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Analysis of Technical Efficiency and the Influence of Socioeconomic Factors on Oil Palm Farming in Muaro Jambi District - Indonesia

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Abstract**—** *Technical efficiency and socioeconomic factors have a significant effect on the productivity of oil palm farming. Therefore, this study aimed to analyze technical efficiency and the influence of socio-economic factors on oil palm farming. Sampling was conducted using the Simple Random Sampling method. The data used are primary data and secondary data. The analysis method used is descriptive analysis and Stochastic Frontier production function analysis with MLE method. The results showed that the average land area of farmers in oil palm plantations was 3.9 ha with an average productivity of 14,638 kg/ha. Production factors that have a significant effect on production are land area, NPK fertilizer, Urea fertilizer and Dolomite. While those that do not have a significant effect are labor and herbicides. The level of technical efficiency achieved was the lowest 0.81 and the highest 0.95 and with an average of 0.86> 0.62 which means that farming is technically efficient. Socio-economic factors such as variables of age and distance from the farm to the farmer's house have the potential to reduce technical inefficiency but have no significant effect and variables that have a significant effect are variables of experience, education, and activeness in farmer groups while factors that increase technical inefficiency that have a significant effect are variables of land area.*

Keywords**—** ***Self-help Pattern, Production Inputs, Production Response, Technical Efficiency, Socio-economic, Technical Inefficiency.***

I. INTRODUCTION

Oil palm is a major export commodity that has many benefits for the Indonesian economy. The development of oil palm plantations began in 1969 when the Indonesian government established the State Plantation Company (PNP) with investment funding by the World Bank The Asian Development Bank. Since the beginning of the growth of oil palm in Indonesia, oil palm plantations are still dominated by large private and state plantations. However, over time smallholder plantations began to experience rapid growth.

Data (Ditjenbun, 2021) states that the productivity of smallholder oil palm plantations in 2019 was 3.24 tons/ha, this figure is still below the national average of 3.97 tons/ha. This means that smallholder plantations are still relatively low and still have the potential to further increase their productivity. Smallholder oil palm plantations in Indonesia still need more attention to be able to increase their productivity.

Jambi Province is the seventh largest palm oil producer in Indonesia with a total oil palm plantation area of 1,034,804 ha and produced 2,884,406 tons in 2019 (Ditjenbun, 2021). Based on the data, around 62.98 percent of oil palm plantations in Jambi Province based on control in 2019 were People's Plantations (PR), PBN was 1.97 percent, and PBS was 35.05 percent.

In 2019, Muaro Jambi Regency was one of the centers of oil palm farming in Jambi Province with the largest total area of smallholder oil palm plantations in Jambi Province, which was 125,888 ha or 19.32 percent of the total area of smallholder oil palm plantations in Jambi Province, and occupied the second position for the area of Producing Plants (TM) of oil palm plantations with an area of 94,791 ha. Muaro Jambi Regency also has the largest number of oil palm farmers in Jambi Province with 57,714 families. However, oil palm productivity in Muaro Jambi is still low compared to other districts, reaching only 2,575 kg/ha. One of the sub-districts that has the largest smallholder oil palm area and the highest production in Muaro Jambi Regency is Sekernan Sub-district, but its productivity is still relatively low, reaching only 2,661 kg/ha. Judging from the Sekernan sub-district oil palm area, its productivity still has the potential to be increased again.

The low productivity of oil palm farming in Sekernan District can be caused by inefficient use of inputs. The use of production inputs such as land, seeds, fertilizers and labor should be carried out properly and efficiently so as to provide benefits to farmers because it will produce high productivity. Productivity is said to be high if the farm produces maximum production with a minimum combination of inputs. (Tajerin & Mohammad, 2005) states that studying technical efficiency is the same as studying productivity. A high level of technical efficiency will reflect high productivity because technical efficiency cannot be separated from the optimal combination of production factors.

Technical efficiency analysis is also carried out to determine technical factors that can affect the managerial ability of farmers to produce efficiently, which can increase the profit of the farmers themselves. Oil palm farming that is still not technically efficient is thought to occur because it is constrained by the risk of socio-economic uncertainty of farmers which causes technical inefficiency. Technical efficiency is closely related to technical inefficiency because technical inefficiency is the residue of technical efficiency. Not achieving technical efficiency is caused by sources of inefficiency both socially and economically.

II. RESEARCH METHOD

This research was conducted in Sekernan District, Muaro Jambi Regency. This research location was chosen purposively with consideration of oil palm farming as a source of family income in the area. This research was conducted in Gerunggung Village. The village was selected with the consideration that it has a high area but low oil palm production. The objects used in this study were independent oil palm farmers. The number of samples used was 60 farmers with plant age groups based on (Fauzi, 2012) namely 3-8 years, 9-13 years, 14-20 years, and 21-25 years. Sampling method using Simple Random Sampling. This study uses primary data obtained directly from independent oil palm farmers through a direct interview system using a questionnaire. The scope of this study is limited to determine the use of production inputs that affect the production produced. To analyze technical efficiency with the stochastic frontier method is done through two stages, namely the analysis of the actual production function and the analysis of the potential production function (frontier), then the ratio between actual production and potential production is the level of technical efficiency which ranges from 0 to 1.

The first stage is to analyze the actual production function using the Ordinary Least Squares (OLS) method. At this stage, estimating technology parameters and production inputs (β_m) using the Ordinary Least Squares (OLS) method. Parameter estimation with the Ordinary Least Square (OLS) method is used to provide an overview of the average performance of the oil palm farming production process in Gerunggung Village at the existing technology level. The form of the actual production function with the OLS method is as follows:

The second stage is to analyze the frontier production function with the MLE Method. At this stage, the overall parameters of the production factor (), intercept (), and variance of the two error components vi and ui are estimated using the Maximum Likelihood Estimation (MLE) method. The Maximum Likelihood Estimation (MLE) method is used to describe the best performance of the farm at the existing technology level. Mathematically, the stochastic frontier function is expressed in the following equation:

$$Y = X_i + ()$$

The transformation form of the Stochastic Frontier function is expressed as follows:

Description:

Y : palm oil production (kg)
: constant or intercept
: land area planted with oil palm (ha)
: amount of labor used (HOK)
: amount of NPK fertilizer used (kg/year)
: amount of Urea fertilizer used (kg/year)
: amount of Dolomite fertilizer used (kg/year)
: amount of Herbicide used (liter/year)
: *disturbance terms*
: technical inefficiency effect
: indicates the i-th farmer

The analysis method to measure the level of technical efficiency of oil palm farming in the research area was estimated using the equation formulated by (Tasman, 2008) as follows:

$$TE_i = \; = exp(-)$$

Description:

TE_i : technical efficiency achieved by the i-th farmer

: actual farm output

: potential output

: *one-side error term* ()

The criteria for farmers who are classified as technically efficient in this study are if the efficiency index value ≥ 0.62 then the oil palm farm is technically efficient. Conversely, if the efficiency value is <0.62 then oil palm farming is still not technically efficient.

The method of analysis to answer the influence of socio-economic factors that cause the technical inefficiency of oil palm farming refers to the equation model developed by (Coelli et al., 2005). The estimation equation model used in this study is as follows :

It is suspected that the factors that negatively affect technical inefficiency are the age of farmers, farming experience, distance from the farm to the farmer's house, education, and activeness in farmer groups. While the factors that have a positive effect on technical inefficiency is the area of land because it is suspected that the wider the farm land, the more difficult it is for farmers to supervise their land and in carrying out garden maintenance.

III. RESULT AND DISSCUSION

Characteristics of Respondent Farmers

Farmer characteristics are factors that influence farmers in managing their farms. Farmer characteristics studied were farmer age, farming experience, and land area.

Table 1. Characteristics of Farmer Respondents in the Study Area in 2022

Characteristics	Average	Percentage (%)
Farmer Age	44,2	25,00
Experience	17,68	33,33
Land Area	3,94	86,67

Table 1 shows that respondent farmers in the study area had ages ranging from 30 years old at the youngest and 59 years old at the oldest. The majority of farmers were between the ages of 45 and 49 years, which is about 25 percent of all sample farmers. The average age of respondent farmers in the study area was 44.2 years old. (Hernanto, 2018) stated that the productive age is between 15 - 50 years old, so the average farmer is still at a productive age so that he is still able to cultivate the farm well to increase production.

The lowest farming experience of sample farmers in the study area is 5 years and the longest is 46 years. The most dominant farming experience is farming experience for 11 - 16 years, namely as many as 20 farmers with a percentage of 33.33 percent. The average farming experience in the study area is 17.68 years. According to (Hernanto, 2018) farming experience is one of the most determining factors for success, in the future farmers will be better at cultivating their farms because of their increasing experience.

The largest land area owned by the sample farmers was 20 ha and the smallest was 1.5 ha. The total land area of respondent farmers is 236.5 ha and the average land area is 3.9 ha. The most dominant land area is in the range of 1.5-5 ha with a frequency of 52 farmers or 86.67 percent. According to (Hernanto, 2018) The types of farmers based on the area of land cultivated are divided into four, namely (1) large farmers, those with land > 2 ha, (2) medium farmers, those with land between 0.5 - 2 ha, (3) narrow farmers, those with land < 0.5 ha, and (4) landless farm laborers. Sample farmers fall into the medium to large farmer groups.

Production Factor Usage

Production factors are very important factors in efforts to increase farm production. The production factors used should be in accordance with the recommendations in order to obtain the expected results. The use of production factors used by oil palm farmers in Gerunggung Village can be seen in the following table.

Table 2. Production Factor Usage in the Study Area in 2022

Production Factors	Total	Average
Herbicides	2.255	37,58
NPK fertilizer	16.320	272
Urea fertilizer	15.699	262
Dolomite	24.305	405

Table 2 shows that the average use of pesticides was at least 10 liters/ha, while the highest use was 60 liters/ha. The average herbicide use in the study area was 37.58 liters/ha. Herbicide use was most dominant in the range of 24 - 30 liters/ha, which was 20 percent of the sample farmers.

The lowest use of NPK fertilizer on oil palm farms in the study area based on sample farmers was 125 kg/ha and the highest was 420 kg/ha. The most dominant use of fertilizer is in the range of 125 - 167 kg/ha and 297 - 339 kg/ha which is about 20 percent. The average amount of NPK fertilizer used was 272 kg/ha. The use of NPK fertilizer in the study area is still relatively low and not in accordance with recommendations by (Balitbang, 2013) which should be the average use of NPK fertilizer for oil palm farming is 350 kg/ha. The use of urea fertilizer for oil palm farming in the study area is most dominant in the range of 267 - 291 kg/ha around 36.67 percent of the sample farmers. The lowest amount of Urea fertilizer use was 167 kg/ha and the highest was 340 kg/ha. The average use of Urea fertilizer by sample farmers was 262 kg/ha. So the use of urea fertilizer in the study area is still not in accordance with the recommendations based on (Balitbang, 2013) of 300-375 kg/ha. The highest use of dolomite is 563 kg/ha and the lowest use is 125 kg/ha. Most farmers used dolomite in the range of 440 - 502 kg/ha which was 33 percent of the sample farmers. The average use of dolomite in oil palm farming in the study area was 405 kg/ha. The average use of dolomite in the study area has exceeded the number of recommendations by (Balitbang, 2013) which is 375 kg/ha for the use of dolomite.

Analysis of the Farm Production Function

Production function analysis was conducted with the aim of seeing how the influence of production factor variables affecting farm production. Before being analyzed, testing was carried out using the OLS (Ordinary Least Square) method. The results of the analysis obtained are the R2 value of 0.99 and the variables that have a significant effect on production are land area, NPK fertilizer, Urea fertilizer, Dolomite and Herbicide. While the variable labor has no significant effect on production.

Table 3. Estimation of Palm Oil Farming Production Function in the Research Area with OLS Method in 2021

Variable	Parameter	Coefficient	t-statistic
Constant			
Land Area		7.0877	41,1611***
Labor		0.4683	13,2746***
NPK		-0.3071	-0,1234ns
Fertilizer		0.1621	4,4555***
Urea		0.1776	3,3478***
Fertilizer		0.0892	2,7849***
Dolomite		0.0260	1,2906ns
Herbicides			
Sigma-squared		0,0008	
Σβi		0.6163	
R^2	= 0,9972		
t-tabel α (0,01), df : 54 = 2,6700			
t-tabel α (0,05), df : 54 = 2,0049			
t-tabel α (0,10), df : 54 = 1,6736			

Description: *** = significant at α (0,01)
** = significant at α (0,05)
* = significant at α (0,10)
ns = not significant

The estimation results of the oil palm production function with the OLS method are as follows:

$$\text{Ln } Y = 7.0877\ (X_1^{0.4683}\ X_2^{-0.3071}\ X_3^{0.1621}\ X_4^{0.1776}\ X_5^{0.0892}\ X_6^{0.0260})$$

Table 3 shows the R^2 value of 0.9972, which means that the independent variables (land area, labor, NPK fertilizer, Urea fertilizer, Dolomite, and herbicide) together can explain the dependent variable (production) by 99.72 percent, while the remaining 0.28 percent is determined by other factors outside the model. The value of Σβi = 0,6163 < 1, meaning that the use of production factors in the study area is in region II of the production curve or the Decreasing Return to Scale area, which means that each additional unit of input produces a decreasing additional output. Variables that have a significant effect on production are land area, NPK fertilizer, Urea fertilizer and Dolomite which have a very significant effect at α (0.01). While the variables that do not have a significant effect on production are labor and herbicide.

Analysis of the Farm Productivity Function

Estimation of the productivity function is carried out with the aim of knowing how the influence of variable production factors on farm productivity. Before being analyzed, testing is done using the MLE (Maximum Likelihood Estimation) method. From the analysis, it can be seen that the value of R^2 is 0,9537, $\Sigma\beta_i$ is 0,8366 < 1, and the value of gamma is 0.9999. Variables that significantly affect productivity are labor, NPK fertilizer, Urea fertilizer, Dolomite, and Herbicide.

Table 4. Estimation of Palm Oil Farming Productivity Function in the Research Area with MLE Method in 2021

Variable	Parameter	Coefficient	t-statistics
Constant			
Labor		7,1480	55,5114***
NPK		0,0201	5,3946***
Fertilizer		0,1369	4,4577***
Urea		0,1840	4,8780***
Fertilizer		0,0834	3,6781***
Dolomite		0,4122	2,2209**
Herbicide			
Sigma-squared		0,0008	3,9758
Gamma		0,9999	51,7049
Σβi		0,8366	
LR test of the one-sided error			16,9181
Log-likelihood function MLE			137,4184
Log-likelihood function OLS			128,9594
R^2	= 0,9537		
t-tabel α (0,01), df : 55 = 2,6682			

t-tabel α (0,05), df : 55 = 2,0040	
t-tabel α (0,10), df : 55 = 1,6730	

Description : *** = significant at α (0,01)
** = significant at α (0,05)

The results of the estimation of the forntier productivity function of oil palm farming with the following equation:

$$\text{Ln } Y= 7{,}1480 \left(X_1^{0,0201}\ X_2^{0,1369}\ X_3^{0,1840}\ X_4^{0,0834}\ X_5^{0,4122}\right)$$

Table 4 shows the R^2 is 0,9537 which means that the independent variables (labor, NPK fertilizer, Urea fertilizer, Dolomite, and herbicide) together can explain the dependent variable (productivity) by 95.37 percent, while the remaining 4.63 percent is determined by other factors outside the model. The gamma value () indicates the presence or absence of inefficiency influence in the model. Statistically, the value of gamma () 0,9999 is close to 1, meaning that the error term is caused by technical inefficiency by 99.99 percent, and the remaining 0.01 percent is caused by external influences. The value of Σβi = 0,8366 < 1, meaning that the use of production factors in the study area is in region II of the production curve or the Decreasing Return to Scale area, which means that each addition of the same proportion of production inputs will result in a decreasing increase in output. Independent variables in the model that have a very significant effect on productivity at the α = 0.01 level are labor, NPK fertilizer, Urea fertilizer and Dolomite fertilizer, and herbicides have a significant effect at the α = 0.05 level.

The coefficient value of the labor variable of 0.0201 is positive with the value of t_{hit} = 5,3946 > $t_{\alpha(0,01)}$ = 2,6682 which means that the labor variable has a very significant effect on increasing FFB productivity. These results are in accordance with research studies (Thamrin, 2016), (Puruhito et al., 2019), and (Febriyanto, 2020) namely labor has a significant effect on increasing productivity. However, different results were obtained in (Asmara et al., 2011), (Ridho et al., 2014), (Sitanggang, 2018), and (Panjaitan et al., 2020) which stated that labor had no significant effect on increasing productivity.

The coefficient value of the NPK fertilizer variable obtained a value of 0.1369 with a positive sign with a value of t_{hit} = 4,4577 > $t_{\alpha(0,01)}$ = 2,6682 which means that the NPK fertilizer variable has a very significant effect on increasing FFB productivity, in line with research (Puruhito et al., 2019), and (Syuhada et al., 2022) which states that NPK fertilizer has a significant effect on increasing productivity.

The coefficient value of the Urea fertilizer variable was obtained at 0.1840 with a positive sign with a value of t_{hit} = 4,8780 > $t_{\alpha(0,01)}$ = 2,6682 which means that Urea fertilizer has a very significant effect on increasing FFB productivity. These results are in accordance with research (Ridho et al., 2014) and (Napitupulu et al., 2020) which state that Urea fertilizer has a significant effect on increasing productivity, but different results are obtained (Nainggolan et al., 2019), and (Puruhito et al., 2019) that urea fertilizer has no significant effect on increasing the productivity of oil palm FFB.

Dolomite variable coefficient was obtained at 0,0834 with a positive sign with a value of t_{hit} = 3,6781 > $t_{\alpha(0,01)}$ = 2,6682 which means that the dolomite variable has a significant effect on increasing FFB productivity. This is in accordance with research by (Napitupulu et al., 2020) that dolomite has a significant effect on increasing productivity, but different results were obtained (Ridho et al., 2014) that dolomite has no significant effect on increasing FFB productivity.

The Herbicide coefficient value obtained is 0,4122 with a positive sign with the value of t_{hit} = 2,2209 > $t_{\alpha(0,05)}$ = 2,0040 which means that Herbicides have a significant effect on increasing FFB productivity with a confidence level of 95 percent. In accordance with research (Syuhada et al., 2022) that herbicides have a significant effect on increasing FFB productivity, but different results were obtained (Ridho et al., 2014) and (Puruhito et al., 2019) that herbicides have no significant effect on increasing the productivity of oil palm FFB.

Technical Efficiency Analysis of Oil Palm Farming

The measurement of technical efficiency is carried out with the aim of seeing how the achievement of production from the comparison of potential production with actual production. The value of technical efficiency is obtained by calculating actual production divided by potential production. Efficient farming if the value of technical efficiency > 0,62.

Table 5.Technical Efficiency of Independent Palm Oil Farming in the Research Area in 2021

	Technical Efficiency	Total Farmers (people)	Percentage (%)
	0,81 – 0,83	7	11,67
	0,84 – 0,86	25	41,67
	0,87 – 0,89	22	36,67
	0,90 – 0,92	4	6,67
	0,93 – 0,95	1	1,66
	0,96	1	1,66
Total	-	60	100,00
Min	0,81		
Max	0,96		
Average	0,86	-	-

The results of the measurement of technical efficiency obtained that the level of technical efficiency achieved by independent oil palm farmers in the study area ranged from 0.81 to 0.96 with an average technical efficiency of 0.86. The average value of the actual technical efficiency of independent pattern oil palm farms in the study area is 0.86 which means that the average productivity achieved by oil palm farmers in the study area is about 86 percent of frontier production and can still be increased by 14 percent more. The average value of the technical efficiency level of oil palm farmers in the study area > 0.62 and the lowest technical efficiency value obtained is 0.81 > 0.62 which means that the overall independent pattern of oil palm farmers in the study area is technically efficient (ET > 0.62), but still needs to be improved again because the technical efficiency obtained by farmers can still be improved by 19 percent more. The technical efficiency figure obtained in this study is still below the technical efficiency in research (Harefa, 2021) which obtained an average technical efficiency of 0.86 with the lowest technical efficiency value of 0.63 and the highest 0.99.

Influence of Socioeconomic Factors on Technical Inefficiency of Oil Palm Farms

Technical inefficiency analysis was conducted to see how the influence of socioeconomic factors on technical inefficiency. The analysis was conducted using the OLS (Ordinary Least Square) method and the results showed that there was no violation of information on *Adj. R2, Prob (F-statistic)* and *Durbin Watson stat* related to classical assumption test.

Table 6. Results of Sources of Technical Inefficiency

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Z1_LAHAN	0.002422	0.000689	3.515984	0.0009
Z2_UMUR	-0.000256	0.000421	-0.608412	0.5455
Z3_PENGALAMAN	-0.001446	0.000305	-4.734702	0.0000
Z4_JARAK	-0.000206	0.000990	-0.207855	0.8361
Z5_PENDIDIKAN	-0.008695	0.002450	-3.548800	0.0008
Z6_KEAKTIFAN	-0.016317	0.005900	-2.765399	0.0078
C	0.269244	0.020744	12.97914	0.0000
R-squared	0.801999	Mean dependent var		0.191333
Adjusted R-squared	0.779584	S.D. dependent var		0.028372
S.E. of regression	0.013320	Akaike info criterion		-5.689783
Sum squared resid	0.009404	Schwarz criterion		-5.445443
Log likelihood	177.6935	Hannan-Quinn criter.		-5.594208
F-statistic	35.77921	Durbin-Watson stat		1.585674
Prob(F-statistic)	0.000000			

Table 6 shows that the *Prob. (F-statistic)* 0,000 < α (0,05) shows that the results are simultaneously significant, meaning that the independent variables contained in the model together have a significant effect on the technical inefficiency of farming. Durbin Watson stat value is 1,585 < 2,00 indicates that the model in the study is free from autocorrelation. Variables that have a significant effect on technical inefficiency in oil palm farming self-help pattern at the level of α = 0,05 are variables of land area, experience, education, and activeness in farmer groups. While the variables that do not have a significant effect on technical inefficiency are the variables of age and distance from the farm to the house.

Land area, experience, education, and activity in farmer groups have a significant effect on technical inefficiency with a positive land area coefficient, and the coefficient of experience, education, and activity in farmer groups is negative. In accordance with (Napitupulu et al., 2020) namely the land area has a significant effect on technical inefficiency with a positive coefficient value, and experience has a significant effect with a negative coefficient. However, different results were obtained (Syuhada et al., 2022) namely land area, experience and education had no significant effect on technical inefficiency

Variables that do not have a significant effect on technical inefficiency are age and distance from home. This result is consistent with (Syuhada et al., 2022) that age has no significant effect on technical inefficiency. However, it is inversely proportional to (Napitupulu et al., 2020) that the distance between the garden and the house has a significant effect on technical inefficiency with a positive coefficient, which means that the further the distance between the garden and the house, the more technical inefficiency will increase.

V. CONCLUSION

Farm management is still not as recommended, especially in the use of fertilizers. The use of NPK and Urea fertilizers is still below the recommendation, while Dolomite has exceeded the recommendation. The average production obtained by farmers is low compared to the national average production and is still below the potential production of oil palm based on the varieties used.

Production factors of land area, NPK fertilizer, Urea fertilizer and Dolomite are production factors that can increase oil palm FFB production. The level of technical efficiency of independent pattern oil palm farming in the research area is technically efficient but still needs to be improved because technical inefficiency is still relatively high.

Socio-economic factors that have a significant effect on technical inefficiency in oil palm farming self-help patterns are land area, farming experience, education and activeness in farmer groups. While factors that do not have a significant effect on technical inefficiency are the age of farmers and the distance of the plantation to the farmer's house.

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