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by Abdurrahman Salim

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Modeling of rainfall and fertilization factor of sugarcane productivity in Asembagus sugar factory Situbondo

I Harlianingtyas^{1*}, D Hartatie² and A Salim³

^{1,2,3}Department of Agriculture Production, Politeknik Negeri Jember, Mastrip street
PO Box 164, Jember 68121, Indonesia

*Corresponding author: ima@polije.ac.id

Abstract. Sugarcane is one of the important plantation crops commodities in plantation sub-sector development in East Java. However, domestic sugar needs are increasing every year, even making the government decide on the policy to import sugar. This situation shows that sugar is a basic requirement in Indonesia. The profitability of sugar agro-industry is influenced by climate and price. Low price and production risks affect the company's sustainable resilience. Rainfall is an important climate element and determines the plant water balance. While the incidence of climate anomalies in Indonesia has been shown to predominantly affect agricultural production and food security, besides that the fertilization process is also a major factor influencing the production of sugar cane produced. Fertilizer can provide nutrients in the soil, so that sugar cane can grow well. Sugar production in Asembagus factory every year has fluctuations, some of the dominant factors are the influence of rainfall and fertilization. The results showed that rainfall(X_1) and fertilization(X_2) significantly affected sugarcane productivity(Y). The regression model is $Y = 33633 + 9,43X_1 - 2,10X_2$. The modeling results are expected to be used as a company recommendation to determine policies in increasing Asembagus sugar factory production and more productive sugarcane cultivation techniques.

1. Introduction

Sugarcane is one of the important annual crop plantation commodities in the plantation sub-sector development in East Java, which is to meet domestic sugar needs and export National Sugar Productivity since 2001 [1]. Domestic sugar needs are increasing every year, even making the government decide on the policy to import sugar. This situation shows that sugar is a staple in Indonesian. In 2002, the government was launched an accelerated increase in sugar productivity in order to achieve sugar self-sufficiency in 2007. Then it was revised by preparing a national sugar road map and targeting the achievement of direct sugar self-sufficiency (household consumption of 2.80 million tons) in 2009. However, the achievement of self-sufficiency is predicted to remain difficult to achieve if it is not accelerated with the construction of a new sugar factory, increasing the consumption of sugar directly above the sugar production capacity of sugar mills in Indonesia [2]. Sugar agro-industry is held hostage by the selling price of the product which is lower than the production cost so that it is powerless to face the latest developments. Increased productivity is relatively slow. Sugar agro-industry has also not been able to dismiss the notion that profitability is



only obtained from a combination of agroclimatological support and prices because sugarcane must be influenced by agroclimatology even though technology can minimize risk while income is directly proportional to production and prices which mean low prices risk the sustainability of the company [3].

Rainfall which is an important climatic element and determines the plant water balance is very noticeable due to climate anomalies. While the incidence of climate anomalies in Indonesia has been shown to predominantly affect agricultural production and food security. Therefore the characteristics of climate anomaly variables need to be quantified (magnitude) so that the impact of climate anomalies can be anticipated earlier and minimized the risk [4]. During the critical phase of the plant, the amount of water given is greater. Each type of plant has a different critical phase. For the sugarcane plant, the critical phase is located at the time of shoot formation and vegetative growth at the age between 0 to 160 days [5]. Besides the rainfall factors that predominantly affect sugarcane production, the fertilization process is also a major factor affecting the production of sugar cane produced. Essential elements such as Nitrogen (N), Phosphate (P), and Potassium (K) are needed in sufficient quantities of sugar cane. Limited availability in the soil, causing these elements to be added through fertilization.

Asempagus factory is one of the sugar factories in Situbondo, which is included in the business unit of PT. Perkebunan Nusantara XI. Sugar production in Asempagus factory each year experiences fluctuations caused by several things, some of the dominant factors are the influence of rainfall and fertilization. This causes losses and decreases the efficiency of the company, because the amount of costs incurred is not balanced with the results received.

To see that the data can have a good impact on production, a statistical analysis is needed that can see the effect of rainfall and fertilizer on sugarcane production. One of the statistical analysis used is multiple linear regression analysis. Multiple linear regression analysis is a statistical method to predict the value of one response variable from more than one predictor variable. It is expected that regression analysis can provide a good model to see the influence of rainfall and fertilizer on sugar production. In line with the Master Plan for Research at the State Polytechnic of Jember Plantation Crops Production Study Program of 2018-2019, namely the technical improvement of the cultivation of plantation crops, this research is expected to provide a method of technical improvement of sugarcane cultivation and recommendations to Asempagus sugar factory Situbondo.

2. Method

2.1 Data Source

Data sources used in this study are secondary data at Asempagus sugar factory Situbondo, which includes rainfall data, fertilization, and sugar production data from 2007 to 2016. Data are taken in stages, because the data collection locations in the archive are different.

2.2 Operational Definition and Research Variables

The variables used in this study are predictor variables and response variables. Predictor variables consist of rainfall and fertilization in 2007 to 2016. While the response variable is sugar production from 2007 to 2016.

1. Rainfall (X1)

Rainfall is the height of rainwater that collects in a flat place, does not evaporate, does not seep, and does not flow. Rainfall of 1 (one) millimeter means that an area of one meter of square in a flat place, there is one millimeter of water or one liter of water collected. The rainfall measured in this study is the rainfall that falls in Situbondo Regency, especially in Asempagus District.

2. Fertilizer (X2)

Fertilization is the provision of ingredients intended to provide nutrients for plants. Generally fertilizers are given in solid or liquid form through the soil and absorbed by the roots of plants.

Fertilization carried out by Asempagus factory is 1 to 2 times in one year, the data is the total amount of fertilizer used per year that contain nitrogen (N), phosphate (P), and potassium (K).

3. Sugar Production (Y)

Sugar production is the amount of sugar produced during harvest every year with unit of ton.

2.3 Step by step for analysis

The steps on multiple linear regression analysis is using the Ordinary Least Square (OLS) method. To get estimator of unbiased parameter until a multiple regression model is formed between rainfall and sugar cane production.

1. By using IBM SPSS 21 software, fertilization and rainfall variables are inputted as independent variables, and the variable of sugar production is entered as the dependent variable. Estimating the regression coefficient parameter with a significant 5%. This means that 95% of the estimated parameters describe the actual situation.
2. Create an appropriate regression model.
3. Make interpretations of the regression model.
4. Identifying the significance of the error, whether the normal distribution assumption is normal, identical and independent.
5. If you have fulfilled the assumptions, then the model obtained can be used.
6. Partial test.

Hypothesis testing is partially carried out to determine the effect of each predictor variable on the response variable by comparing the T value with T of statistics table. Using significant level is $\alpha = 0,05$

Hypothesis :

$$H_0: \beta_i = 0$$

$$H_0: \beta_i \neq 0$$

Test Statistics :

$$t = \frac{b_1}{\left\{ \frac{\sum x_i^2}{n \cdot \sum (x_i - \bar{x})^2} \right\}^{1/2} \cdot s} = \frac{coef_x}{(SE\ coef)_x}$$

Critical area :

Reject H_0 , if $|t| \geq t_{(n-k, \alpha/2)}$ or $P_{value} < 0,05$.

7. Perform simultaneous testing, by performing F test on the estimation results of the regression model. This test is used to determine the effect of the overall predictor variable on the response variable by comparing the F value with the F of statistics table.

Hypothesis :

$$H_0: \beta_1 = \beta_2 = \dots = \beta_m = 0$$

H_0 : minimal there is one of $\beta_i \neq 0$, where $i = 1, 2, \dots, m$

Significant level : $\alpha = 0,05$

Test statistic :

$$F_{count} = \frac{R^2(n-k-1)}{k(1-R^2)}$$

Critical area :

Reject H_0 , if $F_{count} \geq F_{\alpha; p; n-p-1}$ or $P_{value} < 0,05$.

8. Make interpretations of coefficient determination.
9. Conclusions.

3. Result and discussion

The data used to predict the regression model are rainfall, fertilization and production data from 2007 to 2016. By using the Ordinary Least Square (OLS) parameter estimation method, a regression model

between rainfall factor (X_1) and fertilization (X_2) is obtained from the sugar production (Y) formed as follows :

$$Y = 33633 + 9,43X_1 - 2,10X_2$$

The regression model above can be interpreted as follows:

- ✓ The constants in regression equation explain that if rainfall variable (X_1) and fertilizer variable (X_2) are constant, then sugar production is 33633 tons of sugar.
- ✓ Regression coefficient of rainfall variable is 9,43 illustrates that rainfall (X_1) has a positive influence on the amount of sugar production in Asembagus sugar factory. This means that the higher the rainfall will increase sugar production in Asembagus sugar factory. Suppose the variable is constant fertilizer or 0, then each increase in 1 rainfall unit will increase sugar production by 9,43 tons.
- ✓ Regression coefficient of fertilizer variable is $-2,10$ illustrates that fertilizer (X_2) has a negative influence on the amount of sugar production in Asembagus factory. This means that the higher the fertilizer, the sugar production in Asembagus factory will decrease. Suppose the variable rainfall is constant or 0, then each increase in fertilizer dose is 1 unit then the sugar production of Asembagus factory will decrease by 2.10 tons.

To obtain the parameter estimation results with the OLS method, the Best Linear Unbiased Estimator (BLUE), the regression equation model must meet the classical assumptions. Deviations from classical assumptions cause deviations from parameter estimates both the magnitude of the constant and the magnitude of the regression coefficient.

Following are the results of the classic assumption of regression parameter estimation is:

1. Identical test (Glejser test)

Assuming identical residual test can be done with Glejser test. The Glejser test is done by regressing between the value of the independent variable and absolute residual as dependent.

Hypothesis for Glejser test is:

$$H_0: \rho = 0 \text{ (identical residual)}$$

$$H_1: \rho \neq 0 \text{ (residual not identical)}$$

Significant level : $\alpha = 0,05$

Test statistics:

$$F_{count} = \frac{MSR}{MSE} = \frac{[\sum_{i=1}^n (|\hat{\epsilon}_i| - |\hat{\epsilon}|)^2]/p}{[\sum_{i=1}^n (|\hat{\epsilon}_i| - |\hat{\epsilon}|)^2]/(n-p-1)}$$

Reject H_0 , if $F_{count} \geq F_{\alpha;p;n-p-1}$ or $P_{value} < 0,05$.

Tabel 1. Result of Glejser test

Source	DF	SS	MS	F	P-value
Regression	2	8349230	4174615	2,42	0,159
Residual	7	12058551	1722650		
Total	9	20407781			

The results Glejser Test show that the P -value is 0,159 where this value is greater than 0.05. This means that failure to reject H_0 and assuming identical residuals are fulfilled.

2. Assuming normal distribution

Data normality tests can be done with the Kolmogorov – Smirnov test. The hypothesis for the Kolmogorov – Smirnov test is as follows:

H_0 : Residual is normal distribution

H_1 : Residual is not normal distribution

Significant level : $\alpha = 0,05$

Test Statistics:

$$D = \max |F_0(x) - S_N(x)|$$

Where is :

$F_0(x)$ is a function of theoretical cumulative distribution while $S_N(x) = i/n$ is the cumulative probability function of observations from a random sample with i is observation and n is the number of observations.

Reject H_0 , if $D > q(1 - \alpha)$ and q is values based on the Kolmogorov-Smirnov table or P -value, where H_0 is rejected if the P -value $< \alpha$.

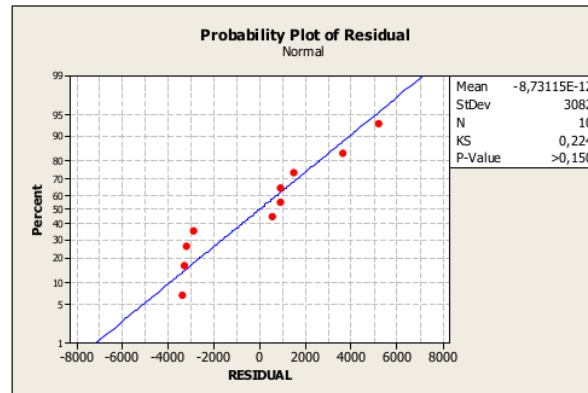


Figure 1. Normality test of Residual

Based on **Figure 1**, the p -Value $> 0,150$ is obtained, that is, the decision to accept H_0 is obtained, and concludes that the residual assumption of the regression with normal distribution is fulfilled. This is also seen from the plot image that spreads along the linear line.

3. Multicollinearity Test

Multicollinearity test is used to determine whether there is a strong correlation between the independent variables included in the formation of the model. To detect whether the linear regression model experiences multicollinearity can be examined using Variance Inflation Factor (VIF), if the VIF value > 10 means multicollinearity has occurred.

The results of the analysis show that the VIF value of each rainfall and fertilization variable is 1,002. This means that there is no multicollinearity between dependent variables.

4. Autocorrelation test

Autocorrelation test is used to test that linear regression model has a correlation between the interfering error in t period with error in the $t-1$ period (before t). There are several ways to test autocorrelation. The first method is by looking at the ACF plot, and the second can be seen from the Durbin Waston (DW) value, if the DW value is located between dU and $(4 - dU)$ or $dU \leq DW \leq (4 - dU)$ means that it is free from Autocorrelation, otherwise if the value of $DW < dL$ or $DW \leq (4 - dL)$ means that there is Autocorrelation. The dL and dU values can be seen in the Durbin Waston table, which is the dL value; dU , α , m , $(k - 1)$. Description: m is the number of samples, k is the total of variables, and α is a significant level.

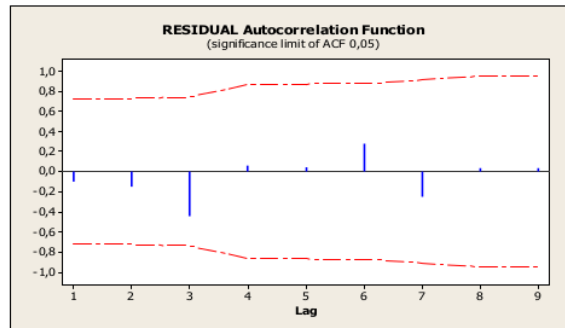


Figure 2. ACF Residual of Regression Model

Indications occur autocorrelation that is if lag 1, lag 2, lag 3 and so on out of the boundary (red line). In Figure 2 there is not a single lag that goes beyond the limit, meaning that by looking at the ACF plot there is no autocorrelation case. The second method is the Durbin Watson test.

Hypothesis :

$H_0 : \rho = 0$ (there is not auto correlation)

$H_1 : \rho \neq 0$ (there is auto correlation)

Critical area : failed to reject (accept) H_0 , if $dU \leq DW \leq (4 - dU)$

Test Statistics :

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

In the Durbin-Watson distribution table with K value (independent variable) = 7, the number of samples 103 and α is 5%, the value of $dL = 0.467$ and $dU = 1.896$, and the value of Durbin Watson is 1.885 and the value of $4 - DW = 2.115$. The value of 2.115 is greater than 1.896, meaning that there is no autocorrelation in the data.

3 Assumption of heteroscedasticity

Heteroscedasticity test is used to test whether in the confounding error liner regression model (e) has the same variance or not from one observation to another observation. To test Heteroskedasticity, it can be seen from the significant value of Rank Spearman correlation between each independent variable and the residual. If the significant value is greater than α (5%) there is no heteroscedasticity, and vice versa if it is smaller than α (5%) then there is heteroscedasticity. The second way is to see visually from the residuals formed from the

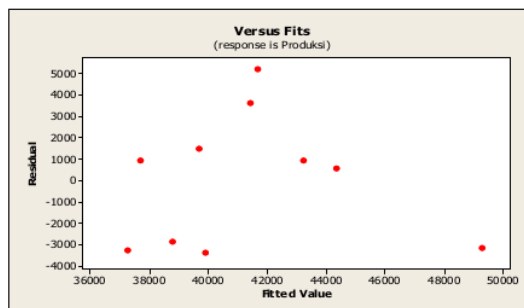


Figure 3. Scatter plot Residual and Production

Table 2. Correlation of Residual Rank Spearman with Independent Variable

		<i>Rainfall</i>	<i>Fertilizer</i>	<i>Residual</i>
<i>Rainfall</i>	<i>Correlation Coefficient</i>	1	-0,297	0,115
	<i>P-value</i>	.	0,405	0,751
<i>Fertilizer</i>	<i>Correlation Coefficient</i>	-0,297	1	0,079
	<i>P-value</i>	0,405	.	0,829

regression model whether to form a polat or not. Based on **Figure 3**, the points spread randomly and did not form certain patterns such as conical or linear. This means that there is no case of heteroscedasticity. In addition to seeing visually the heteroscedasticity test can be done by spearman rank correlation test between the independent variables and the residuals.

From **Table 2** Spearman rank correlation analysis results show that the correlation between rainfall and fertilizer variables has a low correlation coefficient of 0.115 and 0.079, respectively, with a P-value above α (0.05). In the rainfall variable P value is 0.751 and the fertilizer variable is 0.829. This means that the correlation between rainfall and fertilizer to the residual regression model is not significant. Thus, it can be concluded that there is no heteroscedasticity in the multiple linear regression model obtained.

3.1 Partial test (T test)

The results of data processing for partial tests shown in **Table 3** below.

Table 3. Partial test (T test) of rainfall and fertilizer variable

<i>Variabel</i>	<i>Koefisien</i>	<i>SE Koefisien</i>	<i>T</i>	<i>P-value</i>
<i>Constant</i>	33633	7496	4,49	0,003
<i>Rainfall</i>	9,430	3,086	3,06	0,018
<i>Fertilizer</i>	-2,102	5,588	-0,38	0,718

By comparing the T_{count} values in Table 3 with T_{table} ($T_{0,025,7}$) or by comparing the P_{value} with $\alpha = 0,05$. Based on the results of data processing obtained a decision that is on the variable rainfall value $T_{count} > T_{table}$ or $3,06 > 2,36$. In addition, it can be seen from the $P_{value} < \alpha$ or $0,018 < 0,05$, then H_0 is rejected, it means that rainfall has a significant effect on sugar production in Asembagus factory. In the second variable, fertilizer has a value of $T_{count} > T_{table}$ or $|-0,38| < 2,36$. In addition it can be seen from the value of $P_{value} < \alpha$ or $0,718 > 0,05$, then H_0 is accepted, meaning that fertilizer has an insignificant effect on sugar production in Asembagus factory.

3.2 Simultaneous test (F-test)

Results of data analysis of simultaneous test can be seen on Analyze of Variance (ANOVA) in **Table 4**.

Table 4. ANOVA of Rainfall and Fertilizer of Sugar Productivity

Source	df	SS	MS	F	Sig. value
Regress	2	117163678,911	58581839,456	4,798	0,049
Res. Error	7	85469959,253	12209994,179		
Total	9	202633638,164			

Based on the results in **Table 4** the analysis obtained the calculated F value is 4,798 while the F table or $F_{0,05;p;n-p-1} = 4,737$, then the calculated $F_{count} > F_{table}$ or $4,798 > 4,737$, and can be obtained from $P_{value} < \alpha$ or $0,049 < 0,05$, it is decided to reject H_0 means that the overall rainfall and fertilizer variables have a significant effect on sugar production in Asembagus factory.

The goodness of the regression model can be seen from the magnitude of the coefficient of determination or R square, based on the results of the analysis obtained the R square value of 0,578 or 57,8%. This value illustrates that the magnitude of the contribution of rainfall and fertilization variables to the ups and downs or variations in sugar production is 57,8% and the remaining 42,2% is

the contribution of other variables not included in the model proposed in the study. While the R value of 0,760 means that the relationship between rainfall variables, fertilization and sugar production can be said to be strong or close because it is approaching to 1.

4. Conclusion

The regression model obtained is $Y = 33633 + 9,43X_1 - 2,10X_2$. Simultaneous testing shows that rainfall and fertilizer have a significant effect on sugar production in Asembagus factory, but partially only rainfall has a significant effect on sugar production at Asembagus factory. The model obtained also fulfills all the classical assumptions with a *R-square* value of 57.8%.

5. Acknowledgments

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