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Maximising the benefit of domestic and export markets scenario: Predicting models for durian production

(Memaksimumkan manfaat senario pasaran domestik dan eksport: Model ramalan pengeluaran durian)

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Keywords: durian production, moving average, single exponential smoothing, linear programming

Abstract

In this decade, the Malaysian durian industry is focusing towards meeting the domestic and export market demands. In order to continually supply for both of the markets, management of production and marketing need to be strengthened to avoid shortage or surplus of durian fruits. This research is designated to forecast durian production one year in advance (2018) in Peninsular Malaysia using production data from the year 1992 to 2017 and also to quantify the sales volume in both markets to achieve the maximum profit. Forecasting performance of two classical time series methods which are Moving Average (MA) and Single Exponential Smoothing (SES) were compared based on Mean Absolute Percentage Error (MAPE). Model with the least value of MAPE is considered the most accurate prediction. The results revealed that SES with alpha 0.9 is the most appropriate model to forecast durian production in Peninsular Malaysia in 2018. Using the forecasted value of SES, Linear Programming model was then applied to assess the value of estimated quantity in domestic and export markets to achieve the maximum profit in the following year. Results found that the maximum profit of durian production in Peninsular Malaysia is predicted to be around RM4.5b. In order to achieve this maximum profit, the total quantity of domestic and export demands must reach 14,105.93 metric tonnes (MT) and 163,625.07 MT, respectively. These findings may help in determining the appropriate volumes to export durian in order to get the best price and maximise profit.

Introduction

Malaysia alongside with Thailand and Indonesia are the major countries that produce durian commercially for domestic and export markets. At present, there are more than 57,185 ha being planted with durian in Peninsular Malaysia and 28379.1 ha produce good quality durian. Based on statistics published by the Department of Agriculture, Malaysia (DOA 2017), the major producing states in Peninsular Malaysia are Pahang (Raub and Bentong

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districts which produce about 43,712.7 MT), Perak (Batu Kurau district produces 8201.3 MT) and Johor (Muar, Segamat and Tangkak areas generate approximately 29,833.9 MT).

In 2016, more than 17,000 MT durian with the value of 17 million USD were exported to our main markets, especially in Singapore, Hong Kong, China and the United States. However, in 2017 the export volume decreased to 14,000 MT valued at about 16 million USD. According to (Yogambigai Rajamoorthy et al. 2015), domestic demand can be determined using the following equation:

$$C = P + M - X$$

where,

P = Production (MT)
M = Import (MT)
X = Export (MT)

Hence, for the year 2016 and 2017, domestic demands are more than 241,000 MT and 170,000 MT, respectively. Comparing the demands for domestic and export market, the quantity of durian for export market is lower than domestic market due to the seasonality of durian production. One of the reasons is that durian production is usually concentrated from June to August every year. This will lead to oversupply in these month and shortage of fruits in the other months. When there is an excess supply, the durian price will be lower and vice versa.

The decreasing or increasing supply of durian in export and domestic markets depends largely on the climatologicaly problem of production and seasons. Therefore, in order to reduce the supply gap and associated problems, an appropriate method of forecasting supply and demand of durian for both markets is necessary. The forecasting method is crucial to provide future information on durian production that could assist in planning and crop management. However, there are limited studies on durian production forecasting model that could be used to estimate fruit quantity to meet the export and domestic demands.

Therefore, this study emphasiSes on the time series forecasting model and linear programming techniques to estimate durian production. Hence, the objectives of this study are; (1) to generate the best models in forecasting the durian production in Peninsular Malaysia using Time Series method (Moving Average (MA) and Single Exponential Smoothing (SES) models); (2) to forecast durian production in Peninsular Malaysia one year in advance using the fitted forecasting model; and (3) to determine the maximum profit in 2018 for both markets using Linear Programming method.

Literature review

Crop production forecasting technique is a tool of predicting the future crop production over a specific period of time. The forecasted value is an important component for the strategic decision making of the producer, company or even the government. In order to make a worthy forecast, in-depth understanding of the different forecasting methods is very important for practical implementation. An adequate number of data sets is also an important factor to consider when choosing the appropriate forecasting techniques. A classical time series method was used in this study due to the lack of historical durian production data.

Several studies have been conducted to investigate the profitability of using the time series method for forecasting crop production. The simple Moving Average (MA) is the simplest technique to model the crop production (Boken 2000). The study found that MA was the best fitted model for wheat yield as compared to other methods such as linear trend, quadratic trend, simple exponential smoothing, double exponential smoothing, double moving averaging (based on the value of coefficient of determination, R^2), Durbin-Watsin Statistics (DW-S) and coefficient of auto-correlation among residuals (p). These results were in support of the findings from (Johnson et al. 1999) who empirically compared the performance of simple Moving Average (MA) with an Exponentially Weighted Moving Average (EWMA) and they found that the forecast error was 3% lower than using EWMA.

Besides Moving Average, another classical technique to forecast crop production is by using Single Exponential Smoothing (SES) which is easier to implement and uses less information (Boken 2000). This technique can identify the tendency pattern and it is suitable when dealing with trend data (Makridakis et al. 1998). Empirical comparison between ARIMA, Dynamic Linear Model (DLM) and Exponential Smoothing has been done by (Akram et al. 2015) and result showed that Exponential Smoothing was the best and accurate forecasting model of four major crops in Pakistan.

Although, many new sophisticated time series models were developed to forecast crop production worldwide, the use of classical time series method still gives the best performance especially when dealing with small sample size and univariate situation in short term forecasting. According to Christine A. Martin et al. (1989), the classical time series method produced accurate prediction of one year than two years in advance forecasts.

In contrast, the Linear Programming (LP) which is a component of Operations Research study (OR) models has been introduced in an agricultural study as early as 1950's. For example, Waugh (1951) used LP in cost minimisation of feed for livestock. LP can be utilised in critical decision making for example in establishment of new industries, planning for production, distribution, marketing and policy establishment since a lot of real problems could be solved by using LP (Sofi et al. 2015).

Moreover, LP can also be implemented for production planning in order to obtain the maximum benefit under the condition of limited production capacity and inventory. Thus, the production planning can be improved accordingly (Chachiamjane and Kengpol 2007). In Thailand, the LP method was used to plan and determine the appropriate fresh and processed durian production for both domestic and export markets so that the super abundant durian production problem can be solved effectively (Pokterng and Kengpol 2010).

Since we are facing similar problems here in Malaysia, there is a need to apply these techniques to forecast durian production and estimate the appropriate durian quantity for export and domestic markets in Peninsular Malaysia. This will serve as a guideline to producers and other players to maximise their profit with regard to adjustment of crop production.

Materials and methods

Study region and data

Peninsular Malaysia (100°E-104°E; 1°N-7°N) is situated in the tropics that experiences high rainfall, temperature and humidity throughout the year. The durian production data of peninsular Malaysia were obtained from the Department of Agriculture, Malaysia and the record covered a period of 26 years (1992 – 2017). The durian production in Peninsular Malaysia is presented in *Figure 1*. The analysis performed in this study was using Minitab 17 software.

Time series model

The time series method was applied to find the forecast value of durian production in the year 2018. Note that this data consisted of lower than 30 observations which was considered as a small sample size. There are several time series models that can be used for small sample for instance, Moving Average (MA) and Auto-regressive, Exponential Smoothing and many others. However, in this study we used two models based on its suitability.

Moving average model

Moving Average (MA) was used to find the mean of specified set of values and the means were used to forecast the next period. MA formula is,

$$M_t = \frac{y_t = y_{t-1} + \dots + y_{t-k+1}}{k}$$

where,

y_t is the most recent observation of a variable.

k is the number of periods in MA as yearly start at k = 2, 3, …, 5 years

In this project, there were four candidate models to be compared with different number of periods starting from k = 2 until k = 5 to determine the best fitted model. The model efficiency will be compared by using forecasted error method.

Single exponential smoothing

Besides Moving Average (MA) model, Single Exponential Smoothing (SES) model was also chosen. SES produced forecasts by averaging past values with a decreasing (exponential) series of weight. For SES model, we need to find the best smoothing constant, α before comparing both models. There were 3 candidate models for SES with different level α of such as α = 0.10.5, 0.9. The formula of SES model is:

$$\hat{Y}_{t+1} = \alpha Y_t + (1 - \alpha)\, \hat{Y}_t$$

where,

$\hat{Y}_{t+1}$ = new smoothed value or the forecast value for the next period.

Y_t = new observation or actual value of series in period t.

$\hat{Y}_t$ = old smoothed value or forecast value for period t.

α = smoothing contant ($0< \alpha <1$)

Linear programming

Linear Programming is a method of determining the optimal value of a linear function of a set of decision variables,

$\chi_1, \chi_2, \chi_3, \dots, \chi_n$, where $n > 0$.

The combination of the decision variables,

$$f(\chi_1, \chi_2, \chi_3, \dots, \chi_n) = \alpha_1\chi_1 + \alpha_2\chi_2 + \alpha_3\chi_3 + \dots + \alpha_n\chi_n$$

should lie within the set of constraints. For a constraint to be reasonable, all terms in the constraint must have the same units.

Comparison of model efficiency

In comparing the efficiency of two chosen forecasting models between Moving Average and Single Exponential Smoothing Model, several forecasted errors were used such as, Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), Mean

$$MAE = \frac{\sum_{i=1}^{n} |y_i - \hat{y}_t|}{n}$$

$$MSE = \frac{\sum_{i=1}^{n} (y_i - \hat{y}_t)^2}{n}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (y_i - \hat{y}_t)^2}{n}}$$

$$MAPE = \frac{\sum_{i=1}^{n} \left| \frac{y_i - \hat{y}_t}{y_i} \right|}{n} \times 100\%$$

Square Error (MSE), and Root Mean Square Error (RMSE).

The forecasted errors were explained by the following equations:

Results and discussion

Model selection

This section elaborates the statistical analysis of this study. The annual durian production data in Peninsular Malaysia from year 1992 until 2017 was used in order to forecast the durian production one year in advance. *Figure 1* showed the time series durian production plot that consists of 26 observations. Results indicated that durian production in Peninsular Malaysia has fluctuated and decreased over the years.

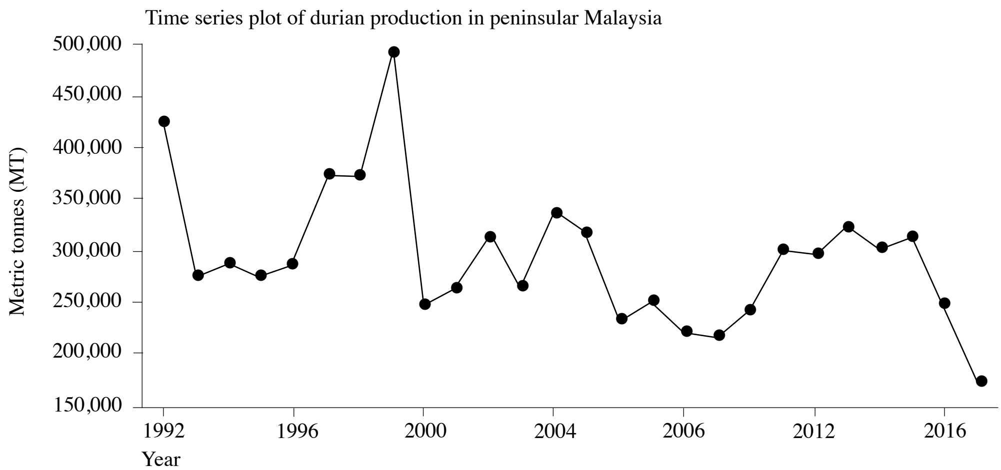
Forecasting a non-stationary data will lead to misinterpretation and give false information. Therefore, a method to transform a non-stationary data into stationary data was applied by differencing at lag = 1 also known as first order differencing to make the series stationary.

$$\nabla y = y_t - y_{t-1}$$

where the symbol ∇ denote the differencing process.

Therefore, the time series plot of durian production after undergoing the first order differencing is shown in *Figure 2*. Results showed that the time series plot of durian production is stationary around constant mean.

After the data had undergone first order differencing, the identification process was applied through visual inspection of the Auto-correlation Function (ACF) and Partial Auto-correlation Function (PACF). The ACF plot in *Figure 3(a)* showed the cut off at lag



Source: Department of Agriculture, Malaysia

Figure 1. Durian production plot in Peninsular Malaysia (1992 – 2017)

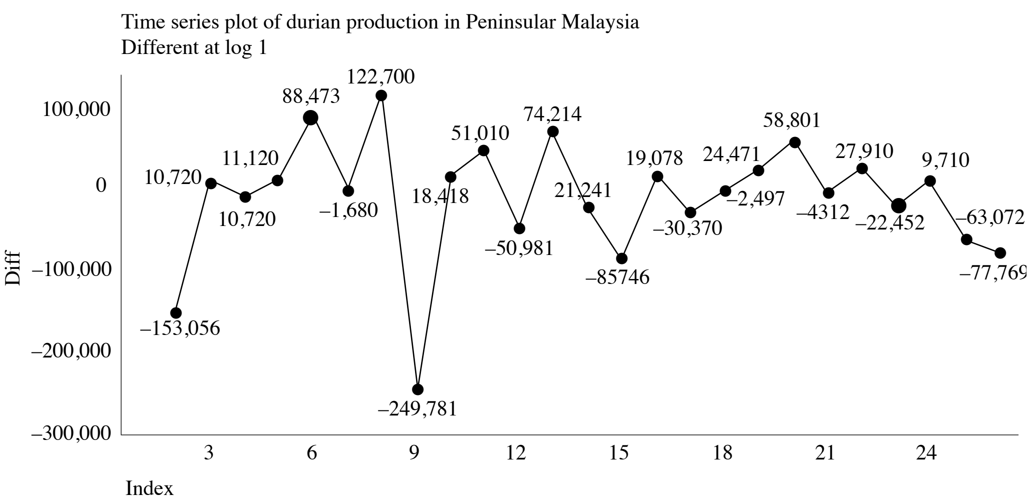
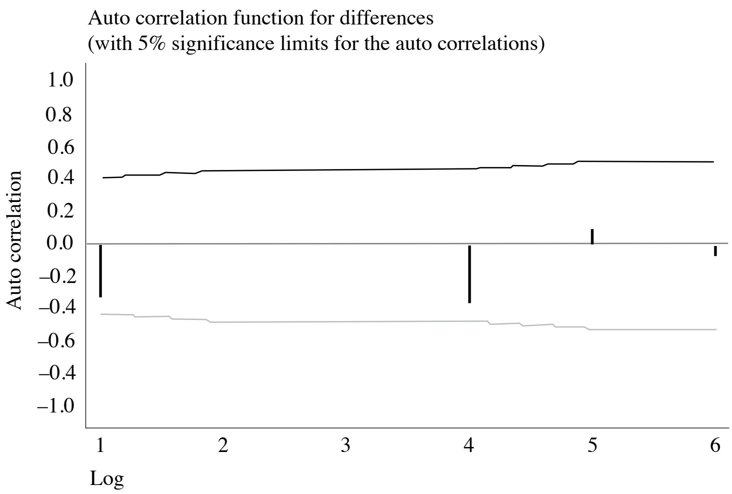


Figure 2. Durian production plot in Peninsular Malaysia after differencing at lag 1

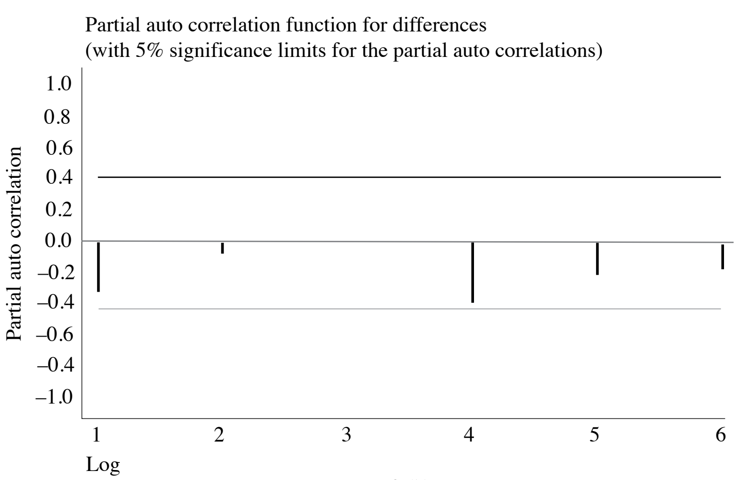
1 and 4, while the PACF plot in *Figure 3(b)* indicated that the coefficients trail off to zero gradually. Therefore, it can be concluded that Moving Average is one of the appropriate models to be used to forecast the durian production in Peninsular Malaysia.

The Moving Average model is used to find the mean of specified set of values that could be used to forecast the next period. Four periods (lag) in Moving Average starting from k = 2, 3, 4 and 5 were compared to determine the fitted model. From *Figure 4*, the four graphs of Moving Average with different lags were well fitted. However, the best fitted model, was chosen by error comparison using the Mean Absolute Percentage Error (MAPE). The values of MAPE for each of the models according to its year length were shown in *Figure 5*. The MAPE values for Moving Average of year 2, 3, 4 and 5 are 378%, 305%, 270% and 153%, respectively. The Moving Average with length 5 years has the smallest error than the other three models indicating that Moving Average with length 5 years was the best fitted model.

Basically, one of the objectives of this study is to generate the best model in order

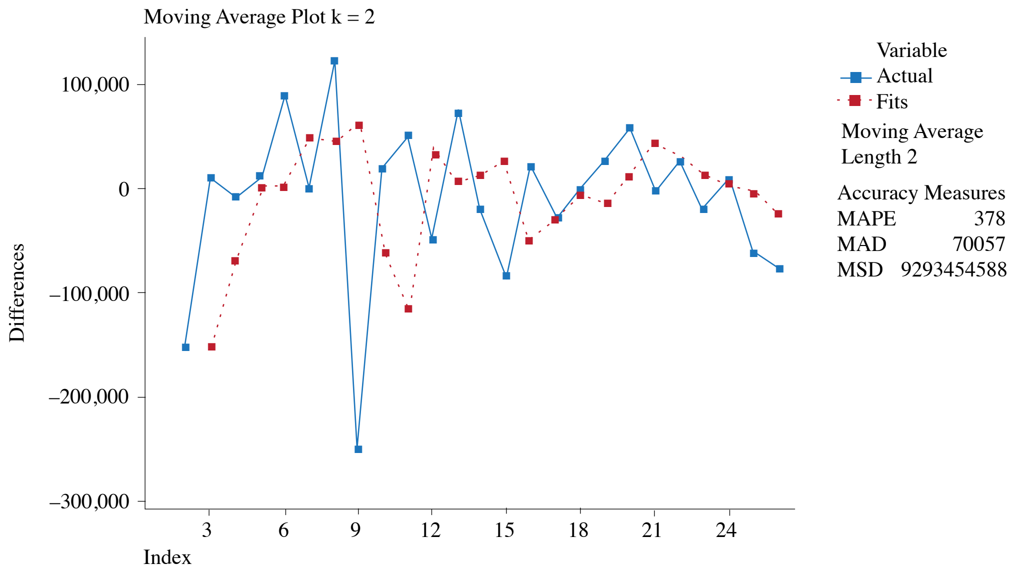


3 (a)



3 (b)

Figure 3. Auto correlation function and partial auto correlation function of durian production in Peninsular Malaysia after differencing at lag 1


Moving Average Plot k = 2
100,000
0
–100,000
–200,000
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Differences
3
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9
12
15
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Index
Variable
Actual
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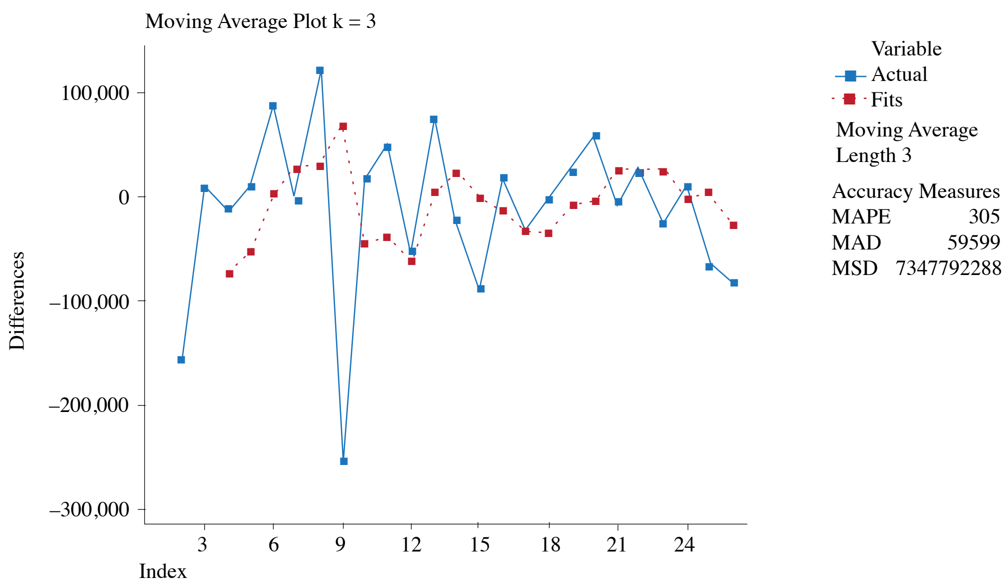
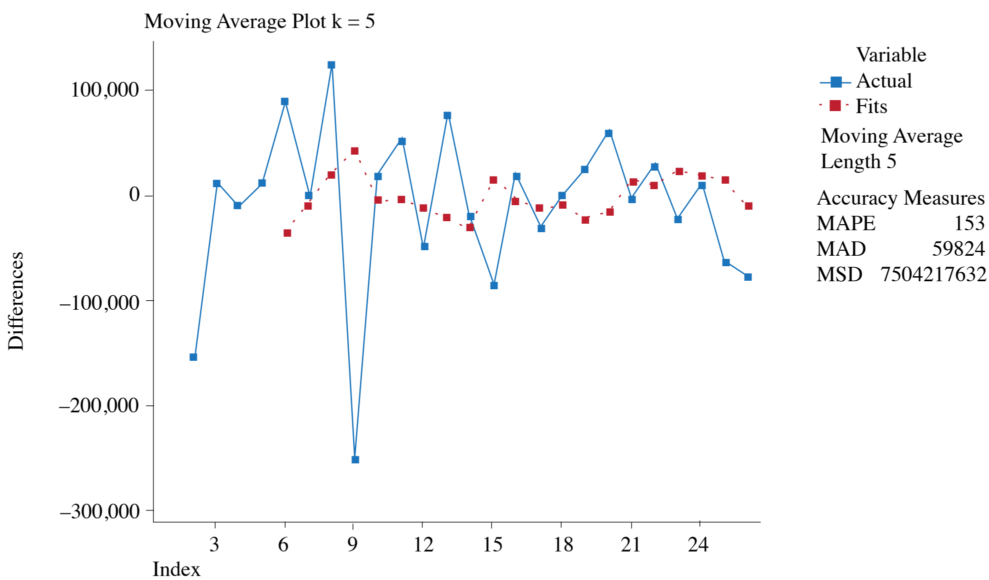
Moving Average
Length 2
Accuracy Measures
MAPE 378
MAD 70057
MSD 9293454588

4(a)


Moving Average Plot k = 3
100,000
0
–100,000
–200,000
–300,000
Differences
3
6
9
12
15
18
21
24
Index
Variable
Actual
Fits
Moving Average
Length 3
Accuracy Measures
MAPE 305
MAD 59599
MSD 7347792288

4(b)

4(c)



4(d)

Figure 4. Plot of moving average of 2, 3, 4 and 5 years of durian production in Peninsular Malaysia

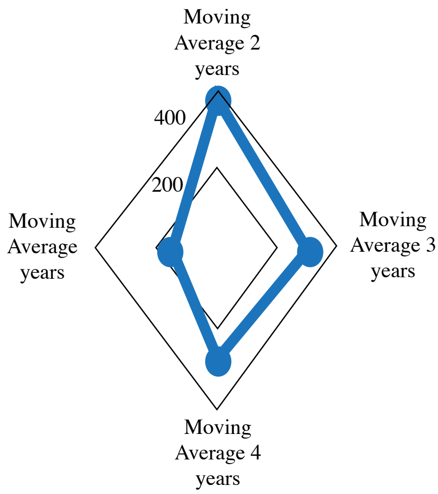


Figure 5. Error comparison of Mean Absolute Percentage Error (MAPE) of Moving Average model

to forecast the durian production in 2018. Besides Moving Average model, another model used for forecasting the small sample was Single Exponential smoothing (SES) model. For SES model, finding the best smoothing constant, α is a must in order to smooth and obtained accurate forecast. The SES model with 3 smoothing constants namely, α = 0.1, 0.5, 0.9 were being compared as shown in *Figure 6*.

The forecasting performances of these 3 models were also identified using MAPE as shown in *Figure 7*. Based on this plot, MAPE of SES model with smoothing constant α = 0.9 is 18%. Meanwhile, the MAPE values for α = 0.1 and α = 0.5 are 20% and 19% respectively. It is therefore proven that SES with α = 0.9 is the best fitted model as it has the lowest percentage of error compared to the other two smoothing constants.

Comparison of model efficiency

In comparing the model efficiency of the two chosen forecasting methods namely Moving Average with lag 5 years, MA(5) and SES with α = 0.9, several forecast errors were used, namely, Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), Mean Square Error (MSE), and Root Mean Square Error (RMSE). The significant of using absolute values or squared values are to avoid positive and negative errors from offsetting each other (Poktern and Kengpol 2010).

Based on *Table 1*, SES with α = 0.9 has the smallest value of MAE, MSE, RMSE and MAPE compared to MA(5). Generally, MAPE is a familiar method to determine the accuracy of the model. Evidently, there is a huge difference of MAPE values between MA(5) and SES with α = 0.9 which is shown in *Table 1*. The MAPE value of MA(5) is 153% which is greater than 50% suggesting that the forecast using this model is inaccurately. In contrast, the MAPE value of SES model is low (18%) indicating that this model is a better forecasting method for durian production. Hence, SES model with the smoothing constant, α = 0.9 will be applied to forecast the durian production for the year ahead.

Forecasting durian production

The durian production forecasted using SES model with smoothing constant, α = 0.9 was shown in *Table 2*. It was estimated that the durian production in 2018 will be about 177,731 MT. It was also shown that the predicted durian production in 2018 is higher than its previous year (*Figure 8*).

Table 1. Error comasrison of forecasting model between IMA (5) and SES (0.9)

Forecast model	MAE	MSE	RMSE	MAPE
IMA(5)	59823.68	7504217632	86626.89	153.5
SES (0.9)	48249.11	5363317501	73234.67	18

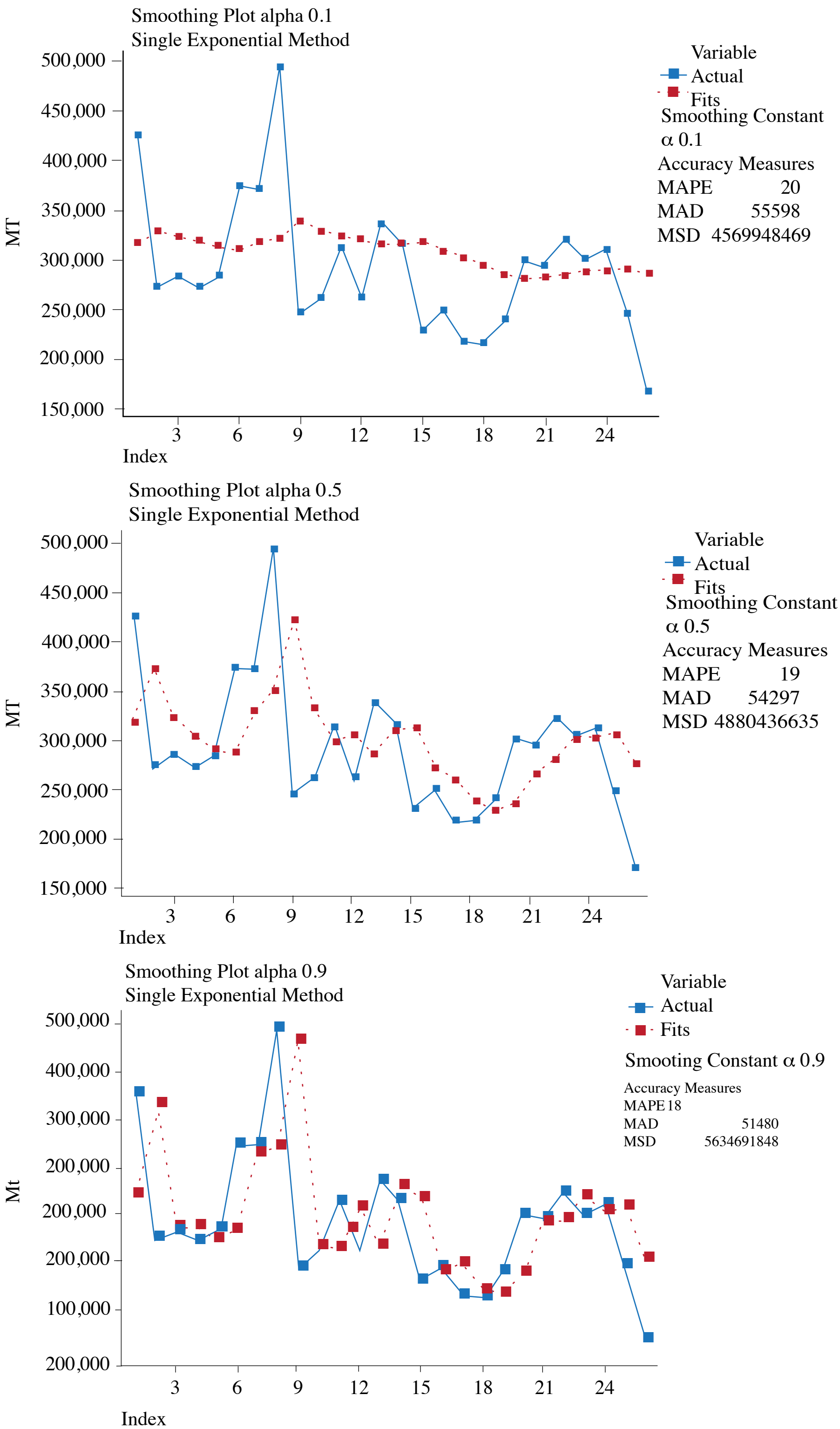


Figure 6. *Single Exponential Smoothing α = 0.1, 0.5, 0.9 of durian production in Peninsular Malaysia*

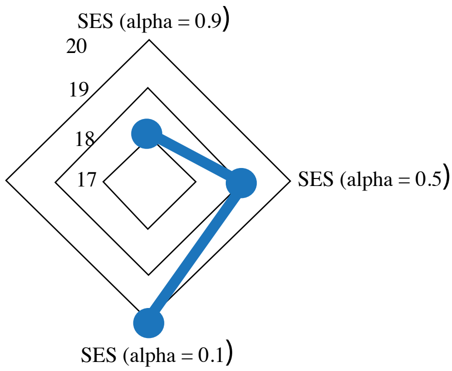


Figure 7. *Error comparison of Mean Absolute Percentage Error (MAPE) of Single Exponential Smoothing (SES) model*

Table 2. Forecast of durian production in Peninsular Malaysia using SES (0.9)

Period	Year	Forecasted value (MT)	95% confidence interval
27	2018	177731	(51607.3, 303854)

Profit maximisation

After knowing the predicted quantity of durian production in the year 2018, Linear Programming model was introduced to find the optimum quantity of durian for maximum profit. This model is a mathematical model that could quantify the maximum profit of durian production in Peninsular Malaysia using the forecasting data of domestic and export market demands. In order to formulate the Linear Programming model, decision variables must be determined correctly. Two decision variables that have been determined are:

χ_1 = The quantity of export demand of durian in Peninsular Malaysia.
χ_2 = The quantity of domestic demand of durian in Peninsular Malaysia.

Therefore, the Linear Programming model is formed based on the decision variables explained by,

$$Max\ Z = \alpha_1 x_1 + \alpha_2 x_2$$

where
α_1 and α_2 are profit coefficients for x_1 and x_2

subject to,
$x_1 \leq 14105000$ (Total Quantity Export in 2017)
$x_2 \leq 170166000$ (Total Quantity Domestic demand in 2017)
$x_1 + x_1 \leq 177731000$ (Forecasted durian production)
$x_1 + x_1 \geq 0$

The forecasted maximum profit of durian production in Peninsular Malaysia was estimated at about RM4.5b. In order to achieve this maximum profit, the total quantity of export demand and local demand must achieve 14,105.93 MT and 163,625.07 MT, respectively.

Conclusion and recommendations

The estimation of durian production using appropriate forecasting techniques is crucial to obtain the most accurate model to be used to calculate the anticipated demand for both domestic and export markets. Based on the forecasting performance using Mean Absolute Percentage Error (MAPE) and with a MAPE value equal to 18%, it was suggested that Single Exponential Smoothing (SES with α = 0.9) was the best model to fit durian production data in Peninsular Malaysia.

The result of Linear Programming indicates that in order to achieve the maximum profit of RM4.5b, the quantity of durian to be exported in 2018 is 14.105 MT which is more or less similar to the amount in 2017. While, the quantity of durian produced for local consumption should achieved 163,625.07 MT to avoid over supply

The present study provides a good analysis for planning and management of durian production to fulfill the demand of domestic and export markets. Similar approach can be extended to other seasonal fruits so that the problem of superabundant or shortage of production can be predicted.

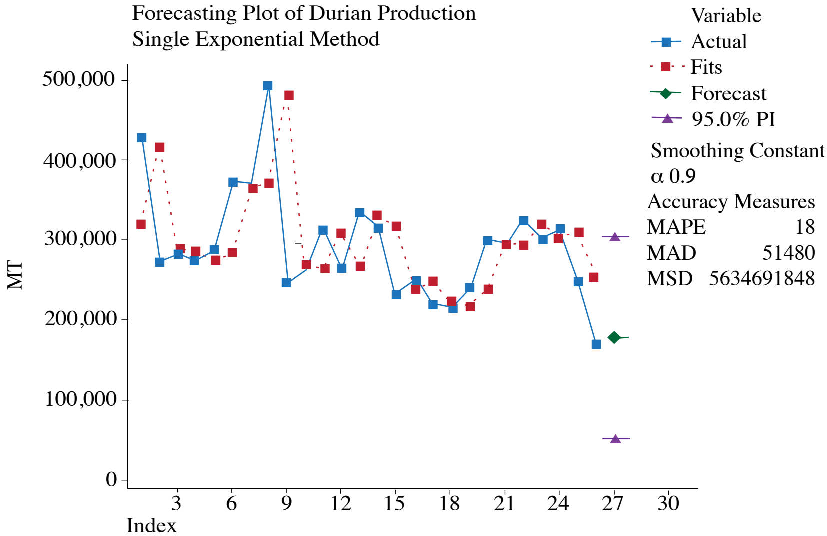


Figure 8. Forecasting plot of durian production in Peninsular Malaysia

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Abstrak

Dekad ini, industri durian di Malaysia memberi tumpuan kepada memenuhi permintaan dalam dan luar negara. Bagi menjamin bekalan berterusan untuk kedua-dua pasaran ini, satu sistem pengurusan pengeluaran dan pemasaran perlu diperkasa bagi mengelakkan kekurangan atau lebihan bekalan. Kajian ini dijalankan untuk meramalkan jumlah pengeluaran durian di Semenanjung Malaysia pada tahun 2018 dengan menggunakan data pada tahun 1992 hingga 2017. Di samping itu, ia bertujuan untuk menentukan kuantiti bekalan bagi pasaran tempatan dan eksport yang dapat memberikan keuntungan maksimum. Prestasi dua model ramalan yang menggunakan kaedah *Moving Average* (MA) dan *Single Exponential Smoothing* (SES) dinilai berdasarkan *Mean Absolute Percentage Error* (MAPE). Model yang menunjukkan nilai MAPE yang paling kecil adalah model yang paling tepat. Keputusan analisis ramalan ini menunjukkan model SES dengan nilai alpha 0.9 adalah yang paling sesuai digunakan untuk ramalan hasil durian di Semenanjung Malaysia. Seterusnya, dengan menggunakan hasil ramalan ini, model pengatucaraan linear digunakan untuk menentukan jumlah jualan bagi pasaran domestik dan eksport yang dapat memberikan keuntungan maksimum. Keputusan analisis menunjukkan keuntungan maksimum yang boleh dicapai ialah RM4.5b jika hasil durian sebanyak 14,105.93 MT (eksport) dan 163,625.07 MT (domestik) dapat dikeluarkan. Hasil kajian ini dijangka dapat membantu dalam membuat keputusan bagi menentukan kuantiti jualan eksport yang sesuai bagi mendapatkan keuntungan yang maksimum.