Increasing utilisation of government-assisted agricultural machinery for rice planting areas

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Abstract. From 2015 to 2019, the Ministry of Agriculture distributed massive machinery assistance with one of the aims was to increase the planting area. However, several studies have shown that the usefulness of government-assisted agricultural machinery is not optimal. This study analyses the utilisation efficiency level of government-assisted agriculture machinery on the increase in rice planting areas. Using stochastic frontier analysis and provincial-level data, this study analysed rice planting areas (2018-2021) and machinery assistance (2017-2020). The results reveal that the national rice planting area is not technically efficient (0.52), with variations across provinces, while the potential exists to increase efficiency by 48%. Water pumps and the number of beneficiary groups significantly affect the technical efficiency. Other machinery types were not statistically significant, potentially because of program concentration in high-density areas. Additional challenges include limited access to repair facilities and spare parts, unskilled operators, and weak management capacity within beneficiary groups. To improve utilisation, central and regional governments should prioritise lower-density areas for machinery distribution, implement support programs for machinery maintenance, provide training programs for operators, and provide technical guidance to managers. By addressing these factors, the program can contribute more effectively to expanding rice-planting areas in Indonesia.

1 Introduction

Machinery plays a vital role in supporting agricultural production by making the process more efficient and effective. With the increasing demand for technological advancements and labour scarcity in the agricultural sector, machine tools have become essential. They accelerate and improve the quality of land preparation and water supply and increase the planting index (IP), leading to higher productivity, reduced yield losses, increased added value through the processing of agricultural commodities, and preservation of environmental functions [1].

From 2015 to 2019, the Ministry of Agriculture distributed a significant amount of machinery support to assist farmers. During this time, a total of 97,201 tractor units were distributed for land processing, which included both 2-wheeled and 4-wheeled tractors.

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Additionally, 70,107 water pumps and 15,245 rice transplanters were distributed for irrigation and planting. Other machinery supports included 113,937 hand sprayers, 801 excavators, and 6,938 cultivators. The Ministry of Agriculture has allocated considerable aid to rice commodities in the food crop subsector.

Farmers use agricultural machinery to increase the cultivation area and planting intensity, as well as improve productivity and efficiency while reducing yield losses. This also enhances the quality and value of agricultural products while saving labour costs and indirectly increasing production [2–4]. Nowadays, agricultural machinery is essential for managing farming businesses as it saves labour costs, speeds up the process, and increases the planting index (IP) [5].

It is hoped that the government's agricultural engineering assistance can be fully utilised. The optimal conditions for using machinery can be viewed from three perspectives. For farmers, optimal conditions mean being able to overcome labour shortages, increasing productivity, improving production quality, minimising yield losses, and increasing the cropping index. The choice of planting patterns adopted by farmers has implications for the need for agricultural machinery. From the machine tool manager's perspective, optimal conditions mean being able to operate the machine tool according to its installed capacity, creating a sustainable machine tool utilisation system, and increasing production. For land processing and planting machinery, the volume is equivalent to the service area per year. This means that the denser the number of machine tools in a work area, the smaller the service volume for each machine tool manager. From the government's perspective, "optimal" conditions mean that policies, programs, and planning in the management of agricultural machinery assistance are effective in supporting the achievement of increasing planting area, productivity, and quality of produce (grain and rice), and align with farmers' goals of increasing business income. This study aimed to determine the extent of the impact of government-provided machinery assistance in rice farming on increasing the technical efficiency of rice, as seen from the increase in planting area.

2 Methodology

The data used were time-series data from 2017 to 2021 obtained from various related agencies, such as the Directorate General of Agricultural Infrastructure and Facilities, the Directorate General of Food Crops, and BPS-Statistics Indonesia. The data collected included data on the area of rice planted per year, rice productivity, number of government-assisted machine tools, number of rice farming households, number of Agricultural Machinery Services Business (UPJA), standard area of rice fields, number of crops, amount of fertiliser, amount of rainfall, number of rainy days, area of rice fields with good irrigation, number of villages with flat topography, area of rice fields planted with other crops, and area of rice fields fallow.

2.1 The Cobb-Douglas stochastic frontier production function

The stochastic frontier function estimation method is used to measure the technical efficiency of planted areas using the Cobb-Douglas stochastic frontier production function.

$$LT_i^* = h(\mathbf{q}_i, \mathbf{s}_i) \exp(v_i - u_i) \quad (1)$$

where LT_i is the planted area in the *ith* province, $\boldsymbol{q}_i$ is the input vector for the cropping area function, $\boldsymbol{s}_i$ is the fixed input vector planting area, and $\exp(v_i - u_i)$ is the error term.

The efficiency of the planted area of a region in the context of the stochastic frontier function is derived as the ratio of the predicted, observed, or actual planted area (LT_i^*) to the predicted maximum planted area (LT_i), as follows:

$$Efficiency\ of\ the\ planted\ area = \frac{actual\ planted\ area}{maximum\ planted\ area} = \frac{(qi,si)\ exp(vi-ui)}{(qi,si)\ exp(vi)} \quad (2)$$

2.2 Specifications for the plant area efficiency model function

$$lnLTi = \beta 0 + \beta 1lnQ1i + \beta 2lnQ2i + \beta 3lnQ3i + \beta 4lnQ4i + \beta 5lnQ5i + \beta 6lnQ6i + \beta 7lnQ7i + \beta 6lnQ8i + vi - ui \quad (3)$$

where:
LT : rice planting area (ha)
*Q*1 : raw area of rice fields (ha)
*Q*2 : number of TR-2 (unit) or equivalent equipment capacity per ha (ha)
*Q*3 : number of TR-4 (unit) or equivalent equipment capacity per ha (ha)
*Q*5 : number of water pumps (unit) or equivalent equipment capacity per ha (ha)
*Q*6 : rainfall (mm/year)
*Q*7 : number of transplanters (unit) or equivalent equipment capacity per ha (ha)
*Q*8 : number of farmer group (unit)

2.3 Specifications for the plant area inefficiency model function

$$[ui] = \delta_0 + \delta_1 L_{1i} + \delta 2L2i + \delta 3L3i + \delta 4L4i + \delta 5L5i + \delta 6L6i + ei \quad (4)$$

where:
*U*i : planting area inefficiency
L1 : extensive rice fields with well-functioning irrigation networks (ha)
*L*2 : number of rain days (day)
*L*3 : number of UPJA (unit)
*L*4 : number of villages with flat topography (unit)
*L*5 : the area of rice fields planted with other crops (ha)
*L*6 : large areas of rice fields fallow (ha)

2.4 Estimation methods

The SPF function in equations (3) and (4) is estimated using the maximum likelihood estimation (MLE) method with the front 41. This is an appropriate tool for estimating the stochastic frontier function.

3 Results and discussion

3.1 Results of stochastic frontier production function analysis

The expansion of the rice planting area can be attributed to pre-harvest agricultural tools and machines, as well as other factors such as rainfall and the number of farming groups. These tools and machines include 2-wheeled tractors (TR-2), 4-wheeled tractors (TR-4), water pumps, and transplanters. According to the results of the stochastic frontier analysis using the maximum likelihood estimation (MLE) method, all variables (except for the number of TR-2 and transplanters) have positive coefficients. Out of the seven relevant variables, raw land area, number of water pumps, rainfall, and number of agricultural farms have a significant impact on frontier production. The standard land area variable has a 1% level of significance and positively affects the increase in the rice planting area. The variables of the number of water pumps, rainfall, and number of crops have a 5% level of significance and positively affect the increase in the rice planting area. This implies that increasing the raw land area, number of water pumps, rainfall, and number of crops leads to an increase in the rice planting area.

After analysing the data, it was found that the variables of the number of TR-2, number of TR-4, and number of transplanters did not have a significant impact on the increase in rice planting area. The results indicate that not all pre-harvest machine tools can automatically increase the planting area. Only water pump machine tools had a significant effect on increasing the planting area. The use of tractors, both 2-wheeled and 4-wheeled, as well as transplanters, did not have a significant effect on increasing the rice-planting area. This finding aligns with the research conducted by Widiastuti (2014), which found that certain agricultural machinery, such as transplanters, does not have a direct effect on rice production but rather on labour efficiency and acceleration of planting time [6].

Table 1. Estimated production function results for rice-planted areas in Indonesia from 2018 to 2021.

Variable	Coefficient	Std-error	t-ratio
(Constant)	1.113	0.544	
Raw area of rice fields (LnX1)	0.776	0.495	15.667***
TR-2 (LnX2)	-0.266	0.168	-1,579
TR-4 (Ln X3)	0.120	0.073	1,644
Water pump (Ln X4)	0.251	0.142	1,758**
Rainfall (Ln X5)	0.124	0.067	1,861**
Transplanter (Ln X6)	-0.0751	0.108	-0.697
Farmer group (Ln X7)	0.151	0.071	2.130**
Sigma-square (σ2)	0.13		
Gamma (γ)	0.99		
L-R test	87.17		
Log LF OLS	-68.35		
Log LF MLE	-24.76		
CRTS	1.08		

***Significant at the 1% level, **significant at the 5% level

Table 1 shows the estimation of the production function for the rice planting area using the MLE method. The log-likelihood value for the MLE method was -24.76, which was higher than that for the OLS method (-68.35). This indicates that the production function using the MLE method is more appropriate for field conditions. The sigma-square inefficiency value of 0.13 is small, which implies that the error term is normally distributed. Moreover, the gamma value of 0.99 is close to 1, indicating that the error term is only influenced by inefficiency and not by noise. The L-R test value of 87.17 (which is lower than the L-R table Kodde and Palm value) demonstrates that Ho is accepted, meaning that there are no inefficiency effects in the production function model. Therefore, the empirical data are well represented by the average production function model.

The use of water pumps can greatly increase crop production and planting frequency. In 1982, Saleh conducted a study on the impact of water pumps on farmers' incomes. At that time, water pump technology was still uncommon, but the study found that it could increase crop frequency by up to 100%. Farmers who previously only planted once a year could now plant twice a year using water pumps. This increase in planting frequency has led to a 125% increase in production and a 216% increase in farmers' income [7,8]. These findings are similar to those of a 2020 study by Franciscus et al., which identified water pumps and combined harvesters as effective machinery for boosting production. In particular, water pumps are essential in lowland areas such as Warureja District during the second planting season [9].

3.2 Technical efficiency of rice planting area

Based on the analysis using SFA, it has been found that rice planting areas in Indonesia from 2018-2021 are not yet technically efficient. The average technical efficiency value is 0.52, which is below the standard of 0.7, set by Farrel (1957) [10]. Java is the only island that is technically efficient, with an efficiency value of 0.72. However, there is still room for improvement, as the efficiency of planting areas on Java can be increased by 28%. Table 2 provides a detailed breakdown of the findings.

Table 2. Technical efficiency of the planting area in Indonesia from 2018 to 2021.

Province	Technical efficiency of planting area				
	2018	2019	2020	2021	Average
Indonesia	0.5679	0.5285	0.5342	0.4590	0.5224
Java	0.7903	0.7516	0.6816	0.6665	0.7225
Non-Java	0.5339	0.4918	0.5047	0.4203	0.4877
Sumatra	0.5145	0.4727	0.5477	0.4078	0.4857
Bali and Nusa Tenggara	0.5857	0.5231	0.5100	0.4978	0.5291
Kalimantan	0.4319	0.4251	0.4720	0.3953	0.4311
Sulawesi	0.6058	0.5565	0.5065	0.4761	0.5362
Maluku and Papua	0.4679	0.4250	0.4171	0.3003	0.4026

On Java Island, the average technical efficiency (excluding DKI Province) was 0.72. The analysis indicates that West Java Province has the highest technical efficiency, whereas D.I. The Yogyakarta Province had the lowest technical efficiency. Beyond Java, South Sulawesi and Lampung Provinces have the highest technical efficiency, while West Papua has the lowest.

It was found that the government's pre-harvest machinery assistance had not been used to its full potential. This is evident from the average technical efficiency value, which remains below 0.7. Studies have shown that the use of agricultural tools and machinery before, during, and after harvest can enhance land use efficiency and support extensification programs by allowing for wider, faster, and simultaneous planting, which in turn increases the cropping index (IP) [11]. However, the suboptimal use of machinery is attributed to low utilisation (as seen in Table 3). Numerous factors contribute to the less-than-ideal use of machine tools. Premature mechanisation can occur if the development system fails to consider technical, economic, infrastructure, and local socio-cultural institutional aspects. This can burden the farming system and society, as well as the government, which has invested a considerable amount nationally [3]. The choice of machine type is crucial, as Ghana and Nigeria have learned from their experience in choosing machines suitable for small areas of land. These countries have taken inspiration from Bangladesh, which has faced similar conditions [12].

According to the analysis of pre-harvest machinery usage levels, water pumps have a higher utilisation rate (74.54%) than tractors and transplanters. Stochastic frontier analysis results reveal that, apart from standard metrics such as land area, rainfall, and number of farmer groups (Poktan), only water pumps and agricultural machinery significantly increase the number of rice planting areas (at a real level of 5%). There are several reasons why water pumps are more optimal than other pre-harvest machinery types, including their versatility in any area regardless of land conditions, ease of use, and because transplanters are not as urgent to use as water pumps, given the availability of labour for planting. The water pump does not eliminate planting workers' livelihoods, which are mostly women. While some studies suggest that transplanters can streamline labour use, increase farming profits, and improve production, water pumps appear to be the more efficient and practical option [13,14].

Table 3. Level of utilisation of pre-harvest machinery with government assistance.

Machinery	2018	2019	2020	2021	Average
Two-wheeled tractor (TR-2)	70.71	69.37	70.25	68.87	69.8
Four-wheeled tractor (TR-4)	62.32	62.62	64.53	63.34	63.2
Water pump	75.95	74.52	73.83	73.87	74.54
Transplanter	40.79	41.48	37.16	38.3	39.43

Source: Directorate General of Agricultural Infrastructure and Facilities, Directorate General of Food Crops, and BPS-Statistics Indonesia (processed)

Compared to other islands in Indonesia, Java has the most technically efficient planting area. However, the assistance provided for pre-harvest machinery on Java Island is not as extensive as the assistance provided outside Java Island. On average, the total amount of assistance for pre-harvest machinery outside Java is almost twice as high as that on Java Island. Even for 4-wheeled tractors, the amount of assistance outside Java is almost four times higher, as is the comparison of the ratio of planted area to the number of assisted machinery (Table 4). The ratio of planted area to assisted machinery on Java Island was always higher for all types of assisted pre-harvest machinery. This means that for one unit of agricultural machinery, the assistance provided on Java Island is able to reach a higher planting area compared to outside the island. Therefore, the technical efficiency of the planting areas on Java Island is quite effective.

Table 4. The ratio between the area of land planted and the amount of agricultural machinery assistance provided from 2018 to 2021.

Region	The ratio between the area of land planted and the number of agricultural machinery assistance provided from 2018 to 2021			
	TR-2	TR-4	Water pump	Transplanter
Indonesia	61.56	759.91	91.02	496.66
Java	81.94	1,783.89	124.25	743.50
Non-Java	49.05	478.10	71.43	370.18
Sumatra	66.45	1,282.22	102.79	541.06
Bali dan Nusa Tenggara	65.18	1,048.76	96.86	526.63
Kalimantan	56.01	767.94	70.39	512.17
Sulawesi	47.93	545.67	58.78	375.71
Maluku dan Papua	52.59	592.21	63.26	407.03

Source: Directorate General of Agricultural Infrastructure and Facilities, Directorate General of Food Crops, and BPS-Statistics Indonesia (processed)

After considering various factors, it can be inferred that the higher efficiency of farming on Java is not solely dependent on the amount of machinery assistance. In fact, the underutilisation of machinery is a key factor, along with other factors such as land area, rainfall, and the number of farmer groups. This suggests that the government's efforts to provide machinery assistance have not been very effective in increasing rice production. It is clear that recipients of aid have not been utilising machinery optimally, as evidenced by a utilisation rate of below 70% for most machinery and only 38.3% for transplanter machinery. The only exception is water pumps, which have a higher utilisation rate of 73.87%.

The utilisation of government-assisted machine tools by aid recipients is often less than optimal due to various factors. These include a lack of coordination between the central government's planning and procurement system and provincial and district/city parties; inadequate monitoring, evaluation, and reporting caused by weak data collection; limited human resources and regional budgets; social and interest conflicts resulting from a lack of coordination and synchronisation in planning and distribution of aid; and unsuitable specifications of tools and machines. Moreover, the agricultural machinery provided by procurement is relatively uniform for each recipient and location, leading to inappropriate farmer groups' needs and location. Additionally, the machinery's low quality, inadequate testing, and lack of after-sales services from third parties make it easily damaged. Spare parts for repair are often expensive, difficult to obtain, and sometimes unavailable. It is also difficult to obtain fuel. Lastly, mentoring, training, and institutional capacity-building activities for the management of assisted machinery are not optimal, and there are obstacles and challenges in optimising the use of machinery by aid recipients. These include uneven density of government-assisted machinery and competition with existing non-government-assisted machinery, costs of mobilising machinery, management capacity and rental operational management, limited operational area coverage, and incompatibility of machine tool specifications with agroecosystem characteristics [15].

4 Conclusions and policy recommendations

4.1 Conclusions

In Indonesia, the rice planting area is not technically efficient at the national level, leaving room for improvement in technical efficiency for larger planting areas. Java Island was the most efficient compared to the other islands. The currently available technology has 48% room for improvement nationally, whereas Java has 17% and 52% outside Java by improving factors that significantly influence efficiency, such as adding water pumps and empowering UPJA.

The inefficiency of rice planting in Indonesia mostly does not originate from the amount of agricultural machinery provided. Other factors, such as standard land area, rainfall, and the number of farmer groups, contribute to this issue. The non-optimal use of machinery is believed to be the cause of inefficiency in rice planting in Indonesia.

The root causes of suboptimal government-assisted machinery are (1) the lack of coordination between the central planning and procurement system and the provincial and district/city parties; (2) poor monitoring, evaluation, and reporting at the centre; (3) social and interest conflicts arising from a lack of coordination and synchronisation in planning, procurement, and aid distribution between the centre and the regions; (4) equipment and machine specifications not matching proposals and needs; (5) insufficient mentoring, training, and institutional capacity-building activities for the management of assisted machinery; and (6) obstacles and challenges in optimising the use of machinery by aid recipients.

4.2 Policy recommendations

Efficiency in rice-planting areas in Indonesia needs to be increased, particularly on islands outside Java. This can be achieved by maximising the use of pre-harvest machinery such as 2-wheeled and 4-wheeled tractors, water pumps, and transplanters. The central and regional governments need to stop aid in areas with high density and increase in the lower and carry out support programs for machinery maintenance (workshops and spare parts providers), training programs, and technical guidance for managers and operators to increase the utilisation of government-assisted agricultural machinery.

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