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Forecasting oil palm and crude palm oil data in Thailand using exponential time-series methods

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Abstract

In this paper, several exponential time-series methods are applied to forecast oil palm prices, crude palm oil prices, and crude palm oil production in Thailand from January to March 2018. The selected methods include Double Exponential Smoothing (DES), the Multiplicative Holt-Winters (MHW), the Additive Holt-Winters (AHW), the Improved Additive Holt-Winters (IAHW), and the Extended Additive Holt-Winters (EAHW) methods. Input data from January 2005 to December 2017 (thirteen years) were collected from the databases of the Office of Agricultural Economics and the Department of Internal Trade. Here, the novelty of our work is twofold. First, three closely related input data types are forecasted and analyzed simultaneously. Second, the well-known time-series forecasting methods (i.e. the DES, the MHW, and the AHW methods) and the efficient methods recently proposed in the literature (i.e. the IAHW and the EAHW methods) are implemented and tested. Therefore, the best forecast results determined by optimal methods are revealed. Our study demonstrates that the DES and the EAHW methods provide the smallest error (measured by Mean Absolute Percentage Error, MAPE) in forecasting oil palm and crude palm oil prices. For crude palm oil production, the IAHW and the EAHW yield better performance. The results also show the trends of the average monthly and yearly data and indicate that during January to March 2018, crude palm oil production in Thai markets should increase and prices will likely be stable. We believe that our research methodology and results can be useful for planning and setting strategy for Thai agriculturists and the government.

Keywords: Crude palm oil prices, Crude palm oil productions, Oil palm prices, Forecasting, Time-series methods

1. Introduction

Oil palm is an important economic crop in Thailand (Figure 1) because its production yield per unit area is significantly higher than that of other oil crops. In 2016, oil palm cultivated areas accounted for 729,600 hectares, which increased by approximately 5.79% over the past five years [1]. Additionally, palm oil is widely used for various purposes in food applications (e.g., cooking oil, margarine, and snacks), industrial commodities (e.g., cosmetics, soap, and candles) and as alternative fuels (e.g., biodiesel). Thus, the utilization of palm oil in Thailand increasing.

The palm oil price in Thailand is influenced by various factors, such as supply and demand, other oil-crop prices, the crude oil price, weather phenomena, the impact of natural disasters, and government policies [2]. As a result, the palm oil price in Thailand varies over time. For example, the crude palm oil price decreased from 31.40 baht/kilogram in January 2017 to 19.12 baht/kilogram in December of the same year [3]. The fluctuation of palm oil prices directly affects smallholder farmers' incomes. Especially in times of low prices, the smallholder farmers, almost 80% of Thai oil palm producers, face financial losses, which prevent sustainability in Thailand's palm oil sector. The Thai Renewable Energy Policy is an important tool to support the palm oil market. It follows a flexible approach regarding the biodiesel blending ratio, allowing it to vary from 3% to 7% by volume of diesel (or B3 to B7) based on the supply situation in the market [1]. Consequently, forecasting accuracy of future events based on appropriate methods can help policy makers and marketing strategists make appropriate decisions and devise suitable strategic plans.

To forecast data, the well-known time-series approaches including the DES, MHW, and AHW methods are widely used. They are properly used for data that trend and where seasonality patterns are present. Although these forecasting methods are not new, they are often used in practice [4-11]. Researchers often apply such methods due to their simplicity, low computational complexity, and high efficiency [4-11]. Forecasting of oil palm prices, palm oil prices, and palm oil

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(a)

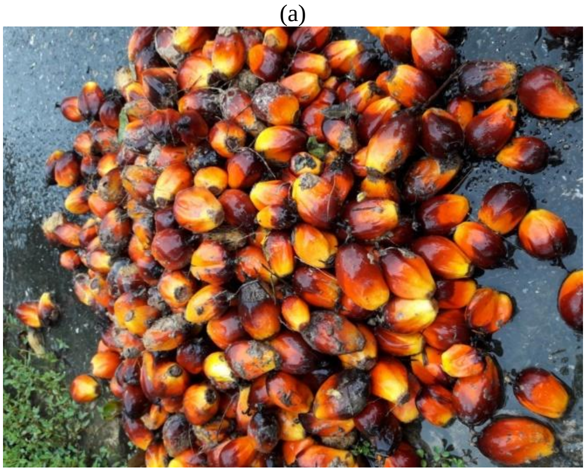

(b)

Figure 1 Oil palm fruit

production using exponential time-series methods has been extensively discussed [12-15].

In [12], a comparison of exponential forecasting methods for palm oil production in Indonesia is presented. The DES, the MHW, and the AHW methods were tested with input data from 2010 to 2014. The authors reported that the AHW method showed the lowest forecasting error compared to other methods. In [13] the exponential smoothing methods were used to forecast crude palm oil prices and exchange rates in Malaysia in 2013. The authors showed forecasting accuracy of the exponential smoothing methods, and also concluded that such methods could be efficiently used for the considered application. Finally, in [14] and [15], forecasting oil prices using time-series methods was introduced. The authors demonstrated that the Holt-Winters methods with the input data from October 2011 to March 2016, collected from the United States Energy Information Administration, for West Texas Intermediate crude oil, provided better results in forecasting oil prices.

The IAHW and the EAHW methods were derived and proposed by Tratar in 2015 and 2016 [16-18]. Such methods were an extension of the traditional AHW method, where the algorithms could perform as the IAHW, the EAHW or the AHW adaptively and automatically, based on the pattern of input data as described in the next section. The authors also showed that the IAHW and the EAHW methods provided good accuracy in forecasting short and long-term heating load data. However, how well the IAHW and the EAHW methods perform in the case of oil palm and crude palm oil data, as proposed in the current study, has not yet been investigated.

Exponential time-series methods were applied to forecast oil palm prices, crude palm oil prices, and crude palm oil production in Thailand during the period of January to March 2018. The DES, the MHW, the AHW, the IAHW, and the EAHW methods were selected for study. Input data from January 2005 to December 2017 (i.e., thirteen years) were collected from the Office of Agricultural Economics, Ministry of Agriculture and Cooperatives, and from the Department of Internal Trade, Ministry of Commerce of Thailand. The major contributions of our work are twofold. First, three closely related input data are forecasted and analyzed simultaneously. Thus, their relationship is revealed. Second, three well-known forecasting methods, the DES, the MHW, and the AHW methods, as well as two recently introduced methods, the IAHW and the EAHW methods, were tested. Therefore, the best forecast results with minimum forecasting error by optimal methods were developed. Additionally, we also show the trend of the average monthly and yearly data for oil palm prices, crude palm oil prices, and crude palm oil production in Thailand.

2. Materials and methods

2.1 Input data

There were three sets of input data to be forecasted and analyzed, oil palm prices, crude palm oil prices, and crude palm oil production. Monthly data from January 2005 to December 2017 were collected from the websites of the Office of Agricultural Economics, Ministry of Agriculture and Cooperatives (for oil palm prices) [19], and the Department of Internal Trade, Ministry of Commerce (for crude palm oil prices and production) [3]. They are illustrated in Tables 1, 2, and 3, respectively, for oil palm prices, crude palm oil prices, and crude palm oil production.

2.2 Forecasting methods

The DES, the MHW, the AHW, the IAHW, and the EAHW methods are described in detail below.

2.2.1 The DES method

The DES method, also known as Holt's Linear Exponential method, is appropriately used to forecast data which show a trend [9-10, 20]. It adds a trend factor to the equation as a way of adjusting for this behavior. Three equations are incorporated in this method, (1) to (3), where L_i is an estimate of the level of the data series at sample number i, X_i is the input value provided in Tables 1 to 3, b_i is an estimate of the trend of the data series at sample number i, α and β are weighting factors (i.e., $1 \leq \alpha, \beta \leq 0$), and Y_{i+m} is the forecast value for the period $i+m$, where m ($m > 0$) is the number of future forecast periods.

$$L_i = \alpha X_i + (1-\alpha)(L_{i-1} + b_{i-1}) \quad (1)$$

$$b_i = \beta(L_i - L_{i-1}) + (1-\beta)b_{i-1} \quad (2)$$

$$Y_{i+m} = L_i + mb_i \quad (3)$$

Table 1 Monthly oil palm prices (baht/kilogram) for January 2005 to December 2017

	Monthly oil palm prices of the years 2005 to 2017												
Months	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
1	2.69	2.85	3.02	5.90	3.31	3.88	8.63	4.89	3.15	5.19	5.47	5.23	5.40
2	2.16	2.76	3.01	5.28	3.90	3.57	7.19	5.46	3.38	5.52	5.76	4.86	5.92
3	2.42	2.38	3.04	4.85	2.89	3.48	5.01	5.71	3.54	4.70	3.97	4.50	4.81
4	2.39	1.92	3.19	4.96	3.18	3.42	4.75	5.73	3.01	3.30	3.30	5.13	4.15
5	2.46	1.95	3.91	4.17	4.18	3.38	5.28	5.20	3.11	3.43	3.61	5.24	4.31
6	2.90	2.06	4.46	5.33	4.14	3.86	5.39	5.04	3.52	3.90	4.19	5.43	3.74
7	3.35	2.21	4.27	5.72	3.51	4.08	4.71	5.52	3.30	4.33	3.68	6.73	3.58
8	3.23	2.47	4.20	4.38	3.84	4.53	5.07	4.95	3.41	4.14	3.37	6.06	3.39
9	2.81	2.47	4.26	3.66	3.39	4.83	5.05	4.38	3.81	3.85	3.42	5.50	3.72
10	3.06	2.33	4.55	2.72	3.25	5.17	4.05	3.66	3.84	4.11	3.91	5.57	3.49
11	2.85	2.74	4.73	2.50	3.85	6.13	4.71	3.82	4.28	4.59	4.19	5.44	3.33
12	2.84	2.97	5.46	2.90	4.36	6.92	4.85	2.91	5.05	5.19	4.51	5.43	2.79

Table 2 Monthly crude palm oil prices (baht/kilogram) for January 2005 to December 2017

	Monthly crude palm oil prices of the years 2005 to 2017												
Months	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
1	16.65	17.82	18.81	35.53	23.63	26.36	58.20	31.68	25.00	33.07	35.44	29.63	31.40
2	14.10	17.34	18.97	34.78	26.18	25.73	57.07	33.05	25.00	34.50	36.39	30.10	31.97
3	15.30	15.40	19.23	34.46	22.05	25.92	36.00	34.71	24.49	31.65	28.54	29.02	28.97
4	15.67	14.11	21.90	33.64	24.01	25.43	36.21	35.90	23.30	27.69	26.15	32.26	26.91
5	16.24	14.78	25.02	33.10	26.61	25.66	36.28	32.86	23.02	27.84	26.17	33.93	26.77
6	16.93	14.36	26.54	36.08	25.99	25.61	34.38	32.79	25.12	26.68	27.43	35.50	23.84
7	18.43	14.59	25.70	34.53	22.72	25.38	30.00	35.08	23.73	26.80	26.22	37.49	23.05
8	18.01	16.28	24.72	26.59	24.56	27.49	31.30	31.46	23.58	25.36	25.29	34.00	22.13
9	17.31	15.06	24.63	22.37	22.65	27.95	30.18	28.89	24.68	24.27	21.50	31.05	22.11
10	18.05	14.61	27.30	17.20	21.48	31.01	28.14	25.62	24.62	25.27	23.97	30.00	21.59
11	17.25	16.85	29.57	17.81	24.00	38.91	30.81	25.30	28.34	29.08	24.94	29.63	20.73
12	16.82	18.47	30.95	20.66	26.90	43.80	30.49	22.95	31.90	30.61	26.00	30.82	19.12

Table 3 Monthly crude palm oil production (metric tons) for January 2005 to December 2017

	Monthly crude palm oil production of the years 2005 to 2017												
Months	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
1	48,348.3	37,235.8	75,633.1	86,608.3	83,585.0	89,568.0	49,965.8	130,127.1	190,823.7	110,592.2	60,449.7	85,652.2	96,750.7
2	54,540.9	68,668.1	73,969.1	115,134.3	84,333.1	114,489.7	71,223.3	123,789.3	157,840.0	131,987.8	93,956.9	109,332.7	110,879.5
3	83,264.7	113,396.9	86,889.5	148,951.3	118,579.1	140,780.3	119,903.5	136,420.3	162,546.9	204,559.9	169,545.7	166,879.1	180,740.8
4	81,986.0	128,698.6	77,806.1	133,871.3	122,636.5	124,297.8	136,278.8	127,853.4	151,158.1	199,945.7	209,645.9	170,696.2	217,009.7
5	79,789.5	122,438.9	80,216.8	168,465.4	116,402.9	130,425.2	165,055.8	133,911.1	173,196.9	237,217.6	239,227.0	148,475.5	224,189.5
6	68,227.2	91,600.1	73,414.6	143,853.7	102,521.2	119,990.6	171,253.8	117,452.5	162,095.4	198,461.7	195,580.7	130,196.3	169,887.0
7	66,333.1	85,809.1	78,821.0	141,235.1	108,375.9	118,336.7	170,619.2	134,117.8	176,227.3	174,780.5	160,435.9	127,011.5	159,035.2
8	67,976.3	97,282.3	94,843.8	129,386.2	117,770.0	106,585.9	165,445.9	168,176.0	186,602.8	142,937.7	152,098.0	144,704.7	186,413.0
9	69,239.0	102,093.5	99,581.6	130,114.4	128,550.3	95,806.4	158,593.3	184,083.2	162,276.6	129,878.1	154,470.7	148,685.9	206,238.5
10	61,848.8	110,888.5	105,753.8	115,786.0	123,265.8	79,920.0	192,014.4	183,739.6	166,583.9	127,726.0	160,573.2	133,706.2	243,361.2
11	48,853.6	93,603.3	97,369.2	86,881.2	87,626.9	57,898.4	180,255.7	178,281.2	138,454.7	90,218.7	132,042.0	131,053.4	253,231.2
12	39,085.3	76,644.5	75,152.1	75,189.8	68,836.7	44,531.5	150,102.3	165,537.8	113,775.4	62,830.2	104,853.8	118,331.0	233,256.7

As suggested by [9-10, 18, 20-21], (4) and (5) were used to set the initial values for L_i and b_i, where n is the number of months in a year. Additionally, optimal values of α and β were also automatically determined. These optimal values were selected to minimize the forecasting error (MAPE) [18]. Here, the minimizing problem was solved using the Solver function in Microsoft Excel. Further details and examples can be found in [18].

$$L_1 = X_1 \tag{4}$$

$$b_1 = (X_n - X_1)/(n - 1) \tag{5}$$

2.2.2 The Holt-Winters method: the MHW and the AHW methods

The Holt-Winters method [9-10, 20] is appropriately used when both trend and seasonality patterns are present in the data series. The Holt-Winters method incorporates three equations. The first is for the level, second for the trend, and third is for seasonality. Generally, there are two Holt-Winters methods, the MHW and the AHW methods, depending on whether the seasonality is modeled in multiplicative or additive forms.

The MHW method is presented in (6) to (9), where (7) and (2) are the same. S_i is the multiplicative seasonal component, γ is the weighting factor (i.e., $1 \leq \gamma \leq 0$), and n is the seasonality length (i.e., the number of months in a year).

$$L_i = \alpha\left(\frac{X_i}{S_{i-m}}\right) + (1-\alpha)(L_{i-1} + b_{i-1}) \quad (6)$$

$$b_i = \beta(L_i - L_{i-1}) + (1-\beta)b_{i-1} \quad (7)$$

$$S_i = \gamma\left(\frac{X_i}{L_i}\right) + (1-\gamma)S_{i-n} \quad (8)$$

$$Y_{i+m} = (L_i + mb_i)S_{i-n+m} \quad (9)$$

As suggested by [9-10, 18, 20-21], (10) is used to initialize the level. To initialize the trend, (5) is used. Finally, to initialize the seasonality component, (11) is used, where $i = 1, 2, 3, \dots, 12$.

$$L_n = (X_1 + X_2 + \cdots + X_n)/n \quad (10)$$

$$S_i = X_i/L_n \quad (11)$$

For the AHW method, shown in (12) to (15), where (13), (7) and (2) are the same. The differences in the other equations are that the seasonal indices are added and subtracted instead of using products and ratios.

$$L_i = \alpha(X_i - S_{i-m}) + (1-\alpha)(L_{i-1} + b_{i-1}) \quad (12)$$

$$b_i = \beta(L_i - L_{i-1}) + (1-\beta)b_{i-1} \quad (13)$$

$$S_i = \gamma(X_i - L_i) + (1-\gamma)S_{i-n} \quad (14)$$

$$Y_{i+m} = L_i + mb_i + S_{i-n+m} \quad (15)$$

As suggested by [9-10, 18, 20-21], the initial values for the level and the trend are the same as those for the MHW method. Additionally, to initialize the seasonal component, (16) is used, where $i = 1, 2, 3, \dots, 12$.

$$S_i = X_i - L_n \quad (16)$$

In both MHW and AHW methods, optimal values of α, β, and γ are automatically determined during the test. They are found by minimizing the MPAE. This optimization was performed using the Solver function in Microsoft Excel.

2.2.3 The IAHW method

The IAHW method was recently proposed [16]. It is presented as equations (17) to (20). The difference between the AHW and IAHW methods is only in (17). The trend factor in (18) and the seasonal factor in (19) are the same. In the IAHW method, α occurs only at the input value X_i and not at the seasonal factor S_{i-m}. Here, when $\alpha X_i > S_{i-m}$ (the smoothed value in period i is higher than the average in its season in period $(i-m)$, the level increases in comparison with the level in the earlier period. The opposite adjustment occurs when $\alpha X_i < S_{i-m}$.

The initial values for level, trend and seasonal components are identical to those in the AHW method. Also, optimal values of α, β, and γ are automatically determined by minimizing the MAPE, and the minimizing was done using the Solver functionality in Microsoft Excel.

$$L_i = \alpha X_i - S_{i-m} + (1-\alpha)(L_{i-1} + b_{i-1}) \quad (17)$$

$$b_i = \beta(L_i - L_{i-1}) + (1-\beta)b_{i-1} \quad (18)$$

$$S_i = \gamma(X_i - L_i) + (1-\gamma)S_{i-n} \quad (19)$$

$$Y_{i+m} = L_i + mb_i + S_{i-n+m} \quad (20)$$

2.2.4 The EAHW method

The EAHW method was recently proposed [17- 18]. It is presented in equations (21) to (24). The difference between the AHW method and the EAHW method is equation (21) for the level. Here, the EAHW allows adjustment of smoothing for the seasonal factors to a greater degree than the AHW method, depending on the value of δ ($1 \leq \delta \leq 0$). If $\delta = \alpha$, the EAHW method reduces to the AHW method. When $\delta = 1$, the EAHW method becomes the IAHW method.

The initial values for level, trend and seasonal components are identical to those for the AHW method. Also, the optimal values of α, β, γ, and δ are automatically determined using the Solver function in Microsoft Excel.

$$L_i = \alpha X_i - \delta S_{i-m} + (1-\alpha)(L_{i-1} + b_{i-1}) \quad (21)$$

$$b_i = \beta(L_i - L_{i-1}) + (1-\beta)b_{i-1} \quad (22)$$

$$S_i = \gamma(X_i - L_i) + (1-\gamma)S_{i-n} \quad (23)$$

$$Y_{i+m} = L_i + mb_i + S_{i-n+m} \quad (24)$$

The algorithm's description and the initial values for the DES, the MHW, the AHW, the IAHW, and the EAHW methods are summarized in Table 4. A brief description of the implementation of the DES method and the Solver function in Excel are shown as an example in Appendix A.

2.3 Performance metric

The forecasting error, i.e., the Mean Absolute Percentage Error (MAPE) [18, 22-24], was chosen as the performance metric. The MAPE was used because it provides an accurate assessment of forecasting methods. It is not prone to change with the magnitude of time series to be forecast [25-26]. Also, it is frequently used in practice [27]. The MAPE is given by (25), where N is the number of data samples, e_i is the forecasting error from $\acute{Y}_i - Y_i$, $\acute{Y}_i$ is the actual data, and Y_i is the data determined by forecasting methods. The 95% confidence interval (CI) is also provided for the average results.

Table 4 Summary of the DES, the MHW, the AHW, the IAHW, and the EAHW methods

Methods	Algorithm description	Initial values
DES	$L_i = \alpha X_i + (1-\alpha)(L_{i-1} + b_{i-1})$ $b_i = \beta(L_i - L_{i-1}) + (1-\beta)b_{i-1}$ $Y_{i+m} = L_i + mb_i$	$L_1 = X_1$ $b_1 = (X_n - X_1)/(n-1)$
MHW	$L_i = \alpha\left(\frac{X_i}{S_{i-m}}\right) + (1-\alpha)(L_{i-1} + b_{i-1})$ $b_i = \beta(L_i - L_{i-1}) + (1-\beta)b_{i-1}$ $S_i = \gamma\left(\frac{X_i}{L_i}\right) + (1-\gamma)S_{i-n}$ $Y_{i+m} = (L_i + mb_i)S_{i-n+m}$	$L_n = (X_1 + X_2 + \cdots + X_n)/n$ $b_1 = (X_n - X_1)/(n-1)$ $S_i = X_i/L_n$
AHW	$L_i = \alpha(X_i - S_{i-m}) + (1-\alpha)(L_{i-1} + b_{i-1})$ $b_i = \beta(L_i - L_{i-1}) + (1-\beta)b_{i-1}$ $S_i = \gamma(X_i - L_i) + (1-\gamma)S_{i-n}$ $Y_{i+m} = L_i + mb_i + S_{i-n+m}$	$L_n = (X_1 + X_2 + \cdots + X_n)/n$ $b_1 = (X_n - X_1)/(n-1)$ $S_i = X_i - L_n$
IAHW	$L_i = \alpha X_i - S_{i-m} + (1-\alpha)(L_{i-1} + b_{i-1})$ $b_i = \beta(L_i - L_{i-1}) + (1-\beta)b_{i-1}$ $S_i = \gamma(X_i - L_i) + (1-\gamma)S_{i-n}$ $Y_{i+m} = L_i + mb_i + S_{i-n+m}$	$L_n = (X_1 + X_2 + \cdots + X_n)/n$ $b_1 = (X_n - X_1)/(n-1)$ $S_i = X_i - L_n$
EAHW	$L_i = \alpha X_i - \delta S_{i-m} + (1-\alpha)(L_{i-1} + b_{i-1})$ $b_i = \beta(L_i - L_{i-1}) + (1-\beta)b_{i-1}$ $S_i = \gamma(X_i - L_i) + (1-\gamma)S_{i-n}$ $Y_{i+m} = L_i + mb_i + S_{i-n+m}$	$L_n = (X_1 + X_2 + \cdots + X_n)/n$ $b_1 = (X_n - X_1)/(n-1)$ $S_i = X_i - L_n$

$$MAPE = \frac{\sum_{i=1}^{N}\left|\frac{e_i}{Y_i}\right|}{N} \times 100;\ e_i = \acute{Y}_i - Y_i \qquad (25)$$

3. Results and discussion

Figures 2, 3, and 4 show a comparison of the MAPE results determined by the DES, the MHW, the AHW, the IAHW, and the EAHW methods with their optimal weighting factors. The MAPE was calculated from the data of months 13 to 156 ($N = 144$, January 2006 to December 2017). For the MHW, the AHW, the IAHW, and the EAHW methods, the input data from January 2005 to December 2005 (i.e., 12 months) was used for setting the initial values of equations (5), (10), (11), and (16).

The results demonstrate that to forecast oil palm prices and crude palm oil prices, the DES and the EAHW methods provide the smallest MAPE, as seen in Figures 2 and 3. Here, considering the 95% CI, the performance by the DES and the EAHW methods is not significantly different. For the case of crude palm oil production in Figure 4, the IAHW and the EAHW methods show better performance than the DES, the MHW, and the AHW methods. Therefore, the results in Figures 2 to 4 show that the EAHW method [17-18] performs well in all cases of the test input data. The errors were 10.43, 7.14, and 10.88, respectively.

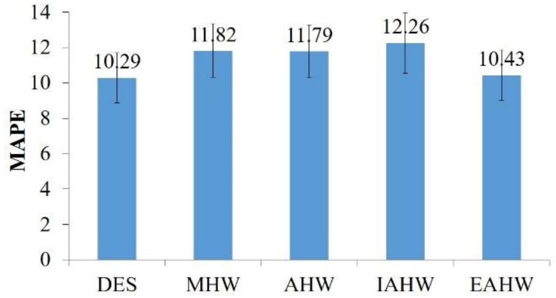


Figure 2 Comparison of the MAPE determined by each forecasting method for oil palm prices

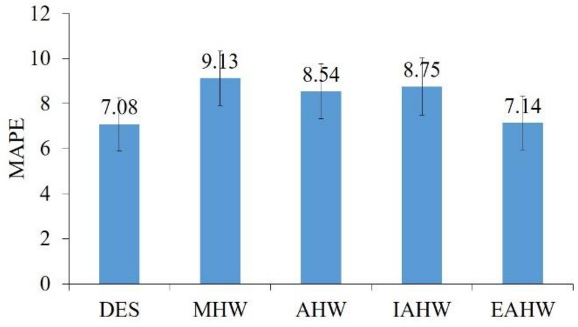


Figure 3 Comparison of the MAPE determined by each forecasting method for crude palm oil prices

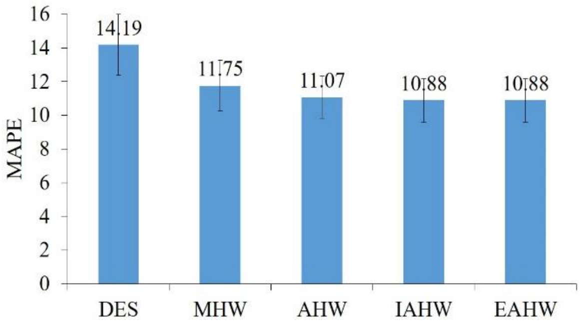
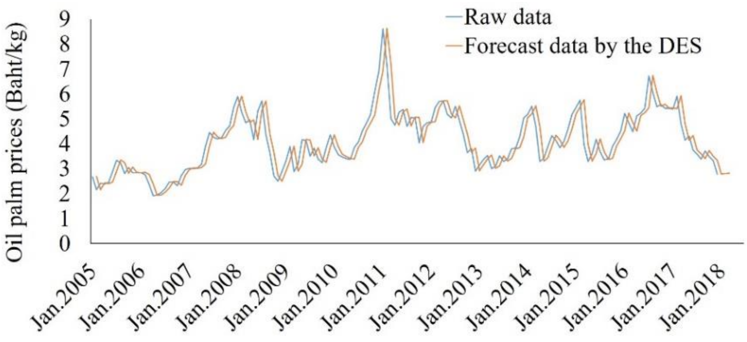
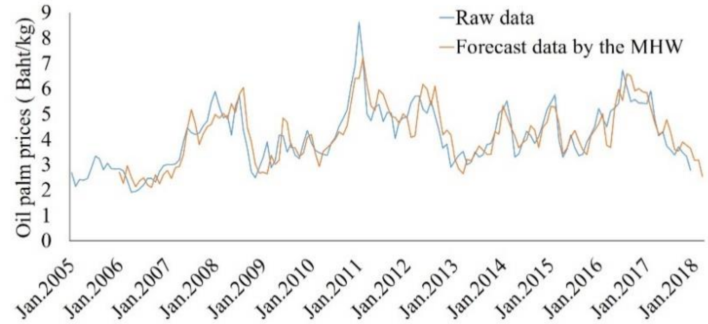


Figure 4 Comparison of the MAPE determined by each forecasting method for crude palm oil production

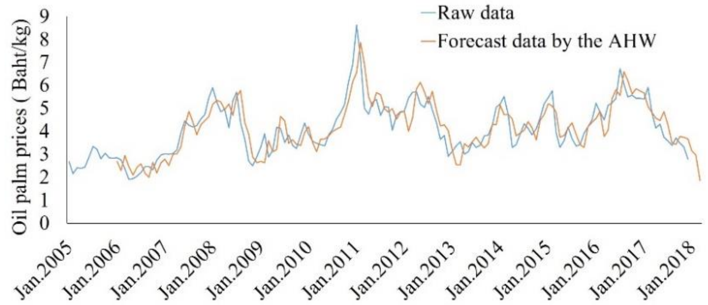
Figures 5, 6, and 7 demonstrate a comparison of the raw data shown in Tables 1, 2, and 3 and the forecast data determined by the forecasting methods with their optimal weighting factors. The optimal weighting factors that give the minimum MAPE value, and the forecast results of January 2018 to March 2018 are provided in Tables 5, 6, and 7. The results of all forecasting methods are given in Figure 5. Figures 6 and 7 show the optimal results of various forecasting methods.



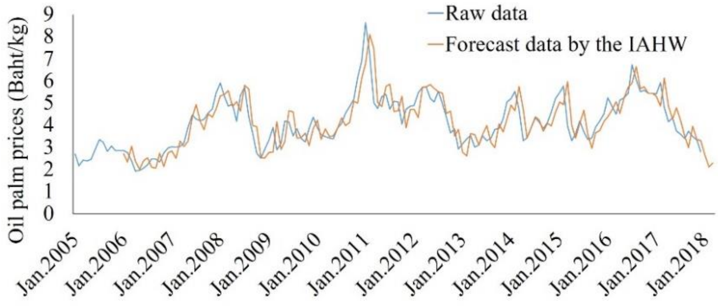
(a) Forecast data by the DES method



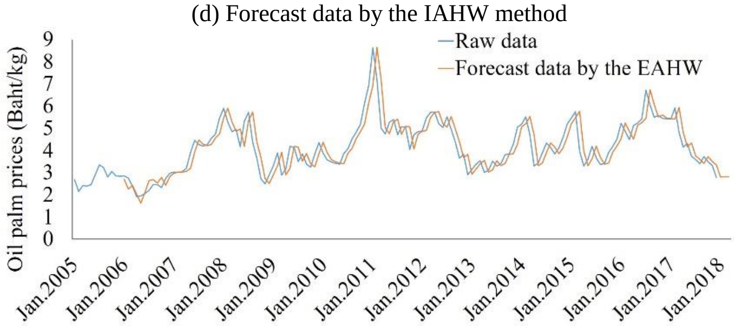
(b) Forecast data by the MHW method



(c) Forecast data by the AHW method

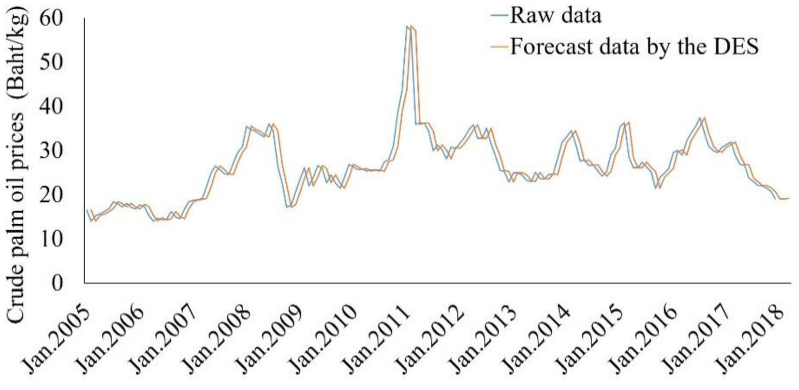


(d) Forecast data by the IAHW method

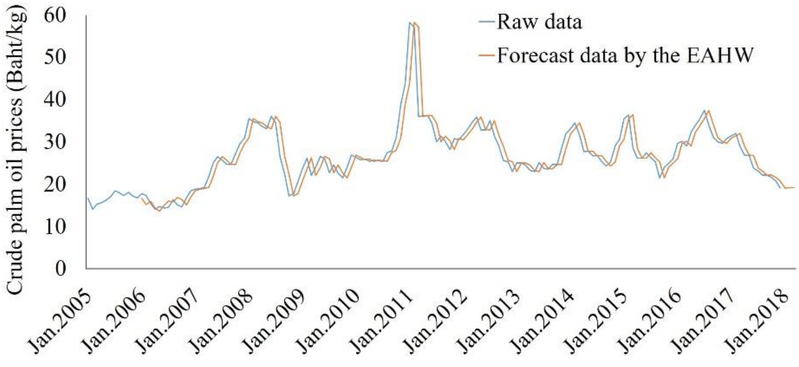


(e) Forecast data by the EAHW method

Figure 5 A comparison of oil palm prices showing the raw data and the forecast values determined by selected forecasting methods with the optimal weighting factors

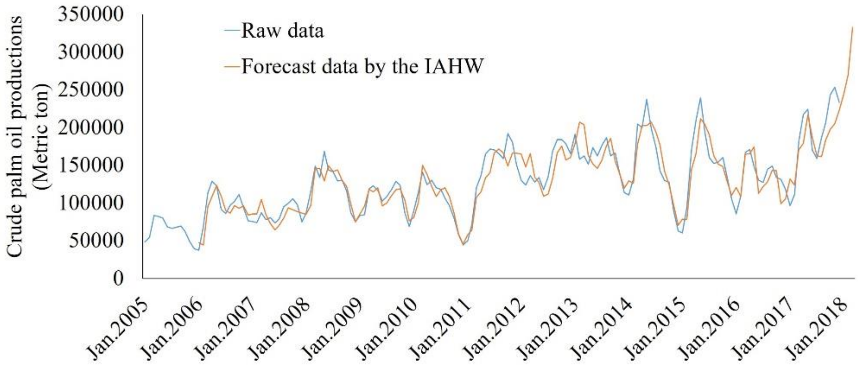


(a) Forecast data by the DES method

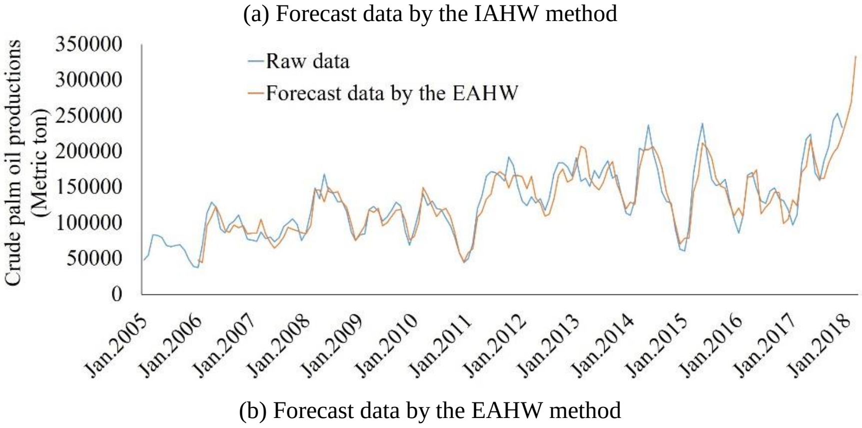


(b) Forecast data by the EAHW method

Figure 6 A comparison of crude palm oil prices showing the raw data and forecast values determined by the DES and EAHW methods with optimal weighting factors



(a) Forecast data by the IAHW method



(b) Forecast data by the EAHW method

Figure 7 A comparison of crude palm oil production showing the raw data and forecast values determined by the IAHW and EAHW methods with optimal weighting factors

Table 5 Optimal weighting factors and forecast oil palm prices from January 2018 to March 2018

Method	Optimal weighting factors				Forecast prices (2018)		
	α	β	γ	δ	Jan.	Feb.	March
DES	1	0	-	-	2.8036	2.8172	2.8309
MHW	0.7432	0	1	-	3.1835	3.1903	2.5371
AHW	0.8133	0	1	-	3.1406	2.9801	1.8759
IAHW	0.9935	≈ 0	1	-	2.6552	2.1025	2.2858
EAHW	1	0	0.9997	0	2.8036	2.8172	2.8309

Table 6 Optimal weighting factors and forecast crude palm oil prices from January 2018 to March 2018

Method	Optimal weighting factors				Forecast prices (2018)		
	α	β	γ	δ	Jan.	Feb.	March
DES	1	0	-	-	19.1355	19.1509	19.1664
MHW	0.7296	0	1	-	22.1754	22.4343	19.3058
AHW	0.9666	0	1	-	19.4058	16.8715	15.5242
IAHW	1	0	0.4177	-	18.9655	16.4309	17.6464
EAHW	1	0	1	0	19.1355	19.1509	19.1664

Table 7 The optimal weighting factors and the forecast crude palm oil productions of January 2018 to March 2018.

Method	Optimal weighting factors				Forecast production (2018)		
	α	β	γ	δ	Jan.	Feb.	March
DES	1	0	-	-	232415	231573	230730
MHW	0.9378	0.0077	1	-	248368	315220	466562
AHW	0.9460	≈ 0	1	-	240906	255035	288756
IAHW	0.9316	0	1	-	244772	269574	332625
EAHW	0.9316	0	0.9999	0.9999	244763	269565	332606

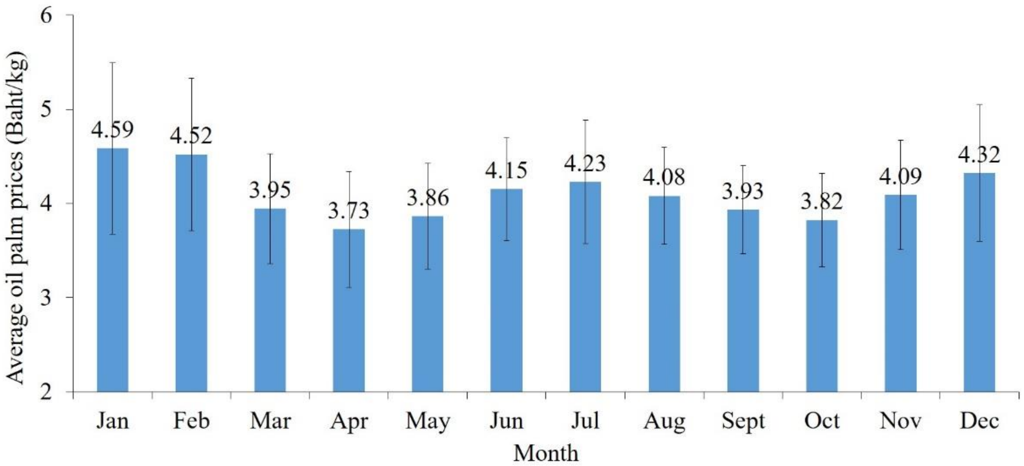


Figure 8 Average monthly prices of palm oil

As seen in Figures 5(a) to 5(e) for oil palm prices and Figures 6(a) and 6(b) for crude palm oil prices, the forecast values determined by the DES and the EAHW methods were closer to the raw data than other methods. Also, in Figures 7(a) and 7(b) (i.e. crude palm oil production), the IAHW and the EAHW methods provide good results.

The results also reveal, as shown in Tables 5 and 6, that the forecast data for January 2018 to March 2018 by the DES and the EAHW methods show the same trend. Oil palm prices were 2.8036, 2.8172, and 2.8309 (by the DES method), and 2.8036, 2.8172, and 2.8309 (by the EAHW method). Crude palm oil prices were 19.1355, 19.1509, and 19.1664 (by the DES method), and 19.1355, 19.1509, and 19.1664 (by the EAHW method). Here, the values of oil palm prices and crude palm oil prices were forecast as stable. For the case of the crude palm oil production in Table 7, the forecast data from January 2018 to March 2018 determined by the IAHW and the EAHW methods suggest the same trend. The forecast values of oil palm production increases. They were 244,772, 269,574, and 332,625 (by the IAHW method), and 244,763, 269,565, and 332,606 (by the EAHW method). These results show a correlation between the prices and production.

The average monthly prices of oil palm (from 2005 to 2017), the average monthly prices of the crude palm oil, and the average monthly production of the crude palm oil are illustrated in Figures 8 to 10. The results in Figures 8 and 9 demonstrate that the trends of the average monthly prices of the oil palm and crude palm oil from 2005 to 2017 were stagnant, but followed a cyclic pattern. For the trend of the average monthly production of crude palm oil in Figure 10, is the opposite of the results in Figures 8 and 9.

Figure 9 Average monthly prices of crude palm oil

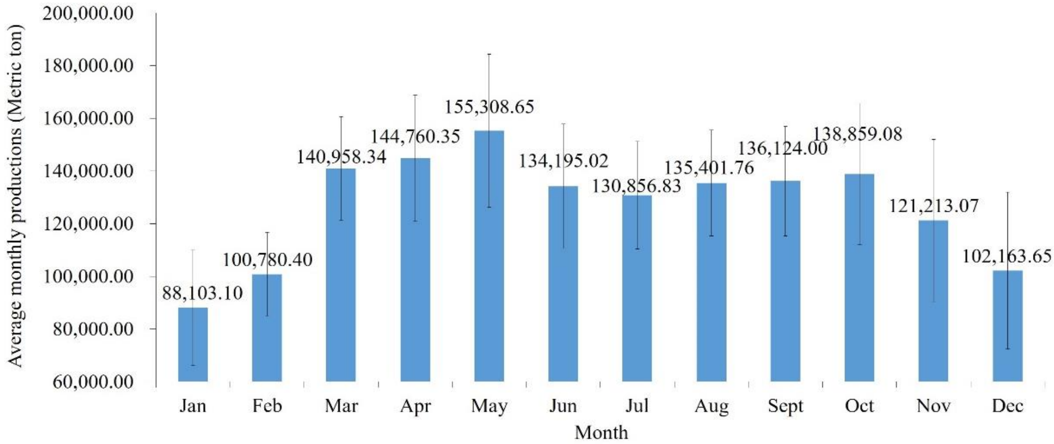


Figure 10 Average monthly production of crude palm oil

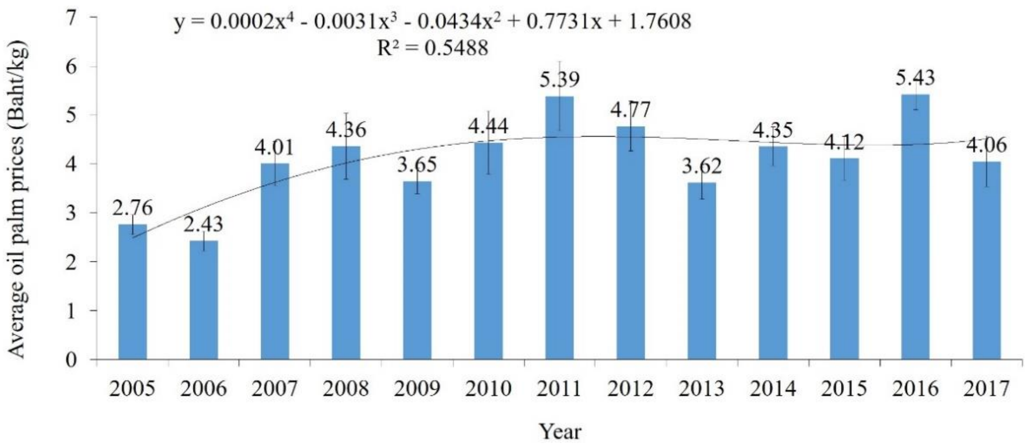


Figure 11 Average yearly price of oil palm.

The average yearly prices of oil palm, the average yearly prices of crude palm oil, and average yearly production crude palm oil are shown in Figures 11 to 13, respectively. A fourth-order polynomial trend line is fitted to the average results, and their respective R-squared values are provided. The results in Figures 11 and 12 indicate that the average yearly price of oil palm and crude palm oil varied little. The trend of the average yearly production of crude palm oil during 2005 to 2017 in Figure 13, it is increasing. Here, there is more possibility that in 2018, the production of crude palm oil will increase in Thailand.

As illustrated by the results in Tables 5, 6, and 7 above, the forecast results of January 2018 to March 2018 indicate that the production will increase and prices will be stable. Therefore, balancing production and prices will be very challenge. As can be seen in Figures 8 to 10, on average at the end of the year, production seem to be low and the prices correspondingly high. However, in the final quarter of 2017,

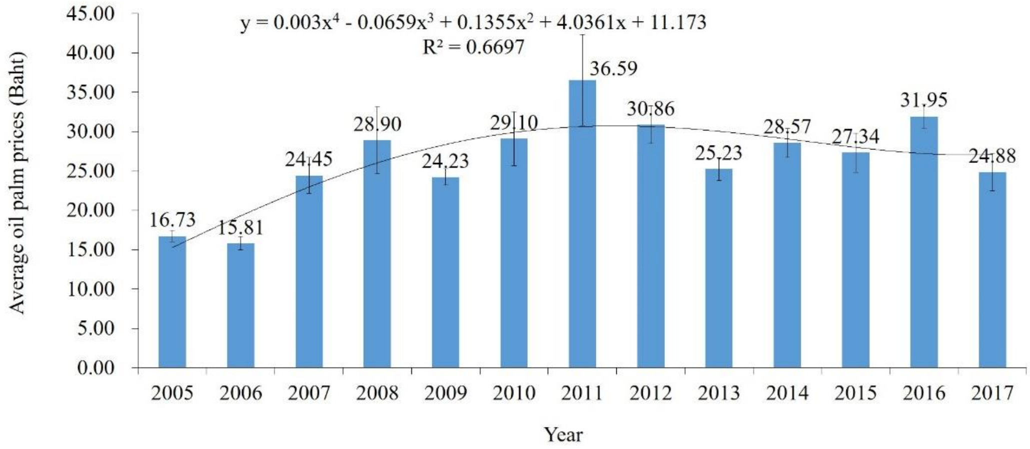


Figure 12 The average yearly prices of crude palm oil.

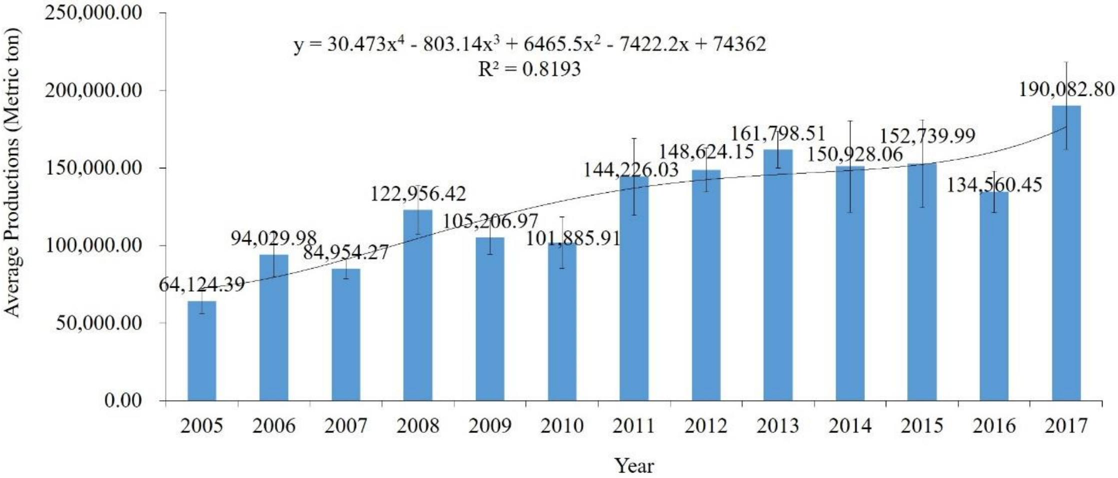


Figure 13 The average yearly productions of crude palm oil.

production increased and prices decreased, as can be seen in Tables 1, 2, and 3. These results indicate that there is now more palm oil production.

4. Conclusions

The current study indicates that the DES and the EAHW methods give the smallest forecasting error in predicting oil palm prices and crude palm oil prices, while the IAHW and the EAHW methods show better performance than others in the case of crude palm oil production. Our findings also suggest that, during January 2018 to March 2018, crude palm oil production in the market will increase and that the prices will likely remain stable. We believe that the research methodology introduced in this work can be further applied to forecast oil palm data for the year 2018. Following an accurate forecasting method, the government can provide useful guidelines for supervising policy and development plans for the palm oil sector. For example, Thailand’s policies on its biodiesel blending ratio and palm oil stock management vary depending on amount of palm oil available to maintain the stability of palm oil prices.

In the future work, although the DES, the MHW, the AHW, the IAHW, and the EAHW methods as well as various forecasting methods that employ exponential smoothing are studied, other forecasting methods such as Artificial Neural Networks (ANN), Autoregressive Integrated Moving Average (ARIMA), and Seasonal Autoregressive Integrated Moving Average (SARIMA) should also be evaluated. This is still an open research issue and needs further investigation. Additionally, more updated oil palm, crude palm oil data and other related input data should be included for evaluation to validate the DES, the MHW, the AHW, the IAHW, and the EAHW methods and to improve forecasting accuracy.

5. Acknowledgments

This work was supported by the Faculty of Agro Industry, Rajamangala University of Technology Srivijaya, the Faculty of Engineering, Thaksin University, Phatthalung Campus, the Faculty of Management Sciences, Nakhon Si Thammarat Rajabhat University, and the Faculty of Engineering, Prince of Songkla University.

6. Appendix A. An example of the implementation of the DES method in Excel program

An example of the implementation of the DES method and the use of the Solver function in Excel are demonstrated here. For more details can be found in [17, 18]. Figure 14 shows a screenshot of an Excel window, where L_i and b_i are calculated. Here, the calculation uses equations (1) and (2). In

Figure 15, the Solver optimization tool with settings is presented. The MAPE is minimized by changing the values of α and β, where the weighting factors are in the range of $1 \leq \alpha, \beta \leq 0$, and their optimal values are determined automatically.

	A	B	C	D	E	F	G
1	DES method					95%CI	1.4343336
2			Alpha	1		SD	8.7817955
3			Beta	0		MAPE	10.288877
4	Month	X_i	L_i	b_i	Y_i	e_i (error)	Abs%error
5	1	2.69	2.69	0.013636			
6	2	2.16	2.16	0.013636	2.703636	-0.543636	25.16835
7	3	2.42	=$D$2*B7+(1-$D$2)*(C6+D6)			0.246364	10.180316
8	4	2.39	2.39	0.013636	2.433636	-0.043636	1.8257893
9	5	2.46	2.46	0.013636	2.403636	0.056364	2.2912047
10	6	2.9	2.9	0.013636	2.473636	0.426364	14.702194
11	7	3.35	3.35	0.013636	2.913636	0.436364	13.02578
12	8	3.23	3.23	0.013636	3.363636	-0.133636	4.1373487

(a) Calculation of L_i: C7 = $D$2*B7+(1-$D$2)*(C6+D6) corresponds to $L_3 = \alpha X_3 + (1-\alpha)(L_2 + b_2)$

	A	B	C	D	E	F	G
1	DES method					95%CI	1.4343336
2			Alpha	1		SD	8.7817955
3			Beta	0		MAPE	10.288877
4	Month	X_i	L_i	b_i	Y_i	e_i (error)	Abs%error
5	1	2.69	2.69	0.013636			
6	2	2.16	2.16	0.013636	2.703636	-0.543636	25.16835
7	3	2.42	2.42	=$D$3*(C7-C6)+(1-$D$3)*D6			10.180316
8	4	2.39	2.39	0.013636	2.433636	-0.043636	1.8257893
9	5	2.46	2.46	0.013636	2.403636	0.056364	2.2912047
10	6	2.9	2.9	0.013636	2.473636	0.426364	14.702194
11	7	3.35	3.35	0.013636	2.913636	0.436364	13.02578
12	8	3.23	3.23	0.013636	3.363636	-0.133636	4.1373487

(b) Calculation of b_i: D7 = $D$3*(C7-C6)+(1-$D$3)*D6 corresponds to $b_3 = \beta(L_3 - L_2) + (1-\beta)b_2$

Figure 14 Implementation of the DES method in Excel

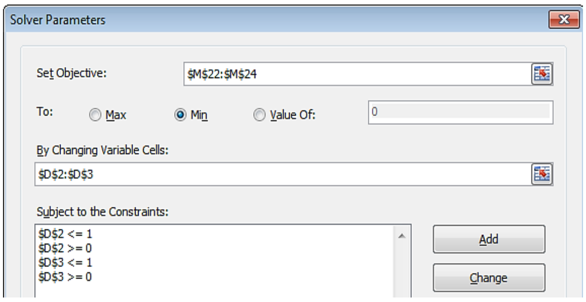


Figure 15 Excel solver settings

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