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Regular Research

Effect of Air Humidity, Wind Speed, and Sea Surface Temperature on Rainfall in Bengkulu City

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Abstract: Rainfall is an essential component of climate, and its variability in equatorial regions such as Indonesia is a significant focus. The study examines the influence of air humidity, wind speed, and sea surface temperature on rainfall in Bengkulu. The method employed in this study was a quantitative technique, utilizing multiple linear regression analysis with the SPSS model. The data used were monthly data on air humidity, wind speed, and sea surface temperature from 2003 to 2023. Normality and multicollinearity tests were conducted to validate the model before the regression analysis. The analysis results show that air humidity significantly and positively affects rainfall, which is consistent with its role in condensation and cloud formation. Conversely, wind speed and sea surface temperature do not significantly influence rainfall. However, these three independent variables (air humidity, wind speed, and sea surface temperature) had a significant effect on rainfall. The regression model explained approximately 63.8% of the variation in rainfall, confirming that air humidity is the main predictor of rainfall in the Bengkulu region.

Keywords: Rainfall; Air Humidity; Wind Speed; Sea Surface Temperature; SPSS

1. Introduction

Rainfall is one of the most important components of climate for survival [1], and is one of the most variable aspects of climate. Indonesia, located on the equator, receives more intense solar radiation, which increases the amount of water vapor in the atmosphere and supports the formation of convective clouds that bring rain [2]. Geography, orography, topography, orientation, and island structure are some of the factors that influence rainfall variations in each region. Rain occurs when moist air masses move upward, and humidity levels play a role in determining atmospheric stability. Therefore, rainfall amounts, duration, frequency, intensity, and distribution vary spatially and temporally. This variation is primarily driven by convection processes, which tend to produce high rainfall in tropical regions [3] [4].

Bengkulu City is the capital of Bengkulu Province, situated along the Indian Ocean coastline. Its strategic geographical position influences the climate of Bengkulu City, which is shaped by both global and regional climate factors [5]. Owing to spatial and temporal sea surface temperature anomalies, sea surface temperature has a significant impact on rainfall intensity [6].

Air humidity is the amount of water vapor in the atmosphere that significantly influences cloud formation and rainfall. Based on the results of this study [7]. data from the BMKG Climatology Station of Bengkulu City for the 2017-2021 period shows a significant correlation between air humidity and extreme rainfall, with a correlation value (r) of 0.661. This study also confirms that air humidity and pressure are the main predictor variables closely related to extreme rainfall in Bengkulu. High humidity saturates the atmosphere with air

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vapor, thus facilitating condensation and the formation of rain clouds.

In addition to air humidity, wind speed also plays an important role in hydrometeorological processes in Bengkulu. Winds blowing from the Pacific Ocean bring moist air that causes high rainfall [8]. In coastal areas, high-speed winds can increase air convergence and accelerate the condensation of water vapor into clouds, resulting in heavy rainfall. This is especially true during the west monsoon, when strong winds from the northwest bring water vapor from the Indian Ocean to Bengkulu [9]. This was based on previous studies [10]. The correlation between temperature, humidity, wind speed, and rainfall in Bonto Bili was 0.72, indicating a strong relationship. The most influential variable was air humidity, while temperature and wind speed had no significant effect on rainfall.

This study builds upon the development of a previous study [7]. Unlike the previous study, this study used sea surface temperature variables and utilized longer data, spanning 21 years (2003-2023). In addition, this study not only focuses on extreme weather events but also examines the Influence of independent variables on the dependent variable in a general context. The method used is multiple linear regression supplemented by classical assumption tests; as a result, it is anticipated that this will contribute to a more profound and comprehensive understanding of hydrometeorological disaster risk mitigation efforts, spatial planning, and water resource management in coastal regions that are susceptible to climate change and extreme weather, such as Bengkulu City. Therefore, the government and the public need to understand the Influence of air humidity, wind speed, and sea surface temperature on rainfall in Bengkulu City, in order to support more informed decision-making in disaster mitigation and natural resource management. This study scrutinizes the effect of independent variables on the dependent variable in Bengkulu.

2. Materials and Methods

2.1 Location and Time of Research

The research location is Bengkulu City, with the research area in the waters of Bengkulu City.

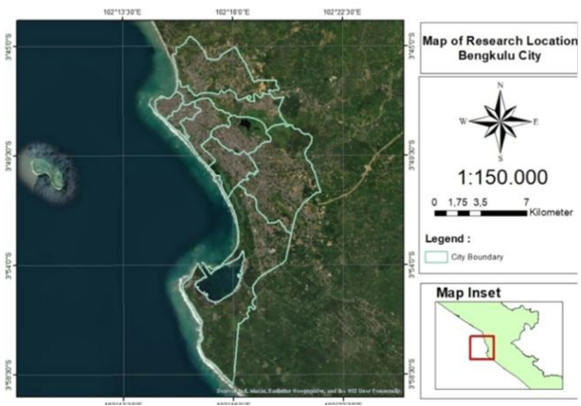

Figure 1. Research location in Bengkulu City Waters

2.2 Materials and Tools

The tools used in this research were ArcGIS 10.7.1 software for creating research maps, SPSS version 29, and Microsoft Excel to create research maps, rainfall data, air humidity, wind speed, and sea surface temperature, and graphs for data processing, respectively. The materials used were secondary data on air humidity, wind speed, sea surface temperature, and rainfall in Bengkulu.

2.3 Research Procedure

This research employed a quantitative approach, with data analysis conducted using the Statistical Package for the Social Sciences (SPSS) software, which serves as a tool for both interactive and batch statistical analysis [11]. The data obtained were analyzed using multiple linear regression models to evaluate the effect of the independent variables, namely, air humidity (X_1), wind speed (X_2), and sea surface temperature (X_3) on the dependent variable, namely, rainfall (Y). Before conducting the regression analysis, classical assumption testing was first carried out, starting with the normality test to check that the data had a normal distribution. Next, a multicollinearity test was performed to detect any correlations between the independent variables. Multiple linear regression analysis was performed by entering the dependent and independent variables into SPSS. The results obtained include the T-test to determine the partial effect of each independent variable on the dependent variable, and the F-test, which is used to identify the simultaneous effect of the independent variables on the dependent variable. In addition, the coefficient of determination was used to estimate the level of correlation or closeness between the dependent and independent variables.

2.4 Data Collection Technique

The data used in this study are rainfall data, air humidity, and wind speed obtained from the BMKG Climatology Bengkulu Station, and sea surface temperature data obtained from https://giovanni.gsfc.nasa.gov/giovanni/ using time series data with a resolution of $0.081^{\circ} \times 0.081^{\circ}$. The data used were monthly data for a 21-year period (2003-2023), which were organized using Microsoft Excel before being imported into SPSS for further analysis.

2.5 Data Analysis

The results obtained from SPSS were analyzed quantitatively by conducting multiple linear regression analysis, following the general equation:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e_i \quad \text{.........(1)}$$

Description: Y = dependent variable, β_0 = constant, $\beta_1, \beta_2\ \beta_3$ = regression coefficients, and X_1, X_2, X_3 = independent variables [12].

The normality test was conducted using the Shapiro-Wilk (SW) or Kolmogorov-Smirnov (KS) test to examine the data's normal distribution. A multicollinearity test was performed to check the Variance Inflation Factor (VIF), ensuring that there was no multicollinearity between the independent variables. Furthermore, multiple regression analysis was performed using the t-test and F-test to determine the significance of the value. The determination coefficient was also analyzed quantitatively to determine the correlation between each variable.

3. Results and Discussion

3.1 Multiple Linear Regression Analysis

Data processing was performed by applying multiple linear regression statistical methods, where the independent variables were air humidity, wind speed, and sea surface temperature. The partial and simultaneous effects of the predictor variables on the dependent variable were analyzed using the T-test and F-test, whereas the correlation strength between the independent and dependent variables was measured using the coefficient of determination. Table 1 displays the regression analysis outcomes between the independent variables and the dependent variable in January obtained through data processing using SPSS software.

Table 1. Multiple Linear Regression Analysis for January

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1994.611	1581.007		-1.262	0.224
	X1	44.721	15.913	0.600	2.810	0.012
	X2	4.252	13.026	0.069	0.326	0.748
	X3	-48.187	40.679	-0.253	-1.185	0.252
a. Dependent Variable: Y						

Table 1 displays the multiple linear regression outcome analysis evaluating the Influence of air humidity (X_1), wind speed (X_2), and sea surface temperature (X_3) on rainfall (Y) in Bengkulu. The analysis was based on monthly data processed using SPSS software, focusing on the individual Influence of each independent variable on the dependent variable. The partial effect was interpreted as the individual contribution of each independent variable to the dependent variable, which was analyzed using the t-test. The decision is made according to the significance value (p-value), where a p-value <0.05 stipulates that the independent variable has a significant partial effect on the dependent variable. A positive regression coefficient indicates a unidirectional relationship between the dependent and independent variables, suggesting that an increase in the independent variable tends to be followed by an increase in the dependent variable. Conversely, a coefficient with a negative value indicates an inverse correlation, where an increase in the independent variable tends to result in a decrease in the dependent variable.

From Table 1, it can be seen that the partial effect of air humidity (X_1) has a significance value of 0.012 < 0.05; thus, this follows the p-value provisions. This study was previously conducted [13], which explained that through the condensation process, high air humidity contributes to cloud formation and rainfall. Meanwhile, wind speed (X_2), with a significance value of 0.748, had no partial effect, indicating that its effect did not reach statistical significance. The study conducted by [14] explained that the linear regression outcomes presented a negative effect of wind on rainfall; that is, as wind increased, rainfall tended to decrease. Sea surface temperature (X_3) has a significance value of 0.252, indicating that it has no partial effect on rainfall. The negative coefficient indicates that sea surface temperature tends to reduce rainfall, although it has no significant effect. This insignificant effect suggests that other factors may also influence rainfall [15], as shown in Table 1. Then, the equation is obtained using equation 1 as follows:

$$Y = (-1994.611) + 44.721\, X_1 + 4.252\, X_2 + (-48.187)\, X_3$$

Based on the general equation in Equation 1, the rainfall equation due to the Influence of the independent variables for each month is obtained as follows:

Table 2. Equation Results of Dependent Variables Against Independent Variables Every Month

Month	Rainfall (mm)	Air Humidity (%)	Wind Speed (knot)	Sea Surface Temperature (°C)	Equation Result
Jan	317.31	84	4	30.13	327.18
Feb	254.05	83	4	30.46	242.22
Mar	305.78	84	4	30.89	332.91
Apr	301.61	85	4	30.83	316.50
May	225.07	84	4	30.70	218.35
Jun	228.00	83	4	30.42	219.52
Jul	173.57	83	3	29.98	157.60
Aug	199.90	83	4	29.39	203.27
Sep	194.21	84	4	28.79	201.00
Oct	238.50	85	4	28.71	253.53
Nov	405.00	86	4	29.42	420.38
Dec	436.95	85	4	29.92	421.16

By comparing the rainfall and the equation outcomes in Table 2, the actual value of rainfall is due to the independent variables. The visual image in Figure 2 shows that the regression model can present the monthly rainfall patterns in Bengkulu City. Rainfall tends to be higher in November and December because Bengkulu is located within the equatorial rainfall pattern, which experiences its two highest peaks during the rainy season [16]. This research is based on BMKG data from the Bengkulu climatology station, which shows that March and December have the highest rainfall [5]. The monsoon winds that blow from Asia to Australia also contribute to the high rainfall. The monsoon winds that

cross the Indian Ocean carry moist air, which then moves towards western Indonesia, including Bengkulu, resulting in the rainy season [17]. Bengkulu's geographical conditions, facing the Indian Ocean, are also influential in receiving humid air masses moving from the Indian Ocean.

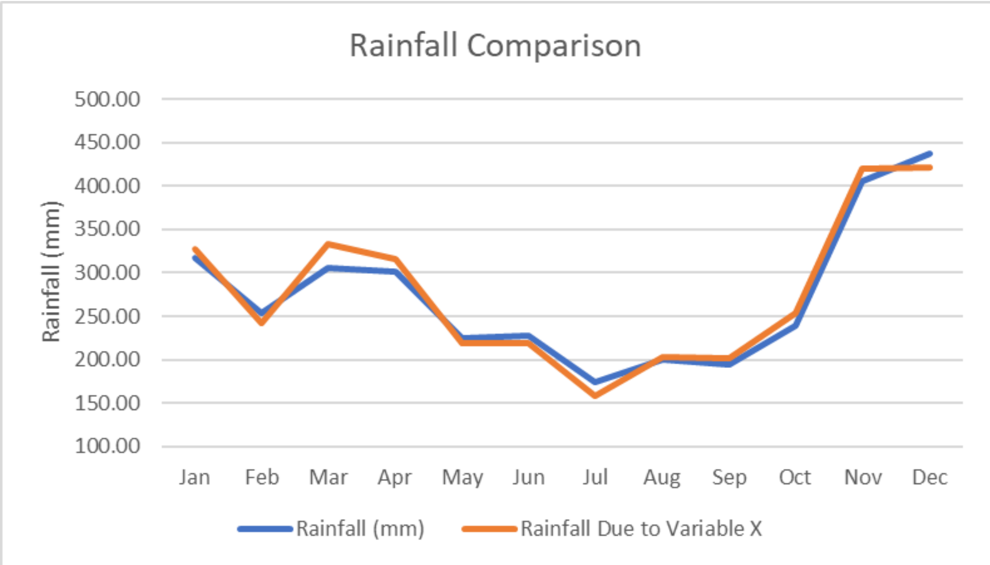

Figure 2. Graph Comparing Rainfall and Rainfall Resulting from Variable X.

The resulting rainfall pattern models from the comparison results were nearly identical, indicating success in capturing the seasonal trends and variability in rainfall. It can be seen that the similarity between rainfall and rainfall is due to variable X, although other factors cause some small differences.

3.2 Normality Test

A normality test was conducted on the dependent variable to determine whether the data were normally distributed. Q-Q plots were used to visualize normally distributed data; if the data had a normal distribution, the points on the Q-Q plot formed a straight line following the diagonal line [18]. As shown in Figure 3, the independent variables X_1 and X_3, as well as the dependent variable Y, are evenly distributed along the diagonal line, which is indicative of a normal distribution. In contrast, the independent variable X_2 is not normally distributed. If the data follows a normal distribution, then the actual values (observed values) will be very close to the expected normal line.

Table 3. Kolmogorov-Smirnov and Shapiro-Wilk Normality Tests

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
X1	0.200	12	0.200*	0.877	12	0.080
X2	0.530	12	<0,001	0.327	12	<0,001
X3	0.142	12	0.200*	0.924	12	0.320
Y	0.175	12	0.200*	0.909	12	0.207

a. Lilliefors Significance Correction

Table 3 presents the normality test outcomes obtained using two methods, namely the KS and SW tests, with a total sample size of 12 data points (12 months), which represents a degree of freedom (df) of 12. The purpose of this test was to check whether the dependent and independent variables had a normal distribution.

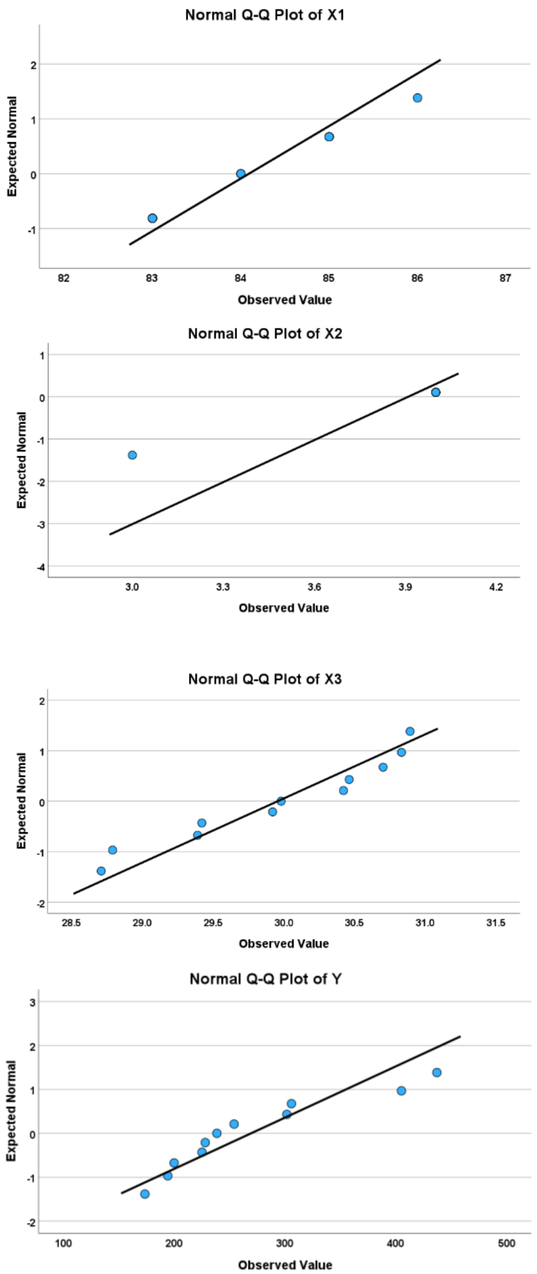

Figure 3. Plot of Normality Test for Variables X_1, X_2, X_3 and Y

Given that the number of samples was less than 50, the Shapiro-Wilk method was chosen as the primary reference in decision-making, and data were distributed normally if the p-value was > 0.05 [19]. According to the results presented in Table 3, the independent variables X_1 and X_3, as well as the dependent variable Y, are normally distributed. Whereas the independent variable X_2 does not meet the normality assumption. This finding is consistent with the visual interpretation shown in Fig. 3.

3.3 Multicollinearity Test

Multicollinearity tests are used to analyze the existence of linear correlations between independent variables in multiple linear regression models [20]. The presence of multicollinearity can make it difficult to interpret the contribution of each independent variable to the dependent variable. The analysis in this test is managed through collinearity statistics, which include tolerance values and VIF. The tolerance value is the proportion of the variance of an independent variable that the other independent variables cannot explain. If the tolerance value was < 0.1, high multicollinearity was considered. The VIF value was used to determine the extent to which the regression coefficient was inflated due to multicollinearity. If the VIF value is < 10, it can be concluded that there is no multicollinearity problem in the model [21].

Table 4. Multicollinearity Test

Coefficients[a]			
Model		Collinearity Statistics	
		Tolerance	VIF
1	X1	0.829	1.206
	X2	0.877	1.141
	X3	0.939	1.065

a. Dependent Variable: Y

Table 4 shows that each independent variable has a reasonably high tolerance value of 0.1 and a low VIF value < 10; thus, there is no significant multicollinearity between the independent variables, so the regression model used is considered valid, and there is no multicollinearity problem.

3.4 T Test

The T-test scrutinizes the individual effect of the independent variable on the dependent variable [22]. X_1 is the coefficient for air humidity, X_2 is the coefficient for wind speed, and X_3 is the coefficient for sea surface temperature. The p-value stipulates statistical significance; if the p-value is < 0.05, the coefficient is considered significant [23]. Table 5. shows that X_1 has a significant Influence on variable Y, while X_2 and X_3 do not have a significant Influence on variable Y.

Table 5. T-test

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-6196.394	1875.108		-3.305	0.011
	X1	62.946	19.414	0.757	3.242	0.012
	X2	34.816	65.148	0.121	0.534	0.608
	X3	34.723	24.186	0.315	1.436	0.189
a. Dependent Variable: Y						

3.5 F Test

The F-test is used to identify the simultaneous Influence of all independent variables on the dependent variable [24]. If the p-value is < 0.05, it can be said that the independent variables have a significant Influence simultaneously on the dependent variable [25]. Based on the outcomes in Table 6, the p-value was 0.035 <0.05. Therefore, the regression model built by including the independent variables X_1, X_2, and X_3 simultaneously has a significant Influence on the dependent variable Y.

Table 6. F-test

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	48182.014	3	16060.671	4.709	0.035[b]
	Residual	27286.162	8	3410.770		
	Total	75468.175	11			
a. Dependent Variable: Y						
b. Predictors: (Constant), X_3, X_2, X_1						

3.6 Coefficient of Determination

The coefficient of determination is a computation in the regression model that illustrates how well the model can describe the variations in the dependent variable owing to the Influence of the independent variable. The R-squared value ranged from 0 to 1. Using this coefficient of determination, the proportion of variability in the dependent variable can be defined by the three independent variables in the regression model. A higher R-squared value indicates a greater ability of the model to describe the correlation between the independent and dependent variables, which also reflects the strength of the correlation between the two [26].

Table 7. Coefficient of Determination

Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.799[a]	0.638	0.503	58.40180
a. Predictors: (Constant), X_3, X_2, X_1				
b. Dependent Variable: Y				

As shown in Table 7, the correlation coefficient (R) value of 0.799 indicates a strong positive relationship between the dependent variable (Y) and the three independent variables (X_1, X_2, X_3). This indicates that an increase in the independent variable tends to be followed by an increase in the dependent variable. The R value, which is close to 1, reflects the regression model's ability to explain data variations effectively. Furthermore, the R-squared value of 0.638 indicates that approximately 63.8% of the variation in the dependent variable can be explained by the independent variables in the model. In comparison, the remaining 36.2% is attributed to factors outside the model. The adjusted R-squared value of 0.503 indicates that, after accounting for the number of independent variables used in the model, approximately 50.3% of the variation in the dependent variable can still be explained by the regression model.

Table 8. Correlation of Variable X to Variable Y

No	Variable	Correlation	Level of Correlation
1	Y - X_1	0.72	Strong Correlation
2	Y - X_2	0.37	Weak Correlation
3	Y - X_3	0.13	Not Correlated
4	Y - X_1, X_2	0.73	Strong Correlation
5	Y - X_1, X_3	0.79	Strong Correlation
6	Y - X_2, X_3	0.40	Weak Correlation
7	Y - X_1, X_2, X_3	0.79	Strong Correlation

Table 8 presents the outcomes of the correlation analysis of the dependent variable with the combination of each independent variable. The correlation values range from 0 to 1. Values close to 1 indicate a strong positive correlation, and values close to 0 indicate a weak correlation. The dependent variable is also high and vice versa if the independent variable is high [27]. Based on Table 8, a strong relationship occurs between the rainfall variable (Y) and the air humidity variable (X_1). This correlation is based on the results of a previous study [28]. This indicates that air temperature is negatively correlated with air humidity and rainfall, while air humidity is positively correlated with rainfall, as high humidity allows for significant rainfall.

4. Conclusions

This study successfully analyzed the effects of air humidity, wind speed, and sea surface temperature on rainfall in Bengkulu using multiple linear regression methods. The results show that air humidity has a significant partial effect and a strong correlation with rainfall. In contrast, wind speed and sea surface temperature did not show substantial partial effects. Simultaneously, these three variables significantly influence rainfall, and the regression model can explain approximately 63.8% of the variation in rainfall. This confirms that air humidity is the main predictor of rainfall in the Bengkulu region.

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Author Contribution: Author 1 was responsible for collecting, processing, and analyzing oceanographic data. Authors 2 and 3 supervised the overall research process, validated the analysis methods used, and provided scientific input during the manuscript development. Author 4 contributed by providing rainfall, air humidity, and wind speed data from the Bengkulu Province Meteorological, Climatology, and Geophysics Agency.

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Ethical Compliance: All data collected during this study will be kept confidential and used only for approved research purposes.

Data Access Statement: All relevant data is contained in the paper.

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