

ANALYSIS OF FACTORS AFFECTING THE PRODUCTIVITY OF RICE FARMING IN BATHIN III ULU DISTRICT, BUNGO REGENCY

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Abstract

This study used primary data obtained from 83 farmer respondents through interviews using a questionnaire. Data analysis was performed using the Cobb-Douglas production function model in natural logarithm form and processed using SPSS 27 software. The results showed that the average land area cultivated by farmers was 0.4 ha, with labor usage of 59.83 HOK/ha/MT, seed application of approximately 23.94 kg/ha/MT, NPK fertilizer application of approximately 201 kg/ha/MT, urea application of approximately 136 kg/ha/MT, and pesticide application of 88.87 ml/ha/MT. Farmers generally planted twice a year using a tiled planting system. The analysis results showed that the five variables in the model explained 85.9% of the variation in rice farming productivity ($R^2 = 0.859$). Partially, NPK and Urea fertilizer variables had a positive and significant effect, while labor (HOK/ha/MT) had a negative and significant effect. Seed and pesticide variables did not have a statistically significant effect. These findings indicate that labor efficiency and the application of appropriate cultivation techniques are key to increasing rice farming productivity in Bathin III Ulu District, Bungo Regency. These findings indicate that the government needs to focus its policies on ensuring the proper provision and distribution oversight of subsidized fertilizers so that they effectively meet farmers' needs, while also enhancing extension programs regarding balanced fertilization, labor efficiency, and the adoption of good cultivation practices. Given that the majority of farmers already use high-yielding seeds, extension efforts should aim to sustain consistent usage alongside appropriate cultivation techniques. Furthermore, training and guidance on proper pesticide application must be strengthened to ensure that farmers not only increase input quantities but also pay attention to the quality and effectiveness of their use.

Keywords: Cobb-Douglas Production Function, Factors Affecting Productivity, Labor Efficiency, Productivity, Rice Farming.

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INTRODUCTION

The agricultural sector plays a crucial role as a key pillar of national development, not only in ensuring food self-sufficiency but also in reducing poverty and driving a sustainable economy. As the fourth-largest rice producer globally, Indonesia's rice commodity holds high strategic value because it is the staple food for the majority of the population. Therefore, the existence of rice farming communities is a crucial determinant in managing food production stability at the regional and national levels. The government continues to strive to increase yields through intensification policies, such as the five agricultural practices, which include the use of superior varieties and balanced fertilization. However, the implementation of these policies at the regional level often faces yield fluctuations due to inefficient allocation of production inputs.

This fluctuating dynamic is evident in the performance of lowland rice farming in Jambi Province. Based on data from the Central Statistics Agency (BPS) for the 2020–2024 period, the harvested area of lowland rice in Jambi Province experienced a significant downward trend, from 84,733 ha in 2020 to only 61,630 ha in 2024. This decline in land area is linear with the decline in average productivity figures from 4.58 tons/ha to 4.55 tons/ha in the same period. Of the 11 regencies/cities in Jambi Province, Bungo Regency was recorded as one of the areas with the second-lowest productivity level after Tebo Regency, namely only 4.39 tons/ha in 2024.

Low productivity is attributed to the use of production inputs—specifically labor, fertilizers, and pesticides—that do not align with recommended guidelines, rendering the utilization of these production factors inefficient. Achieving efficiency in the organization of inputs and production resources aims to optimize resource use to generate output that yields maximum profit. Consequently, the organization of inputs and production resources within farming operations is a crucial factor in achieving optimal production resource allocation.

A review of previous literature shows that extensive research has been conducted on lowland rice production factors, with varying results. Febrianto (2022) studied farming in Jujuhan Ilir District and found that seeds, KCL fertilizer, SP36 fertilizer, pesticides, and labor significantly influenced productivity, while urea fertilizer was insignificant. Conversely, Durori's (2022) research in Pringsewu Regency concluded that labor input (HOK), fertilizer, and pesticides significantly impacted productivity. Furthermore, Hasibuan (2024) in Muaro Jambi Regency identified a negative impact from the use of manure and pesticides, while Puspitasari et al. (2020) in Sambas Regency stated that only urea fertilizer and agricultural mechanization (tractors) significantly impacted yields.

The diversity of empirical findings has given rise to an analytical gap (research gap). Previous research claims indicate that the influence of input factors such as seeds, fertilizers, and pesticides is location-specific and highly dependent on the characteristics of the cultivation area. There is a novelty (contextual novelty) that has not been fully answered in the primary literature: why areas such as Bathin III Ulu District in Bungo Regency continue to experience relatively low productivity fluctuations, even though farmers in the area have been recorded as consistently adopting superior seeds (the Inpara 3 variety) and implementing a twice-yearly cropping index system (IP 200). Previous research has not captured the interaction of input allocation in the specific conditions of the semi-mechanized area in Bathin III Ulu District.

The originality of this study lies in the specific integration of production input variables (labor, seeds, NPK fertilizer, Urea fertilizer, and pesticides) using the Cobb-Douglas production function approach in capturing the inefficiency of input allocation in the conventional semi-mechanical agricultural ecosystem in Bathin III Ulu District. Based on this framework, the hypothesis proposed in this study is that production input factors in the form of labor, seeds, NPK fertilizer, Urea fertilizer, and pesticides simultaneously and partially have

a significant effect on the productivity of lowland rice farming in the research area.

The purpose of this study is to describe the general characteristics and management of lowland rice farming in Bathin III Ulu District, Bungo Regency, and to empirically analyze the influence of production input factors on the productivity level of lowland rice farming in the region. The results of this study are expected to provide scientific contributions to stakeholders in formulating regulations for input distribution and providing appropriate cultivation technique extension.

METHODS

Types and Sources of Data

The data used in this study consist of both primary and secondary data. Primary data were obtained directly through field surveys of 83 wetland rice farmers selected as respondents. The sample size was determined using Slovin's formula with a 10% margin of error, resulting in a sample of 83 farmers from the total population of wetland rice farmers in Bathin III Ulu District. Respondents were selected using a simple random sampling technique, ensuring that every farmer in the population had an equal chance of being chosen for the study. Primary data collection involved the use of structured questionnaires, supplemented by direct interviews and field observations of cultivation activities. The collected data encompassed farmers' socio-economic characteristics—such as age, education level, and family size—as well as farming data for the studied growing season, including cultivated land area (ha), labor usage (man-days/ha/season), and inputs such as seeds (kg/ha/season), Urea fertilizer (kg/ha/season), NPK fertilizer (kg/ha/season), and pesticides (ml/ha/season), alongside rice production (kg). Meanwhile, secondary data were obtained through document reviews from the Bungo Regency Central Statistics Agency (BPS), the Bungo Regency Office of Food Crops, Horticulture, and Plantations, the Bathin III Ulu District Agricultural Extension Center (BPP), and relevant scientific literature.

Research Variables

The analysis of the influence of production factors on the productivity of lowland rice farming in this study was tested using the Cobb-Douglas Production Function. This production function model was chosen because it is able to describe the relationship between the resulting production level and the combination of production inputs simultaneously or partially. To facilitate the process of parameter estimation using the Ordinary Least Squares (OLS) method, the mathematical model of the Cobb-Douglas function was transformed into a linear form of the Natural Logarithm (ln). The formula formulation used in this study is as follows:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5$$

Where:

- Y : Paddy productivity (kg/ha/MT)
- X₁ : Use of labor (HOK/ha/MT)
- X₂ : amount of seed used (kg/ha/MT)
- X₃ : amount of NPK fertilizer use (kg/ha/MT)
- X₄ : Amount of Urea fertilizer used (kg/ha/MT)
- X₅ : amount of pesticide use (ml/ha/MT)
- β₀ : Intercept (nilai konstan)
- β₁... β_n : Regression coefficient

Classical Assumption Test

1. Normality Test

Normality testing is conducted to determine whether the residuals in a regression model follow a normal distribution. This test is crucial because classical linear regression assumes

that residuals must be normally distributed for estimation results and statistical tests to be considered valid. The normality test is applied to the unstandardized residuals, rather than to the independent or dependent variables individually.

Table 1. Normality Test Results: One-Sample Kolmogorov-Smirnov Test.

One-Sample Kolmogorov-Smirnov Test			
			Unstandardized Residual
N			83
Normal Parameters ^{a,b}	Mean		,0000000
	Std. Deviation		,07203867
Most Extreme Differences	Absolute		,050
	Positive		,050
	Negative		-,048
Test Statistic			,050
Asymp. Sig. (2-tailed) ^c			,200 ^d
Monte Carlo Sig. (2-tailed) ^e	Sig.		,883
	99% Confidence Interval	Lower Bound	,874
		Upper Bound	,891
a. Test distribution is Normal.			
b. Calculated from data.			
c. Lilliefors Significance Correction.			
d. This is a lower bound of the true significance.			
e. Lilliefors' method based on 10000 Monte Carlo samples with starting seed 926214481.			

Source : Data Processed by SPSS 27, 2026.

Based on the One-Sample Kolmogorov-Smirnov Test results in Table 1, a significance value (Asymp. Sig. 2-tailed) of 0.200 was obtained. Since this significance value is greater than 0.05, it can be concluded that the residuals are normally distributed (there is no deviation from a normal distribution).

2. Multicollinearity Test

Multicollinearity testing is conducted to determine whether there are high correlations among independent variables in a regression model that could potentially bias parameter estimation results. This test is performed by analyzing the Tolerance and Variance Inflation Factor (VIF) values for each independent variable. The Tolerance value reflects the proportion of an independent variable's variance that cannot be explained by the other independent variables in the model.

Table 2. Multicollinearity Test Results

Coefficients ^a			
Model		Collinearity Statistics	
		Tolerance	VIF
1	Tenaga Kerja	,889	1,125
	Benih	,970	1,031
	Pupuk NPK	,515	1,942
	Pupuk Urea	,512	1,952
	Pestisida	,891	1,123
a. Dependent Variable: Produktivitas			

Source : Data Processed by SPSS 27, 2026.

Based on the multicollinearity test results presented in the Coefficients table, all independent variables exhibit Tolerance values greater than 0.10 and Variance Inflation Factor (VIF) values less than 10. Specifically, the labor variable has a Tolerance of 0.889 and a VIF of 1.125; seed usage has a Tolerance of 0.970 and a VIF of 1.031; NPK fertilizer has a Tolerance of 0.515 and a VIF of 1.942; Urea fertilizer has a Tolerance of 0.512 and a VIF of 1.952; and pesticides have a Tolerance of 0.891 and a VIF of 1.123.

These values indicate the absence of high correlation among the independent variables in the regression model. Consequently, it can be concluded that the research model is free from multicollinearity; thus, the resulting regression coefficient estimates are valid and suitable for further analysis regarding the factors influencing lowland rice farming productivity.

3. Heteroskedasticity Test

A heteroscedasticity test is conducted to determine whether there are differences in residual variances across observations within a regression model. This test aims to ensure that the residual variance remains constant from one observation to another. Heteroscedasticity can be detected by examining a scatterplot of the predicted values of the dependent variable (ZPRED) against the residuals (SRESID).

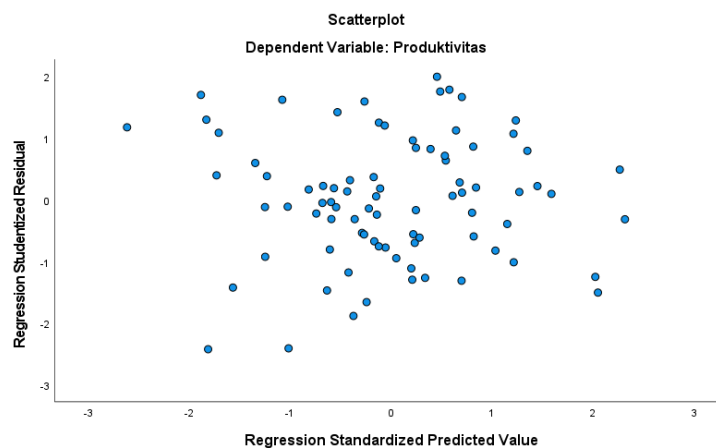


Figure 1. Scatter plot for the heteroscedasticity test.
Source : Data Processed by SPSS 27, 2026.

Based on Figure 1, it can be seen that the points on the diagram are randomly scattered and do not exhibit any specific pattern. Therefore, it can be concluded that the regression model does not suffer from heteroskedasticity.

4. Autocorrelation test

The autocorrelation test aims to determine whether, within a regression model, there is a correlation between the error term in a given period and the error in the preceding period. While autocorrelation typically occurs in time-series data, it can also arise in cross-sectional data under certain conditions.

Table 3. Autocorrelation Test Results

Model Summary ^b					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,927 ^a	,859	,850	,07434	1,892
a. Predictors: (Constant), Pestisida, Pupuk Urea, Benih, Tenaga Kerja, Pupuk NPK					
b. Dependent Variable: Produktivitas					

Source : Data Processed by SPSS 27, 2026.

Based on Table 25, the autocorrelation test using the Durbin-Watson (DW) test yielded a value of 1.892. With a sample size (n) of 83 and five independent variables (k), the lower limit (dL) was 1.55 and the upper limit (dU) was 1.75. Since the DW value falls between dU and 4 – dU ($1.75 < 1.889 < 2.25$), it can be concluded that the regression model does not exhibit autocorrelation. Thus, the classical assumption regarding autocorrelation has been met.

RESULTS AND DISCUSSION

Hypothesis Testing

R2 Test (Coefficient of Determination)

The coefficient of determination (R^2) is used to measure the ability of independent variables to explain variations in the dependent variable in the regression model used. The R^2 value ranges from 0 to 1, where the closer to 1 indicates that the model has a better ability to explain changes in the dependent variable. Conversely, the closer to 0 indicates that the independent variable's ability to explain the dependent variable is lower. In this study, the R^2 value indicates the proportion of productivity variation that can be explained by the variables included in the model, while the remainder is explained by other factors outside the research model such as climate conditions, soil fertility, cultivation techniques, pest and disease attacks, and other factors not observed in the study.

Table 4. Results of the Cobb Douglas Determination Coefficient Test

Model Summary ^b									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,927 ^a	,859	,850	,07434	,859	93,727	5	77	,000

a. Predictors: (Constant), Pestisida, Pupuk Urea, Benih, Tenaga Kerja, Pupuk NPK

b. Dependent Variable: Produktivitas

Source : Data Processed by SPSS 27, 2026.

Based on the model summary table, a correlation coefficient (R) of 0.927 was obtained, indicating a very strong relationship between the independent variables (labor, seed use, NPK fertilizer, pesticides, and urea fertilizer) and productivity. The R-square value of 0.859 indicates that 85.9% of the variation in rice farming productivity can be explained by the independent variables in the model, while the remaining 14.1% is influenced by factors outside the research model. The adjusted R-square value of 0.859 indicates that after adjusting for the number of variables and samples, the model's ability to explain productivity variation remains high, at 85.9%. The F-change value of 93.727, with a significance level of less than 0.001, indicates that all independent variables simultaneously have a significant effect on productivity.

F test (Joint regression test)

The F test is conducted to see the influence of independent variables simultaneously on the dependent variable. The test results can be seen in the table 2.

Table 5. ANOVA Test of Paddy Farming Productivity in Bathin III Ulu District

ANOVA ^a						
	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2,590	5	,518	93,727	,000 ^b
	Residual	,426	77	,006		
	Total	3,016	82			

a. Dependent Variable: Produktivitas

b. Predictors: (Constant), Pestisida, Pupuk Urea, Benih, Tenaga Kerja, Pupuk NPK

Source : Data Processed by SPSS 27, 2026.

Based on the ANOVA table, the Sum of Squares Regression value was 2.590 and the residual was 0.426, with a total variation of 3.016. This indicates that most of the productivity variation can be explained by the independent variables in the model, while the rest is influenced by other factors outside the research model. The calculated F value of 93.727 with a significance level <0.001 indicates that simultaneously the variables of labor, seed use, NPK fertilizer, pesticides, and urea fertilizer have a significant effect on the productivity of lowland rice farming. Thus, the regression model used in this study is declared significant and suitable for use in further analysis.

t-test

The t-test in multiple linear regression is used to assess whether the parameters or regression coefficients in the Cobb-Douglas model have been estimated accurately. Accuracy refers to the ability of each coefficient to explain the influence of the independent variable on the dependent variable, namely rice farming productivity. This test is conducted partially on each independent variable to determine whether it has a significant influence on productivity. The decision-making criteria in the t-test are as follows:

1. If the significance value is less than 0.05, then H_0 is rejected, meaning the regression coefficient has a statistically significant effect.
2. If the significance value is greater than 0.05, then H_0 is accepted, meaning the regression coefficient has no significant effect.

Overview of Paddy Farming

Lowland rice farming in Bathin III Ulu District generally operates twice a year using a tile planting system. Farmers use superior Inpara 3 seeds, and most still employ conventional cultivation methods. This situation indicates that lowland rice farming in the study area has developed quite well, with a cropping index (IP) of 200. However, the resulting productivity is still relatively low compared to several other districts in Bungo Regency. This indicates that

the utilization of production factors is not yet fully optimal.

The average farmer's production inputs include labor of 59.83 HOK/ha/MT, seed of 23.94 kg/ha/MT, NPK fertilizer of 201 kg/ha/MT, urea of 136 kg/ha/MT, and pesticide of 88.87 ml/ha/MT. The use of these production inputs indicates that farmers have utilized production facilities in their rice cultivation activities. However, the level of efficiency of their use varies among farmers, thus affecting the resulting productivity levels. According to Soekartawi (2020), farm productivity is influenced not only by the quantity of inputs used, but also by the accuracy and efficiency of their use.

Cobb-Douglas Regression Analysis Results

Table 6. Cobb-Douglas Analysis Results

		Coefficients ^a						Collinearity Statistics	
Model		Unstandardized Coefficients		Standardized Coefficients		t	Sig.	Tolerance	VIF
		B	Std. Error	Beta					
1	(Constant)	2,797	,615			4,550	,000		
	Tenaga Kerja	-,230	,034	-,304		-6,698	,000	,889	1,125
	Benih	,082	,057	,062		1,431	,156	,970	1,031
	Pupuk NPK	,807	,068	,705		11,799	,000	,515	1,942
	Pupuk Urea	,332	,123	,161		2,697	,009	,512	1,952
	Pestisida	,012	,065	,009		,189	,851	,891	1,123

a. Dependent Variable: Produktivitas

Source : Data Processed by SPSS 27, 2026.

From the table above, it can be seen that the regression coefficients and constants obtained indicate that the regression model can be written as the following equation:

$$\ln Y = 2.797 - 0.230 \ln X_1 + 0.082 \ln X_2 + 0.807 \ln X_3 + 0.332 \ln X_4 + 0.012 \ln X_5.$$

The results of the Cobb-Douglas analysis in this study are as follows:

1) The Influence of Labor Variables on the Productivity of Rice Farming Businesses

The labor variable (X₁) has a regression coefficient of -0.230 with a significance value of 0.000, indicating that labor has a significant effect on lowland rice farming productivity at a 95% confidence level. The negative coefficient implies that every 1% increase in labor usage results in a 0.230% decrease in productivity, assuming other variables remain constant. These results indicate that labor usage in lowland rice farming within the study area has exceeded the optimal level, such that additional labor no longer yields a proportional increase in productivity. According to the Law of Diminishing Marginal Returns, if a factor of production is continuously increased while other factors remain relatively constant, the additional output generated from each additional unit of input will progressively decline (Soekartawi, 2020).

This situation arises because the greatest labor demand occurs during planting, weeding, and harvesting—tasks that are still largely performed manually and require a substantial workforce. Furthermore, mechanization in the study area remains limited, utilized only for specific activities such as land preparation and harvesting. Consequently, the additional labor employed has not been fully offset by gains in work efficiency or the adoption of technology; instead, this has led to diminishing returns, where increasing labor input yields progressively smaller increments in output.

2) The Influence of Seed Variables on the Productivity of Rice Farming Businesses

The Seed variable (X₂) has a coefficient of 0.081 with a significance value of 0.156. Because the significance value is greater than 0.05, seed use does not significantly affect

productivity. Although the coefficient is positive, statistically the effect is not strong enough to explain changes in productivity. This could be due to the relatively similar seed quality among respondents or the use of seeds that meet standards so that they are no longer a differentiating factor in increasing productivity. The results of the study are in line with the study by Laim and Simamora (2022) entitled "Analysis of Factors Affecting the Productivity and Feasibility of Lowland Rice Farming," which states that seed use does not affect the productivity of lowland rice farming.

3) The Effect of NPK Fertilizer Variables on the Productivity of Rice Farming Businesses

The NPK fertilizer variable has a coefficient of 0.807 with a significance value of <0.001 , indicating that NPK fertilizer has a positive and significant effect on productivity. A 1% increase in NPK fertilizer usage leads to a 0.807% increase in productivity, assuming other variables remain constant (*ceteris paribus*). With a Standardized Beta value of 0.705—the highest among all variables—it can be concluded that NPK fertilizer is the most dominant variable influencing productivity. The dominant influence of NPK fertilizer is attributed to its content of essential macro-nutrients—nitrogen (N), phosphorus (P), and potassium (K)—which play crucial roles in the physiological processes of rice plants. Nitrogen stimulates vegetative growth, particularly leaf and tiller formation, thereby enhancing photosynthetic capacity. Phosphorus plays a role in root system formation and development, energy metabolism (ATP), and the support of flowering and panicle formation. Meanwhile, potassium regulates enzyme activity and the translocation of photosynthates, improves water-use efficiency, strengthens stems, and supports grain filling, resulting in denser, higher-quality grain. The availability of balanced nutrients through NPK fertilization enables optimal plant growth across all developmental stages, ultimately boosting rice productivity. These findings align with the study by Anugrah et al. (2024) titled "Analysis of the Influence of Farming Production Factors on Lowland Rice Productivity in Atula Village, East Kolaka Regency," which states that NPK fertilizer influences lowland rice productivity in Atula Village, East Kolaka Regency.

4) The Effect of Urea Fertilizer Use on Rice Farming Productivity

The analysis results indicate that urea fertilizer has a coefficient of 0.332 with a significance value of 0.009. Since this significance value is less than 0.05, urea fertilizer exerts a positive and significant influence on productivity at a 95% confidence level. Statistically, this means that the use of urea fertilizer is proven to contribute significantly to increased productivity. The regression coefficient of 0.332 indicates that every 1% increase in urea fertilizer usage leads to a 0.332% increase in productivity, assuming other variables remain constant (*ceteris paribus*). These findings are likely attributable to the fact that fertilizer application rates at the study site were close to recommended levels; thus, the addition of urea fertilizer in this study was able to boost lowland rice farming productivity. This positive effect is linked to the high nitrogen (N) content of urea fertilizer—approximately 46%—making it a primary nitrogen source for rice plants. Nitrogen plays a crucial role in plant physiological processes, particularly in chlorophyll formation, which supports photosynthesis, protein synthesis, and cell division. Furthermore, nitrogen stimulates vegetative growth—such as leaf development and the formation of productive tillers—thereby enhancing the plant's capacity to capture sunlight and produce photosynthates. The resulting photosynthates are utilized for growth, panicle formation, and grain filling, ultimately contributing to increased rice productivity. This finding contrasts with the study conducted by I. Akbar et al. (2018)—titled "Analysis of Factors Affecting Rice Productivity in Kesesi District, Pekalongan Regency"—which concluded that urea fertilizer did not have a significant effect on lowland rice productivity.

5) The Effect of Pesticide Use on the Productivity of Rice Farming

The pesticide variable (X5) has a regression coefficient of 0.012 with a significance value of 0.851 ($p > 0.05$), indicating that pesticides do not significantly affect rice productivity at the 95% confidence level. This very small coefficient indicates that every 1% increase in pesticide use only increases productivity by 0.012%, so its contribution in explaining output variations is relatively weak. Theoretically, pesticides function to control plant pests (OPT) to prevent yield losses, but the insignificance in this study occurred because the average pesticide application by farmers in the study area was only 88.87 ml/ha/MT, an amount that is still very far below the recommended dose of the Minister of Agriculture Regulation, which is 2,000–3,000 ml/ha/MT. This empirical finding is in line with Bakhri's (2016) research entitled "Factors Affecting Farming Productivity Between Peterongan District and Megaluh District, Jombang Regency" which also stated that the use of pesticides had no significant effect on rice productivity in Megaluh District, Jombang Regency.

CONCLUSION

Wetland rice farming in Bathin III Ulu District, Bungo Regency, generally employs a twice-yearly cropping system using the high-yielding *Inpara 3* variety. Production inputs include labor, seeds, NPK fertilizer, urea, and pesticides. Cobb-Douglas production function analysis reveals that NPK fertilizer and urea have a positive and significant effect on wetland rice productivity, whereas labor has a negative and significant effect. Seed and pesticide variables do not significantly affect productivity. Productivity improvements in Bathin III Ulu District can be achieved through efficient labor utilization, the adoption of agricultural mechanization, and the use of appropriate, balanced fertilizers tailored to crop needs.

This study makes a scientific contribution by demonstrating that increasing wetland rice productivity is not determined solely by increasing the quantity of production inputs, but is instead driven by input-use efficiency, particularly regarding labor and fertilizer. These findings reinforce agricultural production theory, which posits that optimal input combination and allocation yield higher productivity levels than merely increasing input quantities. The practical implication of this study is the need to strengthen agricultural extension programs that emphasize the efficient use of production factors, the application of balanced fertilization based on crop requirements, and the use of mechanization to enhance labor efficiency. Furthermore, these findings offer insights for the government in formulating fertilizer subsidy policies; such policies should not focus exclusively on the provision of subsidized fertilizer but must also encompass targeted distribution oversight and farmer education regarding the application of balanced fertilization in accordance with recommendations.

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