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Forecasting The Production of Crude Palm Oil (CPO) in Indonesia 2022 using the Grey(1.1) Model

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Abstract: Crude Palm Oil (CPO) is a vegetable oil produced from oil palm fruit plants. Palm oil can be used for many things, including for various foods, cosmetics, hygiene products, and can also be used as a source of biofuel or biodiesel. Indonesia is a country with the most CPO production in the world. However, the development of CPO production must be appropriately managed to meet demand from other countries. Therefore, this study aims to predict CPO production in 2022. One of the appropriate statistical methods is the Grey(1.1) model. This model was chosen based on the availability of CPO production data by the Central Statistics Agency, which only presents annual data from 2017 - 2021. So, the number of observations that can be used to predict CPO production in Indonesia is only five observations. The Grey(1.1) model can cover problems in the availability of small amounts of data. There are three main steps in the modelling procedure with Grey(1,1) model, namely forming an Accumulated Generated Operation (AGO) sequence, then forming a Mean Generating Operation (MGO) sequence, and the last step is a prediction with Inverse AGO (1-AGO). This study obtained the 1-AGO sequence on the Grey(1.1) model for CPO production in Indonesia with outstanding accuracy, namely the Mean Absolute Percentage Error (MAPE) value of 0.01%. In addition, a prediction of CPO production in Indonesia for 2022 is made, which is 52590612.99 (an increase of 2339783.668 from 2021).

2010 Mathematical Subject Classification: 97K40, 46N40.
Keywords: CPO, Grey, prediction

1. Introduction

Crude Palm Oil (CPO) is obtained from the extraction or compression process of the fruit flesh (mesocarp) of oil palm from the Elaeis Guineans species and has not been purified. One of the most common uses of vegetable oil from CPO processing is as a raw material for cooking oil. Indonesia is the highest palm oil-producing country in the world. Together with Malaysia, Indonesia has succeeded in meeting the world's CPO needs by up to 85%. Based on data from the Indonesian Central Statistics Agency (BPS) in 2015, the top five importing countries for Indonesian CPO are India, the Netherlands, Malaysia, Singapore, and Spain. India's export volume reached 49.06% of Indonesia's total CPO export volume. The second rank is the Netherlands, with an export volume of 13.41% of the total export volume of Indonesia's CPO. The third rank is Malaysia, with an export volume of 7.98% of the total export volume of Indonesia's CPO. The fourth rank is Singapore, with an export volume of around 7.76% of Indonesia's total CPO volume. The fifth rank in Spain, with 7.46% of Indonesia's CPO export volume [1].

As the largest palm oil-producing country globally, Indonesia has become a significant supplier or exported to other countries for more than three decades [1]. Palm oil that produces palm fruit can be processed into several products in oil, including Crude Palm Oil (CPO)/crude oil and Kernel Palm Oil (KPO)/core oil. Since the Russian invasion of Ukraine, it is feared that there will be a deficit in the supply of domestic CPO products. Therefore, the management of CPO production is essential. This is intended so that production can fulfill the target and prevent losses from production costs, and support management in decision making [2]. To facilitate future production planning, the production estimation process should be based on production data in previous [3,4,5,6].

This study aims to predict CPO production in the future period. One of the models used is the Grey(1,1) model. The data on CPO in Indonesia available at the Central Statistics Agency (BPS) is data on annual CPO production from 2017 – to 2021. As a result, only five observations of CPO production are known. To use the Autoregressive (AR), Moving Average (MA), or ARMA model, certain assumptions are not met, one of which is the minimum number of observations of 40 observations. While the Grey(1.1) model has the advantage that it does not require the assumption of a large number of observations, it can be applied to data with a small number of observations. The principle of modelling using the Grey model with order 1 is the differentiation of 1 step or one time before. The last order, 1 in the Grey(1,1) model, represents the number of variables used. Only one variable was used in this study, namely CPO production in Indonesia. The second section discusses the modelling procedure using the Grey(1,1) model, then proceeds to section three, which discusses the results and discussion of modelling CPO production in Indonesia using the Grey(1,1) model. Furthermore, the conclusions and references are placed after the results and discussion, respectively.

2. The Grey(1,1) Model

Grey forecasting model or Grey model (1,1) is a forecasting model that uses a first-order differential equation with one research variable. The Grey (1,1) model has an advantage over the classical time series model, namely that it does not some assumptions must be met, and forecasting can although the data is limited, the Grey (1,1) model has a weakness that is it is less effective for fluctuating data [7]. In its development, the Grey (1,1) model was modified by Markov chain analysis called the Grey-Markov model. The model uses the concept of a state transition where the state changes from time to time in a data is uncertain; it is the nature of this uncertainty that supports the inclusion of Markov chain analysis in the Grey model [8]. The following is the modeling procedure with Grey(1,1) model:

1. Forming the sequence of Accumulated Generation Operation (AGO)

   AGO is a sequence with the notation $x^{(1)}(k)$ obtained from the accumulation of the actual data sequence $x^{(0)}(k)$ with a positive sequence. Time series data or actual observation data taken in research, arranged into a row [9],

   $$X^{(0)}(k) = \{x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(n)\}$$

   for $k = 1,2, \dots, n$ and n is the number of observations used.

   By using the One-Accumulated Generating Operation (1-AGO) model in the following equation [7]:

$$X^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), k = 1,2, \dots, n$$

and

$$x^{(1)}(1) = x^{(0)}(1)$$

then the resulting AGO sequence below:

$$X^{(1)}(k) = \{x^{(1)}(1), x^{(2)}(2), \dots, x^{(1)}(n)\}$$

2. Forming the sequence of Mean Generating Operation (MGO)
   MGO is the sequence $Z^{(1)}(k)$ which is the average of $x^{(1)}(k)$ and $x^{(1)}(k-1)$. The MGO sequence is used to calculate the value of parameters a and b, based on Equation 3.4. The equation for calculating the MGO value is given as follows [10]:

$$Z^{(1)}(k) = \frac{x^{(1)}(k) + x^{(1)}(k-1)}{2},$$

   for $k = 2,3, \dots, n$, and the sequence of MGO is $Z^{(1)}(k)$.
   The model used to find the values of the parameters a and b is the least squares method shown in the following equation [10]:

$$\begin{bmatrix} a \\ b \end{bmatrix} = (B^T B)^{-1} B^T Y$$

   where

$$Y = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix}, B = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -z^{(1)}(n) & 1 \end{bmatrix}$$

   where a is development coefficient and b is input Grey. These parameters will be used in prediction step.
3. Predicting using Inverse Accumulated Generating Operation (1-AGO)
   Prediction is made by finding a solution of the first-order differential equation in the AGO sequence, $X^{(1)}(k)$, i.e.

$$\frac{dx^{(1)}(1)}{dk} + ax^{(1)}(k) = b$$

   The solution of these equations can be found using the Laplace equation

$$\mathcal{L}\left\{\frac{dx^{(1)}(1)}{dk}\right\} + \mathcal{L}\left\{ax^{(1)}(k)\right\} = \mathcal{L}\{b\}$$

$$\mathcal{L}\left\{x^{(1)}(k)\right\} = \frac{x^{(1)}(0) + \frac{b}{s}}{s+a}$$

with the initial conditions i.e $x^{(1)}(1) = x^{(0)}(1)$ then $x^{(1)}(0) = x^{(0)}(1)$ so that

$$\mathcal{L}\left\{x^{(1)}(k)\right\} = \frac{x^{(0)}(1) + \frac{b}{s}}{s+a}$$

Using the inverse of the Laplace transform, we get

$$x^{(1)}(k) = \mathcal{L}^{-1}\left\{\frac{x^{(0)}(1) - \frac{b}{a}}{(s+a)} + \frac{\frac{b}{a}}{s}\right\} = \left(x^{(0)}(1) - \frac{b}{a}\right)e^{-ak} + \frac{b}{a}$$

with $k > 0$, so that the formula for the predicted value of AGO is as follows [7]:

$$\hat{x}^{(1)}(k+1) = \left(x^{(0)}(1) - \frac{b}{a}\right)e^{-ak} + \frac{b}{a}$$

Thus, the AGO prediction sequence is obtained, i.e

$$\hat{X}^{(1)}(k+1) = \left\{\hat{x}^{(1)}(2), \hat{x}^{(1)}(3), \dots, \hat{x}^{(1)}(n)\right\}$$

After knowing the predicted value of AGO, the last step in determining the results of the Grey model (1,1) is the 1-AGO (Inverse Accumulated Generating Operation) process, namely by subtracting the k-1 term from the AGO value with the kth term shown in Equation 3.8 [10]:

$$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k), k = 1,2, \dots, n$$

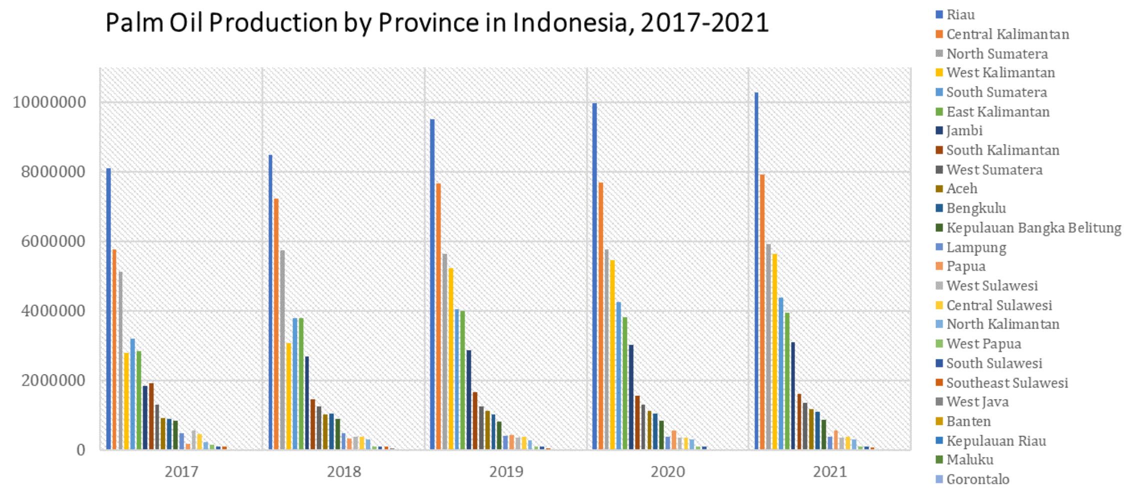
Thus, the results of the Grey (1,1) model are obtained in the form of a sequence

$$\hat{X}^{(0)}(k) = \left\{\hat{x}^{(0)}(1), \hat{x}^{(0)}(2), \dots, \hat{x}^{(0)}(n)\right\}$$

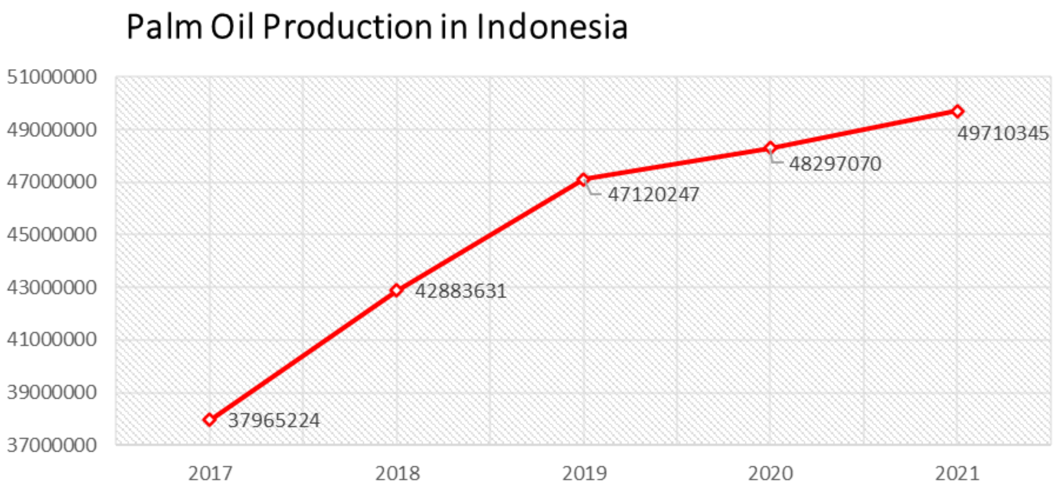
3. Results and Discussion

3.1. Descriptive Statistics

The data used is CPO production in Indonesia in 2017 - 2021. The data is obtained from the Central Statistics Agency (BPS) [11]. As stated earlier, Indonesia is the largest producer of CPO; this can also be seen from the provinces in Indonesia (shown in Fig. 1a). Riau Province is the largest CPO producing province every year, followed by Central Kalimantan, North Sumatra, West Kalimantan, and South Sumatra. The largest CPO producers are dominated by provinces located on the islands of Kalimantan and Sumatra. Meanwhile, several provinces in Indonesia do not produce CPO at all, including DKI Jakarta, Central Java, DI Yogyakarta, East Java, Bali, West Nusa Tenggara, East Nusa Tenggara, North Sulawesi, and North Maluku. Data on CPO production in Indonesia is the total CPO production in each province in Indonesia. Fig. 1b shows increasing CPO production in Indonesia from 2017 - 2021. The average CPO production for the last five years was 45195303.4. Then the variance and standard deviation are 2.283×10^{13};4778332,397 (Table 1).



(a)



(b)

Fig. 1. Palm Oil Production for (a) Each Province, and (b) Indonesia

Table 1. Descriptive Statistics

Total	Mean	Variansi	Standar Deviasi
225976517	45195303,4	$2,283 \times 10^{13}$	4778332,397

3.2. Data Analysis

CPO production data were analyzed using the Grey(1,1) model for $n = 5$ using the following procedure

1. Forming the sequence of AGO, $X^{(1)}(k)$,

   Let $X^{(0)}(k)$ is data series containing each CPO production observation per year, namely

$$X^{(0)}(k) = \{x^{(0)}(1), x^{(0)}(2), x^{(0)}(3), x^{(0)}(4), x^{(0)}(5)\}$$

   then,

$$X^{(0)}(k) = \{37965224, 42883631, 47120247, 48297070, 49710345\}$$

The One-Accumulated Generating Operation (1-AGO) can be calculated by

$$X^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), k = 1,2, \dots ,5$$

then,

$$X^{(1)}(1) = \sum_{i=1}^{1} x^{(0)}(1) \ = 37965224$$

$$X^{(1)}(2) = \sum_{i=1}^{1} x^{(0)}(1) + x^{(0)}(2) = 37965224 + 42883631 = 80848855$$

$$X^{(1)}(3) = \sum_{i=1}^{1} x^{(0)}(1) + x^{(0)}(2) + x^{(0)}(3) = 80848855 + 47120247 = 127969102$$

$$X^{(1)}(4) = \sum_{i=1}^{1} x^{(0)}(1) + x^{(0)}(2) + x^{(0)}(3) + x^{(0)}(4) = 127969102 + 48297070 = 176266172$$

$$X^{(1)}(4) = \sum_{i=1}^{1} x^{(0)}(1) + x^{(0)}(2) + x^{(0)}(3) + x^{(0)}(4) + x^{(0)}(5) = 176266172 + 49710345 = 225976517$$

then the following 1-AGO sequence is generated

$$X^{(1)}(k) = \{37965224, 80848855, 127969102,176266172, 225976517\}$$

2. Forming the sequence of MGO

The MGO can be calculated by

$$Z^{(1)}(k) = \frac{x^{(1)}(k) + x^{(1)}(k-1)}{2}, k = 2,3, \dots ,5$$

then,

$$Z^{(1)}(2) = \frac{x^{(1)}(2) + x^{(1)}(2-1)}{2} = \frac{x^{(1)}(2) + x^{(1)}(1)}{2} = \frac{80848855 + 37965224}{2} = 59407039{,}5$$

$$Z^{(1)}(3) = \frac{x^{(1)}(3) + x^{(1)}(3-1)}{2} = \frac{x^{(1)}(3) + x^{(1)}(2)}{2} = \frac{127969102 + 80848855}{2} = 104408978{,}5$$

$$Z^{(1)}(4) = \frac{x^{(1)}(4) + x^{(1)}(4-1)}{2} = \frac{x^{(1)}(4) + x^{(1)}(3)}{2} = \frac{176266172 + 127969102}{2} = 152117637{,}0$$

$$Z^{(1)}(5) = \frac{x^{(1)}(5) + x^{(1)}(5-1)}{2} = \frac{x^{(1)}(5) + x^{(1)}(4)}{2} = \frac{225976517 + 176266172}{2} = 201121344{,}5$$

so that the MGO sequence is obtained as follows

$$Z^{(1)}(k) = \{59407039{,}5; 104408978{,}5; 152117637{,}0; 201121344{,}5\}$$

To calculate the parameters a and b, the least squares method is used, with

$$Y = \begin{bmatrix} 42883631 \\ 47120247 \\ 48297070 \\ 49710345 \end{bmatrix}, X = \begin{bmatrix} -59407039{,}5 & 1 \\ -104408978{,}5 & 1 \\ -152117637{,}0 & 1 \\ -201121344{,}5 & 1 \end{bmatrix}$$

so that,

$$\begin{bmatrix} a \\ b \end{bmatrix} = \left(\begin{bmatrix} -59407039{,}5 & 1 \\ -104408978{,}5 & 1 \\ -152117637{,}0 & 1 \\ -201121344{,}5 & 1 \end{bmatrix}^t \begin{bmatrix} -59407039{,}5 & 1 \\ -104408978{,}5 & 1 \\ -152117637{,}0 & 1 \\ -201121344{,}5 & 1 \end{bmatrix} \right)^{-1} \begin{bmatrix} -59407039{,}5 & 1 \\ -104408978{,}5 & 1 \\ -152117637{,}0 & 1 \\ -201121344{,}5 & 1 \end{bmatrix}^t \begin{bmatrix} 42883631 \\ 47120247 \\ 48297070 \\ 49710345 \end{bmatrix}$$

$$\begin{bmatrix} a \\ b \end{bmatrix} = \begin{bmatrix} -0{,}045 \\ 41119953{,}360 \end{bmatrix}$$

3. Predicting using Inverse Accumulated Generating Operation (1-AGO)
   Let $\hat{X}^{(1)}(k)$ is the sequence of AGO prediction, namely

$$\hat{X}^{(1)}(k) = \{\hat{x}^{(1)}(1), \hat{x}^{(1)}(2), \hat{x}^{(1)}(3), \hat{x}^{(1)}(4), \hat{x}^{(1)}(5)\}$$

where

$$\hat{x}^{(1)}(k+1) = \left(x^{(0)}(1) - \frac{b}{a}\right) e^{-ak} + \frac{b}{a}$$

$$\hat{x}^{(1)}(k+1) = \left(37965224 - \frac{41119953{,}360}{-0{,}045}\right) e^{-(-0{,}045)k} + \frac{41119953{,}360}{-0{,}045}$$

for $k = 0,1,2,3,4$,
so that,

$$\hat{X}^{(1)}(k) = \{37965224{,}0;\ 81802971{,}9;\ 127681897{,}1;\ 175697041{,}0;\ 225947870{,}3\}$$

After knowing the predicted value of AGO, the last step in determining the results of the Grey model (1,1) is the 1-AGO (Inverse Accumulated Generating Operation) process, namely

$$\hat{X}^{(0)}(k) = \{\hat{x}^{(0)}(1), \hat{x}^{(0)}(2), \hat{x}^{(0)}(3), \hat{x}^{(0)}(4), \hat{x}^{(0)}(5)\}$$

where

$$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k)$$

so that,

$$\hat{X}^{(0)}(k) = \{37965224{,}0;\ 43837747{,}9;\ 45878925{,}2;\ 48015143{,}8;\ 50250829{,}3\}$$

Fig. 2 shows the results of fitted values using the model Grey(1,1) versus observations.

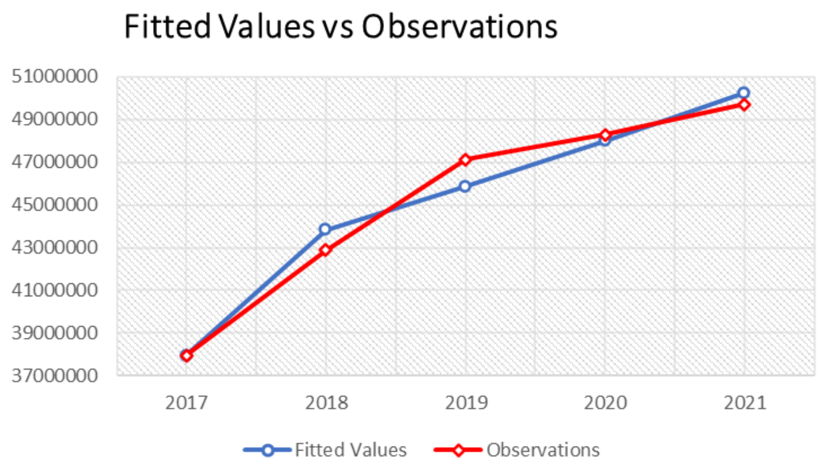


Fig. 2. Fitted Values vs Observations using Grey(1,1) Model

To ensure that the Grey(1.1) model is suitable for predicting the CPO, the relative error from the Grey(1,1) model is calculated, and then the Mean Absolute Percentage Error (MAPE) value is calculated. The relative error sequence, $er(k)$, is shown as follows

$$er(k) = \{0{,}000; 0{,}022; 0{,}026; 0{,}006; 0{,}011\}$$

Based on the relative error sequence, the MAPE value is 0.01% through the MAPE calculation, which means that the Grey(1.1) model is very well used to predict CPO production in Indonesia. The prediction is made for one period ahead, namely the 2022 period. The Grey(1.1) model shows that CPO production in Indonesia in 2022 is 52590612.99. The CPO production increased by 2339783.668 from 2021.

4. Conclusion

Data on CPO production in Indonesia from 2017 – to 2021 can be used to predict CPO production in 2022. The model used is the Grey(1.1) model. With the number of observations being five, the Grey(1.1) model can be said to be good enough to capture the pattern of CPO production in Indonesia from 2017-to 2021. This is evidenced by the minimal MAPE value of 0.01%, indicating that the model is suitable for predicting. The prediction results obtained are an increase in the number of CPO production in Indonesia by 2339783,668 from the previous year. CPO production in Indonesia is predicted to be 52590612.99 using the Grey(1.1) model. Of course, the increase in production figures is accompanied by the need for CPO imports from other countries, which is increasing year by year. Not to mention the other phenomena that may occur, which cause the demand for CPO for countries in the world to increase. One that is visible today is due to the Russian invasion of Ukraine. So that by predicting CPO production, it can be anticipated for other sectors.

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