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Mathematical Model of Paddy Production using Cobb Douglas Method Based On Weather Factors

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ABSTRACT

This research was conducted to model paddy production based on weather factors. This needs to be done to predict crop yields and regulate paddy cropping patterns. In setting the cropping pattern, the weather is selected which consists of temperature, wind speed, and rainfall, as a variable factor of production. Meanwhile, other factors (such as fertilization, sunshine, air humidity, etc.) are assumed to be in catteries paribus conditions. The research method used is a mixed method between qualitative methods which are descriptive details and quantitative methods which are based on weather data and Paddy's harvest data. The aim of this research is to analyze the influence of weather on paddy production results. Analysis is done to get the production function. Parameters are estimated using the Ordinary Least Square (OLS) method by minimizing the sum of squared errors. Based on data analysis, a correlation of 0.899 was obtained with a standard error of .051665515. the results of model testing also show significant results with the F statistic obtained at 33.98 with a p-value of 0.028 which is less than 5%. So it can be concluded that there is a significant relationship between weather and paddy productivity. In such a way that the weather can be used as a reference in determining the prediction of loss risk and paddy production. This model can also be recommended for further research, namely to determine insurance losses that may arise when extreme weather events occur.

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A. INTRODUCTION

Mathematics as a tool to solve real problems (Felipe & Adams, 2005). Both in engineering and economics. In this paper, mathematics is used to solve agricultural problems (Ariyanti et al., 2020). The problems discussed were the results of review papers and observations in the field (Riaman et al., 2022a). The observed problem is paddy production. Paddy production is influenced by various factors (Riaman et al., 2022b). These factors include fertilization, irrigation, pest disturbance, weather changes, and others. This modelling discusses changes in weather on paddy production. This factor was chosen with the thought that the weather cannot be controlled by humans. While other factors can be controlled. The average weather conditions that occur with wide area coverage, long time, topography which is influenced by the distance from the sun to the earth. The position of the sun towards the earth also causes climate differences, the area around the equator has a tropical climate, the area between 23.5°C to 66.5ºC north latitude and south latitude has a subtropical climate, the rest has a polar climate (Riaman et al., 2022b), (Zhang et al., 2017).

This research is a study conducted to analyze the rice production model. The production model is assumed to be influenced by weather variables, which consist of rainfall, wind speed, and temperature. Preliminary research was carried out in detail through literature research conducted by Riaman et al. (2022a), through Mapping in the Topic of Mathematical Model in Paddy Agricultural Insurance Based on Bibliometric Analysis: A Systematic Review Approach. The results of this study are the main studies that form the basis of thought. The results of this study obtained several studies related to the topic, including the research of Pribadi et al. (2019), which discusses the influence of climate on rice production using the Robust model of the combination of expectations and conditional value-at-risk from paddy farming risk management method based on climate variability. The results show that climate change has a positive effect on rice production. Research conducted by Riaman et al. (2022b) also discusses Mathematical Modelling for Estimating the Risk of Rice Farmers' Losses Due to Weather Changes using VaR. The result is that rice plants have a risk of loss in the form of reduced yields caused by weather changes. Research by Riaman et al. (2021a), Singh & Agrawal (2019), and Sun et al. (2018) also discusses the decision making for agricultural risk assessment: An application of extreme value theory. This study investigates decision making for agricultural (climate variable) risk assessment. The results found that the highest risk of loss occurred in November, December, January, February and March.

Based on the results of the literature study above, in this paper the authors formulate and prove mathematically a rice production model as a development from the research of Entezari et al. (2021) which discusses Malaysia's Agricultural Production Dropped and the Impact of Climate Change: Applying and Extending the Theory of Cobb Douglas Production. This study applies and expands the theory of the Cobb Douglas production function to examine the impact of climate change and economic factors on agricultural production. Short-term rainfall, temperature, employment, and trends are statistically significant for determining short-term production growth. The model was developed based on the hypothesis that production increases with increasing rainfall, wind speed and temperature. However, if this increase is not limited, it can reduce production (Riaman et al., 2021b).

Based on the state of the art above, there is a research gap, which is that no research has been found that addresses the convergence of production quantities when the weather improves. In previous research there was no discussion specifically modelling the production function. Previous studies only used existing models and then applied them to the data. The problem with this research topic is that the production function is assumed to be similar to the Cobb-Douglas model. The research was conducted by collaborating on the VaR risk model, the extreme value problem, and the Cobb-Douglas model. The discussion is carried out on mathematical modelling. The rationale was obtained from previous studies which were processed and collaborated to obtain a mathematical model. The results of this hypothesis are stated in proposition 1 and proposition 2. These propositions have been proven mathematically. The urgency of this problem is solved to get the right solution in predicting the amount of rice production caused by weather factors, assuming other conditions are cateris paribus. The results of this forecast can be used as a benchmark or study material to determine policies in the rice production process.

B. METHODS

1. Object of Research

This study uses weather data consisting of rainfall, wind speed, and air temperature data collected from geophysical and meteorological data. Meanwhile, harvest data was obtained and processed from the Central Bureau of Statistics and the West Java Agriculture Service. The data used are data from 2010 to 2022. Considering that the weather data in Indonesia, especially the Bandung Regency, West Java, is different every month, the data presentation is grouped by month. For wind speed data, maximum data, minimum data, and average data are measured. Likewise for air temperature data. Meanwhile, paddy productivity data is calculated on average every month.

2. Research Stages

The stages carried out in this study are as follows:

a. Collecting daily rainfall data in Bandung Regency from 2010 to 2022 obtained from online data from the Meteorology, Climatology and Geophysics Agency. Meanwhile, harvest data was obtained and processed from the Central Bureau of Statistics and the West Java Agriculture Service.
b. Determine the proposition as basic to determine the weather effect using the Cobb-Douglas Model (Sukono et al., 2019). (1) Determination Descriptive Statistics for Regression Model; (2) Determination of Correlation of Research Variables; (3) Parameter Estimation; (4) Determination of the model; (5) Analysis of Variance for the model; (6) Statistical testing.
c. Determine the final model of Paddy Production.

3. Cobb and Douglas Model

In general, crop yields consist of trend outputs, weather outputs, and random error terms. Output trends are determined by factors such as productivity and agricultural technology. Weather output is influenced by weather factors such as drought, flood, rain-fall and temperature (Elavarasan & Durairaj Vincent, 2020). Agriculture is a business that involves the production process to get crops. The production process is influenced by several things, namely business capital in the form of labour, fertilizers, pesticides, and weather in the form of rainfall, wind speed and temperature (Djomo & Sikod, 2012). In economics, the Cobb-Douglas model is referred to as a production function, namely a function that shows the relationship between physical output (output) and factors of production (input). All resources are assumed to be finite, but weather has unlimited characteristics, which cannot be controlled by humans. Meanwhile, the Cobb-Douglas production function discussed in this paper is a side view of model analysis (Sun et al., 2018), (Grimm, S.S.; Paris, Q; Williams, 1087), (Kumbhakar, 2021). While the production output is modified into a production return model. However, this study only discusses that rice production is affected by rainfall, wind speed and temperature. Other factors are assumed to be constant (catteries paribus). This research discusses the relationship between rice productivity as the dependent variable and working capital in the form of rainfall, wind speed, and temperature as independent variables. There are several methods that can be used for analysis, but considering that models related to production are usually nonlinear functions, the relationship between factors of production and rice productivity in this case is assumed to follow the Cobb-Douglas model. In this study developed from Felipe & Adams (2005), Vîlcu (2011), Wang & Fu (2013), Sukono et al. (2019), Entezari et al. (2021), and Riaman et al. (2022b) formulated the propositions of the Cobb-Douglas production model for rice production. This proposition is based on the hypothesis: production increases with increasing rainfall, wind speed, and temperature. However, if this increase is not limited, it can reduce production output.

This proposition is based on the hypothesis: production increases as rainfall, wind speed and temperature increase. However, if this increase is not limited, it can reduce production results. In this study, only three data points were used (rainfall, wind speed and temperature), while other weather components, such as air humidity and duration of sunshine were not included. The reason why these two data are not used is that firstly air humidity has been studied by Riaman et al. and this variable has a linear relationship with rainfall and temperature. Meanwhile, the duration component of sunshine is assumed to be adequate, because the data was taken in an area with fairly uniform solar radiation. Cobb Douglas production function (Cobb and Douglas, 1928) in (Entezari et al., 2021) is a popular economic theory widely adopted to explain a particular physical product that can be produced by two or more physical inputs (such as labour and capital) quantity as in Equation (1),

$$Y = f(A, L, K) = AL^{\alpha}K^{\beta}, \tag{1}$$

where, Y represents production output; $\boldsymbol{A}, \boldsymbol{L}, \textbf{and } \boldsymbol{K}$ denote productivity from total input, physical labour, and physical capital, respectively. The parameters α and β are the output elasticity of capital input and labour input. However, the Cobb Douglas production function does not include the effects of weather as a determinant of agricultural production (Hadjicostas & Soteriou, 2010). Therefore, the variable weather changes as an important factor to expand the Cobb Douglas production theory in this study. The Cobb-Douglas concept can be developed to model rice productivity by modifying several independent variables. For example, the Cobb-Douglas function of the form of equation (1) is *modified* into the Cobb-Douglas concept with elasticity developed by referring to (Riaman et al., 2022b) and (Riaman et al., 2021a), in the following forms,

$$Q = \beta X_1^{\alpha_1} X_2^{\alpha_2} X_3^{\alpha_3} e^{u}, \tag{2}$$

the power in equation (2) represents the elasticity of production, where the scale of business satisfies the property that $\sum_{i=1}^{3} \alpha_i = 1$. If there is variable I as an index that affects production elasticity, then elasticity can be expressed in the form $\boldsymbol{\alpha_i} = \boldsymbol{\alpha_i}(I)$. Equation (2) can be written refers to (Hadjicostas & Soteriou, 2010) modified into equation (3)

$$Q = \beta X_1^{\alpha_1(I)} X_2^{\alpha_2(I)} X_3^{\alpha_3(I)} e^{u}, \tag{3}$$

where $\boldsymbol{Q}$ represents the amount of paddy production/output per year per planting season (kg), $\boldsymbol{\beta}$ represents production under normal conditions, $\boldsymbol{X_1}$ represents rainfall (mm), $\boldsymbol{X_2}$ represents temperature (°C), $\boldsymbol{X_3}$ represents wind speed (m/s), and u denotes the estimated residual of the model and error correction term. Equation (3) can be written in linear logarithmic form like equation (4):

$$\ln Q = \ln\beta + \alpha_1(I)\ln X_1 + \alpha_2(I)\ln X_2 + \alpha_3(I)\ln X_3 + u, \tag{4}$$

assuming that α_i is linear in the parameters and production function discussed in this study is homogeneous ($\alpha_i(I) = \alpha_i$), so it can be estimated using Ordinary Least Square (OLS) (Chen et al., 2015). Parameter estimation and testing process is carried out through the principle of multiple linear regression models. The values of $\boldsymbol{\alpha_i}$ in the Cobb-Douglas equation are respectively the input factor elasticities of $\boldsymbol{X_1}, \boldsymbol{X_2}$, and $\boldsymbol{X_3}$. The sum of the elasticity factors shows the additional level of yield with the following conditions (Ghoshal & Goswami, 2017).

a. If $\sum_{i=1}^{3} \boldsymbol{\alpha_i} = \mathbf{1}$, there is a constant addition of output at the production scale. Constant return to scale, which is a condition where doubling the input by the company will give the same doubling of output (production results).
b. If $\sum_{i=1}^{3} \boldsymbol{\alpha_i} > \mathbf{1}$, there is an increasing return to scale. The scale of results increases (increasing return to scale), which is a condition where the scale of doubling input results in a change in the scale of doubling output that is larger. Suppose the input used is doubled, in fact the output has tripled or quadrupled.
c. If $\sum_{i=1}^{3} \boldsymbol{\alpha_i} < \mathbf{1}$, there is an additional decreasing return to scale. Return to scale decreases (return to scale) that is when the company doubles the inputs used, but the resulting output scale is smaller than the input doubling scale.

The Cobb-Douglas production model in Equation (4) follows the law of diminishing returns, meaning that initially any increase in the value of a factor of production will increase productivity to normal limits, but if additional productivity exceeds normal limits, productivity will decrease (Yingjun & Yuecheng, 2016).

C. RESULT AND DISCUSSION

The results of this study are divided into two parts, which consist of the results of the analysis of mathematical models and the results of data analysis. The results are described as follows.

1. Mathematical Modelling

Based on the results of the literature review, paddy productivity is influenced by weather factors. The dominant weather factors affecting paddy production are rainfall, wind speed and temperature. Based on the research results of (Riaman et al., 2022b) if rainfall, temperature, and wind speed increase, paddy production increases to a certain extent. Excessive increase actually lowers the yield of paddy production. Based on these results, it can be modeled using the Cobb-Douglas model approach. The Cobb Douglas concept can be developed for the model of paddy productivity by modifying several independent variables. For example, the Cobb Douglas function of equation (3) is modified into a form with elasticity developed into the form of equation (5). The effect of variable I can be tested if in the model of equation (5). Equation (5) is called the modified Cobb-Douglas mixture production function. The function in equation (3) is divided into two parts, as written in equation (5)

$$Q^* = \begin{cases} \beta X_1^{\tilde{\alpha}_1(I)} X_2^{\tilde{\alpha}_2(I)} X_3^{\tilde{\alpha}_3(I)};\ \sum_{i=1}^{3} \alpha_i > 1 \\ \beta X_1^{\alpha_1(I)} X_2^{\alpha_2(I)} X_3^{\alpha_3(I)}, \sum_{i=1}^{3} \alpha_i < 1 \end{cases}, \tag{5}$$

where β represent the productivity in ceteris paribus condition. Ceteris paribus means that the assumption taken is to ignore various known and unknown factors that can affect the relationship between production and the quantity of production factors. Based on equation (5), it can be proved that two propositions are as follows.

Proposition 1. *If the sum of* $\sum_{i=1}^{3} \alpha_i > 1$ *and* $\alpha_i > 0$, *then* $\lim_{\mathbf{x}\to\mathbf{1}} Q^*(\mathbf{x}) = \beta$ ($\mathbf{x}$ = *vector*)

Proof. Consider the mixed Cobb-Douglas production function, which is modified as follows

$$Q^*(\mathbf{x}) = \begin{cases} \beta X_1^{\tilde{\alpha}_1(I)} X_2^{\tilde{\alpha}_2(I)} X_3^{\tilde{\alpha}_3(I)};\ \displaystyle\sum_{i=1}^{3} \alpha_i > 1 \\ \beta X_1^{\alpha_1(I)} X_2^{\alpha_2(I)} X_3^{\alpha_3(I)}, \displaystyle\sum_{i=1}^{3} \alpha_i < 1 \end{cases}$$

is a multi-value function, where for the first case $\sum_{i=1}^{3} \alpha_i > 1$ and $\alpha_i > 0$, then the function used$Q^*(\mathbf{x}) = \beta X_1^{\tilde{\alpha}_1(I)} X_2^{\tilde{\alpha}_2(I)} X_3^{\tilde{\alpha}_3(I)}$

$$\begin{aligned} \lim_{\mathbf{x}\to\mathbf{1}} Q^*(\mathbf{x}) &= \lim_{\mathbf{x}\to\mathbf{1}} \beta X_1^{\tilde{\alpha}_1(I)} X_2^{\tilde{\alpha}_2(I)} X_3^{\tilde{\alpha}_3(I)} \\ &= \lim_{\mathbf{x}\to\mathbf{1}} \beta X_1^{\tilde{\alpha}_1(I)} X_2^{\tilde{\alpha}_2(I)} X_3^{\tilde{\alpha}_3(I)} \end{aligned}$$

Limit $\lim_{\mathbf{x}\to\mathbf{1}} Q^*(\mathbf{x}) = \beta$, meaning that $Q^*(\mathbf{x})$ can made arbitrarily close to β if $\mathbf{x}$ if x is close enough to 1. Vector β is called the limit of $Q^*(\mathbf{x})$ at 1, if for every $\varepsilon > 0$, there exist $\delta > 0$, so

$$0 < |\mathbf{x} - 1| < \delta \Rightarrow ||Q^*(\mathbf{x}) - \beta|| < \varepsilon$$

Suppose for every $\varepsilon > 0$, define $\delta = f(\varepsilon) = \frac{\varepsilon}{\beta}$
such that for every $\mathbf{x}$, the expression $0 < |\mathbf{x} - 1| < \delta$, then

$$\begin{aligned} ||Q^*(\mathbf{x}) - \beta|| &= ||\beta X_1^{\tilde{\alpha}_1(I)} X_2^{\tilde{\alpha}_2(I)} X_3^{\tilde{\alpha}_3(I)} - \beta|| = ||\beta(X_1^{\tilde{\alpha}_1(I)} X_2^{\tilde{\alpha}_2(I)} X_3^{\tilde{\alpha}_3(I)} - 1)|| \\ &= \beta||X_1^{\tilde{\alpha}_1(I)} X_2^{\tilde{\alpha}_2(I)} X_3^{\tilde{\alpha}_3(I)} - 1|| \leq ||\beta(X_1^{\tilde{\alpha}_1(I)} - 1)(X_2^{\tilde{\alpha}_2(I)} - 1)(X_3^{\tilde{\alpha}_3(I)} - 1)|| \\ &= \beta \frac{\varepsilon}{\beta} = \varepsilon \end{aligned}$$

Limit $\lim_{\mathbf{x}\to\mathbf{1}} Q^*(\mathbf{x})$ can be calculated through the limit of each component. □

Proposition 1, mathematically, indicates the first case for equation (5). This indicates that if the input conditions are at ceteris paribus, paddy production will only receive production capital. This means that paddy production does not make a profit. Paddy production is only to replace production costs. Meanwhile, for the second case, the proposition 2, is obtained for the number of alphas smaller than 1 or $\sum_{i=1}^{3} \alpha_i < 1$ and positive alpha, then the total production will go to zero.

Proposition 2. *If* $\sum_{1=1}^{3} \alpha_i < 1$ *and* $\alpha_i < 0$, *then* $\lim_{\mathbf{x}\to\infty} Q^*(\mathbf{x})$=0

Proof. For case $\sum_{i=1}^{3} \alpha_i < 1$ and $\alpha_i < 0$, then

$$Q^*(\mathbf{x}) = \beta X_1^{\alpha_1(I)} X_2^{\alpha_2(I)} X_3^{\alpha_3(I)}$$
$$\lim_{\mathbf{x}\to\infty} Q^*(\mathbf{x}) = \lim_{\mathbf{x}\to\mathbf{1}} \beta X_1^{\alpha_1(I)} X_2^{\alpha_2(I)} X_3^{\alpha_3(I)}$$

$\lim_{\mathbf{x}\to\infty} Q^*(\mathbf{x})$=0 or $Q^*(\mathbf{x})$ approaches 0, for $\mathbf{x}$ approaches infinity, if for every $\varepsilon > 0$, we can define $M > 0$, such that $||Q^*(\mathbf{x})|| < \varepsilon$, when $|x| > M$. □

Proposition 2, shows the case, if the weather conditions are not controlled, it will cause production to go to zero. This means that paddy yields will go to zero. Paddy farmers suffered huge losses. Losses, where production costs are also not returned. From the two propositions 1 and proposition 2, that each variable value will represent the partial elasticity of each independent variable with a unique production scale. While the values α_i in the Cobb-Douglas equation are respectively the elasticity of the input factors X_1, X_2, and X_3. In the Cobb-Douglas equation the sum of the elasticity of the input factors can show an additional level of yield.

2. Data Analysis

A summary of the data used is presented in Table 1. The data obtained within a period of approximately 14 years, were processed. In this paper, data analysis of climate variables on paddy production (Q) is carried out as the dependent variable. Weather variables, which consist of wind speed (X_1), average temperature (X_2), and rainfall (X_3), which then act as independent variables. The summary results of data processing are presented in Table 1 in Appendix 1. This section contains data sources, research variables, sampling techniques, data collection methods and data analysis methods. The data analysis method used must be described in detail.

In this paper, data analysis of climate variables on paddy production (Q) is carried out as the dependent variable. Weather variables, which consist of wind speed (X_1), average temperature (X_2), and rainfall (X_3), which then act as independent variables. The data is processed using computer software. The principle used to estimate the regression parameters is to use the principle of the least square method, by first linearizing the model using a natural logarithm transformation. Data processing starts from determining descriptive statistics which aim to describe the relationship between paddy productivity data and weather temperature. The data analyzed are the variables used in this study, namely production per planting season and weather dynamics (rainfall, temperature, and wind speed). The data processed in this study is the result of paddy productivity in rainfall, temperature, and temperature in Bandung Regency, West Java. The results of the data description, which show descriptive statistics are presented in Table 1.

Table 1. Descriptive Statistics For Regression Model

	Mean	Std. Dev	Max	Min	*n*
Q	6.30	1.06	6.74	5.78	40
X_1	3.31	1.27	5.06	2.13	40
X_2	27.96	1.01	28.61	27.44	40
X_3	79.65	1.22	117.87	58.66	40
$\ln Q$	1.831330	.0597251	1.908653	1.754923	40
$\ln X_1$	1.329058	.3476157	1.621959	0.756122	40
$\ln X_2$	3.284493	.0116632	3.353931	3.312002	40
$\ln X_3$	4.421620	.1197856	4.769582	4.071758	40

Table 1, presents the logarithm of the data mean, standard deviation, maximum value, and minimum value. The correlation between variables is calculated to identify the relationship between independent variables and dependent variables or between independent variables with one another. The results are presented in Table 2.

Table 2. Correlation Of Research Variables

		Q	X_1	X_2	X_3
Pearson Correlation	Q	1.000	-.723	.618	-.764
	X_1	-.723	1.000	-.449	.653
	X_2	.618	-.449	1.000	.553
	X_3	-.764	.653	.553	1.000
Sig. (1-tailed)	Q	.	.027	.475	.100
	X_1	.027	.	.054	.301
	X_2	.475	.054	.	.020
	X_3	.100	.301	.020	.

Based on Table 2. the correlation between Q and the independent variables X_1, X_2, X_3 is quite strong, so that paddy production is certainly influenced by these three factors. The parameter estimation of the yield model of paddy productivity with the Cobb-Douglas production function is carried out by transforming it into a linear regression form with the aim of making parameter estimation simpler. In estimating the parameters, the process is carried out twice. Building a model using the Cobb-Douglas production function approach, which is an equation with a non-linear form, so it needs to be converted into a linear form so that parameter estimation can be done more simply. Equation (5) which has been converted into a natural logarithm. The estimation results used the principle of the least squares method, the results are presented in Table 3.

Table 3. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics	
					R Square Change	F Change
1	.899[a]	.808	.667	.051665515	.141	1.870

The coefficient of determination (R^2) in the regression analysis was obtained at 0.808, which means that in the regression analysis the wind speed, temperature, and rainfall variables affect paddy productivity. Meanwhile, estimates for model parameters are presented in Table 4.

Table 4. Parameter Estimation Results

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	$\ln\beta$	3.175	2.884		4.101	.008
	$\ln X_1$	$-.048$	.025	$-.282$	-5.908	.004
	$\ln X_2$	$-.141$	.949	$-.028$	-5.149	.013
	$\ln X_3$	$-.185$	.092	$-.370$	-6.997	.033

Based on the parameter estimation results in Table 4, it can be determined the Cobb-Douglas equation model by referring to equation (5). The Cobb-Douglass regression model for the variables of weather and paddy production is written as follows.

$$\ln\hat{Q} = \ln\beta + \alpha_1(I)\ln X_1 + \alpha_2(I)\ln X_2 + \alpha_3(I)\ln X_3$$
$$\ln\hat{Q} = 3.175 - 0.048\ln X_1 - 0.141\ln X_2 - 0.185\ln X_3.$$

Referring to equation (5), the Cobb-Douglass regression model for the variables of weather and paddy production is written as follows:

$$\hat{Q} = \exp\,[3.175 - 0.048\ln X_1 - 0.141\ln X_2 - 0.185\ln X_3]. \tag{6}$$

The value $\ln\beta = 3.175$, or $\beta = \exp(3.175) = 23.93$, meanwhile the values $\alpha_1 = -0.048$, $\alpha_2 = -0.141$, and $\alpha_3 = -0.185$ so that the production function can be written as

$$\begin{aligned}\hat{Q} &= \exp\,[\ln 23.93 - 0.048\ln X_1 - 0.141\ln X_2 - 0.185\ln X_3]\\ &= \exp\,[\ln 23.93 + \ln X_1^{-0.048} + \ln X_2^{-0.141} + \ln X_3^{-0.185}]\\ &= \exp\,[\ln 23.93\, X_1^{-0.048}\, X_2^{-0.141} X_3^{-0.185}]\end{aligned}$$

$$\hat{Q} = 23.93\, X_1^{-0.048}\, X_2^{-0.141} X_3^{-0.185}. \tag{7}$$

In this case $\sum_{1=1}^{3}\alpha_i = -0.048 - 0.141 - 0.185 = -0.374 < 1$, it means that there is an additional *decrease* in *returns to scale of production* (decreasing return to scale). Based on the results of the Cobb-Douglas regression analysis, the model (7) turned out to meet the classical assumption test consisting of multicollinearity, heteroscedasticity, autocorrelation, and normality tests, and fulfilled the F and t statistical tests, parameter estimation was carried out using the Ordinary Least Square (OLS) principle. The next stage is the classical assumption test consisting of multicollinearity test, heteroscedasticity test, autocorrelation test, and residual normality test. Simultaneous Testing (F-Test). The complete statistical test is presented in the ANOVA table and the results are presented in Table 5.

Table 5. Analysis of Variance

	Df	***SS***	***MS***	***F***	***Significance F***
Regression	.031	3	.010	33.98	.028[b]
Residual/Galat	.108	36	.003		
Total	.139	39			

a. Dependent variable: ln Q

b. Predictors: (constant), lnX_3, lnX_1, lnX_2

Based on Table 5, the F_{count} value is 33.98, with a probability of 0.018 less than 0.05, so the regression coefficients lnX_1, lnX_2, and lnX_3 are not equal to zero. The independent variables simultaneously affect the productivity of paddy. While the value of F_{count} with a significance level of 5% was obtained at 2.92. This means that temperature and rainfall simultaneously affect the yield of paddy productivity. All regression coefficients are negative, so that every increase in the independent variable causes a decrease in paddy production. If each variable increasing then paddy production decreases. Partial Test (t-test), with a significance level of $\alpha = 5\%$, the results obtained t_{table} = 2.02 and t_{count} can be seen in Table 6.

Table 6. *T*-Test Results between Climate Variables and Paddy Productivity

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.175	2.884		1.101	.278
	lnX_1	–.048	.025	–.282	–2.908	.041
	lnX_2	–.141	.949	–.028	–2.149	.003
	lnX_3	–.185	.092	–.370	–3.997	.043

The independent variables simultaneously affect paddy productivity. The regression coefficients are all negative, so that every increase in the independent variable causes a decrease in paddy production. The increase in each unit of the weather variable will reduce paddy production, the impact of changes in wind speed and temperature by 0.048 and 0.141. Likewise, the rainfall regression coefficient is negative, meaning that for every one unit increase in rainfall, paddy production decreases by 0.185 units.

If we compare it with the results of research conducted by (Vîlcu, 2011), (Sukono et al., 2019), and (Entezari et al., 2021), this result is an improvement in terms of the data analysis carried out. These results are also a representation of research (Riaman et al., 2022a) and (Riaman et al., 2022b) as a connecting medium for calculating farmers' risk of loss which is discussed in (Riaman et al., 2021b). Thus, the results obtained from this research can be used to determine the insurance value of farmers' losses caused by weather conditions.

D. CONCLUSION AND SUGGESTIONS

Based on the results of the discussion and analysis of the data carried out, the influence of weather changes consisting of rainfall, temperature, maximum temperature, minimum temperature, and wind speed simultaneously affect rice productivity. Rice production is strongly influenced by wind speed, maximum temperature and minimum temperature with a coefficient of determination of 0.808. This is consistent with the hypothesis that when the weather factor increases, the decline in production approaches zero has been proven mathematically. This means that every increase in wind speed, temperature and rainfall will reduce rice productivity. The results of this data analysis are also in accordance with propositions 1 and 2. Mathematically, if the three weather components are infinite then production will be zero. Likewise, production output will not reach maximum Beta if the weather component is set at a certain value.

This research still has limitations related to data exploration. For further research, attention can be paid to more factors influencing rice yield. The results of this research can also be used as a reference for further research, such as determining the value of collateral for farmers due to crop failure, determining planting periods, determining diversification of agricultural production, and so on.

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