

Production Efficiency of Oil Palm Farming in Smallholder Plantations in East Luwu Regency

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Abstract

This study investigates the factors influencing palm oil production, analyzes production elasticity, and measures the technical efficiency of smallholder oil palm farming in East Luwu Regency. Positioned within existing research on agricultural productivity, this study highlights the gap in understanding the efficiency of small-scale oil palm cultivation in Indonesia. A quantitative approach was employed using descriptive analysis and Stochastic Frontier Analysis (SFA) based on the Cobb-Douglas production function. A sample of 70 farmers was selected through simple random sampling from four villages in the Burau Subdistrict. Primary data were collected via structured questionnaires and interviews, supported by secondary data from relevant institutions. The results reveal that only two of the seven input variables—land area (coefficient: 0.861) and Phonska fertilizer (coefficient: 0.057)—significantly affect production. The average technical efficiency reached 86%, suggesting a 14% potential increase in output without additional input. A gamma value of 0.971 indicates that production variability is predominantly due to inefficiency rather than random factors. The study contributes to the body of knowledge by emphasizing the need for efficiency optimization through improved land use, balanced fertilization, capacity-building programs, and targeted policy interventions.

Keywords: Efficiency, Oil palm farming, Poduction, Smallhoder plantation.



INTRODUCTION

Palm oil (*Elaeis guineensis*) is one of Indonesia's most strategic commodities, serving as a major source of foreign exchange and employment for rural communities. As the world's largest producer of palm oil, Indonesia plays a dominant role in fulfilling global demand for vegetable oil. According to the United States Department of Agriculture (USDA, 2023), Indonesia produced 46.5 million tons of palm oil during the 2022/2023 period, surpassing Malaysia and other producing countries. Approximately 40% of the national oil palm plantation area is managed by smallholders, either through partnerships with nucleus companies or as independent farmers. However, despite controlling a large share of land, smallholder productivity remains significantly lower than that of state or private plantations.

The Directorate General of Plantations (2022) reported that smallholder plantations only produce about 2.6 tons of crude palm oil (CPO) per hectare per year, compared to over 4 tons/ha/year in larger plantations. Contributing factors include suboptimal input use, limited access to agricultural technology, low managerial capacity, and weak institutional support. Studies such as Varina (2020) and Ariyanto et al. (2020) reveal a wide range of technical efficiency among smallholders, from 0.53 to 0.94, indicating the potential for output gains without increasing input use. Despite these findings, systematic research on smallholder efficiency in palm oil farming remains limited in certain regions. In East Luwu Regency, South Sulawesi—one of the palm oil production centers dominated by independent smallholders—the average productivity is still below potential. Data from the Luwu Timur Agricultural Office (2025) indicates that smallholder plantations covering 10,030.75 hectares only yielded 4,416.74 tons of fresh fruit bunches (FFB), or approximately 0.82 tons/ha/year, far below the national average. This underperformance signals a substantial opportunity to enhance productivity through improved production efficiency. One analytical approach frequently applied in agricultural efficiency studies is the Stochastic Frontier Analysis (SFA), particularly using the Cobb-Douglas production function. This method allows for the quantification of efficiency and identification of its determining factors (Coelli et al., 2005). However, studies using SFA to examine smallholder oil palm production in East Luwu are scarce.

Furthermore, national replanting initiatives such as the Oil Palm Plantation Fund Management Agency (BPDPKS)'s *Peremajaan Sawit Rakyat* (PSR) program have yet to fully reach independent farmers in the region due to institutional constraints, land tenure issues, and lack of technical support. These conditions underscore a clear research gap requiring empirical data to support policy decisions. In the context of agribusiness,

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production efficiency directly impacts farmer income, supply chain sustainability, and global competitiveness. Therefore, this study aims to analyze the production efficiency of smallholder oil palm farms in East Luwu Regency using the Cobb-Douglas function and the stochastic frontier model, with specific objectives to (1) identify key production factors affecting palm oil output, (2) measure production elasticity, and (3) assess the level of technical efficiency among smallholders. This research is expected to offer a novel contribution to the literature on agricultural efficiency and support evidence-based policymaking in the palm oil sector.

LITERATURE REVIEW

Palm oil (*Elaeis guineensis*) remains a vital commodity for Indonesia's economy, both in terms of foreign exchange and rural employment. Numerous studies over the past decade have examined various dimensions of palm oil farming efficiency, particularly among smallholders. However, these studies reveal substantial variations in efficiency and highlight a persistent gap in optimizing production inputs. Pasaribu et al. (2018) utilized Data Envelopment Analysis (DEA) to measure technical, allocative, and economic efficiency in smallholder oil palm farming in Indragiri Hilir, finding inefficiencies linked to limited institutional support and suboptimal input use. Similarly, Ridho et al. (2019) employed the Cobb-Douglas production frontier model to evaluate efficiency in independent oil palm farms in Riau, discovering that technical efficiency varied considerably and was heavily influenced by access to inputs and farmer experience.

Other relevant studies, such as Heriyanto and Darus (2019), analyzed the efficiency of rubber production using stochastic frontier models and identified land size and fertilizer application as significant contributors to output. In contrast, Noer et al. (2020) focused on upland rice farming in Lampung, highlighting labor and land as crucial input factors in smallholder systems. In South Sulawesi, Tahir et al. (2020) studied soybean production efficiency and emphasized the role of farmer training and input access as determinants of productivity.

Despite these contributions, limited empirical work has been conducted on palm oil smallholders in Sulawesi, particularly in East Luwu Regency. Existing studies often overlook regional disparities, site-specific challenges, and policy dynamics such as the accessibility of national replanting programs (PSR) managed by BDPKS. This represents a significant gap, as smallholder farmers in this region operate predominantly on self-managed, uncertified land with limited technical support—factors likely to hinder optimal input utilization and efficiency.

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Methodologically, most studies have applied the Cobb-Douglas stochastic frontier production function, valued for its ability to estimate technical efficiency and elasticity of production simultaneously (Coelli et al., 2005). This approach remains widely adopted due to its interpretability, especially in evaluating marginal returns and scale efficiency. However, inconsistencies persist in variable selection, often leading to specification bias or omitted variable problems.

This study positions itself within this empirical context, aiming to address the identified gaps by applying a stochastic frontier analysis (SFA) model to assess the production efficiency of independent smallholder oil palm farmers in East Luwu Regency. It contributes new insights by incorporating localized production data and analyzing the elasticity of inputs such as land, labor, fertilizer, and pesticides. By doing so, this research enhances the understanding of efficiency patterns in under-researched regions and provides evidence-based implications for improving smallholder productivity and informing targeted agricultural policies.

RESEARCH METHOD

This research employs a quantitative approach with a descriptive method to analyze the production efficiency of smallholder oil palm farming in East Luwu Regency. The study utilizes both primary and secondary data. Primary data were obtained through structured questionnaires and interviews with 70 randomly selected farmers across four villages in Burau Subdistrict. Secondary data were sourced from relevant institutions such as the East Luwu Agriculture Office and other official publications. The selection of respondents was conducted using simple random sampling, ensuring each farmer had an equal probability of selection.

The research instrument consisted of a validated questionnaire designed to capture variables such as land area, fertilizer use, pesticide application, labor input, and output volume. Supporting qualitative information—such as education level and farming experience—was also collected. Data collection techniques included direct observation, structured interviews, and document analysis. The theoretical framework guiding this research is the Cobb-Douglas production function, combined with Stochastic Frontier Analysis (SFA), which allows for the measurement of production elasticity and technical efficiency in a statistical model.

Data analysis was carried out using the natural logarithmic transformation of the Cobb-Douglas model, followed by Maximum Likelihood Estimation (MLE) to determine the efficiency scores and elasticity coefficients.

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1. Cobb Douglas

To analyze the production elasticity of oil palm farming in smallholder plantations in Burau Subdistrict, East Luwu Regency, a Cobb Douglas production function regression model was used, formulated as follows:

$$Y = b_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_5 X_5 + e$$

Description:

Y = Total palm fruit production in one harvest period (tons)

X1= Area of land used in a single harvest period (ha)

X2= Plant age (years)

X3= Number of workers employed during a single harvest period (man-days/MD)

X4= Amount of fertilizer used in one harvest period (kg).

X5= Total amount of pesticides used accumulated (L)

e = Errors (error term)

2. Efficiency

The efficiency of input use is calculated using the following equation:

$$PM_{X_i} = b_i \frac{\bar{Y}}{\bar{X}_i}$$

Description :

PM_{X_i} = Marginal product of input use

b_i = amount of each input elasticity

$\bar{Y}$ = average production volume

$\bar{X}_i$ = average number of variables (X) used

RESULTS AND DISCUSSION**Respondent Identity**

In this study, respondents came from four villages in the Burau subdistrict, East Luwu Regency, namely Burau Pantai Village, Lauwo Village, Mabonta Village, and Lagego Village. Information regarding the identity of the farmer respondents is crucial for analysis as it reflects the general conditions that may influence farmers' behavior and productivity. Some of the observed characteristics include age, educational level, number of family dependents, and the size of the land they own. The data is subsequently presented in tabular form.



Table 1. Respondents Indentity

No	Location	Number of Respondents	Average Age (years)	Average Education (years)	Average Family Dependents (persons)	Average Land Area (ha)
1	Burau Pantai	18	47,3	8,1	4,2	0,85
2	Desa Lauwo	20	45,6	7,8	4,5	0,92
3	Desa Mabonta	16	49,2	6,5	4,8	1,12
4	Desa Lagego	16	50,1	7,3	5,0	0,96
Total / Average		70	48,0	7,4	4,6	0,96

The average age of respondents ranged between 45 and 50 years, with a mean of 48 years, indicating that most farmers were in their late productive years. While this age group typically possesses considerable farming experience, they may face limitations in adopting agricultural innovations (Feder et al., 1985). Younger farmers are generally more open to new technologies and practices in agriculture. In terms of education, respondents had an average of 6.5 to 8.1 years of schooling, equivalent to elementary to early junior high school. Education plays a vital role in enhancing farmers' ability to access information, participate in training, and manage their farms efficiently. Low educational attainment is often associated with limited understanding of market systems and modern input use (Mignouna et al., 2011).

Household size ranged from 4.2 to 5.0 members, reflecting the typical structure of rural farming families in Indonesia. Family size significantly influences production decisions and household consumption patterns. While larger households may provide more labor, they also increase the burden of consumption (Ellis, 1993). The average farm size managed by respondents was between 0.85 and 1.12 hectares, indicating small-scale or semi-subsistence farming typical of South Sulawesi. Landholding size is positively correlated with production volume, input investment capacity, and farmers' income potential (Barrett, 1996).

Factors Affecting Palm Oil Production

Based on the results of the stochastic frontier production function estimation, of the seven input variables analyzed—including land area, urea fertilizer, Phonska fertilizer, pesticides, labor, length of formal education, and farming experience—only two variables

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were found to have a statistically significant effect on palm oil production in smallholder plantations in East Luwu Regency, namely land area and Phonska fertilizer. This can be seen in Table 2.

Table 2. Estimated Results of the Stochastic Frontier Production Function for Palm Oil

Variable	Parameter	Coefficient	Elasticity coefficient	Standard error	Calculated t
Constants	α	0.709	7,098	0.570	12,439***
Land Area	β_1	0.861	0,861	0.123	6,991***
Urea Fertilizer	β_2	0.512	0,051	0.944	0,542ns
Phonska Fertilizer	β_3	0.570	0,057	0.256	2,221**
Pesticides	β_4	-0.822	-0,082	0.130	-0,630ns
Labor	β_5	0.859	0,085	0.846	1,014ns
Length of Formal Education	β_6	-0.249	-0,024	0.735	-0,339ns
Farming Experience	β_7	0.127	0,012	0.838	0,152ns
Sigma Squared		0.194	1,946	0.215	0,905ns
Gamma		0.971	0,971	0.314	30,878***

Descriptions: *** : significant at $\alpha = 1\%$

** : significant at $\alpha = 5\%$

* : significant at $\alpha = 10\%$

ns : non-signifikan

known ; t-table ($1\% = 2,66$, $5\% = 2,00$, $10\% = 1,67$)

The gamma value obtained was 0.971 and significant at α of 1%. This indicates that 97.1 percent of the variation in palm oil production is caused by differences in technical efficiency, while the remaining 2.9 percent is caused by external influences that cannot be controlled by farmers (such as climate, pest and disease attacks, and errors in modeling).

The gamma value (γ) in the Stochastic Frontier Analysis (SFA) model does not directly measure goodness of fit, but indicates the proportion of total variation in output caused by technical inefficiency compared to random error. In this study, a gamma value



of 0.971 and significant at $\alpha = 1\%$ indicates that 97.1% of output variation is caused by differences in technical efficiency among farmers, not by random factors. This indicates that the frontier model is highly appropriate for use, as it effectively captures technical inefficiency.

The t-test on the production function shows that the production factors of land area and Phonska fertilizer have a significant effect on oil palm production. Land area has a regression coefficient of 0.861 and a t-value of 6.991, which far exceeds the t-table value at a significance level of 1% (2.66). This indicates that an increase in land area significantly increases oil palm production. This finding aligns with production theory, which states that expanding the scale of cultivation generally has a positive impact on output, particularly in land-based agricultural systems (Soekartawi, 2006).

Phonska fertilizer also showed a significant effect with a regression coefficient of 0.570 and a t-value of 2.221, significant at the 5% level. This indicates that the use of balanced fertilizers, such as Phonska containing nutrients N, P, and K, contributes positively to oil palm productivity. Conversely, other variables such as urea fertilizer, pesticides, labor, formal education, and farming experience did not show a significant effect. This could be due to suboptimal doses or improper application techniques.

The analysis results also indicate that the production factors of urea fertilizer, pesticides, labor, duration of formal education, and farming experience do not have a statistically significant effect on oil palm farming production in smallholder plantations in Luwu Timur District.

Elasticity of Palm Oil Farm Production

Production elasticity describes the extent to which changes in inputs affect output. Based on the results of the study, all influential input variables show inelastic elasticity ($0 < E_p < 1$), except for a few that have negative values, indicating an inverse relationship

Table 3. Statistical Test of the Coefficient of Determination

Variable	Regression coefficient (β) / Elasticity	Elasticity	Interpretation
Land Area	0,861	Inelastis ($0 < E_p < 1$)	1% increase in land area → 0.861% increase in production, effective



			input but moderate response
Urea Fertilizer	0,051	Inelastis ($0 < E_p < 1$)	A 1% increase in urea fertilizer → production increases by 0.051%, a very small effect
Phonska Fertilizer	0,057	Inelastis ($0 < E_p < 1$)	1% increase in phonska fertilizer → 0.057% increase in production, very small effect
Pesticides	-0,082	Negative ($E_p < 0$)	A 1% increase in pesticides → production decreases by 0.082%, indicating excessive or inefficient use
Labor	0,085	Inelastis ($0 < E_p < 1$)	1% increase in labor force → 0.085% increase in production, relatively small impact
Length of Formal Education	-0,024	Negative ($E_p < 0$)	A 1% increase in education duration → a 0.024% decrease in production, which is likely irrelevant to farming practices
Farming Experience	0,012	Inelastis ($0 < E_p < 1$)	1% increase in experience → 0.012% increase in production, very low impact

Source: Results of primary data analysis, 2025

According to Soekartawi (2006), production elasticity describes the percentage change in output that occurs as a result of a 1% change in input:

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- Elastic ($E_p > 1$): Changes in input result in proportionally larger changes in output.
- Inelastic ($0 < E_p < 1$): Changes in input result in smaller changes in output.
- $E_p < 0$: Input has a negative impact on production.
- $E_p = 0$: There is no effect on output.

The land area variable shows an elasticity value of 0.861, indicating that a 1% increase in land area results in a 0.861% increase in palm oil production, assuming other inputs remain constant. This highlights land as a crucial factor, though not perfectly proportional in impact. Among fertilizers, Phonska has a higher elasticity (0.057) compared to Urea (0.051), with Phonska also being statistically significant ($t\text{-value} = 2.221 > t\text{-table} = 2.00$ at $\alpha = 5\%$), while Urea is not ($t\text{-value} = 0.542$). Although both fertilizers contribute minimally to output increase, only Phonska has a significant positive effect, suggesting that resource allocation toward Phonska is more effective than Urea in this context.

Conversely, some inputs show negative elasticity, such as pesticides (-0.082) and years of formal education (-0.024). The negative effect of pesticides may result from improper dosage or mistimed application, while formal education may not translate into relevant technical skills in palm cultivation. As noted by Soekartawi (2006), inputs with negative elasticity values should be critically evaluated, as they may reflect inefficiencies or the presence of unaccounted external factors in the production model.

Palm Oil Production Efficiency Levels in Smallholder Plantations in East Luwu Regency

The results of technical efficiency calculations using the stochastic frontier model show that the average efficiency level of oil palm farmers is 0.860, or 86%. This means that, technically, farmers have almost reached maximum efficiency, but there is still 14% room to increase production without adding more inputs.

Table 4. Palm Oil Production Efficiency Level

Efficiency Level	Technical Efficiency	
	Number of Farmers (people)	Percentage (%)
< 0,5	1	1%
0,51 - 0,60	0	0%
0,61 - 0,70	3	4%
0,71 - 0,80	4	6%



0,81 - 0,90	50	71%
0,91 - 1,00	12	17%
Number	70	
Average	0,860	
Minimum Value	0,407	
Maximum Value	0,958	

Source: Results of primary data analysis, 2025

The distribution of technical efficiency shows that most farmers (71%) have an efficiency between 0.81 and 0.90, while only 17% of farmers are at a very high level of efficiency (above 0.90). Meanwhile, only 1% of farmers have efficiency below 0.50, indicating that most farmers are already quite good at utilizing existing production resources. The average technical efficiency of oil palm farming in the study location is 0.860 or 86%. This indicates that there is still an opportunity to increase production by 14% without adding inputs, simply by managing available resources more efficiently. The significant gamma value of 0.971 at the 1% level indicates that nearly all production variation (97.1%) is caused by technical inefficiency, not by external random factors. This suggests that the frontier model is suitable and valid for analyzing technical efficiency in smallholder oil palm farming systems.

This finding aligns with Battese and Coelli (1992), who stated that improving technical efficiency in small-scale agriculture can lead to significant output increases without the need for new technology adoption. A comparison with Varina's (2020) research in Riau, which found an average technical efficiency of 71%, shows that the efficiency of oil palm farmers in East Luwu is relatively higher, although it has not yet reached optimal conditions.

CONCLUSION

1. The production factors that significantly influence palm oil production are land area and Phonska fertilizer. Land area contributes the most (elasticity of 0.861), indicating that an increase in planting area will have a significant impact on yield. Phonska fertilizer also plays an important role, although with a relatively small influence (elasticity of



0.057), it is statistically significant, indicating that balanced fertilization contributes to crop productivity.

2. Production elasticity shows that most inputs are inelastic ($0 < E_p < 1$), meaning that changes in inputs are not yet fully optimal in increasing output. This finding indicates the need to improve efficiency in input utilization.
3. The average technical efficiency level of farmers reaches 0.860 (86%), meaning there is a 14% opportunity for production increase without additional inputs. A gamma value of 0.971 indicates that output variation is more due to technical inefficiency than random factors, meaning that improvements in farmer capacity and managerial efficiency can have a significant impact on production increases.

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