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Study of Production and Technical Efficiency of Smallholders Oil Palm Plantations in Hatonduhan District, Simalungun Regency, North Sumatera Province

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Abstract
Modern management of smallholder oil palm plantations is very much needed to enable smallholder oil palm plantations to follow the progress of management of large oil palm plantations, both state-owned and privately owned. This study aims to determine how production factors influence production and to determine the technical efficiency of smallholder oil palm plantations. The location of the study was determined purposively based on the consideration of the existence of smallholder oil palm plantations in the area. The sample was determined by quota sampling of 150 samples from two villages, namely Buntu Bayu Village and Buntu Turunan Village, each with 75 samples. The analysis involves applying the Multiple Non-Linear Regression Test (Rank Test) alongside Data Envelopment Analysis, focusing on managing smallholder oil palm plantations throughout 2023. The study results show that, partially, the production of smallholder oil palm plantations is significantly positively influenced by each production factor. Conversely, the output of smallholder oil palm plantations is notably affected by various production factors, including land, labor, fertilizer, and pesticides. Most (78.00%) smallholder oil palm plantations are technically inefficient, with an average technical efficiency value of 0.9755. To achieve a technically efficient production process, smallholder plantation farmers must reduce inputs, namely 2.5416% of the land, 4.0501% of labor, 5.5449% of fertilizer, and 3.1165% of pesticides.

Keywords: Production; Smallholder Oil Palm Plantations; Technical Efficiency

Introduction

Smallholder oil palm plantations represent a specific category of oil palm plantation management in Indonesia. Other forms of management statuses are large state plantations and large private plantations. Data from the Direktorat Jenderal Perkebunan (2024) shows that in 2023, the area of oil palm plantations in Indonesia was 15,435,656 hectares, consisting of 40.76% smallholder plantations, 3.53% large state plantations, and 55.71% large private plantations. It is projected that, in the future, smallholder oil palm plantations will prevail in terms of land area within Indonesia's oil palm sector. Therefore, its existence is also expected to continue to increase its contribution to Indonesia's economic development.

Based on land area, in 2023, North Sumatra Province will be the third-largest region with oil palm plantations and the fifth-largest region with smallholder oil palm plantations in Indonesia. In North Sumatra Province, smallholder oil palm plantations are distributed throughout 22 districts

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and cities. Rapid development can be seen in the highland areas previously dominated by the East and West coasts, including Simalungun Regency. 2023 North Sumatra Province will have 488,414 hectares of smallholder oil palm plantations (Direktorat Jenderal Perkebunan, 2024).

Until now, the performance of smallholder plantations measured by productivity is still below that of large plantations. An analysis of the 2.2 million farmers managing smallholder plantations indicates that these plantations will play a crucial role in shaping the future of the palm oil industry in Indonesia. The primary challenge faced by smallholder oil palm plantations is their low productivity. This situation stems from inadequate management practices employed by farmers. Factors such as insufficient knowledge, limited technical skills in cultivation, and constrained capital resources contribute to subpar management practices. Until now, between smallholder oil palm plantations and large plantations, there is still a relatively high productivity gap, namely between 41 - 64% of the national oil palm plantation productivity of around 7 - 20 tons of FFB / ha/year (Suharno et.al., 2015).

Increasing the productivity and efficiency of smallholder plantations is very important in improving the performance of the plantation sector. The significant contribution of smallholder plantation production to national plantation production means that efforts to increase the efficiency of smallholder plantation production will significantly improve the efficiency of national plantation production (Setiyanto, 2015).

Efforts to increase agricultural production require good and proper management. The management in question is the ability of farmers to coordinate the use of production factors that they control as well as possible so that they can produce as expected. The limited productivity observed in smallholder oil palm plantations across Indonesia, particularly in North Sumatra Province, suggests that the efficiency of oil palm production remains suboptimal. Thus, this study aims to determine the influence of production factors on production and the value of technical efficiency of smallholder oil palm plantations, especially in Hatonduhan District, Simalungun Regency, North Sumatra Province.

Literature Review

According to Debertin (2012), production theory consists of two theories: production theory with one variable input and production theory with two or more variable inputs. The production function is typically expressed as follows:

$$Y = f(x)$$

Where:

Y = Production results (output)

X = Number of the production factors (input) utilized

Numerous production processes necessitate various production factors, leading to the formulation of the production function as follows:

$$Y = f(x_1, x_2, x_3, x_4, \dots, \dots, \dots x_n)$$

Explanation:

Y = Production results/number of products produced (output), is a variable influenced by production factors

X = Number of main production factors used (input), is a variable that influences Y.

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The success of cultivating a type of plant is determined by the cultivated plant cultivar, the environmental/agroecological conditions of the place where the plant is cultivated, and the implementation of management by the farmer entrepreneur (Sasongko 2010). Farming production factors are the main factors needed in farming and, at the same time, become farming inputs. These farming production factors are combined to produce farming production or output through a production process (Arifin, 2015). The new farming production process can run well if the production factors and requirements are met. The farming production factors are classified into four elements, namely land, labor, capital, and skills or management (Daniel, 2002).

According to Nguyen et.al. (2018), measuring and studying production efficiency (including technical efficiency) in farming is a method used to determine the level of input use (input combination) by farmers in producing output as well as to determine the methods that can be used to increase efficiency.

Farrel (1957) proposed that efficiency consists of technical and allocative efficiency. Technical efficiency reflects farmers' ability to obtain maximum output from the amount of input given. There are two approaches to calculating efficiency: the input approach and the output approach. Efficiency measurement focuses on input use (Coelli et.al., 2005). According to (Chotimah, 2019), technical efficiency is a quantity that compares actual and maximum production. Technical efficiency will be achieved if farmers can allocate production factors to achieve high results.

Several studies have been conducted to analyze the technical efficiency of smallholder oil palm plantations in Indonesia. Yahyawileonides' (2022) research used Frontier Function analysis to analyze the technical efficiency of oil palm farming in Sanggau Regency, West Kalimantan. Varina et.al.'s (2020) research analyzed technical efficiency in Indonesia using empirical analysis techniques using the Meta-Frontier approach. Likewise, research Alwarritzi et.al. (2015). Ismiasih (2017) and Fariani et.al. (2019) used Stochastic Frontier analysis to analyze the technical efficiency of smallholder oil palm plantations.

From the description of the study of the technical efficiency of smallholder oil palm plantations above, research on the technical efficiency of oil palm plantations all use Stochastic Frontier analysis with the Cobb-Douglas Production Function. This study used Data Envelopment Analysis (DEA), which is relatively new in similar research.

Research Method

The study area was selected intentionally, taking into account data from the North Sumatra Province BPS (2024) and the Simalungun Regency BPS (2024). This data indicates that Hatonduhan District has the largest smallholder oil palm plantation area within Simalungun Regency, which itself is the regency with the most extensive smallholder oil palm plantation area in the highlands of North Sumatra Province. The sample for this study was determined by Quota Sampling of 150 oil palm plantation farmers. The samples came from 2 villages in Hatonduhan District, namely Buntu Bayu Village and Buntu Turunan Village, each with 75 samples. The study material data was obtained directly from farmers through interviews using a prepared questionnaire, namely data on the management of smallholder oil palm plantations for one year, namely 2023.

1. Study of the Influence of Production Factors on Production

The influence of production factors (land, labor, fertilizer, and pesticides) on production could be assessed using the Cobb-Douglas Production Function via a Multiple Non-Linear Regression Test (Rank Test) according to Archontoulis and Miguez (2015) and Gujarati and Porter (2013) as follows:

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$Y = b_0 X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} e^u$ which can be linearized into

$\log Y = \log b_0 + b_1 \log X_1 + b_2 \log X_2 + b_3 \log X_3 + b_4 \log X_4$ b4logX4 + u

Description:

Y = production (Kg)

X_1 = land area (Ha)

X_2 = labor (HKP)

X_3 = fertilizer (Kg)

X_4 = pesticide (liter)

b_0 = intercept

b_i = regression coefficient

u = error term

The partial effect of each independent variable (X_i) on the dependent variable (Y) will be known through a t-test. The test criteria used are:

1) If the probability value $t_i \geq 0{,}05$ means that X_i partially has no significant effect on Y.
2) If the probability value ti < 0.05, it means Xi has a partial significant effect on Y.

Simultaneous effect of the independent variable (X) on the dependent variable (Y) will be known by conducting the F Test. The test criteria used are:

1) If the probability value $F \geq 0{,}05$ means that X simultaneously has no significant effect on Y.
2) If the probability value $F < 0{,}05$ means that X simultaneously significantly affects Y.

The magnitude of the influence of X_1, X_2, X_3, and X_4 on Y is known from the coefficient of determination (R^2) value. The value of 1 - R^2 represents the extent of the impact from variables that are either absent from the model or not analyzed in the research.

2. Calculation of Technical Efficiency

Technical efficiency is calculated using the DEA (Data Envelopment Analysis) method, a non-parametric approach using a deterministic approach (linear programming). The DEA method analyzes production functions through production frontier mapping (Ferjani, 2011).

According to Coelli et.al., (2005), the TE assumption based on the Constant Returns to Scale assumption can be formulated as follows:

$$\mathrm{Min}_{\theta,\lambda}\theta_k$$

Constraints

$$-y + Y\lambda \geq 1$$

$$\theta_{xk} - X\lambda \geq 0$$

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$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda \geq 0$$

Description:

θ = Technical Efficiency Value ($0 \leq TE \leq 1$)

λ = Vector weight (constant) N x 1 explaining the linear combination of DMU competitors (every n farmers)

Y = Output Quantity (oil palm)

X = Input Quantity (Land, Labor, Fertilizer and Pesticide)

y = Output vector of DMU to j compared to the efficient DMU

$Y\lambda$ = Output at the efficient DMU

$X\lambda$ = minimum input of DMU that is theoretically efficient

The formula above shows that oil palm farmers are on an optimal scale. Banker, Charnes, and Cooper stated that not all entrepreneurs operate on an optimal scale. Therefore, they proposed technical efficiency based on the Variable Returns to Scale (VRS) assumption, often called pure technical efficiency (Pure Technical Efficiency/PTE). The VRS assumption takes into account different management practices between farmers. Adding $\sum \lambda = 1$ to the formula above (CRS) indicates the technical efficiency frontier based on the VRS assumption.

This study uses input-oriented DEA to see how the optimal combination of inputs is based on the output produced. The VRS model (variable return to scale) is also known as pure efficiency. The VRS model is used to estimate efficiency when changes in input use do not result in proportional changes to Output. This model is carried out with the assumption that the company is not or has not yet operated at an optimal business scale. The VRS model shows increasing, constant, and decreasing yield scales (Rusydiana, 2013) in Sulistyaningsih et.al., (2019).

The results of the DEA analysis also provide information on the amount of input farmers should use to achieve a technically efficient production process. Therefore, smallholder oil palm plantation farmers must reduce the use of inputs in the future. The percentage of input reduction can be determined using the following formula:

$$\text{Percentage of input reduction (\%)} = \frac{\text{Actual Input} - \text{Target Input}}{\text{Actual Input}} \text{ x } 100\ \%$$

Note:

Actual input is the input obtained from respondent farmers

Target input is the input recommended by the DEA model

Results and Discussion

1. Descriptive Statistics

In this study, descriptive statistics include input-output variables consisting of input (land, labor, fertilizer, pesticide) and output (production of smallholder oil palm plantations during 2023), as presented in the following description.

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Table 1. Descriptive Statistics of Input Output Variables

No.	Variable Input Ouput	Mean	Min	Max	Std. Dev.
1	Land area (Ha)	2,6363	0,5600	7,0000	1,5006
2	Labor (HKP)	96,9840	24,000	244,0000	96,9840
3	Fertilizer (Kg)	623,8467	60,0000	3.540,0000	570,4847
4	Pesticide (Liter)	12,7467	2,5000	34,0000	7,1954
5	Production (kg FFB)	50.330,6700	11.600,0000	136.000,0000	28.165,1800

Source : Primary Data Processing

2. Influence of Production Factors on Production

How production factors influence the output of smallholder oil palm the plantations can be determined by conducting a Multiple Non-Linear Regression Test (Rank Test) presented in the following description.

Table 2. Results of Multiple Non-Linear Regression Test

No.	Variable	Coeffcient	Probability
1	Constant	7.997,0170	0,000*
2	Land (X_1)	0,7426	0,000*
3	Labor (X_2)	0,1922	0,000*
4	Fertilizer (X_3)	0,0258	0,000*
5	Pesticide (X_4)	0,0312	0,033*
6	F_{count}	0,0000*	
7	Determination Coef.	0,9993	

Source : Primary Data Processing

Note: Significant at α = 0,05

According to the information provided in Table 2, it is possible to formulate the production function for smallholder oil palm plantations as follows:

$$Y = 7.997,0170\ X_1^{0,7426}\ X_2^{0,1922}\ X_3^{0,0258}\ X_4^{0,0312}$$

Description:

Y = production (Kg)

X_1 = land (Ha)

X_2 = labor (HKP)

X_3 = fertilizer (Kg)

X_4 = pesticide (Liter)

a. Partial Influence of Production Factors on Production

Partially, the influence of production factors on production can be explained as described below.

1) Partially, the production of smallholder oil palm plantations is significantly positively influenced by land, as indicated by the land probability value <0.05. The wider the land farmers cultivate, the greater the production of smallholder oil palm plantations. The

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findings of the study align with the findings of Adzani and Arif, (2023), Hasibuan, et al., (2022), Chaira et al., (2022), and Mini et al., (2023) but contradict the research results of Arsyad and Maryam (2017) and Alfayanti and Efendi (2013).

2) Partially, the production of oil palm plantations is positively influenced by labor, as indicated by the labor probability value <0.05. The greater the outpouring of labor, the greater the production of smallholder oil palm plantations. The findings of the study align with the findings of Hasibuan et al., (2022), Chaira et al., (2022), and Siswanto et al., (2020), while presenting a contradiction to the results from Yanita and Suandi (2021), Adzani and Arif (2023) and Mini et al., (2023).

3) Partially, the production of smallholder oil palm plantations is positively influenced by the real value indicated by the probability value of fertilizer <0.05. The greater the fertilizer use, the greater the production of smallholder oil palm plantations. The findings of the study align with the findings of Yanita and Suandi (2021), Hasibuan et al. (2022), Siswanto et al. (2020), Chaira et al. (2022) and Mini et al. (2023), while presenting a contradiction to the results from Siagian et.al., (2018) and Puruhito et.al., (2019).

4) Partially, the production of smallholder oil palm plantations is significantly positively influenced by pesticides, as indicated by the pesticide probability value <0.05. The greater the use of pesticides, the greater the production of smallholder oil palm plantations. The results of this study are in line with the research results of Arsyad and Maryam (2017), Mustari et al. (2020), Yanita and Suandi (2021), and Chaira et al. (2022), while presenting a contradiction to the results from Abdul et al., (2022), Welda et al., (2020), Hasibuan et al., (2022) and Chaira et al., (2022).

b. Simultaneous Influence of Production Factors on Production

Simultaneously, the ways in which production factors influence production can be explained as follows.

1) Simultaneously, the production of smallholder oil palm plantations is significantly positively influenced by land, labor, fertilizer, and pesticide production factors, as indicated by the probability value F <0.05.

2) The determination coefficient, or R^2 value, is 0.9993. This suggests that labor, land, fertilizer, and pesticide production factors account for 99.93% of the output of smallholder oil palm farms. Meanwhile, 0.07% of the production from smallholder oil palm plantations is impacted by other factors not examined in this study.

3) The rate of technical substitution (RTS) is equal to the sum of all regression coefficients, which is 0.9918. If 100% more land area, labor, fertilizer, and pesticide are used, the production process will increase by 99.18% or decrease returns to scale.

3. Technical Efficiency Calculation

The findings of the technical efficiency assessments are detailed in the subsequent description.

Table 3. Technical Efficiency of Smallholder Oil Palm Plantations

No.	Description	Mean	Min	Max	Std. Dev.

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1	Technical Efficiency	0,9755	0,8965	1,0000	0,0228

Source: Processing of Primary Data

Table 3 indicates that the mean technical efficiency of smallholder oil palm plantations is 0.9755, with a minimum value of 0.8965, a maximum of 1, and a standard deviation of 0.2228. That indicates that 97.55% of responding farmers can reduce input utilization while producing technically effective results. Farmers still have the opportunity to achieve a higher potential production level up to the maximum production level as obtained by farmers whose production processes are most technically efficient. The findings of this study indicate that, collectively, farmers have the potential to enhance their technical efficiency regarding technology and input by 2.45%.

The findings reveal that the technical efficiency value of smallholder oil palm plantations exceeds that of earlier research results. Notably, it surpasses the technical efficiency value of 0.8795 documented by Yahyawileonides (2022) for oil palm farming in Sanggau Regency, West Kalimantan Province. Furthermore, it exceeds the 0.70 documented by Syuhada et al., (2022) for cooperative and independent partners in West Pasaman Regency, the 0.6257 noted by Abdul et al., (2022) concerning smallholder oil palm plantations in Indonesia, and the values of 0.6789 and 0.7127 for independent and assisted farmers respectively as reported by Varina et al., (2020). Furthermore, it exceeds the 0.73 reported by Welda et al., (2020) for small-scale oil palm farming in Dharmasraya Regency, West Sumatra, and the 0.81 from Ngaisset and Jia (2020) on smallholder oil palm plantations in Lobaye, Central African Republic.

Based on the technical efficiency value calculation, the research sample can be categorized as efficient or inefficient, as presented in the following description.

Table 4. Share Technical Efficiency Value

No.	Technical Efficiency Value	Total (Sample)	Percentage (%)
1	Efficient (ET Value = 1)	33	22,00
2	Inefficient (ET Value < 1)	117	78,00
	Amount	150	100,00

Source: Processing of Primary Data

Table 4 illustrates that a significant portion (78.00%) of the sampled farmers exhibit a production process that lacks technical efficiency (ET Value <1), while 22.00% demonstrate a technically efficient production process (ET Value = 1).

Further DEA analysis of the production scale (rate technical substitution or RTS) based on technical efficiency shows that the production process of smallholder oil palm plantations is on a production scale, as presented in the following description.

Table 5. Share Production Sclae

No.	Production Scale	Total (Sample)	Percentage (%)
1	IRS (Increasing Returns to Scale)	3	2,00
2	CRS (Constant Returns to Scale)	19	12,67
3	DRS (Decreasing Returns to Scale)	128	85,33

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	Amount	**150**	**100,00**

Source: Processing of Primary Data

Table 5 indicates that out of 150 research samples, the majority, specifically 85.33% of the production scale, is experiencing decreasing returns to scale. 12.67% of the production scale operates under constant returns to scale, while 2.00% functions under increasing returns to scale.

The technical efficiency value of smallholder oil palm the plantations indicates that many are currently operating below optimal efficiency. The DEA analysis can offer insights into the actual and target input usage, facilitating a reduction in input consumption to reach a state of technical efficiency. The description is presented in Table 6.

Table 6. Recapitulation of Actual Input, Target Input and Input Reduction Based on Technical Efficiency Value

No.	Description	Mean	Min	Max	Std. Dev.
	Actual Input				
1	Land Area (Ha)	2,6363	0,5600	7,0000	1,5006
2	Labor (HKP)	96,9840	24,000	244,0000	96,9840
3	Fertilizer (Kg)	623,8467	60,0000	3.540,0000	570,4847
4	Pesticide (Liter)	12,7467	2,5000	34,0000	7,1954
	Target Input				
1	Land Area (Ha)	2,5632	0,5600	7,0000	1,4577
2	Labor (HKP)	92,4925	24,0000	244,0000	47,6596
3	Fertilizer (Kg)	578,9966	60,0000	3540,0000	541,8718
4	Pesticide (Liter)	12,3514	2,5000	34,0000	7,0011
	Input Reduction				
1	Land Area (%)	2,5416	0,0000	10,3488	2,3813
2	Labor (%)	4,0501	0,0000	20,8436	4,6578
3	Fertilizer (%)	5,5449	0,0000	90,6271	10,0856
4	Pesticide (%)	3,1165	0,0000	13,0317	2,9722

Source : Primary Data Processing

According to Table 6, it is evident that to attain a technically efficient production process, smallholder farmers on oil palm plantations need to minimize inputs in the following ways:

Reduce land use by 2.5416% from the use during the study of an average of 2.6363 Ha.

Reduce labor use by 4.0501% from the average of 96.9840 HKP during the study.

Reduce fertilizer use by 5.5449% from the use during the study of an average of 623.8467 Kg.

Reduce pesticide use by 3.1165% from the use during the study of an average of 12.7467 Liters.

Conclusion

Production studies using non-linear regression analysis show that all inputs (land, labor, fertilizer, and pesticides) significantly affect oil palm plantation production in the research area, partially and simultaneously. The results of the technical efficiency study show that most (78%) of farmers are not yet technically efficient. To achieve technically efficient management of smallholder oil palm plantations, farmers are given recommendations for reducing inputs for smallholder oil palm plantations that are not yet technically efficient. The average percentage of input reduction for

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farmers who are not yet technically efficient is 2.5416% land, 4.0501% labor, 5.54449% fertilizer, and 3.1165% pesticide.

The government is expected to always be able to provide counseling on good oil palm farming techniques while being able to help provide production facilities needed by farmers, marketing that supports farmers, and good road infrastructure. Further researchers are expected to be able to conduct more in-depth research, especially related to economic efficiency, so that smallholder oil palm plantation farmers can obtain information on how to use input costs more efficiently in the future.

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