

ANALYSIS OF FACTORS AFFECTING PALM OIL PRODUCTION IN PTPN IV REGIONAL II KEBUN MELATI, PEGAJAHAN DISTRICT, SERDANG BEDAGAI DISTRICT

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Abstract

This study aims to: (1) identify production factors that influence palm oil production at PTPN IV Regional II Kebun Melati; (2) analyze the influence of labor, rainfall, fertilizer, and herbicide partially or simultaneously on Fresh Fruit Bunches (FFB) production; and (3) determine the most dominant production factors. The study was conducted at PTPN IV Regional II Kebun Melati, Pegajahan District, Serdang Bedagai Regency, in January–March 2026, using 60 monthly time series data for the 2021–2025 period. Cobb -Douglas production function analysis was used with the help of SPSS software. All classical assumption tests (normality, autocorrelation, heteroscedasticity, and multicollinearity) were met. The results of the study showed that: (1) simultaneously, labor, rainfall, fertilizer, and herbicide had a significant effect on FFB production (F-count = 66.684, sig. = 0.000); (2) partially, rainfall (sig. = 0.000), fertilizer (sig. = 0.001), and herbicide (sig. = 0.003) have a real and positive effect, while labor (sig. = 0.117) has no significant effect; (3) herbicide is the most dominant production factor with an elasticity coefficient of 0.690; and (4) the Return to Scale value of 1.496 indicates a condition of increasing returns to scale. The coefficient of determination (R^2) value of 0.914 indicates that 91.4% of the variation in FFB production can be explained by these four input variables.

Keywords: Palm Oil, Cobb-Douglas Production Function , Labor, Rainfall, Fertilizer, Herbicide, Return to Scale , PTPN IV Kebun Melati.

INTRODUCTION

Indonesia is an agricultural country with a tropical climate that strongly supports the development of the plantation sector, particularly oil palm (*Elaeis guineensis* Jacq.). This commodity plays a strategic role in the national economy because it contributes significantly to exports and foreign exchange earnings (Alhaji et al., 2024). Indonesia is also the world's largest producer and exporter of *Crude Palm Oil* (CPO), with a global market share of 55% and an export volume of approximately 37.3 million tons. In 2021, the palm oil sector generated foreign exchange of USD 36.21 billion, equivalent to IDR 544 trillion, making it one of the largest foreign exchange contributors for Indonesia (Yumna & Perdana, 2023).

Fresh Fruit Bunch (FFB) productivity is a key indicator of the success of oil palm plantations. FFB production levels are influenced by various interrelated production factors, both agronomic and managerial. Optimal management of these factors is crucial for achieving sustainable and efficient production targets. Therefore, identifying factors affecting FFB production is essential as a basis for developing more effective plantation management strategies.

This study focuses on four production factors suspected of influencing FFB (Fruit Fruit Bunch) yields: labor, fertilization, rainfall, and herbicides. Labor plays a crucial role in cultivation and harvesting, and its quantity and skills determine the effectiveness of field work. Fertilization is a key agronomic factor because it is related to the availability of nutrients needed for optimal plant growth and production. Furthermore, rainfall influences water availability, with excessive or too little rainfall inhibiting plant physiological processes and reducing productivity. Herbicide use also contributes to increased production by controlling weeds that compete with oil palm plants for water, nutrients, and light (Alhaji et al., 2024).

The research was conducted at PTPN IV Regional II Kebun Melati, Pegajahan District, Serdang Bedagai Regency, North Sumatra. This plantation was selected because it has a structured management system, consistent implementation of operational standards, and the availability of well-documented production and input usage data. Furthermore, the representative agro-climatic conditions of the region for oil palm cultivation make Kebun Melati a relevant location for analyzing the effects of labor, fertilization, rainfall, and herbicides on FFB production. The research results are expected to serve as a basis for improving the effectiveness of production factor management to support increased productivity of oil palm plantations.

THEORETICAL BASIS

Production Theory

Production theory explains the relationship between the use of production factors (inputs) and the resulting output. In the plantation sector, production is the result of a combination of various inputs such as labor, fertilizer, capital, technology, and environmental factors used in the crop cultivation process. According to Soekartawi (2003), the production function is a technical relationship that describes how production factors are transformed into output. Therefore, increasing the effectiveness of production input use will increase production results. In oil palm plantations, Fresh Fruit Bunch (FFB) production is influenced by various factors, both technical and environmental. Factors such as labor, fertilization, rainfall, and herbicide use are key inputs in determining oil palm productivity (Soekartawi, 2003).

Cobb-Douglas Production Function

The Cobb-Douglas production function is a widely used model to analyze the influence of production factors on output. This model is able to explain the quantitative relationship between input and output while also showing the contribution of each production factor through its elasticity value. According to Cobb and Douglas (1928), changes in output are influenced by changes in the use of production inputs in the production process. In this study, the Cobb-Douglas production function was used to analyze the effects of labor, fertilization, rainfall, and herbicides on palm oil production. This model was chosen because it is able to measure the magnitude of the influence of each input variable on Fresh Fruit Bunch (FFB) production and explains the efficiency of the use of production factors in oil palm plantation activities (Soekartawi, 2003).

RESEARCH METHODS

This research used a quantitative approach with a case study method at PTPN IV Regional II Kebun Melati, Pegajahan District, Serdang Bedagai Regency, North Sumatra. The research location was selected purposively due to its structured plantation management system and the availability of comprehensive production and input usage data. The study was conducted from January to March 2026 using monthly time series data for the 2021–2025 period (60 observations) (Sugiyono, 2022). The study population comprised all Fresh Fruit Bunch (FFB) production data and production factors used at PTPN IV Regional II Kebun Melati during the 2021–2025 period. Because the study used secondary time series data, all 60 monthly observations were used as the research sample (census sampling). Furthermore, purposive interviews were conducted with department assistants, harvest foremen, maintenance foremen, and administrative staff as supporting informants for the study (Sugiyono, 2022).

The data used consisted of primary and secondary data. Primary data were obtained through interviews and field observations, while secondary data were obtained from company documents, including data on fresh fruit bunches (FFB) production, labor, rainfall, fertilizer use, and herbicide use for the 2021–2025 period (Nazir, 2017). Data collection techniques included documentation studies, interviews, field observations, and literature studies. Data analysis was conducted descriptively and inferentially. Descriptive analysis was used to describe the development of production and the use of production factors during the study period. Furthermore, the influence of labor, rainfall, fertilizer, and herbicides on FFB production was analyzed using the Cobb-Douglas production function transformed into multiple linear regression. Model testing was carried out through classical assumption tests, partial tests (t-tests), simultaneous tests (F-tests), and the coefficient of determination (R^2). In addition, production elasticity and Return to Scale (RTS) values were calculated to determine the level of output responsiveness to changes in production inputs (Soekartawi, 2003).

RESEARCH RESULT

Data Normality

The normality test aims to determine whether the dependent and independent variables in a regression model are normally distributed. A model is considered good if the data are normally distributed. This test can be seen through the PP Plot graph and residual histogram. Based on the test results, the points on the PP Plot graph are spread along the diagonal line and follow the direction of the diagonal line. In addition, the residual histogram shows a distribution shape that approaches a normal curve (*bell-shaped*). Therefore, it can be concluded that the data in this study are normally distributed and meet the assumptions of normality.

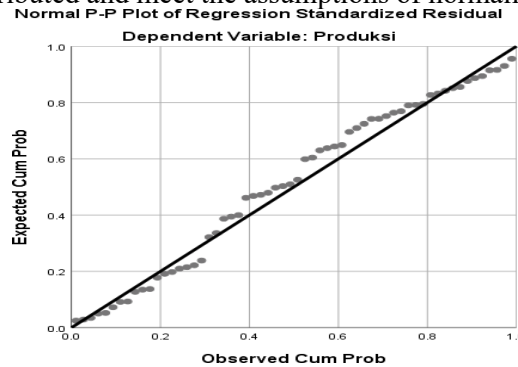


Figure 1. Normality Test Results

Autokorolation

The autocorrelation test aims to determine whether there is a correlation between the residuals in period *t* and period *t-1* in the regression model. This study required an autocorrelation test because the data used was time series, and autocorrelation problems are commonly encountered in studies with this type of data. The method used was the Durbin-Watson test.

Table 1. Autocorrelation Results

Number of Samples (n)	K	dL	dU	DW
60	4	1,443	1,727	1,915

The autocorrelation test results show a Durbin-Watson value of 1.915. With 60 observations and four independent variables, the lower limit (dL) value is 1.443 and the upper limit (dU) is 1.727. Because the Durbin-Watson value is in the range $dU < DW < 4 - dU$, namely $1.727 < 1.915 < 2.273$, the regression model does not experience autocorrelation. Thus, the assumption of residual independence has been met, making the model suitable for further analysis (Ghozali, 2021).

Heteroscedasticity

The heteroscedasticity test aims to determine whether the residual variances of one observation differ from one to another in a regression model. If heteroscedasticity occurs in a regression model, it can cause the estimation model to be inaccurate and inefficient. To determine the presence or absence of heteroscedasticity in a regression model, a scatterplot graph is used. A model is considered free of heteroscedasticity if the points on the scatterplot do not form a specific pattern and are randomly distributed throughout the graph. Based on the test results, the points on the scatterplot do not form a pattern and are randomly distributed throughout the scatterplot. Therefore, it can be concluded that the model does not have a heteroscedasticity problem.

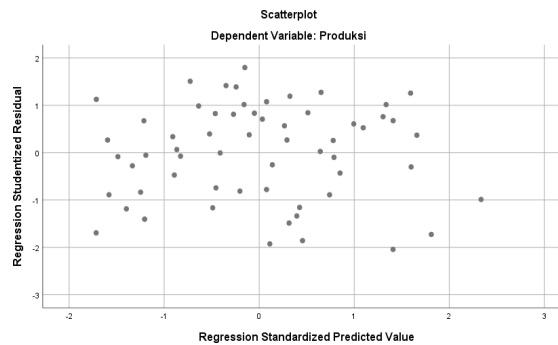


Figure 2. Results of Heteroscedasticity Test

Multicollinearity

Multicollinearity testing was conducted to determine whether there was a high correlation between independent variables in the regression model. A good regression model should not contain multicollinearity problems. Multicollinearity detection was carried out by looking at the *Variance Inflation Factor* (VIF) value, where the model was declared free from multicollinearity if the VIF value was <10 . In this study, the independent variables used included labor (X_1), rainfall (X_2), fertilizer (X_3), and herbicide (X_4). The test results showed that the VIF value of each variable was 1.307 for labor, 1.168 for rainfall, 1.906 for fertilizer, and 1.794 for herbicide. All VIF values were below 10, so it can be concluded that the regression model did not experience multicollinearity. Based on the overall results of the classical assumption test, the research data met the assumption of normality and did not show any autocorrelation, heteroscedasticity, or multicollinearity. Thus, the regression model used meets the *Best Linear Unbiased Estimator* (BLUE) criteria and is suitable for analyzing factors that influence palm oil production at PTPN IV Regional II Kebun Melati.

Production Function Analysis

After the model met all classical assumptions, the analysis continued using the Cobb-Douglas production function. Hypothesis testing included the coefficient of determination (R^2), F test, and t test. The coefficient of determination (R^2) was used to measure the ability of production input variables to explain variations in palm oil production. The F test was used to determine the effect of all production inputs simultaneously on palm oil production, while the t test was used to examine the effect of each production input partially. A variable was declared to have a significant effect if it had a significance value of less than 5% ($\alpha = 0.05$). The results of the production function estimation and hypothesis testing are presented in the following table.

Table 2. Results of the Determination Coefficient (R^2) and Durbin-Watson Tests

Model	R	R Square	Adjusted R Square	Durbin-Watson
1	0.955	0.914	0.899	1,915

ANOVA F Test Results

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	4,167	4	1,042	66,684	0,000
Residual	0,000	55	0,000		
Total	4,167	59			

Table 4. Results of Estimating the Palm Oil Production Function

Variables	Coefficient Regression	t-Count	Sig.	VIF
Constant	4,199	8239,138	0,000	-
Power Work (X ₁)	0.112	1,593	0.117	1,307
Rainfall Rain (X ₂)	0.072	1,343	0,000	1,168
Fertilizer (X ₃)	0.622	0.536	0.001	1,906
Herbicide (X ₄)	0.690	2443,397	0.003	1,794

Coefficient of Determination (R²)

The analysis results show a coefficient of determination (R²) of 0.914 and an *Adjusted R²* of 0.899. These values indicate that 91.4% of the variation in Fresh Fruit Bunches (FFB) production at PTPN IV Regional II Kebun Melati can be explained by the variables of labor, rainfall, fertilizer, and herbicide, while the remaining 8.6% is influenced by other factors outside the model, such as the size of the productive area, plant age, number of producing plants, and other technical factors. The high R² value indicates that the model used has a very good ability to explain variations in palm oil production (Gujarati, 2003).

Simultaneous Test (F Test)

The F-test results showed an F-count value of 66.684 with a significance level of 0.000. A significance value less than 0.01 indicates that the variables of labor, rainfall, fertilizer, and herbicide simultaneously have a significant effect on FFB production. Thus, the production function model used is suitable for explaining the relationship between production factors and oil palm output at Kebun Melati.

Partial Test (t-Test)

The t-test results show that rainfall, fertilizer, and herbicide significantly influence palm oil production at the 99% confidence level ($p < 0.01$). Conversely, the labor variable did not significantly influence FFB production because it did not meet the established significance level. These findings indicate that the increase in palm oil production at Kebun Melati is more influenced by agroclimatic factors and the use of production facilities than by changes in the number of workers.

Cobb-Douglas Production Function

Based on the regression estimation results, the Cobb-Douglas production function equation is obtained as follows:

$$\text{LnY} = 4.199 + 0.112\text{LnX}_1 + 0.072\text{LnX}_2 + 0.622\text{LnX}_3 + 0.690\text{LnX}_4$$

with:

Y = Fresh Fruit Bunch Production

X₁ = Labor force

X₂ = Rainfall

X₃ = Fertilizer

X₄ = Herbicide

The regression coefficients in the Cobb-Douglas model indicate the elasticity of each production factor. The highest elasticity value was found for herbicides (0.690), followed by fertilizer (0.622), labor (0.112), and rainfall (0.072). These results indicate that increased herbicide and fertilizer use contributed more to production increases than other factors.

Return to Scale (RTS)

Return to Scale value is obtained from the sum of all regression coefficients, namely:

$$\text{RTS} = 0.112 + 0.072 + 0.622 + 0.690 = 1.496$$

The RTS value of 1.496 (>1) indicates that palm oil production activities at Kebun Melati are in a state of *Increasing Returns to Scale*. This condition indicates that a 1% increase in all production inputs will increase

output by 1.496%. Thus, the use of production factors at Kebun Melati is still at a productive stage and has the potential to be improved to achieve higher production efficiently.

DISCUSSION

The Influence of Labor on Palm Oil Production

The results showed that labor had a regression coefficient of 0.112 with a significance value of 0.117 ($p > 0.05$), thus having no significant effect on palm oil production. However, a positive coefficient indicates that a 1% increase in labor tends to increase FFB production by 0.112%. This condition indicates that labor utilization at Melati Plantation is relatively optimal, so changes in labor numbers do not have a significant impact on production. These results align with the findings of Pranata and Afrianti (2020) and Juliani (2005) who stated that labor does not significantly influence palm oil production.

The Effect of Rainfall on Palm Oil Production

Rainfall has a positive and significant effect on palm oil production, with a regression coefficient of 0.072 and a significance value of 0.000 ($p < 0.01$). This means that a 1% increase in rainfall will increase FFB production by 0.072%. Rainfall plays a crucial role in supporting plant physiological processes, particularly photosynthesis, nutrient absorption, and fruit formation. These results align with research by Ginting et al. (2017) and Pranata and Afrianti (2020), which found that rainfall significantly impacts palm oil production.

The Effect of Fertilizer on Palm Oil Production

The fertilizer variable has a regression coefficient of 0.622 with a significance value of 0.001 ($p < 0.01$), thus having a positive and significant effect on palm oil production. This indicates that a 1% increase in fertilizer use can increase FFB production by 0.622%. This finding indicates that fertilization is an important factor in increasing plant productivity by providing the necessary nutrients. The results of this study are consistent with those of Ginting et al. (2017), Juliani (2005), and Manurung (2018), which stated that fertilizer significantly affects palm oil production.

The Effect of Herbicides on Palm Oil Production

Herbicides were the variable with the greatest influence on palm oil production, with a regression coefficient of 0.690 and a significance value of 0.003 ($p < 0.01$). This means that a 1% increase in herbicide use can increase FFB production by 0.690%. This positive effect demonstrates the importance of weed control in reducing competition for nutrients, water, and light between weeds and oil palm plants. The results of this study support the findings of Gultom et al. (2021) who stated that herbicide use significantly increased palm oil production.

Return to Scale Analysis

The Return to Scale (RTS) value was 1.496, calculated from the sum of all production input elasticity coefficients ($0.112 + 0.072 + 0.622 + 0.690$). An RTS value greater than one indicates an Increasing Return to Scale condition, meaning a 1% increase in all production inputs will increase output by 1.496%. This condition indicates that the use of production factors in Kebun Melati is still at a productive stage and has the potential to be increased to obtain higher production efficiently (Soekartawi, 2003).

CONCLUSION

Based on the results of the Cobb-Douglas analysis, labor, rainfall, fertilizer, and herbicide simultaneously have a significant effect on FFB production at PTPN IV Regional II Kebun Melati. Partially, labor has a positive but insignificant effect, while rainfall, fertilizer, and herbicide have a positive and significant effect, with herbicide as the most dominant factor. The R^2 value of 0.914 indicates that 91.4% of production variation can be explained by the model, while the rest is influenced by other factors. In addition, the RTS value of 1.496 indicates a condition of increasing returns to scale, which means that proportional increases in input can still increase output significantly.

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