 839.46 thousand/ha (US $76.31/ha), and hydro tillers, at IDR 701.26 thousand/ha (US $63.75/ha) on average. The ANOVA that there was no significant difference in the average fixed costs per hectare across power tillers, but there was a significant difference in the average variable and total costs per hectare ($p \leq 0.05$).

The relative importance of items contributing to the overall costs of the three types of power tillers are depicted in Figs. 2–4. The greatest single cost contributor for the three types of power tillers was generally operator wage (ranging from 29 % for moldboard plows to 50 % for hydro tillers), followed by depreciation (ranging from 26 % for hydro tillers to 44 % for both rotary tillers and moldboard plows), and fuel (ranging from 8 % for rotary tillers to 11 % for hydro tillers). Overall, repair and maintenance costs were relatively low (ranging from 4 % for rotary tillers to 7 % for moldboard plows). These results reflect the low repair and maintenance costs resulting from greater machine control. The relative newness of the studied machines also contributed to the lower costs, as serious breakdowns occurred.

3. Revenue and profit

The average revenue was found to vary slightly across power tillers of the same type. This is because the custom rate was largely determined by field conditions, such as weed growth, water supply, and distance between farmland and machinery centers. As shown in Table 2, the highest average revenue was found to be from rotary tillers at IDR 1,122.73 thousand/ha (US $ 102.07/ha), followed by moldboard tillers, at IDR 1,104.55 thousand/ha (US $100.41/ha), and hydro tillers, at IDR 1,050.00 thousand/ha (US $95.45/ha). The ANOVA confirmed that the average total revenue per hectare did not significantly differ across power tillers ($p > 0.05$).

According to Table 2, the average profit was found to be IDR 283.27 thousand/ha (US $25.75/ha) for rotary tillers, IDR 245. 58 thousand/ha (US $22. 32/ha) for moldboard plows, and IDR 348.74 thousand/ha (US $ 31.70/ha) for hydro tillers, which represented averages of 25 %, 22 %, and 33 % of total revenue, respectively. The average seasonal profit per hectare varied across power tillers, and hydro tillers were the most profitable. The ANOVA results indicated that the average profit per hectare varied significantly across power tillers ($p \leq 0.05$).

Larger seasonal working areas can be more profitable because of their lower cost per hectare. Increasing number of hectares covered per season is an easy way to increase profit without changing the custom rates. However, the profit differences across power tillers more likely reflect the different levels of operation efficiency, as indicated by the lower cost per hectare for hydro tillers.

4. Break-even point

The break-even point (BEP) determines how much a machine needs to work per season to economically justify its possession. According to Table 2, hydro tillers reach the BEP most quickly, with a seasonal area of 3.07 ha. Both rotary tillers and moldboard plows require larger seasonal areas, of 5.14 ha and 4.29 ha, respectively,

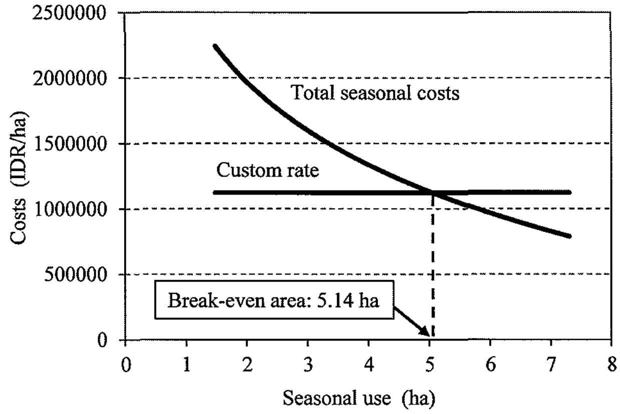

Fig. 5 Break-even analysis for rotary tillers

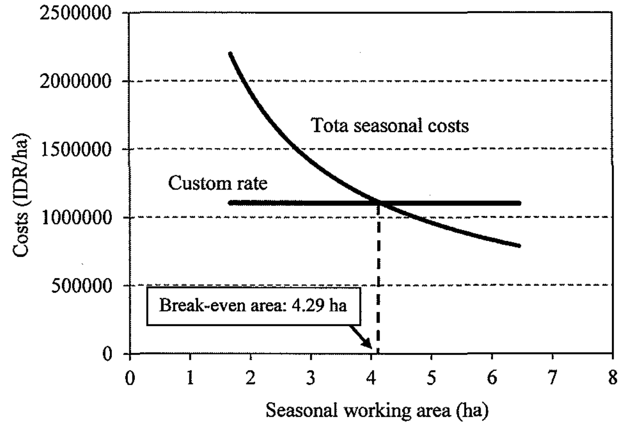

Fig. 6 Break-even analysis for moldboard plows

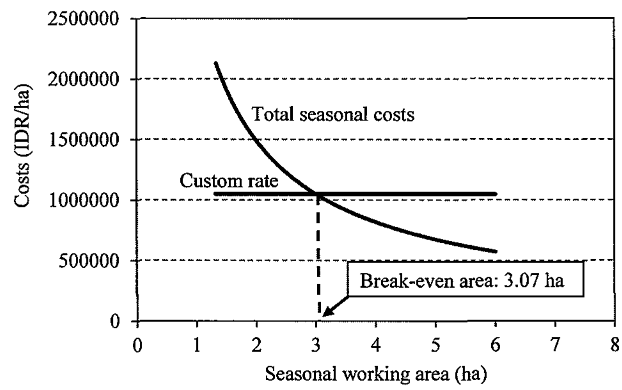

Fig. 7 Break-even analysis for hydro tillers

to reach the BEP. These figures mean that to justify owning a hydro tiller, rotary tiller, or moldboard plow in Riau, the owner must farm an area of at least 3.07, 5.14, and 4.29 ha, respectively. There was a highly significant difference in the break-even area across power tillers ($p \leq 0.001$).

The above comparison can be generated by using break-even analysis as illustrated in Figs. 5–7. The break-even area depends on estimated seasonal costs and custom rates. For example, the break-even area will decrease with an increasing custom rate. The same effect is also brought about the low seasonal costs. Thus it can be argued that the custom rate and costs are important factors in determining the BEP.

IV Conclusions

In this study, of the three most commonly used power tillers in Riau Province (rotary tillers, moldboard plows, and hydrotillers), hydro tillers were found to have the best working performance in terms of working hours per hectare (18.86 h/ha), hectares per working day (0.40 ha/day), and working days per hectare (2.49 days/ha), although these performance parameters did not significantly differ the studied power tillers. Depreciation and operator costs represented a substantial portion of total expenses for all three types of power tillers. Hydro tillers had the lowest costs per hectare and were the most profitable, with average total costs of IDR 701, 26 thousand/ha (US $63.75/ha) and average profits of IDR 348.74 thousand/ha (US $31.70/ha). Significant differences were found in the average total costs and profits per hectare across power tillers. In Riau, hydro tillers must cover 3.07 ha to reach the BEP, whereas rotary tillers and moldboard plows must cover 5.14 and 4.29 ha, respectively. Highly significant differences in break-even areas were found across the three power tillers. The results suggest that farmers would benefit most from using hydro tillers to perform tillage operations because the machine offers better working performance, provides economic benefits (lower cost and purchase price), and allows owners to quickly break even under flooded conditions.

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「技術論文」

インドネシアカンパー区の小規模米作農業における三種の耕うん機の経済的・機能的評価

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要 旨

インドネシア，カンパー地域において，3種類の耕うん機についてコストと作業性能についての現地調査を実施した。この地域の7つの地区の中からロータリ式22台，はつ土板プラウ式11台，フロート式耕うん機27台を調査対象とし，2012年および2013年においてこれらの機械の管理者・作業従事者・整備士に対するインタビューを実施してデータの収集を行った。その結果，フロート式耕うん機が，作業能率，運用コスト，利益において最適であるとの結論が得られた。耕うん機における損益分岐点は3.07 ha/1シーズンであった。それゆえ，性能面・経済面ならびに所有を正当化する理由として，本研究では該当農家に対しフロート式耕うん機の選択を提案する。

［キーワード］作業性能，経済的比較，耕うん機，小規模米作

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