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Multiple Linear Regression Model for Analyzing the Determinants of Rice Production in Sumatra

Gino Erman Agusta[1*], Adi Dewanto[2], Ningrum Astriawati[3]

[1] Postgraduate Program Department Of Electronics And Informatics Engineering Education, Universitas Negeri Yogyakarta (55281) , Indonesia

[2]Program Department Of Electronics And Informatics Engineering Education, Universitas Negeri Yogyakarta (55281) , Indonesia

[3] Mathematics Lecturer, Sekolah Tinggi Maritim Yogyakarta (55284) Sleman, Indonesia

Corresponding Author: Gino Erman Agusta, UNY, ginoerman.2024@student.uny.ac.id

Abstract

Rice production was a crucial component in maintaining national food security, particularly in Sumatra, which was known as one of Indonesia's rice granaries. This study aimed to analyze the determinant factors affecting rice production in Sumatra using a multiple linear regression approach. Secondary data utilized in this research included 224 observations from eight provinces in Sumatra, covering the period from 1993 to 2020. The independent variables analyzed included Year, Harvest Area, Rainfall, Humidity, and Average Temperature, with Rice Production as the dependent variable. The resulting multiple linear regression model was expressed by the following equation: Rice Production (Y) = −63442498.904 + 32535.572 × Year + 4.622 × Harvest Area + 46.106 × Rainfall − 3993.403 × Humidity − 62701.579 × Average Temperature. Data processing was performed using SPSS software, which included normality testing, linearity testing, simultaneous F-test, and coefficient of determination analysis. The normality test results indicated that the residuals of the model were normally distributed (Asymp. Sig. = 0.227 > 0.05). The linearity test showed a significant linear relationship between the independent variables and rice production, with no deviation from linearity. The regression model demonstrated a coefficient of determination (R^2) value of 0.877, meaning that 87.7% of the variation in rice production could be explained simultaneously by these five variables. Furthermore, the F-test results indicated that the regression model was statistically significant (Sig. = 0.000). These findings suggested that the five variables significantly influenced rice production and could serve as a basis for strategic decision-making in the agricultural sector. The

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resulting model also held the potential as a predictive tool in planning policies to enhance rice production in the future.

Keywords: Multiple Linear Regression, Harvest Area, Rainfall, Humidity, Average Temperature, Rice Production

INTRODUCTION

Multiple linear regression is a powerful statistical technique used to examine the relationship between a single dependent variable and multiple independent variables at the same time (Uyanık & Güler, 2013). In the context of rice production, this model allows for identifying and measuring the influence of several factors affecting rice production, such as agroclimatic conditions (rainfall, humidity, and temperature), harvest area, as well as the development of technology and agricultural policies. By using multiple linear regression, researchers can estimate the contribution of each factor to fluctuations in rice production, providing a clearer picture of the most influential factors that can be used to formulate more accurate and data-driven agricultural policies.

In multiple linear regression analysis, the dependent variable is rice production, which is influenced by the interaction of several contributing factors (Wassmann et al., 2009). The selected independent variables include factors that can affect harvest results, such as the area of land used for rice cultivation, rainfall that directly impacts plant growth, air humidity related to the process of photosynthesis and rice grain formation, as well as the average temperature that affects the duration and quality of rice plant growth (Dubey et al., 2018; Niyomugabo et al., 2024). Additionally, the development of agricultural technology and government policies in managing agriculture can also influence production outcomes, although these factors are more indirect (Tey & Brindal, 2012).

The multiple linear regression model allows researchers to analyze the extent of each factor's contribution to rice production (Yan et al., 2005). Therefore, this model can provide a more comprehensive picture of the variables that significantly affect rice production in a specific region, particularly in Sumatra, which is one of the main rice production centers in Indonesia. Furthermore, this model also enables the analysis of interactions between various factors that could potentially affect production outcomes simultaneously, This is challenging to analyze using other statistical methods that focus solely on the relationship between a single dependent variable and a single independent variable (Hu et al., 2019; Song, 2018; Yang, 2013).

When applying this multiple linear regression model, it's crucial to account for the

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fundamental assumptions, including the existence of a linear relationship between the independent and dependent variables, as well as the absence of multicollinearity among the independent variables (Ahmad et al., 2021; J. H. Kim, 2019; Kyriazos & Poga, 2023). Multicollinearity arises when two or more independent variables exhibit a strong correlation, which can skew regression parameter estimates and diminish the model's accuracy. (Pamujianto et al., 2023). Therefore, selecting appropriate independent variables and checking the model assumptions are crucial for obtaining valid and reliable analysis results.

Additionally, multiple linear regression analysis techniques using statistical software such as SPSS enable researchers to test the statistical significance of each variable (McCormick & Salcedo, 2017). A t-test is used to determine whether the effect of each independent variable on the dependent variable is statistically significant (T. K. Kim, 2015). While an F-test is used to examine whether the regression model as a whole can explain the variation in rice production effectively (Shah et al., 2020). By understanding the simultaneous effects of these variables, agricultural policy planning can be more targeted and evidence-based, ultimately supporting national food security.

Furthermore, the multiple linear regression model developed from this research can be used to formulate predictions for future rice production. By considering historical data and anticipated values of the variables, this model can provide useful prediction scenarios for long-term planning in the agricultural sector. For example, if there are changes in rainfall patterns or average temperatures, this model can predict how such changes will affect future rice production, allowing governments and farmers to take necessary adaptive measures, such as changing planting patterns or selecting rice varieties that are more resilient to climate change.

Ultimately, this research aims to significantly enhance the understanding of the factors influencing rice production in Sumatra, providing a solid foundation for developing more effective and adaptive agricultural policies in response to changing environmental conditions. Furthermore, the findings from this multiple linear regression model are intended to serve as a valuable reference for policymakers, agricultural practitioners, and researchers working to improve rice production and ensure Indonesia's food security amid global climate change and shifting socio-economic dynamics.

METHOD

Research Design

This research uses a quantitative approach with multiple linear regression analysis to identify the influence of several factors on rice production in Sumatra. The research design is

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descriptive-analytical, aiming to describe the relationships between variables that affect rice production and to examine the contribution of each variable to rice production results.

Population and Sample

The population in this study consists of rice production data from the Sumatra region from 1993 to 2020. The sample for this research is drawn from secondary data obtained from the Central Statistics Agency (BPS) and related agricultural reports. Eight provinces are included in the sample: Aceh, North Sumatra, West Sumatra, Riau, Jambi, South Sumatra, Bengkulu, and Lampung. The variables analyzed include Year (period), Harvest Area (hectares), Rainfall (mm), Humidity (%), and Average Temperature (°C), based on data available from each province in Sumatra.

Research Variables

The variables used in this study are divided into two types:

- **Dependent Variable**: Rice Production (in tons) (Y)
- **Independent Variables**:

a. Year (period, to examine the impact of changes over time on rice production) (X1)
b. Harvest Area (in hectares, to assess the effect of land area on rice production) (X2)
c. Rainfall (in mm, to evaluate the effect of rainfall conditions on agricultural output) (X3)
d. Humidity (percentage/ %, to assess the effect of air humidity on rice production) (X4)
e. Average Temperature (in degrees Celsius/ ^{0}C, to measure the impact of temperature on rice production) (X5)

Data Collection Techniques

The data used in this study are secondary data obtained from the Central Statistics Agency (BPS) of Sumatra, local agricultural offices, and annual agricultural production reports. The data used range from 1993 to 2020, including information on rice production, harvest area, rainfall, humidity, and average temperature for each province in Sumatra.

Data Analysis Techniques

Data analysis was performed using SPSS (Statistical Package for the Social Sciences) software. The steps of analysis are as follows:

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a. **Normality Test**: This test is conducted to ensure that the data used meets the normality assumption required for regression analysis. To test whether the residuals in the regression model are normally distributed, a One-Sample Kolmogorov-Smirnov Test is used. This test is appropriate for large sample sizes (n > 50), making it suitable for the data in this study, which consists of 224 observations. Testing is performed through SPSS by selecting unstandardized residuals as the variable to be tested. The test results are then compared with a significance level (α) of 0.05. The decision criteria are:

- If the Asymp. Sig. (2-tailed) > 0.05, the residuals are considered to be normally distributed.
- If the Asymp. Sig. (2-tailed) ≤ 0.05, the residuals are considered not to be normally distributed.

b. **Linearity Test**: This test is conducted to determine whether there is a linear relationship between the dependent variable and each independent variable in the regression model. This is an important part of validating the assumptions of multiple linear regression. The method used is the "Test for Linearity" available in SPSS. A relationship is considered linear if there is a significant linear relationship and no significant deviations from linearity.

c. **Simultaneous F-Test**: The simultaneous F-test is used to test whether all independent variables together have a significant effect on the dependent variable (in this case, rice production) (Dekanawati et al., 2023). This test examines the overall significance of the regression model. It tests the null hypothesis that all regression coefficients for the independent variables are zero (no effect). If the p-value for the F-test is less than 0.05, the null hypothesis is rejected, indicating that the regression model has a significant effect on rice production. Additionally, a t-test is used to test whether each regression coefficient (independent variable) individually has a significant effect on the dependent variable (rice production).

d. **Multiple Linear Regression**: To examine the relationship between the dependent variable (rice production) and the independent variables (year, harvest area, rainfall, humidity, average temperature), multiple linear regression is used. Multiple linear regression is a statistical technique that allows the analysis of the influence of more than one independent variable on a dependent variable simultaneously (Astriawati, 2016). The general form of a multiple linear regression model with p independent variables can be written as follows:

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$$Yi = \beta 0 + \beta 1\ X1i + \beta 2\ X2i + ... + \beta p\ Xpi + \varepsilon i \quad \text{.....(1)}$$

Where:

Yi	=	the value of the dependent variable (e.g., rice production) for observation i, for i = 1, 2, ..., n.
β0	=	constant (intercept), the value of Y when all independent variables X1, X2, ..., Xp are zero.
β1, β2, ..., βp	=	regression coefficients representing the influence of each independent variable on the dependent variable.
X1i, X2i, ..., Xpi	=	values of independent variables for observation i.
Ei	=	error term or disturbance, representing the difference between the observed

In this study, rice production (Y) is influenced by five factors: year (X1), harvest area (X2), rainfall (X3), humidity (X4), and average temperature (X5). Multiple linear regression is chosen because it allows for identifying and measuring the contribution of each independent variable to changes in rice production. Using this model, we can obtain coefficients that describe the direct influence of each factor on rice production, as well as interactions between variables that may affect prediction results.

e. **Coefficient of Determination (R^2) Analysis**: The coefficient of determination (R^2) is a statistical metric used in regression analysis to evaluate how effectively the independent variables in a model account for the variability in the dependent variable. R^2 values range from 0 to 1, where values nearer to 1 suggest that the model provides a better explanation of the data's variation.

d Rice Production Prediction

Based on the obtained regression model, rice production in Sumatra will be predicted for future years by inputting values for variables such as year, harvest area, rainfall, humidity, and average temperature. Prediction scenarios will be performed by considering different conditions, such as hotter or colder weather, as well as variations in rainfall and humidity.

RESULTS AND DISCUSSION

Normality Test

To confirm that the residuals follow a normal distribution, we applied a One-Sample Kolmogorov–Smirnov (K-S) test. The results of the test were presented in Table 1 below.

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Table 1. One-Sample Kolmogorov-Smirnov Test

One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residual
N		224
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	407690.82509497
Most Extreme Differences	Absolute	.200
	Positive	.200
	Negative	-.111
Test Statistic		.200
Asymp. Sig. (2-tailed)		.227[c]

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

The Asymptotic Significance (2-tailed) value obtained from the One-Sample Kolmogorov-Smirnov Test was 0.227, which was greater than the significance level of 0.05. Therefore, it was concluded that the residuals of the regression model were normally distributed in a statistical sense. Consequently, the null hypothesis (H_0), which stated that the residuals followed a normal distribution, was not rejected. This result indicated that the assumption of normality in the multiple linear regression model was satisfied, thus enhancing the model's credibility in clarifying how the independent variables relate and rice production in Sumatra.

Linearity Test

The linearity test was performed to verify whether the independent variables maintain a linear relationship with the dependent variable (rice production) was linear. This test was performed using the Test for Linearity between each independent variable and rice production. The output was presented in Table 2 in the form of an ANOVA test.

Table 2. ANOVA Test

ANOVA Table						
		Sum of Squares	Df	Mean Square	F	Sig.
Y * X1	Linearity	10021041549707.460	1	10021041549707.460	7.158	.008

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	Deviation from Linearity	16352230068925.074	26	628931925727.888	.449	.991
Y * X2	Linearity	294992230321903.700	1	1346996485488.145	.930	.001
	Deviation from Linearity	5794781117905.201	219	1448695279476.300	.931	.627
Y * X3	Linearity	533842402912.571	1	533842402912.571	.368	.005
	Deviation from Linearity	294458387918991.100	218	1350726550087.115	.932	.629
Y * X4	Linearity	823248787396.047	1	823248787396.047	.522	.006
	Deviation from Linearity	230624354591172.160	178	1295642441523.439	.822	.812
Y * X5	Linearity	509569172848.970	1	509569172848.970	.346	.049
	Deviation from Linearity	170660253514863.300	134	1273583981454.204	.865	.778

Decision Criteria for the Linearity Test

For the Linearity Test, the rule of thumb was: when the p-value listed under “Linearity” fell below 0.05, the link between the independent and dependent variables was deemed significantly linear. If the significance value under Deviation from Linearity was greater than 0.05, it indicated that there was no significant deviation from linearity. Based on Table 2, the results of the linearity test for each independent variable were summarized in Table 3 as follows:

Table 3. Linearity Test Results for Each Independent Variable

Variable Independent	Sig. Linearity	Sig. Deviation from Linearity	Conclusion
Year	0.008	0.991	Linear and no deviation
Harvested Area	0.001	0.627	Linear and no deviation
Rainfall	0.005	0.629	Linear and no deviation
Humidity	0.006	0.812	Linear and no deviation
Average Temperature	0.049	0.778	Linear and no deviation

The regression model yielded an R-value of 0.936, indicating a very strong relationship between the independent variables (Year, Harvested Area, Rainfall, Humidity, and Average

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Temperature) and the dependent variable (Rice Production). The R Square value of 0.877 suggested that 87.7% of the variation in rice production could be explained by the five independent variables. This demonstrated that the constructed model was effective in explaining the variability in rice production. Furthermore, the Adjusted R Square value was 0.874, implying that the regression model remained robust and stable even when the number of independent variables was reduced or modified. This supported the reliability of the model for future prediction purposes.

Simultaneous F-Test

A simultaneous F-test was applied to determine whether the five predictors—Year, Harvested Area, Rainfall, Humidity, and Average Temperature—jointly exert a statistically significant impact on the dependent variable, Rice Production, within the multiple-linear-regression framework. The ANOVA results supporting this F-test are summarized in Table 4.

Table 4. ANOVA Output

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	263721778062552.900	5	52744355612510.586	310.217	.000[b]
	Residual	37065233377255.960	218	170024006317.688		
	Total	300787011439808.900	223			

a. Dependent Variable: Y

b. Predictors: (Constant), X1,X2,X3,X4,X5

Based on Table 4, The ANOVA output for this test showed a Sum of Squares for Regression of 263721778062552.900, with degrees of freedom (df) equal to 5, corresponding to the number of independent variables in the model. The Mean Square for Regression was calculated as 52744355612510.586 by dividing the Sum of Squares by its degrees of freedom. The F-value obtained was 310.217, indicating the ratio of variance explained by the regression model to the unexplained variance (residual). The p-value (Sig.) was 0.000, which is below the standard significance threshold of 0.05. This result suggests that the model is statistically significant. In other words, the null hypothesis—stating that all regression coefficients are zero—was rejected. The very small p-value (0.000) confirmed that the regression model had a significant impact on rice production, the dependent variable.

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Multiple Linear Regression Model and Interpretation

The multiple linear regression model (equation) was derived from the coefficients presented in Table 5 below.

Table 5. Coefficients Output

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-63442498.904	6976507.137		-9.094	.000
	X1	32535.572	3421.354	.227	9.510	.000
	X2	4.622	.120	.926	38.551	.000
	X3	46.106	27.614	.041	1.670	.096
	X4	-3993.403	6209.345	-.017	-.643	.521
	X5	-62701.579	26022.443	-.065	-2.410	.017

a. Dependent Variable: Production

From Table 5 above, the multiple linear regression model (equation) was estimated as follows:

$$\mathbf{Y=-63442498.904+ 32535.572X_1+ 4.622X_2 +46.106X_3 -3.993.403X_4-62701.579X_5}\text{.....2)}$$

Where:

Y = Rice production (tons)

X_1 = Year (Period)

X_2 = Harvested Area (hectares)

X_3 = Rainfall (mm)

X_4 = Humidity (percentage %)

X_5 = Average Temperature (°C)

Interpretation of the Coefficients:

1. **Constant (–63442498.904):** This is the baseline rice production value when all independent variables (year, harvested area, rainfall, humidity, and temperature) are zero. Although physically impossible (as there can be no "year 0"), this constant is mathematically necessary as the starting point for the predictive model calculations.

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2. **Year (X1), Coefficient: +32535.572.** This indicates that for each increase of one year (e.g., from 2022 to 2023), rice production is expected to increase by 32535.572 tons, assuming other variables remain constant. This reflects the potential growth in production over time, which might be influenced by advancements in technology, agricultural policies, or improved efficiency.
3. **Harvested Area (X2), Coefficient: +4.622.** For every 1-hectare increase in harvested area, rice production is expected to increase by 4.622 tons, assuming other factors remain constant. This shows a positive relationship between the area planted and production, which is typical in agricultural practices.
4. **Rainfall (X3), Coefficient: +46.106.** A 1 mm increase in rainfall will lead to an increase in rice production by 46.106 tons, assuming all other variables are constant. This suggests that adequate rainfall is crucial for rice growth.
5. **Humidity (X4), Coefficient: –3993.403.** An increase of 1% in air humidity will decrease rice production by 3993.403 tons, assuming all other variables remain constant. High humidity can create conditions conducive to plant diseases or weed growth, which may negatively affect rice yield.
6. **Average Temperature (X5), Coefficient: –62701.579.** A 1°C increase in average temperature will reduce rice production by 62701.579 tons, assuming other factors remain constant. Excessive heat can accelerate evapotranspiration and cause heat stress in plants, leading to reduced yield.

In summary, rice production tends to increase over time, with larger harvested areas and sufficient rainfall. However, production will decrease if air humidity is too high or if the average temperature rises significantly. This model is useful for forecasting future rice production and can help policymakers in developing strategies for climate adaptation, planting schedule management, and land and water management.

Analysis of the Coefficient of Determination (R^2)

The coefficient of determination (R^2) was a statistical measure used to indicate how well the independent variables in a regression model explained the variation in the dependent variable. Based on the Model Summary table, the results were as shown in Table 65 below:

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Table 6. Model Summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.936[a]	.877	.874	412339.67347

a. Predictors: (Constant), Suhuratarata, Tahun, LuasPanen, Curahhujan, Kelembapan

b. Dependent Variable: Produksi

From Table 6 above, it was shown that R (0.936) indicated a very strong relationship between the independent variables and rice production. The R Square (R^2) value of 0.877 indicated that 87.7% of the variation in rice production could be explained by the independent variables in the model, namely Year, Harvest Area, Rainfall, Humidity, and Average Temperature. Meanwhile, the remaining 12.3% was explained by other factors outside the model that were not included in this analysis.

Rice Production Prediction

Based on the multiple linear regression model that accounted for variables such as harvest area, rainfall, humidity, and average temperature, rice production in 2026 was predicted to be approximately 15796239 tons.This model considered important factors such as a larger harvest area (650 hectares), sufficient rainfall (250 mm), 80% humidity, and an average temperature of 30°C. Under these conditions, rice production in 2026 was expected to experience a significant increase compared to previous years.

The increase in harvest area and adequate rainfall played a positive role in boosting production. The larger the area harvested, the greater the yield, while sufficient rainfall supported the growth of rice plants. However, high humidity and temperature could reduce production because excessive humidity increases the risk of plant diseases, while higher temperatures could cause thermal stress on rice plants, hindering their growth.

With this prediction, farmers and related parties could use this information to plan better agricultural strategies, such as managing irrigation, setting optimal planting schedules, and anticipating potential extreme weather risks. With proper management, rice production in 2026 could achieve more optimal results, ensuring better food security in the future.

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CONCLUSION

This study utilized a quantitative approach with multiple linear regression analysis to examine the impact of five independent variables—Year, Harvest Area, Rainfall, Humidity, and Average Temperature—on rice production in Sumatra from 1993 to 2020. Data from the Central Bureau of Statistics (BPS) and other related institutions, covering eight provinces in Sumatra, were analyzed using SPSS software. Testing included normality, linearity, and the simultaneous F-test, with results showing normally distributed residuals, linear relationships between the variables, and a significant overall model (F-value = 310.217, $p < 0.05$). The resulting regression equation indicated that rice production increased over time with larger harvest areas and sufficient rainfall, but declined with higher humidity or increased average temperatures. The resulting multiple linear regression model was expressed by the following equation: Rice Production (Y) = −63442498.904 + 32535.572 × Year + 4.622 × Harvest Area + 46.106 × Rainfall – 3993.403 × Humidity – 62701.579 × Average Temperature. The model's R^2 value of 0.877 suggested that 87.7% of the variation in rice production could be explained by the independent variables, while the remainder was influenced by other factors.

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