

EVALUATION OF ADDITIVE AND EXTENDED ADDITIVE HOLT-WINTERS METHODS: ONE-YEAR AHEAD FORECASTING OF CRUDE PALM OIL PRODUCTION IN THAILAND

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Abstract

Evaluation of a traditional additive Holt-Winters (AHW) method and an extended additive Holts-Winters (EAHW) method for one-year ahead forecasting of crude palm oil production in Thailand is presented in this paper. The crude palm oil production figures from January 2005 to December 2018 (14 years), collected from the database of the Department of Internal Trade, Ministry of Commerce, Thailand are used as input data to be forecast. As investigated in our previous works, the traditional AHW and the recently proposed EAHW methods provided good accuracy in the case of short-term forecasting (i.e. 3 months) of crude palm oil production, but how well they work for one-year ahead has not been studied. Therefore, the AHW and the EAHW methods used for forecasting crude palm oil production of the years 2018 and 2019 are evaluated in this paper. The trends of the forecast data (i.e. monthly crude palm oil production throughout the year) are presented, and the findings are also analyzed in comparison with the related statistical data gathered from the past. Our study reveals that both the AHW and EAHW methods can be used to forecast one-year ahead data. They show the same forecasting error as measured by mean absolute percentage error, and they also provide the same trend of the forecast data for the years 2018 and 2019. However, we have found that, for the year 2018,

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the forecast data provided by the AHW method are significantly closer to the actual data than are the case with the EAHW. Finally, we also illustrate and analyze the comparison of the crude palm oil production with the raw data of the years 2016, 2017, and 2018, the average data of the years 2005 to 2018, and the forecast data of the years 2018 and 2019, which are results of interest for Thailand.

Keywords: Holt-Winters, forecasting, one-year ahead, crude palm oil production, Thailand

Introduction

The oil palm is the most important economic oil crop in Thailand. It is used to produce crude palm oil by a milling process. The characteristics of the oil palm and crude palm oil are illustrated in Figure 1. The domestic consumption of crude palm oil is in two main areas: for food (edible oil) and non-food (soap, cosmetics, lubricants, animal feed, and biodiesel) production.

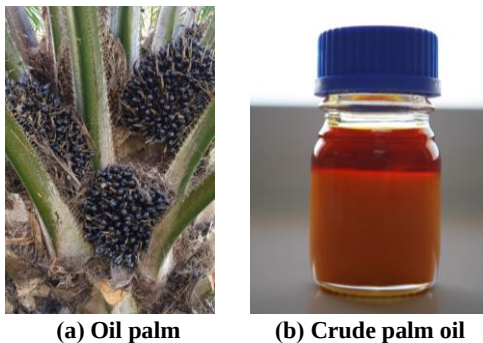


Figure 1. a) Oil palm and b) crude palm oil

Over the past decade, the annual production and price have shown fluctuating trends due to many factors such as palm oil demand, substitute oil crop quantities and their prices, the weather phenomenon, the impact of natural disasters, and government policies (Mungmee *et al.*, 2013). To maintain adequate supplies, the Thai government regulates biodiesel production by raising or lowering the proportion of B100 used in the diesel fuel mixture by considering the current domestic production of crude palm oil (Petchseechoung, 2017). However, decision-making on the energy

policy may be difficult to undertake because of the fluctuating trends during a year. Therefore, an accurate forecasting technique for crude palm oil production in the one-year ahead period plays a key role to help the government make timely decisions and maintain the appropriate price that affects the oil palm business certainty and the income of smallholders.

As studied by several works (Siregar *et al.*, 2016; Suppalakpanya *et al.*, 2019a, 2019b, 2019c; Ahmad and Ahmad, 2013), to forecast crude palm oil data as time-series data the well-known exponential smoothing methods are widely applied, such as Holt's linear exponential smoothing method, the additive Holt-Winters (AHW) method, the multiplicative Holt-Winters (MHW) method, and the extended Holt-Winters (EAHW) method. Here, they are suitably used for input data when trends and seasonality behaviors are present, like crude palm oil data. Although the exponential smoothing methods are not new as revealed in the research literature, they are popularly used in practice and various applications as reported in many works (Brown, 1956; Winters, 1960; Gardner, 1985; Hunter, 1986; Kalekar, 2004; Montgomery *et al.*, 2008; Gelper *et al.*, 2010; Booranawong and Booranawong, 2017); these researchers applied such methods due to their simplicity, robustness, low complexity, and efficiency. Based on the research literature, the works related to forecasting palm oil data using exponential smoothing methods are described here, and they are summarized in Table 1.

In Siregar *et al.* (2016), a study of exponential smoothing methods for forecasting

Table 1. The comparison of the related works and this work

Ref.	Time-series forecasting methods	Palm oil data	Case study
Siregar <i>et al.</i> (2016)	Holt's linear exponential smoothing, AHW, and MHW	Palm oil production	Indonesia
Ahmad and Ahmad (2013)	Exponential smoothing	Crude palm oil price	Malaysia
Suppalakpanya <i>et al.</i> (2019a)	Double exponential smoothing, AHW, MHW, IAHW, and EAHW Contribution: - Several exponential time-series methods were applied to forecast oil palm and palm oil data in Thailand - Three-month ahead forecasting	- Oil palm price - Crude palm oil price - Crude palm oil production	Thailand
Suppalakpanya <i>et al.</i> (2019b)	AHW, MHW, and EAHW Contribution: - Forecasting methods with different initial trend values for forecasting crude palm oil data in Thailand were studied - Three-month ahead forecasting	- Crude palm oil price - Crude palm oil production	Thailand
Suppalakpanya <i>et al.</i> (2019c)	Double exponential smoothing, AHW, MHW, IAHW, and EAHW Contribution: - Different sets of input data including 3-year data, 6-year data, 9-year data, and 12-year data were applied as the inputs for forecasting methods - Three-month ahead forecasting	Crude palm oil production	Thailand
This work	AHW and EAHW Contribution: - One-year ahead forecasting - Forecasting of monthly crude palm oil production of the years 2018 and 2019 are presented. - The comparison of the crude palm oil production; the raw data of the past years, the average data of all years, and the forecast data of the years 2018 and 2019 are illustrated and analyzed. *Note that the optimal initial trend value (Suppalakpanya, <i>et al.</i> (2019b)) and the optimal set of input data (Suppalakpanya <i>et al.</i> (2019c)) are also considered in this work	Crude palm oil production	Thailand

palm oil production in Indonesia was introduced. Five-year input data from 2010 to 2014 were tested with Holt's linear exponential smoothing method, the AHW, and the MHW methods, respectively. The results indicated that the AHW method showed better forecasting results. In Ahmad and Ahmad (2013), the authors applied exponential smoothing methods to forecast crude palm oil prices in Malaysia. The authors reported that such methods could be properly used for the considered application.

In Suppalakpanya *et al.* (2019a), several exponential time-series methods including Holt's linear exponential smoothing, the MHW,

the AHW, and the EAHW methods were applied to forecast oil palm prices, crude palm oil prices, and crude palm oil production in Thailand. We note that the EAHW method was the extended version of the AHW method proposed by Tratar and Srmcnik (2016) and Tratar *et al.* (2016), which will be described in the next section. The results demonstrated that the EAHW method provided the smallest error (as measured by the mean absolute percentage error, (MAPE)) in forecasting all input data. In Suppalakpanya *et al.* (2019b), an evaluation of the AHW, the MHW, and the EAHW methods with different initial trend values for forecasting crude palm oil production and

prices in Thailand were studied. The authors reported that the EAHW method provided good accuracy in forecasting selected input data as indicated by the MAPE results. The authors also showed that, by applying the different initial trend values to the forecasting methods, the level of forecasting accuracy was significantly different. Finally, in Suppalakpanya *et al.* (2019c), a study of Holt's linear exponential smoothing, the AHW, the MHW, and the EAHW methods, for forecasting crude palm oil production in Thailand was presented. The major contribution of such a work was that different sets of input data including 3-year data, 6-year data, 9-year data, and 12-year data were applied as the inputs for all forecasting methods. The results indicated that the traditional AHW and the EAHW methods gave the smallest forecasting error, and they significantly showed accurate forecast results when 12-year input data were applied.

However, for the works in Suppalakpanya *et al.* (2019a, 2019b, 2019c), three-month ahead forecasting as short-term forecasting was the focus; one-year ahead forecasting and the illustration/and analysis of the comparison of crude palm oil production (i.e. the raw data of the past years, the average data of all years, and the forecast data of the years 2018 and 2019) were not the scope of those works. We note that the optimal initial trend value studied in Suppalakpanya *et al.* (2019b) and the optimal set of input data introduced in Suppalakpanya *et al.* (2019c) are considered and included in this paper.

Based on the efficiency of the exponential smoothing methods in practice as mentioned above, in this paper the AHW and the EAHW methods as the exponential forecasting methods are used to forecast monthly crude palm oil production in Thailand for the years 2018 and 2019. Fourteen-year crude palm oil production data from January 2005 to December 2018 collected from the database of the Department of Internal Trade, Ministry of Commerce, Thailand are used as input data. Here, the trends of the forecast data (i.e. monthly crude palm oil production throughout the year) can be revealed, and the findings are also analyzed in comparison with

the related statistical data gathered from the past. Finally, a comparison of the crude palm oil production is also illustrated and analyzed; the raw data of the years 2016, 2017, and 2018, the average data of the years 2005 to 2018, and the forecast data of the years 2018 and 2019 are used.

Materials and Methods

Input data, forecasting methods (i.e. AHW and EAHW methods), and the performance metrics used to evaluate the accuracy of the forecasting methods are described in this section.

Input data as the monthly crude palm oil production from January 2005 to December 2018 (14 years) were collected from the database of The Department of Internal Trade (2018) and are shown in Table 2. In this paper, 2 sets of experiments are tested. The monthly crude palm oil production figures of the years 2005 to 2017 are used as the input data for the AHW and the EAHW methods to forecast the monthly crude palm oil production of the year 2018 (i.e. January 2018 to December 2018). Here, by comparing the actual data and the predicted data, the accuracy of the AHW and EAHW methods can be investigated. Then, the monthly crude palm oil production figures of the years 2005 to 2018 are applied as the input data for both methods to forecast the monthly crude palm oil production of the year 2019 (i.e. January 2019 to December 2019).

The AHW and the EAHW forecasting methods are summarized here. As stated in the introduction section, the AHW and the EAHW methods are in the exponential smoothing family. Both the traditional AHW method and the EAHW method, as the extended version of the AHW method proposed by Tratar and Srmcnik (2016), are often used to forecast data when both the trends and seasonality patterns are present in the data series (Holt, 2004; Kalekar, 2004; Montgomery *et al.*, 2008).

The AHW method incorporates 3 equations: the first for the level, the second for the trend, and the third for seasonality, where the seasonality is modeled in an additive form. The AHW method is expressed in Equations

(1) to (4), where L_i is the estimate of the level of the data series at the sample number i , X_i is the input value (i.e. the crude palm oil

production in Table 2), b_i is the estimate of the trend of the data series, S_i is the seasonal component, α , β , and γ are the weighting factors with values between 0 and 1, Y_{i+m} is the forecast value (i.e. the forecast crude palm oil production) for the period $i+m$ (i.e. m is the number of forecast periods ahead), and n is the seasonality length (the number of months in a year; 12). As recommended by Holt (2004), Kalekar (2004), Montgomery *et al.* (2008) and Tratar and Srncnik (2016), to initialize the level, the trend, and the seasonal components, Equations (5), (6), and (7) are used, respectively, where $i = 1, 2, 3, \dots, 12$. The optimal values of the weighting factors (i.e. α , β , and γ) are automatically determined during the test. They are determined by minimizing the MAPE value, and the minimization problem is solved using the Solver function in Microsoft Excel.

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

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

$$S_i = \gamma(X_i - L_i) + (1 - \gamma)S_{i-n} \quad (3)$$

$$Y_{i+m} = L_i + mb_i + S_{i-n+m} \quad (4)$$

$$b_1 = \frac{X_n - X_1}{n-1}; n = 12 \quad (5)$$

$$L_n = \frac{X_1 + X_2 + \dots + X_n}{n} \quad (6)$$

$$S_i = X_i - L_n \quad (7)$$

The EAHW method was recently proposed by Tratar and Srncnik, (2016) and Tratar *et al.* (2016). It is shown in Equation (8), where the difference between the AHW and the EAHW methods is only the equation for the level. The trend and the seasonal components remain unchanged. Here, the EAHW method allows the smoothing of the seasonal component more or less than the traditional AHW method, depending on the value of δ , where δ is the weighting factor ($0 \leq \delta \leq 1$). If δ is equal to α , the EAHW reduces to the AHW method. The initial values for the level, the trend, and the seasonal components are identical to those for the AHW method. Also, the optimal values of the weighting factors (i.e. α , β , γ , and δ) are automatically determined using the Solver function in Microsoft Excel.

Table 2. Monthly crude palm oil production (metric tons) from January 2005 to December 2018

Month	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
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	222,167.4
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	210,838.8
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	258,318.2
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	228,574.4
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	193,817.2
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	198,461.5	195,580.7	130,196.3	169,887.0	151,749.6
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	174,780.5	160,435.9	127,011.5	127,011.5	159,035.2	137,307.9
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	159,832.6
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	171,085.9
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	201,021.4
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	205,394.2
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	217,610.8

$$L_i = \alpha X_i - \delta S_{i-m} + (1 - \alpha)(L_{i-1} + b_{i-1}) \quad (8)$$

To evaluate the accuracy of the AHW and the EAHW methods, the forecasting error referred to the MAPE (Chatfield, 2001; Tratar and Srncnik, 2016) and is chosen as the performance metric. The MAPE is employed because it provides an accurate and fair comparison of the forecasting methods. It is not prone to change in the magnitude of the time series to be forecast (Gentry *et al.*, 1995; Alon *et al.*, 2001) and it is often applied in practice as reported by Ravindran and Warsing (2013). The MAPE is expressed in Equation (10), where e_i is the error from $\hat{Y}_i - Y_i$, $\hat{Y}_i$ and Y_i are the actual data and the forecast data, respectively, and N is the number of data samples. We note that the 95% confidence interval is also provided for the average results.

$$MAPE = \frac{\sum_{i=1}^N \frac{|e_i|}{|Y_i|}}{N} \times 100 = \frac{\sum_{i=1}^N \frac{|\hat{Y}_i - Y_i|}{|Y_i|}}{N} \times 100 \quad (10)$$

In summary, the forecasting system proposed in this work is summarized in Figure 2. The input data are the monthly crude palm

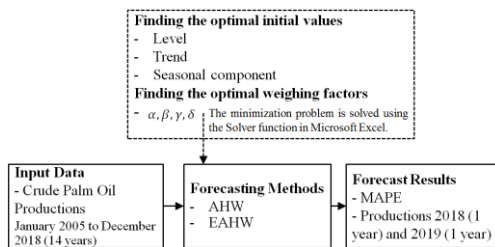


Figure 2. The forecasting system proposed in this paper

oil production (14 years). The forecasting methods are the AHW and the EAHW methods. The optimal parameters initialized for each forecasting method and the optimal weighting factors for the level, trend, and seasonal components are also determined. Finally, the MAPE and the forecast results of 2018 and 2019 (one-year ahead) are reported.

Results and Discussion

The comparison of the MAPE results determined by the AHW and the EAHW methods with their optimal weighting factors to forecast monthly crude palm oil production of the years 2018 (i.e. January 2018 to December 2018) and 2019 (January 2019 to December 2019) are shown in Table 3. The optimal weighting factors which give the minimum of the MAPE are listed in Table 4. We note that, to forecast 2018, the MAPE is calculated from the forecast results of January 2006 to December 2017 ($N = 144$), and to forecast 2019, the MAPE is calculated from the forecast results of January 2006 to December 2018 ($N = 156$). Here, in the AHW and the EAHW methods, the input data of the first year (12 months; January 2005 to December 2005) are used for setting the initial values.

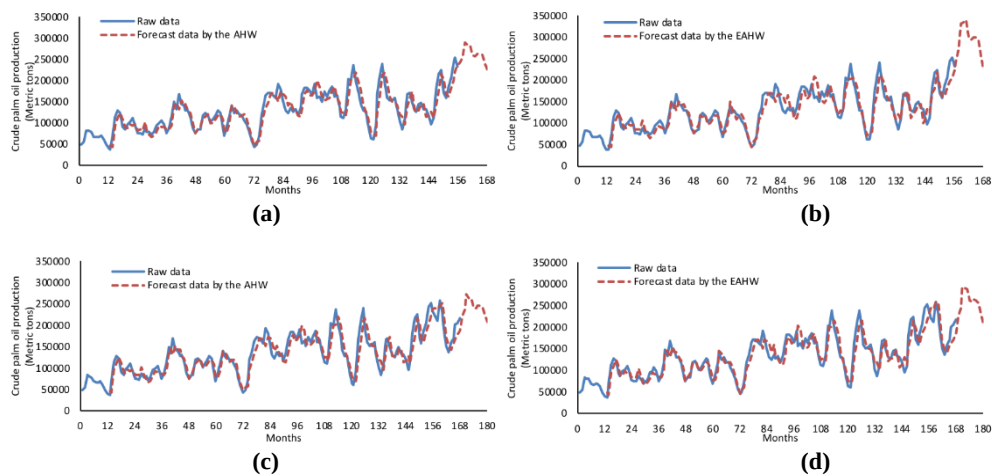
The results in Table 3 show that, to forecast one-year ahead of crude palm oil production, both the AHW and the EAHW methods provide the same results indicated by the average MAPEs. Here, by considering the 95% CI, the performance by both methods is not different. In addition, the results in Table 4 also demonstrate that the AHW and the EAHW methods require the same level of the

Table 3. The comparison of the MAPE results determined by the AHW and the EAHW methods to forecast monthly crude palm oil production of the years 2018 and 2019

Methods	Average MAPE (to forecast 2018)	95% CI	Average MAPE (to forecast 2019)	95% CI
AHW	11.0675	1.2662	11.1153	1.1792
EAHW	10.8838	1.2860	10.9781	1.1629

Table 4. The optimal weighting factors for the AHW and EAHW methods to forecast monthly crude palm oil production of the years 2018 and 2019

Methods	Optimal weighting factors (to forecast 2018)			
	α	β	γ	δ
AHW	0.946	≈ 0	0.999	-
EAHW	0.931	0	1	1
Methods	Optimal weighting factors (to forecast 2019)			
	α	β	γ	δ
AHW	0.946	≈ 0	1	-
EAHW	0.961	0	0.999	0.999

**Figure 3.** The comparison of the crude palm oil production between the raw data and the forecast data determined by the AHW and the EAHW methods, to forecast the data of the years 2018 and 2019

- (a) Forecast data by the AHW method for the year 2018
- (b) Forecast data by the EAHW method for the year 2018
- (c) Forecast data by the AHW method for the year 2019
- (d) Forecast data by the EAHW method for the year 2019

optimal weighting factors to predict the data of the years 2018 and 2019.

Figure 3 demonstrates the comparison of the crude palm oil production between the raw data in Table 2 and the forecast data determined by the AHW and the EAHW methods, to forecast the data of the years 2018 and 2019. As seen in Figure 3, the forecast data determined by both the AHW and EAHW methods are closer to the raw data. These results relate to the MAPE results as introduced in Table 3. A good matching result represents a good forecasting accuracy of the

forecasting method. Figure 4 also illustrates the comparison of the MAPE result of each input sample determined by the AHW and the EAHW methods to forecast the data of the year 2019. Such a result reveals that the distribution of the forecasting errors by both methods is quite the same. Note that the average MAPEs in these cases are 11.1153 and 10.9781, as shown in Table 3.

However, by observing the forecast results in Figure 3, we have found that the predicted data of the year 2018 forecast by the AHW method is significantly lower than in the

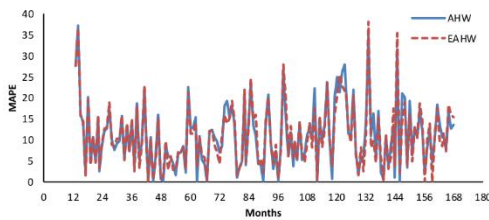


Figure 4. The comparison of the MAPE result of each input sample determined by the AHW and the EAHW methods, to forecast the data of the year 2019

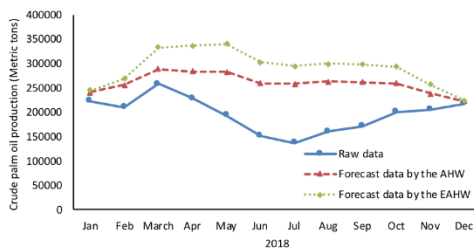


Figure 5. The comparison of the crude palm oil production among the raw data of the year 2018, the forecast data of the year 2018 by the AHW method, and the forecast data of the year 2018 by the EAHW method

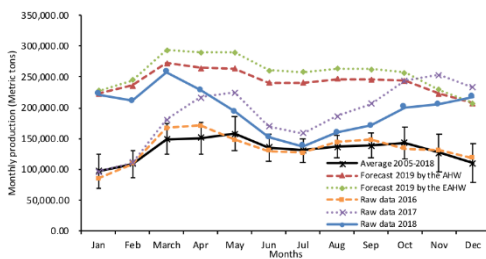


Figure 6. The comparison of the crude palm oil production among the raw data of the year 2016, the raw data of the year 2017, the raw data of the year 2018, the average data of the years 2005 to 2008, the forecast data of the year 2019 by the AHW method, and the forecast data of the year 2019 by the EAHW method

case the EAHW method. As seen in Figure 5, the comparison of the crude palm oil production among the raw data of the year 2018, the forecast data of the year 2018 by the AHW method, and the forecast data of the year 2018 by the EAHW method, the results demonstrate that the forecast data of the year 2018 by the AHW method (January 2018 to December 2018) are closer to the actual data of the year 2018 than in the case of the forecast data of the year 2018 by the EAHW method. Here, the forecast data by the EAHW method are higher than in the case of the EAHW method throughout the year. The result also demonstrates that the AHW and the EAHW methods show the same trend of the forecast data. They follow a circular pattern.

Figure 6 shows the comparison of the crude palm oil production among the raw data of the year 2016, the raw data of the year 2017, the raw data of the year 2018, the average data of the years 2005 to 2008, the forecast data of the year 2019 by the AHW method, and the forecast data of the year 2019 by the EAHW method. Here, the results show that: a) the trend of the average data of the years 2005 to 2008 follows the circular pattern, b) the trends of the raw data of the year 2016 and the raw data of the year 2017 follow the circular pattern, and almost all the raw data of the year 2017 are higher than the raw data of the year 2016 and the average data of the years 2005 to 2008, c) for the raw data of the year 2018, the monthly crude palm oil production increases at the end of the year (note that, for the raw data of the year 2017, the monthly crude palm oil production is also high at the end of the year), and finally, d) the forecast data of the year 2019 by the AHW and the EAHW methods indicate that the predicted monthly crude palm oil production of the year 2019 is higher than other results. We note that, as seen by the results in Figure 6, the predicted monthly crude palm oil production of the year 2019 decreases at the end of the year, like the average data of the years 2005 to 2018 and the raw data of the year 2016. However, this result should be continuously monitored and followed, since the raw data of the years 2017 and 2018 show that production was high at the end of the year.

The findings of this work can be useful as information for planning an optimal strategy of Thai agriculturists and the government; in the case of the government, it can be useful as a guideline for supervising policy and development plans for the oil palm sector. For example, the government's policies on the biodiesel blending ratio and palm oil stock management vary depending on the amount of palm oil production and maintenance of the stability of palm oil prices. If crude palm oil production in Thailand can be accurately predicted, a suitable plan for managing the use of biodiesel can be set immediately.

For example, as announced by the Thai government during 2015 to 2017, the biodiesel blending ratio was changed from 3.5% to 6% by volume of diesel (or B3.5 to B6) during April 2015, 7% to 5% during July 2016, and 5% to 7% during May 2017. Here, the change depends on the amount of crude palm oil production in Thailand. As illustrated by the forecast results in Figure 5, we found that the crude palm oil production from January 2018 to March 2018 will increase. Thus, the biodiesel blending ratio should be kept at 7% or higher, and the exportation of crude palm oil production should be supported more to prevent the decrease of crude palm oil prices.

Conclusions

In this paper, the AHW and the EAHW methods as time-series forecasting methods are used to forecast crude palm oil production in Thailand for the years 2018 and 2019. Our study demonstrates that both the AHW and EAHW methods can be used to forecast one-year ahead data, and they show the same forecasting error as measured by the MAPE results. The AHW and the EAHW methods also provide the same trend of the forecast crude palm oil production for the years 2018 and 2019.

We found the following results:

- The trends of the average data of the years 2005 to 2008 follow the circular pattern;
- The trends of the raw data of the years 2016 and 2017 follow the circular pattern, and

almost all the raw data of the year 2017 are higher than the raw data of the year 2016 and the average data of the years 2005 to 2008;

- For the raw data of the years 2017 and 2018, the monthly crude palm oil production figures are high at the end of the year;

- For the year 2018, the forecast data provided by the AHW method are significantly closer to the actual data than in the case of the EAHW method;

- Finally, for the forecast data of the year 2019 by the AHW and the EAHW methods, the monthly crude palm oil production is higher than in other years.

In future work, although the AHW and the EAHW methods as different exponential smoothing methods of the Holt-Winters family are applied and studied in this work due to their benefit as presented in the paper, to forecast crude palm oil data in Thailand more updated oil palm data, crude palm oil data, and other related input data should be included for evaluation to validate the AHW and the EAHW methods and to improve forecasting accuracy. Moreover, other forecasting techniques such as artificial neural network (ANN) and autoregressive integrated moving average (ARIMA) should also be tested. Such solutions are still an open research issue and need further investigation.

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