Evaluation of technical efficiency traditional agriculture among smallholder maize farmers in East Java

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Abstract. The low productivity of maize in traditional agriculture has worsened the demand and supply of maize production. This gap indicates the important role of the small farmer sector in producing maize. However, this also indicates that there will be serious consequences for food security in Indonesia if maize farmers experience crop failure. Because of these conditions, this article will analyze the technical efficiency of traditional maize farming using a randomly selected sample of 70 farmers. This research uses a stochastic frontier model of technical efficiency analysis through a linearized Cobb-Douglas production function to determine the input production elasticity coefficient, technical efficiency, and the determining factors of technical efficiency. This study found that maize production responded positively to increasing the amount of seed, urea fertilizer, and NPK fertilizer. Efficiency analysis shows that traditional farming activities for smallholder maize farmers are classified as technically efficient with a Technical Efficiency value of 0.821, which means farmers can combine inputs to produce optimal output. The results of this research empirically prove that small-scale agriculture in maize farming activities has a better level of technical efficiency. The results of this research also highlight the role of farmer groups in improving technical efficiency through better agricultural extension services and other access.

1 Introduction

Even though it has a vital role in the economy and fulfilling people's consumption, small-scale agricultural activities are often faced with several problems, such as limited land ownership, access to capital, access to counseling or training and the ability of farmers to adopt technology. [1-2]. This problem occurs in many developing countries, including Indonesia. This problem has significantly impacted agricultural performance, such as low productivity and lower efficiency levels due to the need to combine inputs optimally and decrease income [3-4]. Of course, this is a significant concern for the development of the agricultural sector, especially in rural areas, which contributes a lot to meeting food needs, boosting the economy and absorbing local labor.

Theoretically, farmers need to increase productivity and production efficiency to support agricultural development in rural areas to gain access to higher incomes [4-5]. hese efforts require access to more significant but still sustainable production intensification, especially in small-scale agriculture, to maintain the agricultural environmental ecosystem [7]. Apart from that, the government also needs to play a role in improving the managerial abilities of farmers. Several popular programs in the region are counseling, programs in farmer groups and other training oriented toward increasing the managerial capacity of agricultural cultivation [8].

Likewise what happened to agriculture in East Java. One of them is a small-scale corn farmer. The characteristics of farmers who are still involved in small-scale farming activities are also limited by several obstacles. The most crucial problems that receive much attention are limited land ownership and difficulties in adopting technology. Researchers conducted a preliminary study at the research location, the average land ownership of corn farmers is still limited to 0.2 – 0.7 hectares. Researchers also found that many corn farmers in East Java still use traditional cultivation technologies, such as local corn seeds and rain-fed water systems. The two findings in the preliminary research in previous research also influenced productivity, efficiency and income [8–10]. The emergence of the problem of decreasing productivity and corn production has also worsened the demand and supply of corn production in East Java. However, this also indicates that there will be severe consequences for the food security of corn commodities in Indonesia if there is a decrease in corn production while the demand continues to increase. Therefore, it is important to evaluate farming performance with measurement determinants based on corn farmers' productivity and technical efficiency on a small-scale farming scale in East Java.

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This research will provide a significant contribution regarding the technical efficiency of small-scale corn farming as an initial stage to support agricultural development in rural areas. Several studies and observations on technical efficiency analysis of corn commodities [11–14]. However, this research will present a different case study focusing on small-scale corn farming and farmers with small land holdings in the area producing the most significant corn production in East Java, namely Madura Island. Not much research has focused on measurement. Due to the previously mentioned conditions, this research aims to analyze technical efficiency and factors that influence the technical inefficiency of traditional small-scale corn farming in East Java.

2 Method

2.1 Research data

We used the Multistage sampling method to determine the research location in this research. The first stage selects a province and two districts or cities. Sumenep and Pamekasan were chosen deliberately because they have potential and are areas with the highest levels of corn production in East Java (figure 1). The second stage selects sub-districts and villages based on information from authorized institutions (Agriculture Department and Agricultural Extension Center). Lenteng District represents Sumenep Regency and Larangan District represents Pamekasan Regency in selecting the location for this research.

Corn farmer respondents were chosen deliberately by considering that respondents were corn farmers with traditional farming systems with narrow or small farming land ownership and had access to information that was easier to obtain. We selected 35 farmers in each district as respondents, so the total respondents in this study were 70 farmers. The enumerators in this research are students around the research location who understand Indonesian and Madurese. Data was collected from interviews and structured surveys using questionnaires focused on rain-fed corn farming activities. We conducted this research in August – September 2023.

Fig. 1. The Location of the study area in East Java, Indonesia.

2.2 Data analysist

2.2.1 Technical efficiency

We use the Cobb-Douglas Stochastic Frontier production function to estimate the factors that influence production levels and the level of technical efficiency. In this model, the dependent variable is the production level, and the independent variables are production inputs. The Cobb-Douglas Stochastic Frontier production function model is as follows in equestion (1).

$$ln\, Y = \beta_0 + \beta_i lnX_i + v_i - u_i \quad (1)$$

Where $ln\ Y$ is the logarithmic result of the production level, Where ln Y is the logarithmic result of the production level, ln So the function for estimating technical efficiency is as follows: So the function for estimating technical efficiency is as follows in equestion (2).

$$ET_G = \left(\frac{1}{n}\right) \sum_{i=1}^{n} \left(\frac{Y_i}{\hat{Y_i}}\right) \quad (2)$$

ET_G is the result of estimating the technical efficiency of the respondent group, Y_i is the I-th production quantity *(output)* ke-I $\hat{Y_i}$ is the production quantity estimated at the I-th observation obtained from the Cobb-Douglass frontier production function. The technical efficiency value ranges from 0 – 1. To estimate the effect of technical inefficiency, following function in equestion (3).

$$ui = \delta_0 + \delta_i Z_i \quad (3)$$

Where ui is the effect of technical inefficien, δ_i is constanta and Z_i is variable i. To help analyze factors that influence production, the level of technical efficiency and factors that influence technical inefficiency, we use the help of the application Frontier 4.1.

3 Result and discussion

3.1. Factors that influence corn production

Tabel 1. Estimation results of cobb-douglas stochastic frontier production function parameters for traditional corn farming on smallholder farmers.

Variable	Final MLE Estimates	
	Coefficient	Std. Error
Constanta	3,922	0,343
Seed	0.242***	0,061
Urea fertilizer	0.469***	0,032
Organic fertilizer	0.127	0,088
NPK fertilizer	0.091***	0,026
Labor	0.073	0,067
sigma-squared	0.147***	0,003
gamma	0.999***	0

Note: *,**,*** denote significant on 10%, 5% and 1%.

So far there has been a lot of literature evaluating the technical efficiency results of maize farming in Indonesia, including East Java and its surroundings. In this research, the author will present estimation results using the stochatic frontier approach used in analyzing factors that influence maize production, namely the Maximum Likelihood Estimation (MLE) approach, the estimation results can be seen in Table 1.

Based on estimation results using the MLE approach using Frontier 4.1 software. It can be known that there are variables that have a significant effect and those that have an effect but are not significant. The influence of production factor variables includes:

a. Seed

Based on Table 1, the Seed variable, a production factor, has a positive coefficient value of 0.242, which means that the seed variable significantly influences an error level of 1%. Thus, the seed factor has a real effect on corn production in the research area, following the hypothesis that the seed factor has a positive effect on production. The indication that seed factors have a positive effect on production is because the seeds used by farmers at the research location are licensed seeds or are superior seeds, namely hybrid seeds. Currently, many farmers are starting to switch to hybrid seeds, compared to local Madurese corn seeds, hybrid seeds have the advantage of higher production levels of around 150% - 200% higher [16].

b. Urea fertilizer

The urea fertilizer variable has a positive coefficient value of 0.469 and has a significant effect at the 1% level. This variable also has a positive coefficient, which means that this variable has a direct relationship with production. Hence, the hypothesis, namely that the urea fertilizer factor has a positive effect on corn production, has been answered at the research location. This is due to farmers' low ability and skills in using fertilizer and the availability of urea fertilizer at the research location. Farmers' access to urea fertilizer at the research location is also limited. So, less urea fertilizer is used than the technical recommendations for corn cultivation at the research location.

c. Organic fertilizer

Based on the production factor estimation results for the organic fertilizer variable (Table 1), the coefficient value for organic fertilizer is 0.127, which means that the organic fertilizer factor has no significant effect on corn production at the research location. This indication is because, at the research location, farmers' interest in using organic fertilizer inputs during their farming activities is minimal, even though the respondent farmers predominantly have cattle or goats whose dung can be used as organic fertilizer. However, based on the results of this research, something new was discovered, namely that corn farmers in the research location still use chemical fertilizers.

d. NPK fertilizer

The NPK fertilizer variable has a positive coefficient value of 0.091. This value means that this variable has a positive effect on production factors. This means that the NPK fertilizer variable has a significant or actual effect on production factors. These results indicate that the use of NPK fertilizer at the research location was due to a lack of fertilizer availability due to farmers experiencing fertilizer scarcity problems. Meanwhile, NPK fertilizer input in corn farming is the most important part of producing quality corn production.

e. Labor

The estimation results in Table 1 show that the Labor factor has a coefficient value of 0.073 and has no real effect on corn production at the research location. This indicates that farmers carrying out their farming activities at the research location are considered adequate. After all, farmers there still empower the culture of cooperation.

f. Sigma-squared, gamma

Sigma-squared (σ) and gamma (γ) values obtained from estimation using the MLE method are 0.14 and 0.99. From the results of this research, a value (σ) that is greater than zero means that there is the influence of technical inefficiency in the production function model. A gamma value (γ) of 0.99 indicates that the errors or errors caused by the technical inefficiency component are 99%; this figure means that the difference between actual production and maximum production is more due to the effects of technical inefficiency, while the remaining 1% is caused by random error variables or variables outside the model being built such as climate or weather changes and pest attacks and plant diseases.

3.2. Maize farming technical efficiency level

Analysis of the level of technical efficiency in maize farming aims to determine the highest and lowest efficiency levels as well as the average efficiency achieved by farmers in maize farming at the research location. The level of efficiency achieved by respondents at the research location can be seen in Table 2.

Tabel 2. Frequency distribution of technical efficiency maize farming.

TE	Farm	%
0 - 0.2	0	0,000
0.21 - 0.40	0	0,000
0.41 - 0.60	1	1,429
0.61 - 0.80	24	34,286
0.81 - 1.00	45	64,286
Total Farmers	70	

Based on data from Table 2, the number of farmers who have the highest technical efficiency value, namely at the twin's efficiency level of 0.82-1.00, is 64.28% or 45 maize farmers from the total respondents. At the technical efficiency level, between 0.61-0.80 for 24 maize farmers or 34.28% and 0.41-0.60 for 1 person or 1.42%. Based on this data, farmers still have a 1-20%

opportunity to increase maize production. The different levels of efficiency between farmers indicate differences in the use of production factors for each farmer.

Apart from that, differences in efficiency levels can be caused by factors such as farmer age, farming experience, agricultural extension, and farmer groups. Farmers in the research location, on average, have a level of technical efficiency that is far from one. This shows that maize farmers in the research location still have opportunities to increase technical efficiency or actual production, which is yet to be close to potential production (see Table 3).

Tabel 3. Frequency distribution of technical efficiency maize farming.

No	Statistic	TE
1	Average	0.821
2	Min	0.553
3	Max	0.999

Based on data from Table 3, it can be seen that the lowest technical efficiency level for maize farming is 0.55, which means that respondents at this efficiency level are able to achieve 55% of potential maize production obtained from a combination of the use of production factors, namely seeds, use of Urea Fertilizer input, Organic Fertilizer input. , NPK Fertilizer input, and Labor. These results mean that there is still a 45% opportunity for farmers to increase maize farming production by using more efficient production factors. Meanwhile, the highest efficiency level is 0.99. This means that farmers in the research location have reached 99% of the potential maize production obtained from the combined use of production factors. Based on the results of this estimation, there is only a 1% opportunity for farmers to increase their farming production in order to reach a level of technical efficiency.

Based on the estimation results, the average respondent farmer has a low level of technical efficiency, namely 0.82, which means that the average farmer has only achieved 82% of potential maize production. There is still 18% that farmers need to achieve to increase their production in order to achieve efficiency or reach the level of potential production. Technical efficiency for each respondent can be seen in Table 4.

Tabel 4. Frequency distribution of technical efficiency maize farming.

TE	Farm	%
< 0.8	27	39
≥ 0.8	43	61
Total	**70**	**100%**

Table 4 shows that the number of farmers at the efficient level is higher (43 farmers with a percentage of 61%) compared to inefficient farmers (27 farmers with a percentage of 27%). This means that the farmer's ability to manage maize farming has reached potential production levels. To be able to increase the efficiency of maize production, it is necessary to increase its ability to combine existing production factors through training, agricultural extension, being active in farmer groups, and adopting new and better technological innovations.

There are differences with the research results [17] which shows that the average value of technical efficiency in maize farming is 79.2 and 89.4 for the CCF and UCCF groups, respectively. The average difference in technical efficiency between the two groups is 10.2, which indicates that, due to inefficiency, there is the potential for quite large output losses.

3.3. Factors affecting technical efficiency of maize farming

In this research, the factors included in the model are farmer age, farming experience, agricultural instructor, and farmer group. The results of the analysis of inefficiency effects can be seen in Table 5.

Tabel 5. Results of estimation of factors affecting inefficiency maize farmers.

Variable	Final MLE Estimates	
	Coefficient	Std. Error
Constanta	0.142	0.539
Age (years)	-0.062	0.11
Experience (years)	0.217***	0.082
Agricultural counseling (times)	-0.071	0.046
Farmers group (1 if farmers join farmer group; 0 otherwise)	-0.388**	0.159
sigma-squared	0.014	0.003
gamma	0.999	0

Note: *,**,*** denote significant on 10%, 5% and 1%.

a. Age

The coefficient value for the farmer's age factor has a negative sign, namely -0.062. Thus, the farmer's age factor has a negative but not significant effect on the effect of technical inefficiency in corn farming. This shows that the effects of inefficiency or the distance from achieving technical efficiency will decrease as farmers age. The results of this study are consistent with the results obtained [18]. In contrast, several previous studies noted increased efficiency with age associated with farming experience [18]. In contrast, several previous studies noted an increase in efficiency with age that was associated with farming experience [17-18].

b. Experience

Based on the estimation results in Table 5, it shows that the farming experience coefficient is positive and has a significant effect on technical inefficiency with an error rate of 1%. The experience variable coefficient is 0.217, with an indication that an increase of 10% will increase technical efficiency by 0.217% per unit. The indication is that the farmer experience variable has a real influence, whereas the respondent farmer variable always has a new pattern with different maize cultivation every year. This is supported by research [18] which states that farming experience makes a positive contribution to the efficient use of production resources.

c. Agricultural counseling

The data explained in Table 5 shows that the coefficient value for agricultural extension has a negative sign, namely -0.071. Thus, the extension factor has a negative but not significant effect on the effect of technical inefficiency in maize farming with an error rate of 1%. This shows that the more ineffective the implementation of extension services to maize farmers, the more inefficiency effects will decrease or the further away from achieving technical efficiency. This is also indicated by the need for a more massive implementation of agricultural extension at the research location. So, farmers' knowledge and understanding decreases and has an impact on the efficiency and inefficiency of maize farming management.

d. Farmers group

Based on the estimation results shown in Table 5, it was found that the coefficient value for the farmer group factor has a positive sign and the magnitude is 0.388, so the farmer group factor has a positive sign and has a real influence on the effects of technical inefficiency in maize farming with an error rate of 5%. Farmer groups are measured based on the frequency of farmer participation in farmer groups. This is in accordance with the initial expectations of the research, namely a positive effect. On average, farmers in the research location actively participate in farmer groups more than twice. Farmer groups have a real influence on the effects of inefficiency because, within farmer groups, they are provided with information and understanding about farming. Apart from that, the benefits of farmers who are members and active in farmer groups, apart from access to information, farmers who are members of them also get access to assistance, both at the village and national level, such as fertilizer, seeds, agricultural tools, and quality maize seeds.

4 Conclusion

Based on the research results, the factors that have a real influence on maize production are seeds, urea fertilizer, and NPK fertilizer. Meanwhile, labor and organic fertilizer factors have little effect. Meanwhile, the level of technical efficiency of maize farming in the research location is the lowest, namely 0.55, and the highest level of efficiency of maize farming is 0.99, with the average respondent farmer having a technical efficiency level of 0.82. This means that the average farmer has only achieved 82% of potential maize production, and there is still 18% for the average farmer to increase their production. The factor that has a negative influence on the effect of inefficiency is age, which means that as the age of the respondent increases, technical efficiency will decrease because increasing the age of farmers will have an impact on the difficulty of receiving understanding and adopting new knowledge in farming. Meanwhile, the experience factor and farmer groups have a positive influence on the inefficiency effect, which means that the more experience farmers have, the more farmers' efficiency will increase, as well as the factor of participation in farmer groups.

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