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Technical Efficiency of Smallholder Oil Palm Farms in Batanghari District Jambi Province, Indonesia

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Abstract. Smallholder oil palm farming is the main livelihood in Batanghari District, although its productivity has not shown maximum results. Maximum productivity achieved, it is necessary for farmers to do their business efficiently. This study aims to analyze technical efficiency and socio-economic factors that affect the technical efficiency of smallholder oil palm farming in Batanghari District. The research sample was determined using the multistage sampling method, which was used to sample farmers using simple random sampling. The number of respondents was 100 farmers. The stochastic frontier production function was used for data analysis. The results showed that the average technical efficiency of oil palm farming was 0,89 and had reached efficiency. However, this level can still be increased by 0,11 to achieve the highest level of technical efficiency. The technical efficiency of farming is affected by socio-economic factors, namely farming experience, distance from home to the farm, and the existence of partnerships. Based on the study's results, the technical efficiency of oil palm cultivation can be improved by utilizing production parameters precisely and accurately and increasing farmers' resources to achieve maximum production. For sustainable agricultural development, further research is needed to analyze the economic efficiency of oil palm farming so that the overall picture of both technical and economic efficiency can be seen.

Keywords: oil palm farming; production factors; technical efficiency

INTRODUCTION

Oil palm plantations in Jambi Province are experiencing relatively rapid development. This can be seen from the land area development, which has increased yearly, namely from 2016 by 467.573 ha, and continues to grow to 526.749 ha in 2020. The rapid growth of oil palm crops is affected by the selling price of Fresh Fruit Bunches (FFB), which is good and relatively stable and has promising prospects that provide hope for the sustainability of farmers' lives in the future so that many encourage rubber farmers and rice farmers to convert crops into oil palm crops. The development of oil palm crops and FFB prices are presented in (**Table 1**).

Table 1. Development of oil palm land area and prices in Jambi Province

Years	Land area (Ha)				Average FFB price (Rp.Kg^{-1})*
	Immature crops	Producing crops	Non-yielding crops	Total	
2016	110.340	338.302	18.931	467.573	1.315
2017	108.733	368.305	20.956	497.994	1.481
2018	108.046	376.374	22.042	506.462	1.307
2019	101.770	323.846	96.594	522.210	1.498
2020	108.009	318.791	99.949	526.749	1.498

Source : Dinas Perkebunan Provinsi Jambi (2021)
Notes: * Average price of FFB from 3-25 years old

This increase in land area also occurred in the Batanghari District, namely from 2016, covering 48.797 ha, and increased to 53.152 ha in 2020 (Dinas Perkebunan Provinsi Jambi, 2021). However, the increase in land area is not directly proportional to the productivity produced. In reality, the productivity of smallholder oil palm crops in Batanghari District in 2020 is still low at 17,609 tons.ha^{-1} when compared

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to the productivity of the oil palm research center, which is in the range of 23 to 27 tons.ha^{-1}/year (PPKS, 2023).

Low productivity can be caused by the use of production factors that are often ignored, such as fertilization not by the recommended dose; the use of fertilizer types is not appropriate when associated with soil types, for example, in mineral soil types that have neutral soil pH it is not appropriate to use dolomite fertilizer continuously, because there will be a significant change in soil pH so that the development of microorganism activity in the soil will be reduced and the availability of nutrients becomes unbalanced. Dolomite fertilizer mainly increases soil pH because it contains CaO (lime), which is more appropriate for peat soil. This is in line with Sani (2011), who stated that, in general, peat soils show a real resistance to changes in pH when compared to mineral soils. As a result, peat soils require more lime to raise the pH to a level almost equivalent to mineral soils. The research of Nainggolan et al. (2021) explained that proper use of fertilizers, especially chemical fertilizers, significantly affects productivity. Likewise, pesticide production factors must be by the dose and method of application.

An inappropriate number and combination of production factors directly impact production yields and costs incurred by farmers, so utilizing the available production factors must be done efficiently to manage their plantations successfully. Failure to optimize the utilization of production factors by farmers can result in untapped opportunities to increase farm income and generate a surplus (Nurdiani et al., 2023). Therefore, it is essential to look at the efficiency of production factors. This reality is based on the fact that a high level of efficiency will result in maximum production because it cannot be separated from the use of an optimal combination of factors of production. Calculating the value of technical efficiency is one of the methods that can be used to determine the efficiency of the use of production factors in oil palm farming. Technical efficiency refers to the capacity of a business unit to achieve the highest possible output by utilizing a certain amount of inputs (Kumbhakar & lovell, 2000).

Farming also highly depends on the farmer's management skills (Puspitasari, 2017). Management capability can affect the level of technical efficiency (Sularso & Sutanto, 2020). The ability of each farmer to manage their farming business depends on the farmer's socio-economic situation. Socio-economic factors such as formal education, farming experience, land ownership status, and extension have been analyzed in many studies, namely in (Ahdinigtyas et al., 2022; Damayanti et al., 2023; Varina et al., 2020; Yuhendra et al., 2022). Based on the explanation above, this study aims to analyze technical efficiency and socio-economic factors that affect the technical efficiency of smallholder oil palm farming in Batanghari District.

METHODS

This research was conducted in Batanghari District, Jambi Province. Data was collected from September to November 2023. The determination of the research sample was carried out using the multistage sampling method, where from eight sub-districts, two sub-districts were selected that had the highest and lowest productivity, namely Maro Sebo Ulu and Maro Sebo Ilir Sub-districts. Each sub-district selected two villages, namely Kembang Sri Village, Teluk Leban Village, Terusan Village, and Danau Embat Village. The total number of respondents was 100 farmers selected from a total population of 537 farmers using a simple random sampling method. Data was analyzed using a stochastic frontier production function assumed as the cobb-douglas equation. This equation was then transformed into natural logarithm form (Formula 1).

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$$\ln Y = \ln \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + V_i - U_i \quad \text{........(1)}$$

Description:
Y = Oil palm productivity ($kg.ha^{-1}$)
β_0 = Constant
X_1 = Number of trees ($trees.ha^{-1}$)
X_2 = Labor ($wd.ha^{-1}$)
X_3 = Urea fertilizer ($kg.ha^{-1}$)
X_4 = Dolomite fertilizer ($kg.ha^{-1}$)
X_5 = NPK fertilizer ($kg.ha^{-1}$)
X_6 = Herbicide ($l.ha^{-1}$)
X_7 = Plant age (years)
β_1-β_7 = Variable regression coefficient
V_i = Random error
U_i = Technical inefficiency

Expected parameter coefficients:
$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6 > 0$ and $\beta_7 > 0$ or $\beta_7 < 0$.

The technical efficiency of oil palm farming uses the equation formulated by Coelli et al. (2005), namely:

$$TE = \frac{Y_i}{Y^*} = \frac{\exp(X_i\beta + V_i - U_i)}{\exp(X_i\beta + V_i)} = \exp(-U_i) \quad \text{........(2)}$$

Description:
TE = Technical efficiency
Y_i = Actual output
Y^* = Estimated frontier output

To determine the factors that contribute to the technical efficiency of oil palm in Batanghari District, an analysis was conducted using the inefficiency equation model developed by Coelli et al. (2005). The equation model used is:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 \quad \text{.. (3)}$$

Description:
U_i = Technical inefficiency effect
δ_0 = Intercept
δ_i = Estimated parameter
Z_1 = Formal education (years)
Z_2 = Farmer age (years)
Z_3 = Farming experience (years)
Z_4 = Distance from house to the farm (km)
Z_5 = Land status (1 = owned, 0 = rented)
Z_6 = Extension (1 = attended extension, 0 = did not attend extension)
Z_7 = Partnership (1 = join partnership, 0 = did not join partnership)

Expected parameter coefficients:
$\delta_1, \delta_3, \delta_5, \delta_6, \delta_7 < 0$, $\delta_2 < 0$ or $\delta_2 > 0$ and $\delta_4 > 0$

RESULTS AND DISCUSSION

Factors Affecting Oil Palm Farming Production

Production results can be determined by the use of production components, such as the number of trees, labor, fertilizers, herbicides, and plant age. The factors affecting oil palm production in Batanghari District can be seen in (**Table 2**).

Table 2 shows the R-squared value of 0,908. This means that the independent variables can explain 90,8% of the dependent variation, while the remaining 9,2% is affected by factors outside the model. The variable number of trees has a significant effect and has the highest coefficient value of all production factors used. The data shows that the main factor to increase production yield should be the increase in the number of trees. This is because an increase in the number of trees by 1% will result in an increase in production of 3,338%. The importance of the number of trees in the main increase in oil palm production is corroborated by the results of research by Abdul et al. (2022) and also Ismiasih & Afroda (2023), where the factor of the number of tree stands will affect production, the more the number of trees, the higher the productivity. Likewise, from the research study of Mustari et al. (2020) where the variable number of trees has a significant effect on production. In the research area, the resulting production is still not optimal because the average use of the

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number of trees is still below the standard, namely 129 trees.ha^{-1}. Meanwhile, the recommended use is 136 trees.ha^{-1} for a spacing of 9,2m x 9,2m x 9,2m (Pahan, 2011).

Table 2. Estimation results of stochastic frontier production function using the MLE method in Batanghari District in 2022

Variable	Coefficient	Standard error	T-value	Sig.
Konstanta	6,446	0,993	6,493	0,518
Number of trees (X_1)	3,338*	0,194	1,724	0,088
Labor (X_2)	0,010	0,010	1,018	0,311
Urea Fertilizer (X_3)	0,058***	0,017	3,354	0,001
Dolomite fertilizer (X_4)	0,019	0,018	1,089	0,279
NPK Fertilizer (X_5)	0,178***	0,024	7,334	0,000
Herbicide (X_6)	0,070***	0,015	4,648	0,000
Plant age (X_7)	0,069**	0,032	2,127	0,036
R-squared	0,908			
Prob. F-statistic	0,000			

Notes:
***: significant effect at 1% α
** : significant effect at 5% α
* : significant effect at 10% α

The coefficient value of labor is 0,010. This means that every 1% increase in labor will cause an increase in production by 0,010%. The average use of labor in the study area is 39,84 wd.ha^{-1}/year and is still far below the ideal average use of labor for oil palm crops that produce as much as 80,50 wd.ha^{-1}/year (Pahan, 2011). The labor variable has no significant effect on production. In line with the research of Yanita & Suandi (2021), labor has no significant effect. This is because the use of labor is not only based on the number of workers, but labor skills also affect production results, especially in maintenance activities. Therefore, in addition to increasing the number of workers, it is necessary to improve the quality of labor skills. Workers who are more skilled in oil palm cultivation activities will have a better understanding of farm management.

The coefficient value of urea fertilizer is 0,058. As a result, production will increase by 0,058% for every 1% increase in the amount of urea fertilizer. The average use of urea fertilizer in the study area is 369,15 kg.ha^{-1} and has met the criteria of the recommended fertilization standard of urea fertilizer ranging from 340-442 kg.ha^{-1}/year (PPKS, 2023). The urea fertilizer variable has a significant effect on production. This finding is in line with the research of Napitupulu et al. (2020), which showed that the use of urea fertilizer has a significant effect on increasing production.

The coefficient value of dolomite fertilizer is 0,019. This means that every 1% increase in dolomite fertilizer will cause an increase in production by 0,019%. In the research area, the average use of dolomite fertilizer was 212,33 kg.ha^{-1}, much lower than the recommended standard. The recommended dose of dolomite fertilizer, according to PPKS (2023), palm oil productivity is 306-374 kg.ha^{-1}/year. The dolomite fertilizer variable has no significant effect on production. This can be caused by the use of inappropriate fertilizers on the type of mineral soil cultivated by Batanghari oil palm farmers, where dolomite fertilizer has the main function of neutralizing soil pH, which is more intended for peat soil. In line with Sani (2011) states that peat soils usually show low pH stability, in contrast to

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mineral soils. As a result, peat soils require more lime to increase the pH to a level almost equivalent to mineral soils.

The coefficient value of NPK fertilizer is 0,178. Consequently, production will increase by 0,178% for every 1% increase in NPK fertilizer. The average use of NPK fertilizer was 242,14 kg.ha^{-1}, much lower than the recommended productivity set by Pusri (2021) of 544-816 kg.ha^{-1}/year. The NPK fertilizer variable has a significant effect on production. In line with research by Puruhito et al. (2019), the NPK fertilizer factor significantly affects oil palm yield.

The coefficient value of herbicide is 0,070. Every 1% increase in herbicides results in a 0,070% increase in production. The herbicide variable has a significant effect on increasing production. This finding is in line with research by Syuhada et al. (2022), which shows that herbicide significantly affects oil palm production. The average level of herbicide use in the study area was 6,95 l.ha^{-1} and already slightly exceeded the standard of the recommended herbicide of 6,2 l.ha^{-1} (Pahan, 2011).

The coefficient value of plant age is 0,069. Every 1% increase in plant age results in a 0,069% increase in production. The yield of FFB on a farm depends on the age distribution of the plants on the farm. Greater age variability in young plants leads to lower yields. As plants develop, their output increases (Risza, 2011). In the study area, the average plant age is 11 years. Production of oil palm plants shows an increasing trend in yield starting at the age of 4 to 7 years. Then, the plant's age of 8 to 15 years produces maximum stable and sloping productivity. After that, there began a decline at the age of 16 years (Pahan, 2011). Likewise, the research results by Suhartono et al. (2023) show that optimum and sloping production occurs at the age of 8 to 13 years. The plant age variable has a significant effect on production. In line with research by Ismiasih (2017), the plant age variable significantly affects oil palm production.

Technical Efficiency of Oil Palm Farming

The analysis was conducted to determine whether oil palm farming in Batanghari District was technically efficient. The results of technical efficiency achieved by respondent farmers are in (**Table 3**).

Table 3. Distribution of respondent farmers by technical efficiency score in Batanghari District in 2022

Technical efficiency score	Number of farmers (People)	Percentage (%)
<0,50	0	0
0,51 – 0,60	7	7
0,61 – 0,70	7	7
0,71 – 0,80	8	8
0,81 – 0,90	12	12
0,91 – 1,0	66	66
Total	100	100
Average	0,89	89
Maximum	0,99	99
Minimum	0,55	55

In **Table 3**, overall, oil palm farming in Batanghari District is technically efficient, with an average of 0,89 greater than or equal to 0,7 (≥ 0,7). This is in line with research by Ismiasih (2017) on plantations in West Kalimantan Province that have achieved technical efficiency with an average of 0,83. Nevertheless, the technical efficiency figure in Batanghari District shows that farmers have not yet reached the maximum level of

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technical efficiency (= 1). Therefore, farmers still have an opportunity of 0,11 or 11% to achieve maximum technical efficiency. This can be achieved by optimizing the main inputs that have a large influence, especially the number of trees, urea fertilizer, NPK fertilizer, herbicides, and plant age.

Oil palm growers in the study sites have achieved technical efficiency levels ranging from 0,55 to 0,99. Variations in efficiency levels among farmers arise from the use of different input factors as well as the technical skills of farmers in allocating inputs.

The majority of 66 oil palm farmers have a technical efficiency level of > 0,90 or almost reaching the maximum value. This achievement is partly due to the factor of average plant age of 13-14 years old, which is the age of productive plants and peak production (peak production slopes or flattens the age range of 8-15 years).

Another supporting factor is the level of soil fertility that is cultivated quite well because in the opening of many plantations in the area of ex-forest land, where humus or the availability of nutrients is still sufficient so that it can affect the increase in production even though from one side the use of production inputs has not been maximized.

In addition, the use of various input factors such as fertilizers, the number of trees and herbicides have all been applied. However, the treatment techniques still do not follow the optimal standard norms, namely in the use of fertilizers with doses, still not according to the right dose, the cause is the high price of fertilizers, the type of fertilizer given is still not accommodated and has not used kieserite (MgO) fertilizer or borax micro fertilizer, so it has not been able to achieve maximum technical efficiency (= 1). As for the level of technical efficiency < 0,90 from 34 farmers, one of the main factors is the average plant age of 6 years, and physiologically the plant productivity is still low.

Besides being influenced by the allocation of production input use, differences in technical efficiency levels can also be influenced by socio-economic factors. This factor further impacts the management of oil palm cultivation by farmers.

Socio-economic Factors Affecting Technical Efficiency of Oil Palm Farming

Differences in the level of efficiency achieved among farmers indicate that there are differences in farmers managing existing inputs. Differences in management can be caused by socio-economic factors such as formal education, age, farming experience, distance from home to the farm, land ownership status, participation in extension activities, and partnership participation. The results of estimating technical inefficiency of oil palm farming in Batanghari District are presented in (**Table 4**).

In **Table 4**, the LR-test value of 72,897 is greater than the critical value of Kodde Palm with 5% α level, which means that the model can explain the technical inefficiency effect. The sigma-squared (σ2) value of 0,022 or more than zero indicates that the model of technical inefficiency effect is normally distributed. The gamma value (γ) of 0,986 indicates that 98,6% of the residual variation in the stochastic frontier production function model is caused by technical inefficiency (U_i), while the remaining 11,4% is caused by random error (V_i) outside the model.

The formal education variable has a negative regression coefficient and has no significant effect. The coefficient value indicates that the longer the farmer takes formal education, the higher the level of technical efficiency. Formal education has no significant effect because it is not only the level of education but also farming skills and experience that are very important in supporting the achievement of efficiency. This is also in line with research by Yuhendra et al. (2022), which shows that formal education has no significant effect on the technical efficiency of oil palm.

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The farmer age variable has a negative regression coefficient and has no significant effect. The coefficient value shows that the older the farmer, the more the level of technical efficiency increases. This finding is consistent with the research of Ariyanto et al. (2020), which showed that the age of farmers had no significant effect on the technical efficiency of farming. Rusli (2012) defines the productive age range as 15-64 years, and the efficiency value increases at the productive age, but in the research area, especially at the age of 69-76 years, there is an increase in technical efficiency. There should be a decrease in technical efficiency because at that age, endurance is decreasing, which is getting weaker. Also, when making decisions, there can be mistakes. The reality in the field is that the increase in technical efficiency is due to the fact that the farm is managed by his family.

Table 4. Estimation results of technical inefficiency of oil palm farms in Batanghari District in 2022

Variable	Coefficient	Standard error	T-value	Sig.
Constant	0,908	0,754	1,205	0,231
Formal education (Z_1)	-0,113	0,080	-1,403	0,164
Farmer age (Z_2)	-0,033	0,094	-0,351	0,726
Farming experience (Z_3)	-0,574***	0,090	-6,372	0,000
Distance from house to farm (Z_4)	-0,108***	0,040	-2,705	0,008
Land status (Z_5)	0,908	0,754	1,205	0,231
Extension (Z_6)	-0,028	0,055	-0,511	0,611
Partnership (Z_7)	-0,580**	0,240	-2,419	0,018
Sigma squared	0,022			
Gamma	0,986			
LR-Test	72,897			

Notes:
***: significant effect at 1% α
** : significant effect at 5% α

The farming experience variable showed a negative regression coefficient and significant effect. The coefficient value shows that the longer the farming experience, the higher the technical efficiency. The longer the farmer is in farming, the better and more efficient his insight in dealing with problems during farming. These findings are in line with research conducted Damayanti et al. (2023) and also Napitupulu et al. (2020), which showed that the farming experience variable had a significant effect on the technical efficiency of oil palm. Based on their experience, farmers can better deal with the uncertain conditions on their farms and make the most rational decisions. Farmers with more experience tend to have more networks so that they can receive information related to technology and other things faster. Therefore, farmers with more experience tend to have better managerial skills than less experienced farmers.

The variable distance from the house to the farm has a negative regression coefficient value and significant effect. This is not linear with the hypothesis put forward, which is positive. This means that the further the distance from the house to the farm, the higher the technical efficiency. The distance from the house to the farm has a significant effect on the long distance because the average farmer who cultivates his farm follows a partnership pattern, where all the use of inputs in maintaining the garden is carried out by the company and cooperates with the cooperative as a farmer representative.

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The variable of land ownership status has a positive coefficient value and has no significant effect. In line with the research of Ahdinigtyas et al. (2022), land ownership status has no significant effect and has a positive coefficient value on the level of technical inefficiency. This shows that farmers who work on privately owned land and farmers who work on non-privately owned land have the same opportunity to manage their land to achieve a high level of technical efficiency. All farmers in the study area are owners of their own land, where farmers do not have to pay rent for their land. Oil palm farmers who own their land and do not have to pay rent for their land will be more negligent in running their farms.

The extension variable has a negative regression coefficient and no significant effect. The coefficient value shows that involvement in extension activities refers to increasing technical efficiency. However, participating in extension activities in the field is not always directly proportional to increased technical efficiency. The extension variable does not significantly affect technical efficiency due to farmers' low level of trust in agricultural extension workers. In addition, most oil palm farmers in the study area prefer to rely on their experience and the cultivation techniques that they are used to. This is in line with the findings obtained by Varina et al. (2020), which state that extension has no significant effect.

The partnership variable shows a negative regression coefficient and has a significant effect. This shows that with the establishment of cooperation, the level of technical efficiency will increase. From the distribution of technical efficiency level, farmers who participated in the partnership had a much higher score than those who did not participate. This research is in line with Wafi (2023), which also provides similar results in that the partnership has a significant effect on reducing the technical efficiency of farmers. The partnership pattern between smallholders and the company using the primary cooperative credit for members pattern is the landowner farmer surrenders 30% of his land to the credit guarantee investor (as avalist), while the farmer's ownership is reduced to 70%. The development of plasma plantations owned by the primary cooperative credit for members participating farmers uses soft credit facilities obtained from banks through investors. In working on the plantation, everything is done by the investor, and a cooperation agreement is made with the cooperative as the representative of the farmers. Farmers will get the proceeds from the sale of FFB by the company after deducting 30% debt and 30% maintenance costs. If the farmer's debt has been settled, the sales proceeds are only deducted by 30% of maintenance costs. Of course, the partnership pattern in the plantation development is made by the company, where the management of cultivation techniques is professional, so the productivity obtained is much better than that of those who do not partner.

CONCLUSION

Oil palm farming in Batanghari District is already technically efficient at an average of 0,89. However, it can still be increased again by 0,11 to achieve maximum technical efficiency. The main determinants that significantly impact improving technical efficiency are farming experience and distance from the house to the farm significant at α (1%), and partnership significant at α (5%). Efforts to increase the technical efficiency of oil palm cultivation include the proper and accurate utilization of production factors according to the standards set by official institutions appointed by the government, such as the number of trees, namely 136 trees.ha^{-1} with a spacing of 9,2m x 9,2m x 9,2m, fertilization must be the right type according to the type of soil, the correct dose of each age of the plant according to official recommendations, the right way to apply fertilizer to plants, the right time to apply fertilizer during the rainy season or

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soil conditions are still moist. Then, the use of herbicides must be adjusted to the type of weeds on the farm with the correct dose and type. For example, systemic herbicides or glyphosate should be used to eradicate tares weeds because tares have rhizome roots, as well as skilled labor and understanding of oil palm cultivation techniques to increase farmers' resources to achieve maximum production. In research studies, farmers never apply single fertilizers such as phosphate, potassium, magnesium (kieserite), and boron. This is because they are expensive, even though these fertilizers are very important for the physiological development of plants both vegetatively and generatively in order to achieve maximum production. In this case, the government needs to subsidize these fertilizers at affordable prices so that farmers can apply all of them at the recommended standard dose and achieve maximum productivity. Thus, the hope of sustainable development will be realized. To develop this research, it is necessary to conduct further research on the analysis of the economic efficiency of oil palm farming so that the overall picture of both technical and economic efficiency can be seen.

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