

## TECHNICAL EFFICIENCY AND THE FACTORS THAT AFFECT IT IN RICE PRODUCTION IN INDONESIA

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### ABSTRACT

Most of the population of Asia depends on consuming rice to support their lives. This implies that rice production needs attention. The existence of inefficiencies in lowland rice production could reduce rice yields for consumption, so the measurement of technical efficiency in lowland rice production needed to be studied. This research aimed to analyze the level of technical efficiency in lowland rice cultivation and identify the factors affecting it. The research was done in the Palolo and Torue subdistrict of Indonesia. The number of samples used was 249 lowland rice farmlands, consisting of 106 and 143 farmers of organic and inorganic lowland rice cultivation, respectively. The results show that land, fertilizer, seeds, and labor had a positive and significant effect on lowland rice production. The average technical efficiency of lowland rice cultivation was around 78.2%. The results also show that manager education, extension contacts, superior seeds, and organic lowland rice cultivation have a significant effect on the level of technical efficiency in lowland rice production. We concluded that there is an opportunity for farmers to increase lowland rice yields if they can manage production factors in an efficient manner. The government could provide support for farmers, such as formal and informal education, extension, superior seeds, and ready-to-use organic materials.

**Contribution/Originality:** This study contributes to the existing literature on the development of organic rice, thus requiring knowledge of the concept of efficiency. The concept of efficiency played an important role in increasing the organic rice yield and was widely recognized by researchers and policymakers. The study findings will be used to improve opportunities for farmers to increase lowland rice yields.

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## 1. INTRODUCTION

Global rice consumption has increased parallel with the increase in global population, as is the case in Indonesia. There, rapid population increase has demanded the availability of rice in sufficient quantities, adequate quality, and with rapid cultivation time. This need has encouraged the emergence of a modern agricultural system characterized by a high dependence on fertilizers and pesticides containing synthetic chemicals (Cui et al., 2020; Suhardianto, Baliwati, & Sukandar, 2007).

The use of chemical inputs, however, will reduce the level of soil fertility, decrease biodiversity, and increase attacks on pests, diseases, and weeds (Zhao et al., 2016). Another negative impact is contamination of agricultural products by chemical materials which, in turn, will have a negative impact on human health (Navaranjan et al., 2013; Slusky et al., 2012). Public awareness of the dangers to health and the environment has caused a shift in cultivation to an organic system (Al-Taie, Rahal, AL-Sudani, & AL-Farsi, 2015). Organic farming has become part of recent efforts to promote agricultural systems that are both socially and ecologically sustainable (Cabusora et al., 2021; Chouichom & Yamao, 2010).

When organic rice in Indonesia was starting to be developed, it was affected by a number of factors. One of the key factors was the public's need for the types of food that provide good health. Farmers began to restructure rice production according to changing market needs. The increasing demand for organic rice not only promoting healthy foods, but also allowed for environmental protection.

The development of organic rice in Indonesia was still being managed using low-yield agricultural technology, so it was necessary to identify productivity behavior and its components. Organic rice production could be made more efficient by achieving enhanced output at current input levels, which could be done by identifying productivity behavior and its components. The concept of efficiency plays an important role in increasing organic rice yield and is widely recognized by both researchers and policymakers. This research aimed to assess resource productivity and evaluate the technical efficiency of organic and inorganic rice production, and determine the main factors affecting technical efficiency (TE).

## 2. MATERIALS AND METHODS

### 2.1. Description of the Research Area and Techniques of Data Collection

The research was done in Central Sulawesi, Indonesia, which is located between 2° 22' N and 3° 48' S and between 119° 22' and 124° 22' E. This province has land at various heights above sea level: 0–100 m, 20.2%; 100–500 m, 27.2%; 501–1000 m, 26.7%; and <1,001 m, 25.9%. Central Sulawesi comprises 12 regencies and one city with a total area of 61,841.29 km<sup>2</sup>. The temperature in this province ranges from 27 to 28 °C and annual rainfall is 71.7–217.8 mm (BPS, 2018).

This research used cross-sectional data from lowland rice farmer households. Primary data were collected using a questionnaire from May to August 2020. Data on production input and output collected included: harvested area, fertilizer, number of seeds, labor, and amount of rice. Also, variables that resulted in variations in technical efficiency in lowland rice production were also collected, including manager's age, gender, and education, extension contacts, number of family members, types of seed used, and the lowland rice cultivation system applied. The research location was selected purposively in Palolo and Torue subdistricts because these were found to be organic lowland rice cultivation regions. The numbers of samples used were based on 249 lowland rice cultivation farms. The samples of organic lowland rice cultivation were selected purposively, being taken from 106 farmers, with 143 farmers randomly selected for samples of inorganic lowland rice cultivation.

### 2.2. Specification of the Empirical Model

The methodological tool used to achieve the objectives of this research was stochastic frontier analysis. Stochastic production frontier measures business efficiency, which is affected by factors outside the farmer's control because it can be taken into account as the inefficiency of these factors and errors during measurement.

Lowland rice production in the research area was likely to be affected by several factors beyond the farmer's control, such as natural disasters and pests; besides that, measurement errors could not be avoided. Based on this, we used the stochastic production frontier to achieve our research objectives. We used the Cobb–Douglas model of stochastic production frontier (1 and 2) described by Coelli, Rao, and Battese (1998):

$$\ln q_i = \beta_0 + \beta_1 \ln x_i + v_i - u_i \quad (1)$$

$$\text{or } q_i = \exp(\beta_0 + \beta_1 \ln x_i) \cdot \exp(v_i) \cdot \exp(-u_i) \quad (2)$$

where  $q_i$  represents the output of the  $i^{\text{th}}$  cultivation;  $x_i$  is the input from the  $i^{\text{th}}$  cultivation;  $\beta$  is the parameter to be estimated;  $v_i$  is a statistical disturbance; and  $u_i$  reflects the technical inefficiency of lowland rice cultivation. The measure of technical efficiency (TE) is the ratio of observed output to stochastic frontier output (3):

$$TE_i = \frac{q_i}{\exp(x_i \beta + v_i)} = \frac{\exp(x_i \beta + v_i - u_i)}{\exp(x_i \beta + v_i)} = \exp(-u_i) \quad (3)$$

TE values range between zero and one.

TE of lowland rice production in Central Sulawesi was measured by considering the output obtained per farmer as the dependent variable. The yield of lowland rice cultivation was measured in tonnes. The independent variable is the production input used by farmers in lowland rice cultivation, so the formula (4) is written as follows:

$$\ln Y = \beta_0 + \sum_{i=1}^5 \beta_i \ln X_{ij} + v_i - u_i \quad (4)$$

Where:

$Y$  = rice produced (tonnes) by the  $i^{\text{th}}$  farmer.

$X_i$  = lowland rice harvested area (ha) by the  $i^{th}$  farmer.  
 $X_2$  = number of fertilizer (kg) used by the  $i^{th}$  farmer.  
 $X_3$  = number of lowland rice seeds (kg) used by the  $i^{th}$  farmer.  
 $X_4$  = number of labor (days of people work) used by the  $i^{th}$  farmer.  
 Technical inefficiency ( $u_i$ ) can be defined in the following Equation 5:

$$u_i = \lambda_0 + \sum_{k=1}^7 \lambda_k Z_{jk} \quad (5)$$

$Z_1$  = manager's age (years);  $Z_2$  = manager's gender (1 if male, 0 otherwise);  $Z_3$  = manager's education (years);  $Z_4$  = extension contacts (frequency);  $Z_5$  = number of family members (soul);  $Z_6$  = superior seeds (1 if the seed is superior, 0 otherwise); and  $Z_7$  = organic lowland rice cultivation (1 if organic, 0 otherwise).

### 3. RESULTS AND DISCUSSION

#### 3.1. Factors in Lowland Rice Production

The parameter estimations of the Cobb–Douglas model stochastic production frontier are presented in Table 1.

Table-1. Parameter estimation of the Cobb–Douglas production function.

Variable	Maximum likelihood estimate		
	Parameter	Coefficient	Standard error
Intercept	$\beta_0$	4.377	0.165
lnLand	$\beta_1$	0.183**	0.051
lnFertilizer	$\beta_2$	0.211**	0.043
lnSeed	$\beta_3$	0.196**	0.040
lnLabor	$\beta_4$	0.345**	0.055
Sigma squared	$v_i$	0.025**	0.003
Gamma	$u_i$	0.965**	0.010
log likelihood function		240.054	
LR test of one-sided error		415.140**	
mean efficiency		0.782 = 78.2%	

Note: \*\* significant at  $\alpha$  1%.

Table 1 shows that the four variables considered in the production function (land, fertilizer, seed, and labor) had a significant effect in explaining variations in rice production at the farming level. The four variables considered were positive and significant at the 1% level. This suggested that land, fertilizer, seed, and labor are still important in explaining lowland rice production in the research area. Given that the form of the production function is Cobb–Douglas, the coefficient value directly reflect its elasticity. The positive production elasticity from land, fertilizer, seed, and labor indicated that each increase in these variables would increase the yield of lowland rice. With the increase in land allocation for lowland rice, the numbers of fertilizer and seed applications, and labor by 1% each, lowland rice production could increase by 0.18, 0.21, 0.20, and 0.35%, respectively. This research is in line with that of Effendy (2010), Antara and Effendy (2018), and Geffersa, Agbola, and Mahmood (2019), who stated that land, fertilizer, seed, and labor were important production factors supporting lowland rice yields.

#### 3.2. TE

The average technical efficiency achieved by farmers in lowland rice production in the research area was 0.782. This suggested that the average productivity achieved was 78.2% of the frontier, namely the maximum productivity that could be achieved with the best management system at that time.

The distribution of lowland rice farmers according to the level of technical efficiency can be seen in Figure 1.

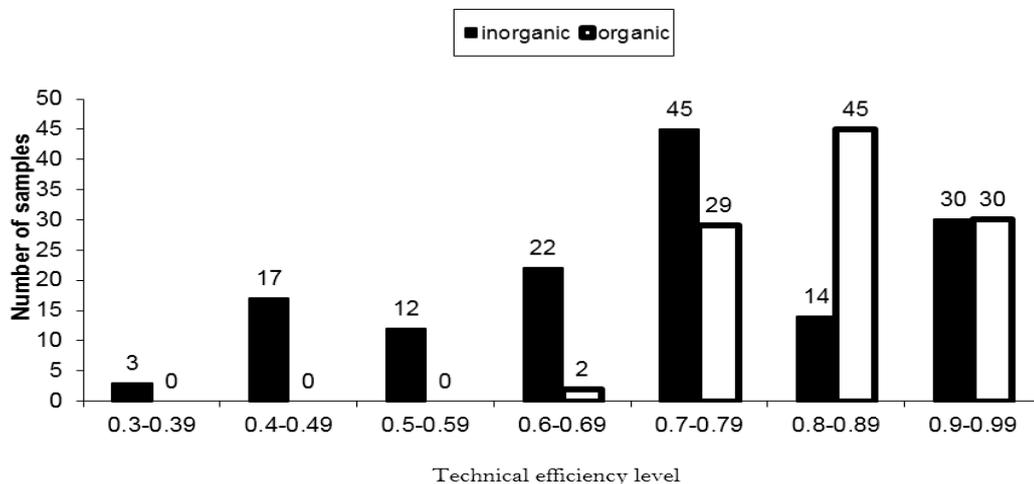


Figure-1. Technical efficiency.

Figure 1 shows that the level of technical efficiency of organic lowland rice farmers was higher than that of inorganic lowland rice farmers. The level of technical efficiency of organic lowland rice farmers ranged from 0.6 to 0.99, and for inorganic lowland rice farmers from 0.3 to 0.99. The proportion of farmers who were close to the frontier (TE ~1) was around 24% while those below 0.6 was around 13%, showing that there was still an opportunity for farmers to increase productivity with the resources at their disposal. To achieve this, better managerial skills were required. Mastery of information and decision making in managing production factors had to be improved. Farmers who had a technical efficiency level close to 1 had little chance to increase productivity. To increase the productivity of farmers, more advanced technological innovations were needed than existing ones.

### 3.3. The Determinant of TE

The stochastic production frontier estimation results in Table 1 show a gamma value of 0.965 and significant at the 1% level, reflecting that random errors that could not be explained in the production function model could be explained in the inefficiency function. The variables that were thought to affect the TE of lowland rice cultivation are listed in Table 2.

Table-2. Parameters estimated to affect TE.

Variable	Parameter	Coefficient	Standard error
Constant	$\lambda_0$	0.818	0.085
Manager's age	$\lambda_1$	0.000	0.002
Manager's gender	$\lambda_2$	0.002	0.004
Manager's education	$\lambda_3$	-0.020**	0.007
Extension contact	$\lambda_4$	-0.068**	0.017
Number of family members	$\lambda_5$	0.010	0.007
Superior seed	$\lambda_6$	-0.036**	0.008
Organic lowland rice cultivation	$\lambda_7$	-0.098**	0.045

Note: \*\* significant at  $\alpha$  1%.

Table 2 shows that, of the seven variables thought to affect technical efficiency, only four were significant, namely manager's education, extension contact, superior seed, and organic lowland rice cultivation. The coefficient of these variables was negative and significant at the 1% level, implying that improving these variables would increase technical efficiency in lowland rice production.

The results showed that the level of manager's education had a significant effect on the level of technical efficiency of lowland rice cultivation; the education coefficient had a negative and significant effect at the 1% level. This meant that farmers with higher education attained relatively higher levels of technical efficiency. Education could increase the farmer's insight in seeking more advanced agricultural technology information. Education gives farmers the ability to manage information from various sources and apply new technologies to lowland rice cultivation so they can increase yields. Educated farmers were able to adopt better technology such as superior seed, fertilizer, and pesticide more rapidly than those without education. These results are in line with the findings of Ali and Khan (2014) and Alemu, Tegegne, and Beshir (2018), who stated that education can increase the productivity of human resources (farmers).

Extension contact had a significant effect on the level of technical efficiency in lowland rice production; the sign of extension contact coefficient was negative and significant at the 1% level. This implied that farmers who frequently followed agricultural extension would reduce the effects of technical inefficiency in lowland rice production. Farmers who often followed lowland rice agricultural extension tended to have a higher level of technical efficiency than those who did not. This finding is in line with the arguments of Ahmed, Haji, and Geta (2013), Effendy et al. (2019), Effendy, Hanani, Setiawan, and Muhaimin (2013), Emmanuel, Owusu-Sekyere, Owusu, and Jordaan (2016), and Mann and Warner (2017), which showed that the extension provided would increase the productivity of farmers and suppress the effects of unwanted technical inefficiency. The extension was informal education that could build the managerial capacity of a farmer (Mangisoni, Chigowo, & Katengeza, 2019). Farmers who followed lowland rice agricultural extension were quicker to adopt better technology than those who did not. Farmers in the research area often received lowland rice agricultural extension services: for example, adopted lowland rice cultivation techniques, learned better pest and disease control, and gained overall better harvest and post-harvest results.

Superior seed was stated in dummy variables (1 if superior seeds, 0 if otherwise). The sign of superior seed coefficient was negative and significant at the 1% level in affecting the degree of technical efficiency of farmers in lowland rice production. Lowland rice cultivation that used superior seed was more efficient than farmlands that were using local seeds. The results of this research are consistent with the findings of Bhatt and Bhat (2014), Dessale (2019), and Effendy et al. (2019), who stated that superior seed could suppress technical inefficiency in agricultural production. The use of superior seed in lowland rice cultivation could reduce the effect of technical inefficiency so that the maximum productivity tended to be achieved. This implied that increase in lowland rice production is dependent on the type and quality of seed available.

Organic lowland rice cultivation in this research was stated as a dummy variable (1 if organic, 0 if otherwise); the sign of organic lowland rice cultivation coefficient was negative and significant at the 1% level. This showed that organic lowland rice cultivation can reduce the effects of technical inefficiency in lowland rice production. Farmers who cultivated organic lowland rice tended to have a higher level of technical efficiency, implying that organic

materials can increase soil productivity so that the effect of technical inefficiency would be suppressed (Effendy et al., 2019). Organic materials from manure and leaves could increase the nitrogen and organic C content in the soil. Returning rice straw to lowland rice cultivation could increase the potassium content; rice straw is a good source of macronutrients (Bu et al., 2020).

#### 4. CONCLUSION

The technical efficiency of lowland rice cultivation could be increased through better management of the resources owned by farmers, especially land, fertilizer, seed, and labor. To increase technical efficiency in lowland rice production, the productivity of farmers should be increased in managing production factors. Increasing productivity of farmers in their organizations makes it necessary to pay attention to their education, participation in extension, the seed used, and applied cultivation. Education status also proved relevant, with research results showing that managers with higher education were better able to deal with efficiency in the lowland rice production process. This implied that efforts were needed to increase the knowledge of poorly educated farmers through extension services. Extension positively and significantly affected technical efficiency in lowland rice production. It is necessary to provide extension for farmers because it could increase their knowledge regarding the use of superior seed, organic materials, and post-harvest handling. The use of superior seed and organic materials in lowland rice cultivation could suppress inefficiency in production, so that the results could reach the frontier set.

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