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Research Article

Employing the Cobb-Douglas Function Model to Examine How Input Allocation Affects Rice Production: In Search of Ways to Improve the Rice Farming Management

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Abstract: Agricultural production is a significant contributor to Indonesia's economy. Due to the fact that it is a staple food, rice is a crop that is extremely important to the agricultural sector of the country. The rice production in the Bantaeng Regency has had a consistent decline over the past five years, falling short of the set target. The phenomenon is believed to be attributed to several stages in the production process. Given this, our study objective was to determine the factors that impact rice production in the regency. The field survey for data collection was conducted at the beginning of 2023. The data was collected by the structured interview approach. Then, data analysis in the study was carried out using the Cobb-Douglas function model. The study showed that certain production factors, such as land area, pesticides, herbicides, land processing workers, and plant workers, had a substantial positive impact on rice production. Factors such as seeds, urea fertilizer, NPK fertilizer, maintenance labor, and harvesting labor have no effect on rice production. Rice producers can improve their rice growing practices to boost their rice production. These findings offer important perspectives and a roadmap toward improving rice production management. Variables such as land acreage, pesticides, herbicides, land processing workers, and plant workers should be considered as factors that can boost rice production in the future.

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1. Introduction

Rice (*Oryza sativa* L.) is often considered among the world's most significant food crops. In addition to being indispensable for Indonesia (Tenriawaru et al., 2023) and its people (Salam et al., 2019), it is cultivated as a primary source of nutrition (Paita et al., 2015). The community very much needs this commodity (Onibala et al., 2017) because of its benefits as a staple food that is most often consumed by the community compared to other staple foods (Heriansyah et al., 2022). In addition, rice is an indicator of the Indonesian economy (Sudiharto, 2020). Then, about 20 million farmer households in rural areas depend on rice farming. The population in Indonesia is 275 773.8 people (BPS, 2022), and it is predicted to increase yearly. The increase in population demands an increase in rice production to balance the fulfillment of food needs. Food availability, especially rice, is one of the most important indicators of food security in a region with a dense population (Ishaq et al., 2017). Based on the data provided by the Central Bureau of Statistics, the quantity of milled dry grain (MDG) generated from rice in the year 2021 was 54.42 million tons, which was 0.43 percent less than the amount produced in 2020, which was 54.65 million tons of MDG. Bantaeng Regency is one of the regions that prioritizes rice as a food crop. The community develops the rice commodity because it can survive in the area; besides the production is high enough to be a source of income for farmers (Hartati, 2018). Table 1 displays the rice performance in Bantaeng Regency from 2017 to 2021.

Table 1. Description of rice commodity in Bantaeng Regency in 2017-2021

Years	Harvested Area (ha)	Production (ton)	Productivity (ton ha^{-1})
2017	16 531	94 700	57.29
2018	17 931	91 159	50.84
2019	10 701	53 088	49.61
2020	10 253	52 651	51.35
2021	9 554	50 884	53.26
Average	12 994	68, 96	52.47

Source: (BPS Kabupaten Bantaeng, 2022)

Table 1 shows that agricultural production in Bantaeng Regency is going down. Ten years of data show that rice crops produce an average of 5.2 tons per acre. According to the Bantaeng Regency Central Statistics Agency (BPS Kabupaten Bantaeng, 2022), the minimum goal for rice production in 2020 is 10 tons per hectare. Realizing the current production gap is important for comprehending problems with rice yield. Therefore, the objective of this investigation was to delve into the factors that affect rice farming in Bantaeng Regency.

2. Research Methods

2.1. Conceptual framework construction

2.1.1. Factors influencing rice production

Land productivity has significance in agricultural management (Maulidiyah et al., 2024; Salam et al., 2024). It is widely acknowledged that the more land area cultivated, the bigger the yield. High production will increase farmers' revenue. These findings are supported by studies by Manggala & Boedirochminarni (2018) and Salam et al. (2019). They show that land area is a measure of production that affects rice production in a good way. Additionally, the amount of rice that is cultivated is significantly impacted by the seed. This indicates that seed can be considered a production element that has a significant impact on the amount of rice that is produced (Mba et al., 2022). When it comes to the development of rice, it was shown that seeds have a positive and statistically significant impact. Hulzannah et al. (2022) also found something like this. These results clearly demonstrate a strong and positive connection between the number of seeds placed and the amount of rice that grows.

Urea fertilizer has become an essential factor for rice producers because it directly increases productivity. As a result, urea fertilizer plays an important role in determining rice yield. Thus, it may be concluded that increased fertilizer use can improve rice production (Khoerunisa et al., 2021). Furthermore, the production of NPK fertilizer may have an effect on the production of rice. There is a statistically significant relationship between the NPK fertilizer variable and rice yield, as stated by Rainel et al. (2017). Among the most important elements that influence rice production is the use of pesticides. The study done by Rahman et al. in 2023 backs up this explanation. Since that's what they found, chemicals have a big and good impact on rice farming. Farmers who grow rice will be safe from bug and disease infestations as long as they use the right amount of pesticides and nowhere near too much. Also, chemicals have a big effect on the growth of rice. Herbicides used in the right amount and the right conditions for weed growth will help rice production (Hamid et al., 2018).

Additionally, many research studies demonstrate that recruiting workers to work on farms has a good and significant impact on rice output. On the other hand, using agricultural machinery like tractors is likely to increase rice production (Ridha, 2017; Suyatno et al., 2018). Planting activities in rice farming involve moving seedlings from the nursery to the planting field to get the results of cultivated rice plant products. Ridha's (2017) research shows that labor variables used in planting activities have a significant positive impact on rice production. Getting rid of weeds, fertilizing, and controlling pests and diseases all help rice output (Zarwazi et al., 2017).

2.1.2. Constructing conceptual framework

Based on the literature research we carried out earlier, we conceptualized a framework for this project, which can be shown in Figure 1. According to the information presented in Figure 1, the aspects that had the most significant impact on rice production were land area, seeds, urea and NPK fertilizers, pesticides and herbicides, and land processing, planting, maintenance, and harvest labor.

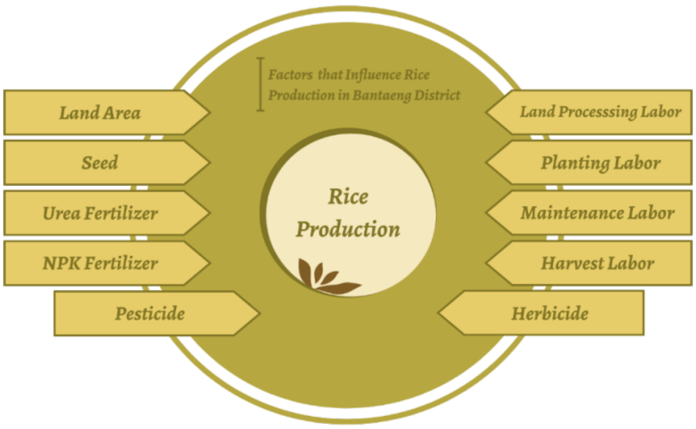
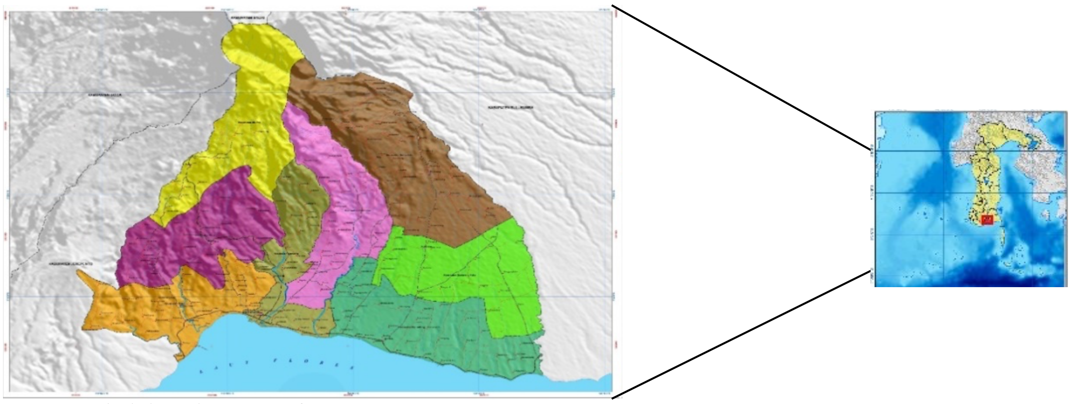


Figure 1. Conceptual framework.

2.2. Research location and data source

The study was conducted in 2023 at Bantaeng Regency, South Sulawesi Province, Indonesia (Figure 2). Rice farmers in the research areas provided primary data. Five villages were randomly selected to represent the variation of rice farming conditions across Bantaeng Regency. Random sampling was the technique employed for selecting 120 rice farmers for interviews. In selecting the rice farmers, a list of all farmers in the five villages was made. Then, the farmers were randomly selected using the list. This technique was chosen to ensure that every farmer in the population had an equal chance of being selected. Survey data was collected using a structured interview method.



Source: Administration Map of Bantaeng Regency.

Figure 2. Research location.

2.3. Dependent and independent variable construction

This study incorporated both dependent and independent factors. Table 2 displays a set of 10 independent factors that have the potential to influence the dependent variable. The anticipated outcome of this inquiry was to yield substantial favorable findings. Nevertheless, in the event of a negative signal, augmenting production inputs has the potential to decrease rice yield.

Table 2. Variables of dependent and independent

Dependent and Independent Variables					
A.	**Dependent Variables:**	**Y = Rice Production (kg)**			
B.	**Variables of Independent**		**Measurement Unit**	**Expected Results***	**References**
	Name of Variables	**Symbols**			
	1. Land Area	LA	ha	+/Sig.	Puspitasari (2017), Manggala & Boedirochminarni (2018), Anggilina et al. (2023)
	2. Seed	SE	kg	+/Sig.	Hulzannah et al. (2022)
	3. Urea Fertilizer	UF	kg	+/Sig.	Puspitasari (2017), Rainel et al. (2017), Khoerunisa et al. (2021)
	4. NPK Fertilizer	NF	kg	+/Sig.	Rainel et al. (2017)
	5. Pesticide	PE	L	+/Sig.	Rahman et al. (2023)
	6. Herbicide	HE	L	+/Sig.	Hamid et al. (2018), Rainel et al. (2021)
	7. Land Processing Labor	LPL	man-days	+/Sig.	Suyatno et al. (2018)
	8. Planting Labor	PL	man-days	+/Sig.	Rainel et al. (2017), Ridha (2017)
	9. Maintenance Labor	ML	man-days	+/Sig.	Ridha (2017), Zarwazi et al. (2017)
	10. Harvest Labor	HL	man-days	+/Sig.	Ridha (2017)

*Sig. = Significant, L=Liter.

2.4. General model and specification of the Cobb-Douglas equation

The Cobb-Douglas Production Function (CDPF) Analysis was utilized to assess the impact of the utilization of production factors on rice cultivation. From a mathematical standpoint, the CDPF Analysis can be represented by Equation 1.

$$Y = \alpha X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} \dots e^{u} \quad (1)$$

Where: Y=Dependent variable, X=Independent variable, α=Constant value, b=Regression coefficient, e=Natural logarithm (2,718), u=Error (disturbance term). Furthermore, Equation 1 is transformed into logarithmic form to make it easier to use, so Equation 2 is obtained.

$$\ln Y = \alpha + b_1 \ln X1 + b_2 \ln X2 + b_3 \mathrm{Ln} X3 + ... + b_i \ln X_i + e \quad (2)$$

The purpose of this study is to investigate the influence that independent factors have on the dependent variable, which is rice production. Following that, the CDPF Analysis was specified, as will be seen in Equation 3, and Table 2 can be consulted for each symbol that is included in the equation.

$$\ln Y = \alpha + b_1 \ln LA + b_2 \ln SE + b_3 \ln UF + b_4 \ln NF + b_5 \ln PE + b_6 \ln HE + b_7 \ln LPL + b_8 \ln PL + b_9 \mathrm{Ln} ML + b_{10} \mathrm{Ln} HL + e \quad (3)$$

2.5. Classical assumption and model testings

Before moving on to the raw data, homogeneity, multicollinearity, and heteroskedasticity were examined. The typical Kolmogorov-Smirnov (K-S) test investigates variable distribution. For heteroscedasticity and multicollinearity (Ernawati, 2019), it used VIF and scatterplot graphs. The model has t- and F-tests. An F-test finds statistically whether every independent factor influences the dependent variable. Independent factors affect the dependent variable if F-count > F-table at 95% confidence. When all other parameters are held constant, the t-test determines the independent variable's influence on the dependent variable. When the t-count surpasses the t-table, the independent variable has a 95% chance of influencing the dependent variable. If t-count < t-table, the independent variable has no significant impact on the dependent variable.

3. Results

3.1. Classical assumption test results

This is what the K-S test showed in Table 3. The amount of significance was 0.200, which is greater than 0.05. So, we can say that the study's results are spread out in a normal way.

Table 3. K-S normality test results

One-Sample K-S Test		
		Unstandardized Residual
N		120
Normal Parameters[a]	Mean	0.000
	Standard Deviation	0.323
Most Extreme Differences	Absolute	0.052
	Positive	0.052
	Negative	-0.047
Test Statistic		0.052
Asymp. Sig. (2-tailed)		0.200
a.Test distribution is Normal		

Table 4 illustrates the study's multicollinearity analysis. Table 4 indicates no multicollinearity because all variables have tolerances over 0.1 and VIFs below 10. Figure 3 is an unpatterned scatterplot. Above and below the Y-Axis zero mark, data points are randomly dispersed. Data in this study lacks heteroscedasticity.

Table 4. Multicollinearity test results

Coefficients[a]		
	Collinearity Statistics	
Dep. Variables	**Tolerance**	**VIF**
(Constant)		
ln_LA	0.357	2.799
ln_SE	0.373	2.683
ln_UF	0.517	1.934
ln_NF	0.511	1.957
ln_PE	0.879	1.137
ln_HE	0.917	1.090
ln_LPL	0.521	1.920
ln_PL	0.424	2.358
ln_ML	0.874	1.144
ln_HL	0.767	1.304

a. Dependent Variable: ln_Y

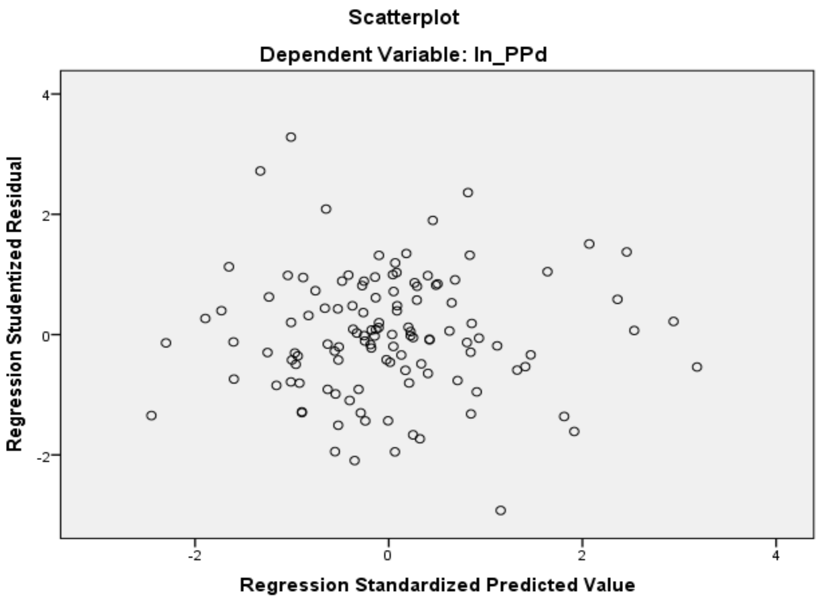


Figure 3. The result of the heteroscedasticity test.

3.2. Model testing results

3.2.1. F-test results

Table 5 indicates 29.868 F-count and 0.001 significance. The F distribution table provides 1.92 at 5% alpha. The significance level is less than 0.05, surpassing the critical F-value. Thus, all variables studied significantly affect rice yield.

Table 5. F-Test results

ANOVA						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
	Regression	34.045	10	3.405	29.868	< 0.000
	Residual	12.424	109	0.114		
	Total	46.470	119			

3.2.2. t-test results

The t-table showed 1.981 with 5% (alpha) significance and n-k degrees of freedom. T-test results from this investigation are in Table 6. As indicated in Table 6, land area, seeds, herbicides, land processing labor, planting labor, maintenance labor, and harvest labor affect rice output. A comparison of the t-count and the t-table demonstrates this, as does the significance value, which is lower than 0.05. There was no impact on rice production from the use of pesticides, urea, or NPK fertilizer. A significance value that is more than 0.05 or a t-count number that is lower than the t-table implies that this outcome is the case.

Table 6. Results of t-test

Coefficients[a]		
Independent Variables	**t**	**Sig.**
(Constant)	11.040	0.000
ln_LA	2.897**	0.005
ln_SE	2.493*	0.014
ln_UF	0.084	0.933
ln_NF	0.535	0.594
ln_PE	-0.908	0.366
ln_HE	3.895**	0.000
ln_LPL	2.273*	0.025
ln_PL	2.558*	0.012
ln_ML	2.266*	0.025
ln_HL	2.435*	0.017
a. Dependent Variable: ln_Y		

* Significant at the confidence level of 95%, ** significant at the confidence level 99%.

3.3. The Cobb-Douglas function analysis results

Table 7 displays the results of the regression analysis that illustrates the impact of several production parameters on rice yield. In addition, Table 7 shows that regression coefficients can be broken down into two groups: unstandardized coefficients and standardized coefficients. As shown in Equation 4, the researchers used standardized factors to make the results easier to understand.

Table 7. Regression analysis results

Coefficients[a]			
	Unstand. Coefficients		**Stand. Coefficients**
Independent Variables	**B**	**Standard Error**	**Beta**
(Constant)	5.765	0.522	
ln_LA	0.290**	0.100	0.240**
ln_SE	0.256*	0.103	0.202*
ln_UF	0.006	0.076	0.006
ln_NF	0.044	0.082	0.037
ln_PE	-0.040	0.044	-0.048
ln_HE	0.122**	0.031	0.201**
ln_LPL	0.163*	0.071	0.156*
ln_PL	0.196*	0.077	0.195*
ln_ML	0.174*	0.077	0.120*
ln_HL	0.116*	0.048	0.138*
a. Dependent Variabel: ln_Y			

* Significant at the confidence level of 95%, ** significant at the confidence level 99%.

$$\ln Y = \alpha + 0.240 \ln LA + 0.202 \ln SE + 0.006 \ln UF + 0.037 \ln NF - 0.048 \ln PE + 0.201 \ln HE + 0.156 \ln LPL + 0.195 \ln PL + 0.120 \ln ML + 0.138 \ln HL + e \quad (4)$$

Table 6 contained a t-count of 2.897, which indicated that the amount of land area had a substantial impact on the amount of rice produced. On the other hand, the basic t-table had a t-count of 1.981, which was far higher than this. The data led to the calculation of a regression coefficient of 0.240, which shows that the quantity of land area leads to an increase in the amount of rice produced for consumption. When all other aspects of the situation remain unchanged, an increase of one percent in land area leads to a 0.240% increase in rice paddy produced. This study confirmed Anggilina et al. (2023)'s findings that land area had a favorable and significant effect on rice output.

Based on the findings of the T-tests, it was determined that the seed variable does have an impact on the amount of rice produced. While the value of the fundamental t-table was 1.981, the t-count was found to be 2.493, according to the findings. It can be seen from the regression coefficient of 0.202 that this variable contributes to an increase in rice production. A one percent increase in seed yield results in a 0.202% increase in rice production, provided all other variables remain the same. The conclusions of this study were consistent with the findings of previous research carried out by Hulzannah et al. (2022). There is a significant increase in the quantity of rice produced as a result of these trials on seeds.

The t-value for land processing labor was 2.273, which was greater than the needed 1.981, and the regression coefficient for land processing labor was 0.156, on the other hand. The data presented here illustrates the statistical relationship between the land processing labor variable and rice paddy productivity. A one percent increase in the amount of labor used to process land results in a 0.156% increase in rice paddy produced, provided that all other factors remain unchanged. Ridha (2017) and Suyatno et al. (2018) conducted studies that demonstrate that the labor involved in land processing has a considerable impact on rice production. These findings lend support to the aforementioned finding. This is due to the fact that increasing the number of people who are engaged in land cultivation supports production management, which is more severe.

Planting effort boosts rice yield statistically. The regression coefficient (0.195) and t-test (t-count 2.558 > t-table 1.981) support this. If all other variables remain constant, 1% planting labor boosts rice paddy productivity by 0.195%. Previous studies by Rainel et al. (2017) and Ridha (2017) found that labor variables positively and statistically significantly affect rice yield. T-test results for the maintenance labor variable showed a calculated t-value of 2.266, greater than the t-table limit of 1.981. The results show that paddy output was affected by maintenance. Maintenance labor increased rice paddy productivity with a regression coefficient of 0.120. If all other parameters stay constant, 1% maintenance labor boosts rice paddy production by 0.120%. Rice paddy upkeep requires professionals because it influences productivity. This workforce must know rice plant treatment techniques. Research shows maintenance work boosts rice yield (Ridha, 2017; Zarwazi et al., 2017).

After that, the following independent variable, harvest labor, showed an effect that was both positive and substantial. The essential t-value from the t-table was 1.981, but the t-count value of 2.435 turned out to be higher than that. The harvest labor variable revealed a 0.138 regression coefficient, indicating a positive effect on rice output. Increasing Harvest Labor by 1% raises paddy output by 0.138%, assuming that all other circumstances stay constant. Harvesting entails stacking, threshing, cleaning, and transporting. It takes a lot of labor. Research conducted by Ridha (2017) revealed that harvest labor in rice farming activities positively and significantly influenced rice output.

This study also evaluates urea and NPK fertilizers, which boost rice production. Note that the effect is not statistically significant. The critical t-value is 1.981, however, the urea fertilizer variable has a t-count of 0.084. This implies no statistically significant effect on rice paddy productivity. The standardized coefficients test shows a positive variable value. This finding aligns with the outcomes of studies conducted by Nugroho et al. (2021), which concluded that the application of urea fertilizer has a favorable albeit statistically negligible impact on rice yield. Urea fertilizer yields beneficial outcomes when applied by recommendations or requirements. However, excessive use of urea fertilizer might lead to a decline in rice production. In order to preserve the fertility of rice plants, it is important to incentivize farmers to utilize urea fertilizer following the specific characteristics of their field (Congge et al., 2019). The NPK Fertilizer Variable has a t-count value of 0.535, less than the critical t-value of 1.981. This suggests that there is no statistically significant effect on rice production. Nevertheless, the standardized coefficients test indicates that the variable exhibits a positive value. The result of this study corresponds to the research findings of Noor & Isyanto (2021). Puspitasari & Musyafak (2020) showed that NPK fertilizer had a beneficial albeit statistically negligible impact on rice output. The utilization of NPK fertilizer yields negligible impact due to the low subsidies provided to farmers, resulting in a scarcity of this fertilizer.

Finally, a single independent variable negatively affects rice production statistically: the pesticide variable. At 95% confidence, the coefficient value of -0.048 is greater than 0.05. A 1% pesticide increase reduces rice output by 0.048%, according to the pesticide coefficient -0.048. The results of investigations carried out by Moonik et al. (2020) and Panjaitan (2019) are consistent with this finding. These studies have demonstrated that pesticides have a negative influence that is statistically insignificant.

3.4. Coefficient of determination analysis results (R^2)

According to the test data in Table 8, the coefficient of determination (R^2) was 0.733. Seventy-three percent of the difference in production can be explained by the Cobb-Douglas Equation Function model's output factors, as shown in Equation 4. Other factors that weren't considered in the model account for the last 26.7%.

Table 8. The results of the determination coefficient test (R^2)

Model Summary[b]				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	0.856[a]	0.733	0.708	0.33762

3.5. The regressed results, farm managerial and policy recommendations

In the short term, as well as over the course of the long term, a relationship that is both constructive and significant acts as the foundation for the creation of strategies that are efficient management of agriculture. Table 9 contains our recommendations for two different strategies that would support increased rice production. First and foremost, the government must provide assistance to farmers seeking to increase the amount of land under cultivation, as well as guarantee the availability of subsidized fertilizers and make it easier for rice farmers to acquire them. A second need is that agricultural extension officers should provide assistance to farmers in the administration of herbicides in the correct manner.

Table 9. Farm managerial and policy implications

Variables of Dependent and Independent							
A.	Dep. Variables:	Y = Rice Production (kg)					
B.	Indep. Variables	MU	Expected and Regressed Results			Farm Managerial (FM) and Policy Implications (PI)	
	Names of Variable		Expected Results*	Regressed Results*	C	FM Implications	PI
1.	Land Area (LA)	ha	+/Sig.	+/Sig.	Confirmed	Increased use of arable land.	o The government needs to assist farmers in expanding cultivated land and ensure the availability and ease of rice farmers in obtaining subsidized fertilizers.
2.	Seed (SE)	kg	+/Sig.	+/Sig.	Confirmed	Increased use of seeds, especially certified seeds.	
3.	Urea Fertilizer (UF)	kg	+/Sig.	+/Insig.	Unconfirmed	-	
4.	NPK Fertilizer (NF)	kg	+/Sig.	+/Insig.	Unconfirmed	-	
5.	Pesticide (PE)	L	+/Sig.	-/Insig.	Unconfirmed	-	
6.	Herbicide (HE)	L	+/Sig	+/Sig.	Confirmed	Use of pesticides according to dosage.	o Agricultural extension officers need to assist farmers with proper herbicide application.

Table 9. Farm managerial and policy implications (continued)

Variables of Dependent and Independent						
7.	Land Processing Labor (LPL)	man-days	+/Sig	+/Sig.	Confirmed	Increased use of labor in land cultivation, planting, maintenance, and harvesting processes.
8.	Planting Labor (PL)	man-days	+/Sig	+/Sig.	Confirmed	
9.	Maintenance Labor (ML)	man-days	+/Sig.	+/Sig.	Confirmed	
10.	Harvest Labor (HL)	man-days	+/Sig.	+/Sig.	Confirmed	

*MU = Measurement Unit, **Sig. = Significant, Insig. = Insignificant.

4. Conclusions

In light of the findings of this study, it is reasonable to draw the conclusion that the variables of land area, seeds, urea fertilizer, NPK fertilizer, pesticides, herbicides, land processing labor, planting labor, maintenance labor, and harvesting labor, which were investigated with the help of the Cobb-Douglas Function Analysis method, had a significant impact on rice production in the area under investigation. Seven of the ten independent factors positively and significantly impact rice paddy production. These seven factors make up most of the independent variables. The variables include land area, seeds, herbicides, land processing, planting, maintenance, and harvesting labor. Urea fertilizer and NPK fertilizer positively affect rice production; however, their influence is statistically insignificant. However, the variable pesticide had a negligible and non-significant impact on rice paddy output in the studied area. These findings offer important perspectives and a roadmap toward improving rice production management. Hence, in order to enhance rice production in the designated area, rice farmers can optimize rice farm management by augmenting the utilization of land area, seeds, herbicides, land processing labor, planting labor, maintenance labor, and harvesting labor.

Ethical Statement

Ethical approval is not required for this study because the research does not contain Bioethics Act on animals and humans.

Conflict of Interest

The Authors declares that there are no conflicts of interest.

Funding Statement

No financial support was received.

Author Contributions

Muslim Salam: Conceptualization, Methodology, Formal analysis, and Funding acquisition.
Yulistyah Rustan: Data curation, Software, and Original draft preparation.
Rusli M. Rukka: Data curation, Project administration, and Validation.
Rahmadanih: Supervision and Funding acquisition.
Rafiqah Maulıdıyah: Review and editing, Validation, and Resources.
Ahmad Imam Muslım: Review and editing.
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