Modeling of Factors Affecting the Productivity of Sugarcane in Jember Regency

by Irma Harlianingtyas

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Abstract. Sugar is one of the strategic commodities in the Indonesian economy. The main raw material for making sugar in Indonesia comes from the sugar cane plant. Sugarcane is a seasonal plantation commodity crop, wherein one year there is only one harvest. Sugarcane productivity is largely determined by agro-climate, in addition to the cultivation technique factor. Apart from climatic factors, the area of milled sugarcane is strongly influenced by the price of sugar at the farmer level, especially 1-2 years before production. This study aims to determine the factors that affect the productivity of the sugarcane in Jember Regency which is poured into a mathematical model. The factors that are thought to affect sugar production in Jember Regency are rainfall (X1), number of rainy days(X2), planting area(X3), sugarcane production(X4), humidity (X5), and temperature(X6) from 1990-2020. The method used in solving this problem is a linear regression with detailed analysis to form an optimum mathematical model. The mathematical model obtained is $Y = -5,192X_1^{1,16}X_2^{0,242}X_3^{0,141}X_4^{0,132}X_5^{14,1}X_6^{31,9}$. The results of the analysis are expected to be used as recommendations by the government to determine policies in increasing the productivity of sugarcane in Jember Regency.

1. Introduction

Sugarcane is the main raw material for making sugar in Indonesia. Sugar cane is one of the seasonal crop plantation commodities which is important in the development of the plantation sub-sector in East Java, among others, to meet domestic sugar needs and to export the National Sugar Productivity since 2001 [1]. The productivity of sugarcane fluctuates from year to year and tends to slightly increase at a rate of 0.3% per year. The inability of companies to minimize the negative impact of extreme climate causes productivity to fluctuate. In wet climates in 2010 and 2012, for example, sugarcane productivity reached 81.9 and 76.1 tonnes per hectare. Meanwhile, in normal climatic conditions, sugarcane productivity ranges from 72-76 tons per hectare [2].

In 2002 the government launched an accelerated program to increase sugar productivity to achieve sugar self-sufficiency in 2007. Then revised it by compiling a national sugar road map and targeting the achievement of direct sugar self-sufficiency (household consumption of 2.80 million tons) by 2009. However, the achievement It is predicted that self-sufficiency will remain difficult to achieve without accelerating the construction of a new sugar factory, increasing direct sugar consumption is still above the sugar production capacity of sugar factories in Indonesia [3]. Domestic demand for sugar continues to increase every year, even making the government decide on a policy to import imported sugar. This situation shows that sugar is a basic need of the Indonesian population.

The sugar agro-industry is held hostage by-product selling prices which are lower than production costs, so they are unable to face the latest developments. Productivity increases have been relatively slow, far behind production costs. The sugar agro-industry also has not been able to dismiss the notion that profitability is only obtained from a combination of agro-climate support and price because sugarcane is influenced by agro-climate although technology can minimize risk, whereas income is directly proportional to production and prices, which means that low prices are at risk of affecting the sustainability of the company.[4].

Rainfall, which is an important climate element and determines the water balance of plants, has a very significant effect due to climate anomalies. Meanwhile, the incidence of climate anomalies in Indonesia has been proven to predominantly affect agricultural production and food security. For this reason, the characteristics of the climate anomaly variables need to be quantified so that the impact of climate anomalies can be anticipated early and the risk is minimized [5]. At the critical stage of the plant, the amount of water given is greater. Each type of plant has a different critical phase. For sugarcane, the critical phase is at the time of shoot formation and vegetative growth at the age of 0-160 days [6]. A climate that is too extreme wet or dry can prevent farmers from expanding [7].

The productivity of sugarcane recorded in the Jember Central Statistics Agency has fluctuated from year to year, data in 2017, sugarcane productivity in Jember Regency was 5.21 tonnes/hectare. Meanwhile, sugarcane production data in 2017 was recorded at 46374 tons, in 2018 it decreased to 38152 tons [8]. This is due to various factors, both on-farm at the farm level and off-farm at the factory level as well as their influence on domestic prices and import needs [9]. Production planning is an estimate or calculation of all activities that will be carried out in the future, such as determining the products to be produced, the materials needed, and when the product must be finished producing [10]. Forecasting is an important tool in planning effective and efficient [11]. The purpose of this study is to show the influence of rainfall, the number of rainy days, humidity, air temperature, production, and land area on sugar productivity in Jember Regency, then how to modeling rainfall, the number of rainy days, humidity, air temperature, production and land area on sugarcane productivity in Jember Regency, so it can be predicted that sugarcane productivity in Jember Regency in the following year.

2. Method

The analysis in this study used descriptive statistics and multiple linear regression.

2.1. Data Source

This study uses secondary data obtained from data from the Central Statistics Agency of Jember Regency, where the data used are rainfall data, the number of rainy days, humidity, air temperature, sugarcane land area, sugarcane production, and sugarcane productivity from 2006-2019.

2.2. Operational Definition and Research Variables

The dependent variable in this study is the productivity of sugarcane in Jember Regency from 2006-2019 in tonnes/ha. Then the independent variables in this study, there are seven variables, including the following:

- Sugarcane production (X1) is the amount of sugarcane per year produced on the land of the Asembagus sugar factory, both grown alone and from sugar cane farmers who have partnered with Asembagus sugar factory with tonnage units.
- Rainfall (X2) is the average water discharge that falls in Jember Regency
- The number of rainy days (X3) is the number of rainy days which is the total rainy days that are calculated per year.
- Humidity (X4) is the level of wetness of the air because air-water is always contained in the form of water vapor, the data of which is obtained from the Central Statistics Agency in percentage units.
- Air temperature (X5) is a quantity that determines the cold and hot air in that place using a room thermometer in degrees Celsius.
- Sugarcane production (X6) is the total yield of sugarcane that is entered into the agricultural data of Jember Regency in tonnage units.
- Land area (X7) is all sugarcane plantations belonging to the sugar factory (PTPN) as well as land owned by farmers which are located in the Jember Regency.

2.3. Construct Model

Regression analysis is a statistical method to predict the value of one or more response variables (dependent variable) of several predictor variables (independent variable). If X1, X2,. . ., Xn is the predictor variable as much as p which has a relationship with a response variable Y, so in general, the linear regression model with one response variable is

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_p x_p + \varepsilon \quad (1)$$

If presented in matrix notation the formula above becomes

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix} = \begin{bmatrix} 1 & x_{11} & x_{12} & \cdots & x_{1p} \\ 1 & x_{21} & x_{22} & \cdots & x_{2p} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & x_{n1} & x_{n2} & \cdots & x_{np} \end{bmatrix} \begin{bmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_p \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_p \end{bmatrix} \quad (2)$$

or

$$\boldsymbol{Y} = \boldsymbol{\beta X} + \boldsymbol{\varepsilon} \quad (3)$$

With the error condition becomes

$E(\boldsymbol{\varepsilon}) = \mathbf{0};$

$Cov(\boldsymbol{\varepsilon}) = E(\boldsymbol{\varepsilon\varepsilon}') = \sigma^2\mathbf{I}$[9].

The assumptions that must be met in multiple regression analysis are:

- No multicollinearity (correlation between independent variables)
- Heteroscedasticity (constant error variance)
- Normality (errors are normally distributed)
- Autocorrelation (an error is random)

3. Result and discussion

The data used to determine the regression model are rainfall data, number of rainy days, humidity, air temperature, sugarcane production, sugarcane land area, and sugarcane productivity from 2006 to 2019. Then the response variable is sugarcane productivity, and the variable free is rainfall, number of rainy days, humidity, air temperature, sugarcane production, and sugarcane land area. The following is a descriptive analysis of climate parameters based on the data contained in Jember Regency.

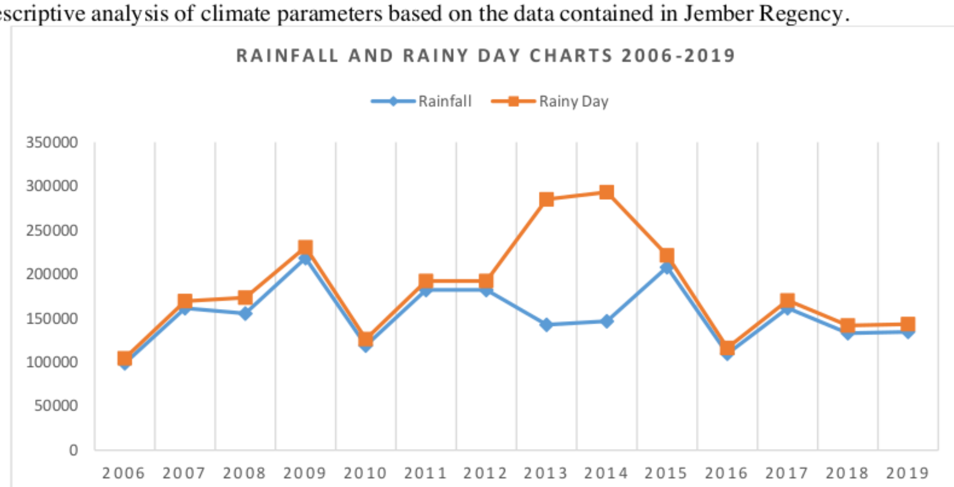

Figure 1.Graph of Rainfall and Rainy Day, 2006-2019

Based on the graph of rainfall and rainy days that occurred in Jember Regency from 2006 to 2019, it can be seen that the highest rainy day occurred in 2014, then fell the following year, while the rainfall that occurred in Jember Regency averaged 153821.07 mm per year. While the average number of rainy days is 29106 per year. Rainfall and rainy days greatly affect the generative phase of sugarcane, which makes sugarcane growth continue and there is no opportunity for the cooking process so that the yield is low [12].

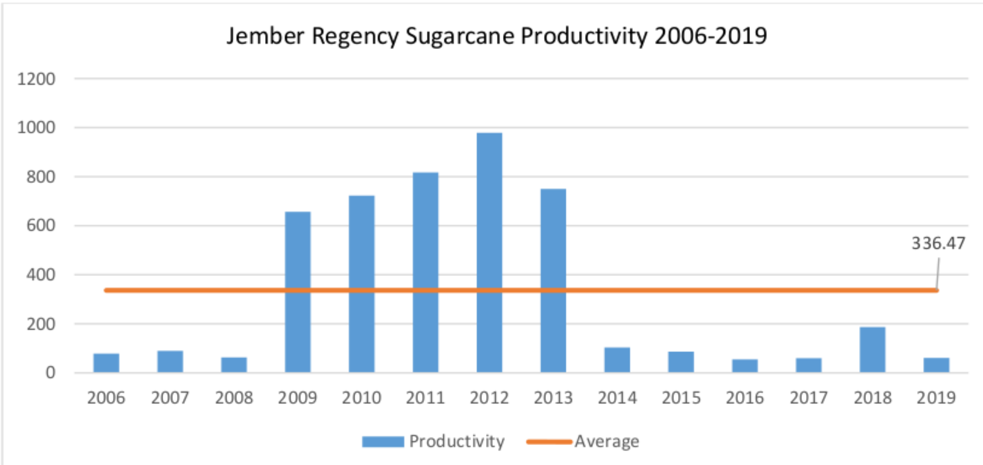

Figure 2. Sugarcane Productivity in Jember Regency, 2006-2019

Based on Figure 2, it can be seen that the productivity of sugarcane from year to year has fluctuated, this is the many factors that affect one of them is climate. The average productivity of sugarcane in Jember Regency during the last 15 years was 336.47 tonnes/ha.

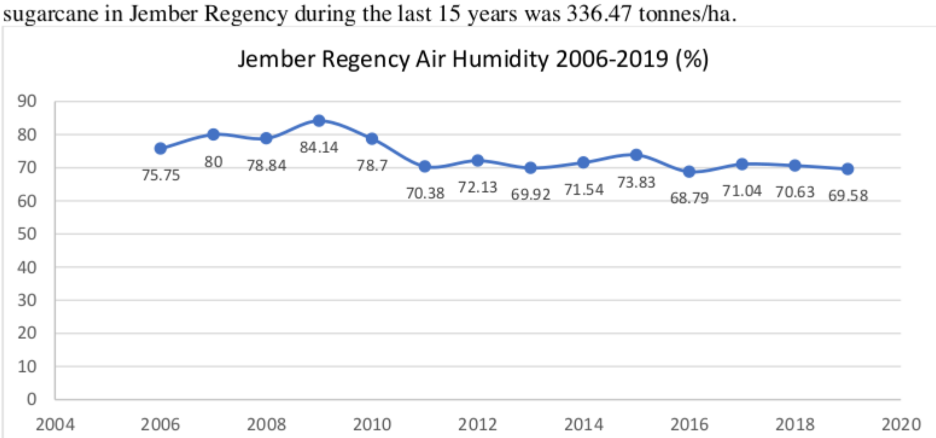

Figure 3. The humidity of Jember Regency, 2006-2019

Based on Figure 3, it can be seen that air humidity from 2006 to 2019 experienced non-extreme fluctuations. This is known from the measured average humidity in Jember Regency from 2006 to 2019 of 79,95%.

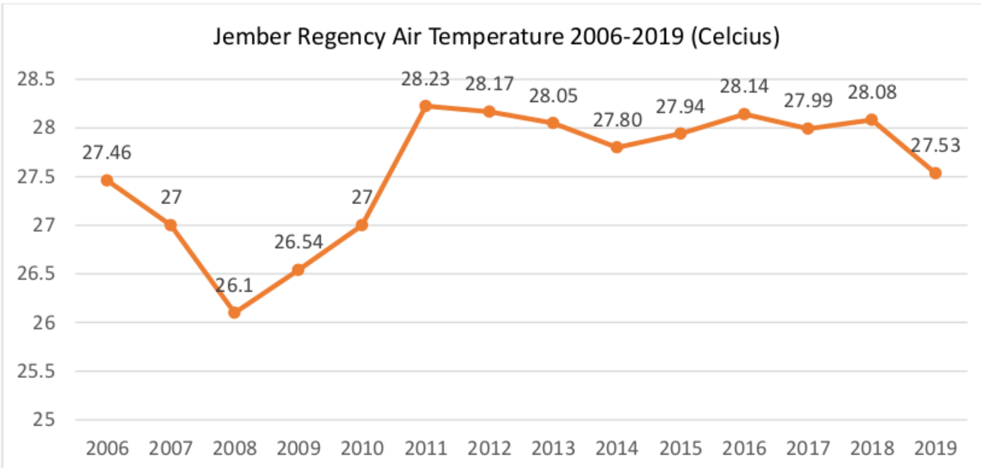

Figure 4. Air temperature in Jember Regency, 2006-2019

The lowest temperature or air temperature per year in Jember Regency occurred in 2008, namely 26.1 degrees Celsius and the highest temperature occurred in 2011, namely 28.23 degrees Celsius. The average air temperature from 2006 to 2019 is 27.5 degrees Celsius. After performing a regression analysis with the Ordinary Least Square (OLS) method, the following analysis results were obtained.

3.1. Simultaneous Test

The results of data analysis on the simultaneous test or simultaneous test can be seen from the Analysis of Variance in Table 1.

Tabel 1. Results of the Analysis of Variance

Model	*df*	*Sum of square*	*Mean Square*	F-count	*P-value*
Regression	6	459710	76618	0,45	0,822
Residual	7	1178873	168410		
Total	13	1638583			

Based on the results of the simultaneous test in Table 1, it shows that the P-value is more than 0.05, or the F-count is smaller than the F table (3.86) so that it is decided to fail to reject H0, this means that all independent variables simultaneously have no significant effect on productivity. For this reason, it is necessary to analyze the effect of each independent variable on sugarcane productivity.

3.2. Partial Test

The results of data processing on the partial test or each of the independent variables that affect sugarcane productivity can be seen in Table 2 as follows.

Tabel 2. T-test results

Variabel	Coefisien	SE Coefisien	T-Count	P-value	VIF
Constanta	-14947	14716	-1,02	0,344	

Rainfall	0,00116	0,00471	0,25	0,813	2,11
Rainy day	0,00133	0,00248	0,54	0,608	1,15
Planting area	0,0174	0,0322	0,54	0,606	1,15
Production	-0,00000	0,000002	-0,29	0,779	1,74
Humidity	57,2	61,6	0,93	0,384	6,60
Temperature	389	397	0,98	0,360	5,49

It can be seen in Table 2 that there are no partially significant variables. This is indicated by the P-value which is more than 0.05, besides that when compared with the T-table value (1.89) the statistical t-value is smaller than the T-table so that it is concluded that there are no independent variables which partially significant effect. on sugarcane productivity.

Based on the results of the R2 recession analysis of 28.06%, this means that the contribution of the independent variables, namely rainfall, rainy days, sugarcane production, humidity, temperature, and the area of planting land to productivity fluctuations of 28.06% and the rest is influenced by other factors. The small coefficient of determination and no significant independent variables indicate a bias in the regression model obtained. Therefore it is necessary to fulfill classical assumptions.

The result of parameter estimation using the regression method with the OLS approach which is Best Linear Unavailable Estimator (BLUE), the regression equation model must meet classical assumptions. Deviation from classical assumptions causes deviations from parameter estimates, both the magnitude of the constant and the magnitude of the regression coefficient.

3.3. Normality Test

The normality test is performed to determine the residuals obtained from the difference between the y estimates and the original y data following a normal distribution. The data normality test used the Kolmogorov Smirnov test with the following hypothesis testing:

H0: The data is normally distributed

H1: The data are not normally distributed

Significance level: 5% (0.05)

The results of the normality test show the following results:

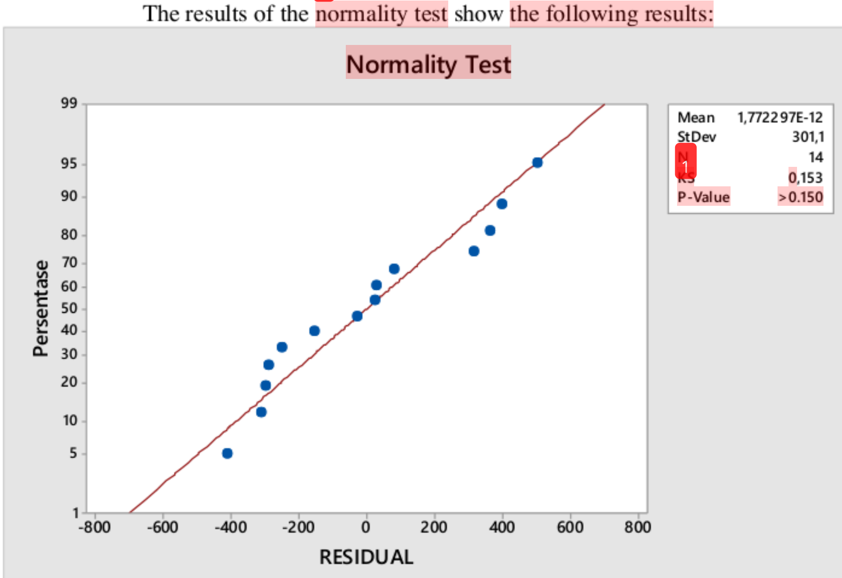

Figure 5. Residual Normality Test

The results of the normality test can be seen from the p-value which is more than 0.05 and it can be seen visually that the residual points follow the normality line. This shows that the residuals meet the assumptions that are normally distributed.

3.4. *Multicollinearity of variable*

The second assumption that must be fulfilled is that there is no multicollinearity between the independent variables. One way to detect multicollinearity is by looking at the Variance Inflation Factor (VIF) if the VIF value> 10 indicates multicollinearity. Based on Table 4, the VIF value on all independent variables is <10, so it can be concluded that there is no multicollinearity between the independent variables in the regression model.

3.5. *Autocorrelation Test*

The third assumption that must be fulfilled is that there is no autocorrelation between residuals, or there is no relationship or influence from the first data residual to the next data residual. One of the ways to detect autocorrelation is the Durbin Watson test.

Hypothesis :

$H_0 : \rho = 0$ (there is no autocorrelation)

$H_1 : \rho \neq 0$ (there is autocorrelation)

Critical area: Failed to reject (accept) H_0, if $dU < DW < (4 - dU)$

Durbin Watson Statistics :

$$DW = \frac{\sum_{t-2}^{n}(e_t - e_{t-1})}{\sum_{t=1}^{n} e_t^2}$$

Where Durbin-Watson Statistics = 0.7782, while from the Durbin Watson table with the number of variables 7 (p = 7), and the number of observations 14 (n = 14), it is obtained dU = 2.8477 and dL = 0.2856. Because Durbin Watson's statistical value is between dU and dL, it can be concluded that the Durbin Watson test results are inconclusive. So that autocorrelation checking uses other methods. One way to detect autocorrelation between residuals can be seen from ACF plotting.

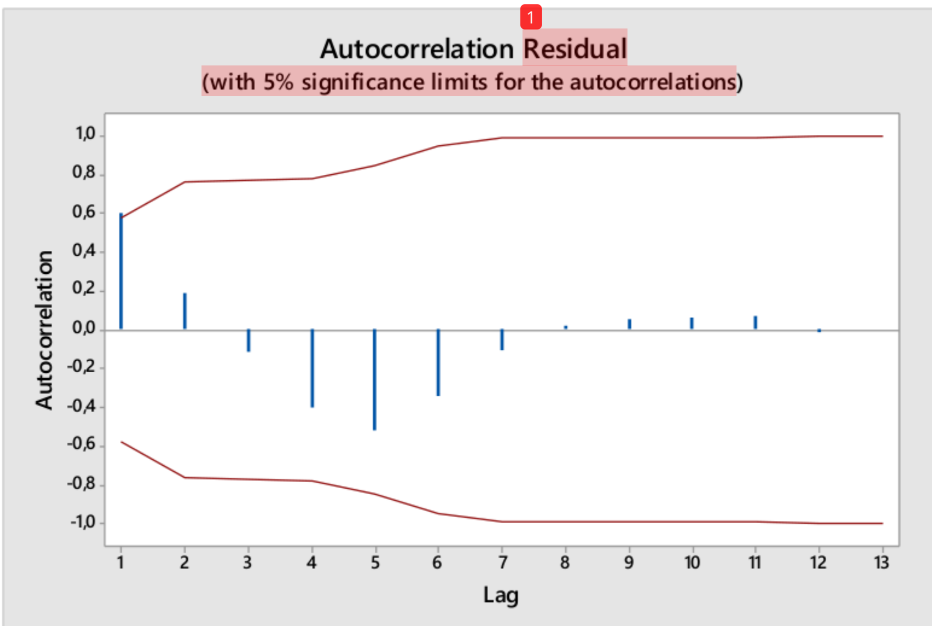

Figure 6. Residual Autocorrelation

Based on the results of the autocorrelation image, it can be seen that there is a lag (lag 1) that exceeds the red line, where the red line is the upper and lower limit of the autocorrelation line. So it can be concluded that there is autocorrelation between the residues from observation t to observation t-1. Besides, autocorrelation can be detected by non-parametric tests, namely run tests, where:

Hypothesis:

H0: the residual is not independent

H1: the residual is independent

Test statistics :

Tabel 3. Run Test Results

	Unstandardized Residual
Cases < Test Value	7
Cases >= Test Value	7
Total Cases	14
P-value	0,026

The results of the run test show that the p-value is less than α (1.00> 0.05), so it can be concluded that the residuals are dependent, or there is a relationship between the residuals with each other. So that the assumption that there is no autocorrelation is not fulfilled. So that the model corrective action that needs to be done is to transform the data into natural logarithms [13].

3.6. Heteroskedasticity Test

The heteroscedasticity test aims to determine whether the residuals are homogeneous invariance (homoscedasticity). The best regression model must meet the requirements of homoscedasticity or homogeneous residuals. Heteroscedasticity testing uses the Park test, namely by lifting the residuals and then using the natural logarithm (Ln), then regressing them with the independent variables.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	6	52,7543	8,7924	6,33	0,014
Total Curah Hujan	1	3,4968	3,4968	2,52	0,157
Total Hari Hujan	1	0,1489	0,1489	0,11	0,753
LUAS AREA TANAMAN	1	1,4236	1,4236	1,03	0,345
PRODUKSI (KWINTAL)	1	17,9312	17,9312	12,91	0,009
KELEMBAPAN UDARA	1	8,7674	8,7674	6,31	0,040
TEMPERATUR	1	24,6901	24,6901	17,78	0,004
Error	7	9,7190	1,3884		
Total	13	62,4733			

Figure 7. Analysis of Variants

Based on the results of the Park test in Figure 7, it shows that there is a p-value that is less than 0.05. This shows that residual is not homogeneous or heteroscedasticity occurs. Apart from the Park test, it can be seen visually from the plot of the residue versus the Y estimated variable as follows.

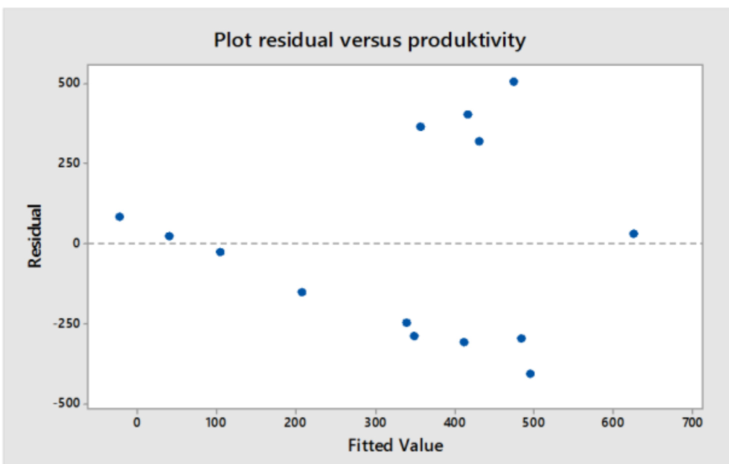

Figure 8. Scatter plot between residuals and Y-fit

Based on Figure 8, it shows that the scatter diagrams formed form a pattern like a funnel or a trumpet. So that the residuals are assumed to be not identical or homogeneous a variant. So for corrective action, it is necessary to carry out a natural transformation on all variables then remodeled.

3.7. Regression model

Linear regression analysis is used to apply the basic method of estimating the Ordinary Least Square (OLS) parameter, therefore to fulfill the classical assumptions in regression, a natural logarithmic transformation (Ln) is carried out and the following regression model is obtained.

$$\text{Ln } Y = -180+1{,}16\text{Ln}(X_1)+0{,}242\text{Ln}(X_2)+0{,}141\text{Ln}(X_3)+0{,}132\text{Ln}(X_4)+14{,}1\text{Ln}(X_5)+31{,}9\text{Ln}(X_6)$$

From the regression equation, it can be simplified into the following equation.

$$Y = -5{,}192 X_1^{1,16} X_2^{0,242} X_3^{0,141} X_4^{0,132} X_5^{14,1} X_6^{31,9}$$

The regression model shows that the regression coefficient on the rainfall variable (X1) is 1.16 which means it has a positive effect on sugarcane productivity. It can be assumed that if the rainfall (X1) increases by 1 unit, the increase in sugarcane productivity is 0.148 tonnes/ha with the assumption that other independent variables are constant. Then the regression coefficient on the variable number of rainy days (X2) is 0.242 which means that it harms productivity. It can be assumed that if the number of rainy days (X2) increases by 1 unit, the productivity of sugarcane decreases by -1.42 ton/ha with the assumption that other independent variables are constant. While the regression coefficient on the variable planted area (X3) was 0.141 which means it has a positive effect on sugarcane productivity. It can be assumed that if the planted area (X3) increases by 1 hectare, there will be an increase in sugarcane productivity by 0.343 tonnes/ha, assuming that other independent variables are constant. The regression coefficient on the sugarcane production variable (X4) is 0.132 which means it has a positive effect on sugarcane productivity. It can be assumed that if sugarcane production (X4) increases by 1 quintal, there will be an increase in sugarcane productivity by 2.02 tonnes/ha with the assumption that other independent variables are constant. The regression coefficient of the humidity variable has a positive effect on sugarcane productivity, this can be seen when the humidity increases by one percent, the sugarcane productivity increases by 2.65 tonnes/ha. Then the regression coefficient of the air temperature variable has a positive effect on sugarcane productivity, it can be seen that when the temperature rises 1 degree Celsius, the sugarcane productivity increases by 3.46 tons/ha.

4. Conclusion

The mathematical model of the analysis of the effect of rainfall, number of rainy days, planting area, sugarcane production, humidity, and air temperature on sugarcane productivity is as follows

$$Y = -5{,}192 X_1^{1,16} X_2^{0,242} X_3^{0,141} X_4^{0,132} X_5^{14,1} X_6^{31,9}$$

5. Acknowledgments

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6. References

[1] East Java Provincial Plantation Office 2011 *Strategic Plan 2008-2013*

[2] Indonesian Sugar Association 2014 *Indonesian Sugar Outlook 2014* (Jakarta: ISA)

[3] Directorate of Seasonal Crop Cultivation 2008 Sugar *Self-Sufficiency Acceleration*

[4] A Suwandi 2015 *Sugar Industry Transformation* (Surabaya: XI News)

[5] W Estiningtyas, E Surmaini, and K S Hariyanti 2009 Preparation of Planting Period Scenarios Based on Rainfall Forecasts at Food Production Centers *J. Meteorol. dan Geofis.* **9** 1

[6] C Hanum 2009 *Plant Ecology* (Jakarta: USU Press)

[7] Ministry of Agriculture of the Republic of Indonesia 2014 *Food Outlook Analysis 2015-2019*

[8] Central Bureau of Statistics for Jember Regency 2018 *Sugarcane Production Data 2007-2018*

[9] L Ernawati and E Suryani 2013 Analysis Of The National Sugar Productivity Factors And Their Effects On Domestic Sugar Prices And Imported Sugar Demand Using A Dynamic System, *J. Tek. POMITS* **1** 1 pp 1–7

[10] S Kusumadewi 2003 *Artificial intelligence (techniques and applications) (*Yogyakarta: Graha Ilmu) pp 278

[11] S Makridakis, S C Wheelwright, and V E McGee 1999 Forecasting Methods and Applications

Vol. 1 ed U S Ardiyanto and A Basith

[12] L D Indarwati, S.Fajriani, and R Soelistyono 2019 Effect of El Nino and La Nina on Sugarcane Productivity and Yield (Saccharum officinarum L.)(Case Study in Pitu District, Ngawi Regency) *J. Agricultural Production* **6** 10

[13] D N Gujarati 2016 Basic Econometrics (Jakara: Salemba Empat)

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