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Forecasting Annual Coffee and Rubber Production in Aceh Using Exponential Smoothing

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Abstract. Aceh Province has great potential in the plantation sector as one of the contributions to economic growth and development in Indonesia. Based on data from Statistics Indonesia and Department of Agriculture and Plantations, the leading commodities of Aceh are oil palm, coffee, cocoa, rubber, coconut, nutmeg, pepper, patchouli, clove, and sugarcane. Aceh plantation statistics showed that leading commodities, especially rubber and coffee, have fluctuated significantly from year to year and it was affected by national and regional economies. This research applied the exponential smoothing time series model to study the behavior of Aceh's annual coffee and rubber production as well as make five years forecasts. Annual coffee and rubber production data from 1979 to 2017 was obtained from Statistics Indonesia and Department of Agriculture and Plantations of Aceh Province and analyzed using exponential smoothing. The forecasting results show that annual coffee production increase continuously from 2018 to 2022, it was increased by 2.73% annually with Mean Absolute Percentage (MAPE) value 12%. The forecasting results of annual rubber production (tons) from 2018 to 2022 has increased and decreased annually with MAPE 12%

1. Introduction

The plantation sector in Indonesia contributes to economic growth and development, this can be seen from the results of plantation crops that are included in the superior commodity. Each province in Indonesia has a variety of superior commodities based on the area of the plantation and its geographical location. Aceh is a province of Indonesia, located at the northern end of Sumatera. Aceh is geographically located at 4,695135 latitude and 96,749397 with Global Positioning System (GPS) coordinates of $4^0 41' 42{,}486'' N$ and $96^0 44' 57{,}8292''$. Aceh has the potential in the plantation sector which includes oil palm, coffee, cocoa, rubber, candlenut, cloves, nutmeg, patchouli, pepper, areca nut, sugar cane, tobacco and cottonwood trees.

Based on data from Statistics Indonesia and Department of Agriculture and Plantations, the leading commodities of Aceh are oil palm, coffee, cocoa, rubber, coconut, nutmeg, pepper, patchouli, clove, and sugarcane. The data showed that the leading commodities especially coffee and rubber has significantly fluctuated from year to year (as shown in fig.1 and fig.5). Therefore it's affected to national and regional economies. In this case, an analysis is needed to predict or forecast the number of results of leading commodities in the region of Aceh. Forecasting can help in analysing the results of the

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production of regional leading commodities, especially coffee and rubber in the next five years. One method that can be used in forecasting is the exponential smoothing model.

Exponential smoothing model is a time series analysis that continuously makes improvements related to forecasting by taking the smoothing average of past values from a time series data by decreasing exponentially. The data used in this method is given the weight symbolized alpha (α), where this weight is determined freely by trial and error. The alpha values range from 0 to 1. Alpha values that produce the smallest error rate will be selected to use in the forecast model. According to Gardner (Billah, 2006), the exponential smoothing method are relatively simple but robust to forecasting. They are widely use in business for forecasting demand for inventories.

The aimed of this study is to predict the results of coffee and rubber production in Aceh province using the exponential smoothing model. The prediction give five years forecast of annual coffee and rubber production yearly.

2. Method

This research uses exponential smoothing model. The Exponential Smoothing model consists of single exponential smoothing, double exponential smoothing and triple exponential smoothing. This research concentrates on the double exponential smoothing and triple exponential smoothing. Double exponential smoothing use if the data has trends, the forecast is found using two smoothing constants, α and γ with values between 0 and 1. If the data have trend and seasonal pattern then use the triple exponential smoothing with three smoothing constants, denoted by α, γ and β. The data used in this study were historical data of annual coffee and rubber production from 1979 - 2017, which is 39 years. The procedure of data analysis using exponential smoothing as follows:

- Plot the data and observe the characteristic of data.
- Check the trend and the seasonal pattern of the data by using ACF (Autocorrelation Function) and PACF (Partial Autocorrelation Function) plot.
- Choose the appropriate exponential smoothing model based on data trend and seasonal pattern.
- Determine the exponential smoothing constant that gives the minimum MAPE (Mean Absolute Percentage) value.
- Forecast the next five years data using the exponential smoothing model from 2018-2022
- Check the accuracy of the model by calculating the MAPE value.

3. Result and Analysis

3.1 Descriptive analysis of annual coffee and rubber production

Descriptive statistics of annual coffee and rubber production data are presented in the table 1 below

Table 1. Descriptive statistics of annual coffee and rubber production

	Coffee	Rubber
Mean	40,552.95	42,756.59
Median	40,302.00	42,291.00
Std. Deviation	10,798.88	25,938.40
Variance	1.166×10^8	6.728×10^8
Range	49,982	87,414
Minimum	18,511	3,092
Maximum	68,493	90,506
Sum	1,581,565	1,667,507

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Table 1 shows that the average coffee production over the past 39 years is 40,553 tons with the maximum production of 68,493 tons and the minimum production is 18,511 tons. The variance value of the data is 1.166×10^8 with standard deviation of 10,788.88. Based on the variance and standard deviation, it can be explained that the coffee production data varies. This can also be shown based on the range value of the coffee production data that is equal to 49,982. Thus it can be concluded that the coffee production data varies and fluctuated. Table 1 also shows that the results of rubber production in Aceh Province had the most production of 90,506 tons and the lowest of 3,092 tons. The average rubber production in the past 39 years is 42,756.56 tons. Annual rubber production gives variance values and standard deviations of $6{,}728 \times 10^8$ and 25,938.40, respectively. Based on the value of the standard deviation of rubber production has a deviation as far as 25,938.40 to the average production, this means that the annual rubber production also fluctuated.

3.2 Forecasting annual coffee Production

Figure 1 shows a graph of annual coffee production from year 1979 to 2017. From the figure, we can see that the data fluctuated significantly. We also can see that the data has an upward trend but it is not yet known whether there is a seasonal pattern or not.

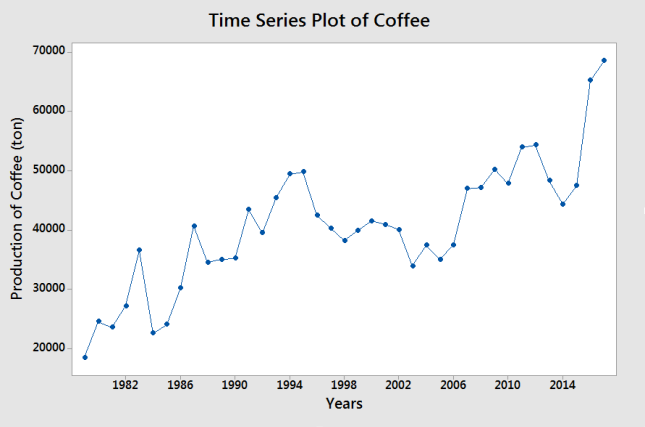

Figure 1. The data plot of coffee production from 1979 to 2017

To find out the existence of trend and seasonal pattern from the data of annual coffee production can be shown through the results of the ACF (Autocorrelation Function) plot as shown in figure 2.

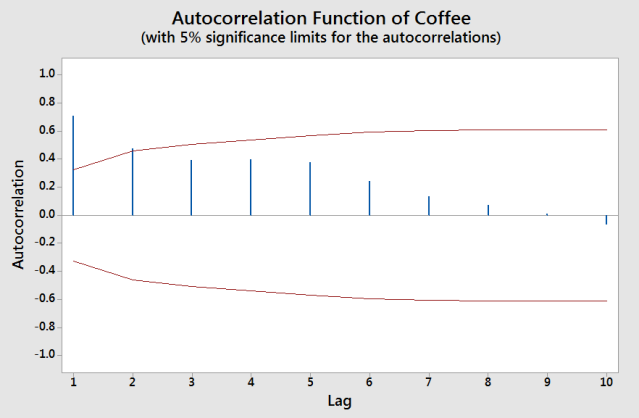

Figure 2. ACF plot of annual coffee production

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Figure 2 shows that the data has trend, it can be shown from the lag movement which is slowly decreasing to 0. Lag in the figure also does not experience repetition in certain periods so that the data does not have a seasonal pattern. The trend pattern also which is linear trend shows at figure 3.

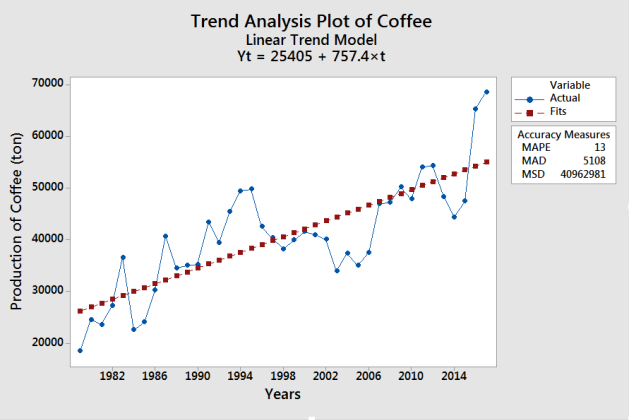

Figure 3. Trend analysis plot of annual coffee production

From figure 3 it is clearly seen that the data has linear trend, this is shown from the line of fit which has increased linearly. When the line fits increases or decreases linearly, the data is said to have a trend. Based on the results of testing of annual coffee production data (tons), the appropriate model of exponential smoothing method is double exponential smoothing. This is because the data has trend but no seasonal pattern.

3.2.1 Determining the value of α and γ

In modelling the annual data production using double exponential smoothing, first, we have to determine the best value of α and γ. The value of α is a smoothing constant for actual data and γ is smoothing constant for trend. The choice of the optimal constant can be done by trial or error. A good parameter values α and γ are obtained from the smallest MAPE value. The table 2 below shows MAPE value according to different α and γ

Table 2. Shows MAPE value according to different α and γ

No	α	γ	MAPE (%)
1	0,8	0,1	12,32
2	0,7	0,1	12,21
3	0,9	0,1	12,37
4	0,6	0,1	12,17
5	0,6	0,2	12,47
6	0,4	0,1	12,52
7	0,5	0,2	12,46
8	0,4	0,2	12,51
9	0,6	0,3	13,07
10	0,5	0,3	12,88

The results shown in the table 2, based on a criteria of least MAPE that the best forecast is when the value of $\alpha = 0{,}6$ dan $\gamma = 0{,}1$ with MAPE 12,17%. From the value, we forecast the next five years of annual coffee production as shows at table 3.

Table 3. Data forecasting of annual coffee production for next 5 years

Year	2018	2019	2020	2021	2022
Forecast (tons)	66,860	68,762	70,665	72,567	74,469

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The forecasting results show that annual coffee production increase continuously from 2018 to 2022, it was increased by 2.73% annually. The increasing coffee production in the next 5 years can also be seen from the actual data plot and forecasting data using double exponential smoothing method as shown in Figure 4.

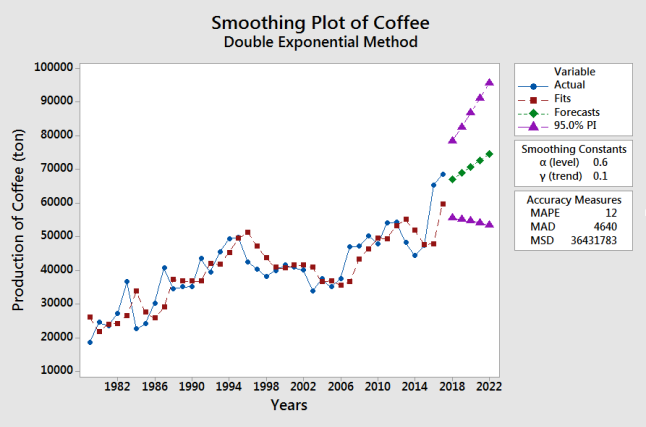

Figure 4. Plot actual data and forecasting data of coffee production

In figure 4 shows MAPE value of the coffee production forecast is 12%. This shows that the average percentage of errors between actual data and forecasting data is small. Thus, it can be concluded that the double exponential smoothing model provides excellent forecast results in forecasting the annual coffee production in Aceh province.

3.3 Forecasting annual rubber production

The data plot in Figure 5 shows that the rubber production has increased and decreased or in other words, rubber production has fluctuated from year to year. It is seen that rubber production (tons) experienced a fairly rapid increase in the 24th and 26th periods or in 2002 and 2004 and decreased in 14th period (1992).

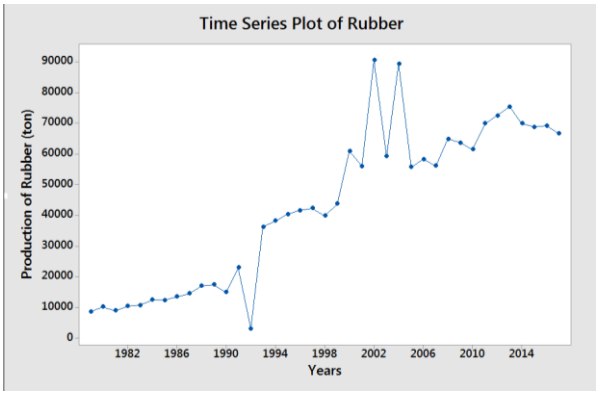

Figure 5. The data plot of rubber production from 1979 to 2017

In figures 6 and 7 it can be seen that the results of rubber production has trend and seasonal pattern based on ACF (Autocorrelation Function) plot where the lag movement is slowly decreasing towards 0 and there are many ACF values outside the interval/ horizontal line and that shows the data is not stationary or has trend. The seasonal pattern shows from the PACF (Partial Autocorrelation

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Function) graph where the value is repeated in a certain period. To see there is a trend or not, it also can be seen from trend analysis model plot as shown in the figure 8.

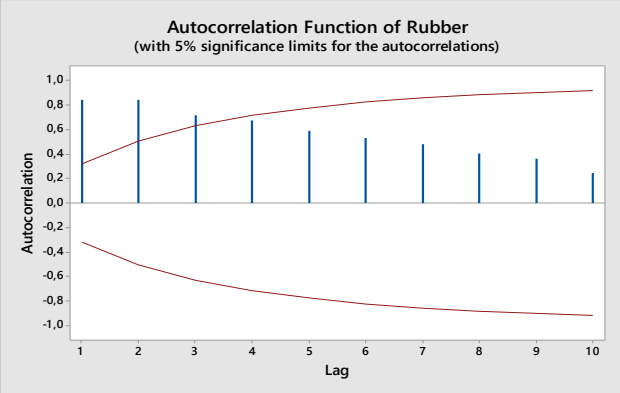

Figure 6. ACF plot of annual rubber production

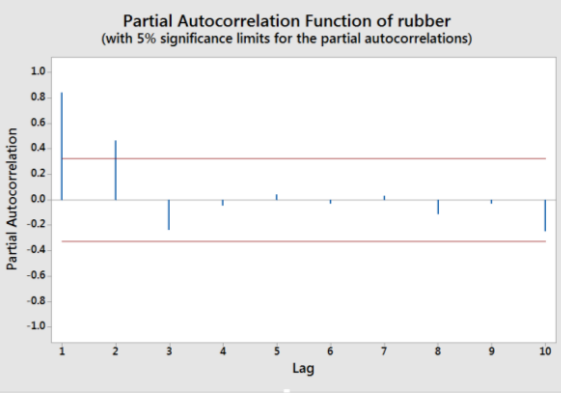

Figure 7. PACF plot of annual rubber production

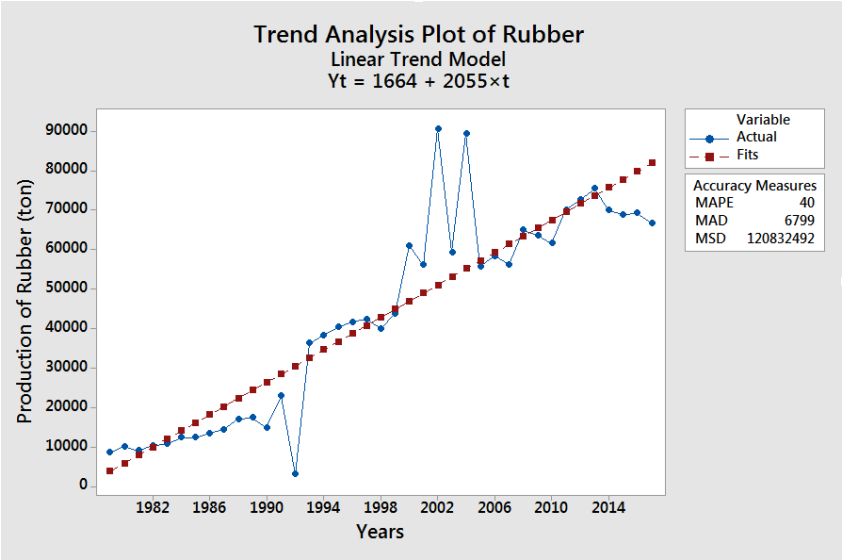

Figure 8. Trend analysis plot of annual rubber production

Based on the results of testing of annual rubber production data (tons), the appropriate model of exponential smoothing method is triple exponential smoothing. This is because the data has trend and seasonal pattern.

3.3.1 Determining the value of α, γ and β

There are three smoothing values in triple exponential smoothing modeling, namely α, γ, and β. The determination of these values is done by a trial and error process that aims to get the optimal smoothing values. Smoothing value are said to be optimal if these value have a least MAPE (10%-20%). Table 4 shows some values of α, γ and β.

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Table 4. Shows MAPE value according to different α, γ *and* β

No	α	γ	β	MAPE (%)
1	0,9	0,1	0,1	8,88
2	0,9	0,2	0,1	9,27
3	0,9	0,1	0,2	8,98
4	0,8	0,1	0,1	9,28
5	0,9	0,3	0,1	9,71
6	0,8	0,2	0,1	9,36
7	0,8	0,3	0,1	9,68
8	0,8	0,1	0,2	9,50
9	0,8	0,4	0,1	10,07
10	0,8	0,2	0,2	9,58

The results shown in the table 4, based on a criteria of least MAPE that the best forecast is when the value of $\alpha = 0{,}9$, $\gamma = 0{,}1$ and $\beta = 0{,}1$ with MAPE 8,88%. From the value, we forecast the next five years of annual rubber production as shows at table 5 below.

Table 5. Data forecasting of annual rubber production for next 5 years

Year	2018	2019	2020	2021	2022
Forecast (tons)	33,517	34,586	29,846	46,514	6,350

The forecasting results show that annual rubber production (tons) from 2018 to 2022 has increased and decreased. We can see that from year 2018 to 2019, rubber production increased by 3.18% and then decreased by 13.7% in 2020. Besides, the forecasting results show the highest rubber production results occurred in 2021 (46,514) tons, it was increased by 55.8% from the previous year. However, the rubber production declined rapidly by 86,34%. The plot results between actual data and forecasting data using the triple exponential smoothing method shows in figure 9.

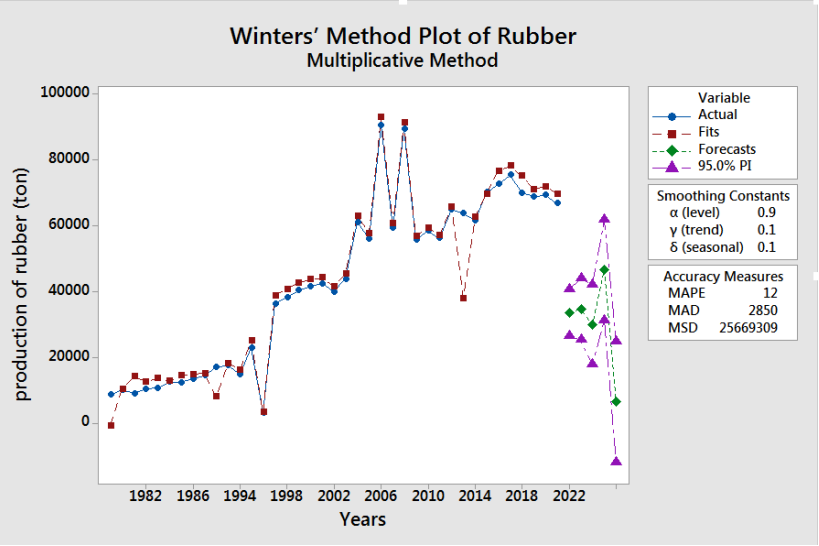

Figure 9. Plot actual data and forecasting data of rubber production

The Mean Absolute Percentage (MAPE) value of rubber production forecast gives the same result as coffee at 12%. This shows the average percentage errors between actual data and forecasting

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data is small. Thus, it can be concluded that the triple exponential smoothing model provides excellent forecast results for forecasting rubber production in Aceh Province as shown in table 5.

4. Conclusion

The data used in this study are data from coffee and rubber production from 1979 – 2017. Coffee and rubber production for 39 years experienced a time fluctuation, this is indicated by the standard deviation values of coffee and rubber, respectively 10,788.885 and 25,939.402. Based on the results of the ACF and PACF plots, coffee production data has trend but there is no seasonal pattern, and rubber production data has trend and seasonal pattern. Therefore, coffee production forecasting is modelled by double exponential smoothing with smoothing constants $\alpha = 0.6$ and $\gamma = 0$. Meanwhile, rubber production forecasting is modeled with triple exponential smoothing with smoothing constants $\alpha = 0.9$, $\gamma = 0.1$ and $\beta = 0.1$

The forecasting results show that annual coffee production (tons) increase continuously from 2018 to 2022, it was increased by 2.73% annually. The forecasting results of annual rubber production (tons) from 2018 to 2022 has increased and decreased. From year 2018 to 2019, rubber production increased by 3.18% and then decreased by 13.7% in 2020. Besides, the forecasting results show the highest rubber production results occurred in 2021 (46,514) tons, it was increased by 55.8% from the previous year. However, the rubber production declined rapidly by 86,34%. The forecasting result gives a good prediction with the Mean Absolute Percentage (MAPE) value 12%.

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