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FORECASTING OF CRUDE PALM OIL BY USING *FUZZY TIME SERIES* METHOD (STUDY CASE : PT. BUANA MUDANTARA PLANTATION)

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ABSTRACT

PT. Buana Mudantara is a company engaged in palm oil production. The production of oil palm at this company varies every period, so the problem that often occurs is insufficient supply and demand. Therefore, it is necessary to forecast future oil palm production. The method used in this research is the Fuzzy Time Series method which has advantages, among others, that the calculation process does not require a complicated system, so it is easier to develop and can solve the problem of forecasting historical data in the form of linguistic values. This method provides a level of accuracy calculated using the MAPE (Mean Absolute Percentage Error) of 9,05895% *. The results show that the forecasting of the amount of oil palm production in November 2019 - March 2020 is respectively* 615963,56288 *ton, ton, ton* 671289,30635726615,04980698952,17808 *tons and tons* 671289,30635.

Keywords: *Fuzzy Time Series, Palm Oil, Forecasting, Production, Time Series*

INTRODUCTION

The oil palm plant (Elaeis guineesis) is one of the few crops that produces oil for commercial purposes. The world's demand for palm oil in 2012 was 52.1 million tonnes, and by 2020 it is expected to increase to 68 million tonnes. In 2016, Indonesia became the first producer in the world with a production of 34 million tonnes of total world production of approximately 62 million tonnes and exports of 25 million tonnes of the total exports of various countries in the world which were approximately 46 million tonnes with total domestic consumption. as much as 9.47 million tons(Fuadah & Ernah, 2018). Oil palm production varies per period. So the company must consider the amount of palm oil supply which will then be processed into palm oil, so that the amount of demand and supply is sufficient. In this case, companies need to know the forecast for future palm oil production.

Forecasting is the prediction of events that will occur in the future. Forecasting is often divided into three types, namely short-term forecasting, medium-term forecasting and long-term forecasting. Short-term forecasting includes predictions for the coming days, weeks, or months. It includes medium-term forecasting is the prediction of events in the next one or two years. Things that include long-term forecasting are predictions for the next few years (Pambudi et al, 2018).

There are several methods that can be used to predict future production, one of which is the Fuzzy Time Series method. This method captures patterns from past data and is then used to project future data. The requirement for data to be processed using fuzzy time series is that the data must be in the form of a time series without missing data. Based on the explanation above, the authors are interested in conducting research to predict oil palm production at PT. Buana Mudantara uses the Fuzzy Time Series method.

The formulation of the problem in this study are, what is the forecast value of oil palm production at PT. Buana Mudantara November 2019 - March 2020 using the Fuzzy Time Series method ? and how accurate is the Fuzzy Time Series method in predicting oil palm production using MAPE (Mean Absolute Percentage Error) ?.

The objectives of this study are, obtain forecast value of oil palm production at PT. Buana Mudantara in November 2019 - March 2020 using the Fuzzy Time Series method and seeing the

accuracy of the Fuzzy Time Series method in predicting oil palm production using MAPE (Mean Absolute Percentage Error).

Fuzzy time series is a new concept proposed by Song and Chissom based on fuzzy set theory and the concept of linguistic variables. Fuzzy time series is a concept that can be used to predict problems in which historical data is formed in linguistic values, in other words the previous data in the fuzzy time series is linguistic data, while the latest data as a result are real numbers. The Fuzzy Time Series method will be implemented to predict the amount of production for the next month based on existing historical data. Forecasting systems with fuzzy time series capture patterns from past data which are then used to project future data (Fauziah et al, 2016). The data collected must meet the requirements to be collected periodically based on the time sequence in hours, in days, weeks, months, quarters or years (Nugroho, 2016). The advantages of this method include that it does not require data stationary assumptions as in conventional forecasting methods (Ramadhani et al, 2019).

MATERIALS AND METHODS

Sources of data used in this study are secondary data and the type of data used is quantitative, namely data in the form of numbers, namely the amount of oil palm production at PT. Buana Mudantara from January 2017 to October 2019. The following are the steps in forecasting using the Fuzzy Time Series method, namely :

1. Historical Data Fuzzification.

   The process carried out at this step is as follows :

   a. Defines the set universe interval $U = [X_{min}, X_{max}]$ containing all historical data (Gemilang, 2017).
   b. Divide U into intervals of the same length.
   c. Defines a fuzzy set on U which the linguistic value is based on the partition interval u_i, that is A_i it is a fuzzy set of linguistic values u_i so that it can be written :

$$A_i = \sum_{j=1}^{n} \frac{f(u_j)}{u_j} \quad (1)$$

   Where :
   $f(u_j) = 1$ for $j = i$
   $f(u_j) = 0{,}5$ for $j = i - 1$ and $j = i + 1$
   $f(u_j) = 0$ for j others.

   d. Fuzzification of historical data based on the interval the historical data is located, which has a membership function value of 1, that is $y(t)$ can be fuzzified to A_i if $y(t) \in u_i$, where $f(u_i) = 1$ on A_i. In this case, fuzzy $y(t)$ to write as $F(t) = A_i$.

2. Fuzzy Time Series Forecasting Order 1

   a. Form a fuzzy logic relationship group.

   The purpose of forming this relation group is to see the trend of the relations connected to each fuzzy set of historical data. The process is as follows :

   1. Forming a fuzzy logic relationship, which is connecting the fuzzy set $F(t-1) \rightarrow F(t)$ for each t or in other words if A_i is fuzzy $F(t-1)$ and A_j is fuzzy $F(t)$, then $A_i \rightarrow A_j$.
   2. Form a group of fuzzy logic relations, that is if $A_i \rightarrow A_{j1}$ then in another historical $A_i \rightarrow A_{j2}$, then $A_i \rightarrow A_{j3}$, and so on if any, then the fuzzy relationship group for A_i can be written as $A_i \rightarrow A_{j1}, A_{j2}, \dots, A_{jn}$.

   b. Foresee

   Before forecasting, first determine the weighting of the formed relation group (FLRG). Suppose the FLR formed based on historical data is $A_1 \rightarrow A_1$, $A_1 \rightarrow A_2$, $A_1 \rightarrow A_1$, $A_1 \rightarrow A_1$, $A_1 \rightarrow A_3$, $A_1 \rightarrow A_3$, then (FLRG) that is formed is $A_1 \rightarrow A_1, A_2, A_1, A_1, A_3, A_2$. Thus, it is weighted in a way that each A_1 on the right side is given a value $1,2,3, \dots, n$ (with n the number A_1 on the right side), each A_2 on the right side is given a value $1,2,3, \dots, n$ (with n the number A_2 on the right side) and so on. So that the FLRG $A_1 \rightarrow A_1, A_2, A_1, A_1, A_3, A_2$ is weighted [1,2,3,1,2,1]. In general, the weighting can be written as follows :

   $w_1 = A_1$ the first right side is 1

$w_2 = A_2$ the first right side is 1
$w_3 = A_1$ the second right side is worth 2, and so on.

Furthermore, to forecast at time -t it is necessary to have a trend of the fuzzy set relation from time $(t-1)$, if at the time $(t-1)$ the fuzzy set of historical data is A_i, then the trend of the relation (group of fuzzy logic relations) is $A_i \rightarrow A_{j1}, A_{j2}, \dots, A_{jn}$, then the historical data for year t is the result of defuzzification of one of the following rules :

1) If the FLR of A_i what is formed is an empty set $(A_i \rightarrow \emptyset)$ the forecasting data at time t is the middle value of the interval i which is formulated as follows :

$$\widehat{F}(t) = m_i \tag{2}$$

2) If the FLR of A_i what is formed is a one-to-one relation $(A_i \rightarrow A_j)$, then the forecasting data at time t is the middle value of the interval j which is formulated as follows :

$$\widehat{F}(t) = m_j \tag{3}$$

3) If the FLR of A_i what is formed is a relation from one to many $(A_i \rightarrow A_j, \dots, A_k)$, then the forecast data at time t are formulated as follows :

$$\widehat{F}(t) = \frac{am_j + \cdots + bm_k}{a + \cdots + b} \tag{4}$$

3. Forecasting Fuzzy Time Series Order 2

a. Form a fuzzy logic relationship group.

The purpose of forming this relation group is to see the trend of the relations connected to each fuzzy set of historical data. The process is as follows :

1) Forming a fuzzy logic relationship, which is connecting the fuzzy set $(F(t-2), F(t-1)) \rightarrow F(t)$ for each t or in other words if A_i it is fuzzy $F(t-2)$, A_h it is fuzzy $F(t-1)$ and A_j it is fuzzy $F(t)$, then $A_i, A_h \rightarrow A_j$.
2) Form a group of fuzzy logic relations, that is if $A_i, A_h \rightarrow A_{j1}$ then in another historical $A_i, A_h \rightarrow A_{j2}$, then $A_i, A_h \rightarrow A_{j3}$, and so on if any, then the fuzzy relationship group A_i, A_h can be written as $A_i, A_h \rightarrow A_{j1}, A_{j2}, \dots, A_{jn}$.

b. Foresee

Before forecasting, first determine the weighting of the formed relation group (FLRG). Suppose the FLR formed based on historical data is $A_1, A_2 \rightarrow A_1$; $A_1, A_2 \rightarrow A_2$; $A_1, A_2 \rightarrow A_1$; $A_1, A_2 \rightarrow A_1$,; $A_1, A_2 \rightarrow A_3$; $A_1, A_2 \rightarrow A_3$, then (FLRG) that is formed is $A_1, A_2 \rightarrow A_1, A_2, A_1, A_1, A_3, A_2$. Thus, it is weighted in a way that each A_1 on the right side is given a value $1,2,3, \dots, n$ (with n the number A_1 on the right side), each A_2 on the right side is given a value $1,2,3, \dots, n$ (with n the number A_2 on the right side) and so on. So that the FLRG $A_1, A_2 \rightarrow A_1, A_2, A_1, A_1, A_3, A_2$ is weighted [1,2,3,1,2,1]. In general, the weighting can be written as follows :

$w_1 = A_1$ the first right side is 1
$w_2 = A_2$ the first right side is 1
$w_3 = A_1$ the second right side is worth 2, and so on.

Furthermore, to forecast at time t it is necessary to have a trend of the fuzzy set relation from time $(t-2), (t-1)$, if at the time $(t-2), (t-1)$ the fuzzy set of historical data is A_i, A_h, then the trend of the relation (group of fuzzy logic relations) is $A_i, A_h \rightarrow A_{j1}, A_{j2}, \dots, A_{jn}$, then the historical data for year t is the result of defuzzification of one of the following rules :

1) If the FLR of A_i, A_h what is formed is an empty set $(A_i, A_h \rightarrow \emptyset)$, the forecasting data at time t is the middle value of the interval i, h which is formulated as follows :

$$\widehat{F}(t) = \frac{m_i + m_h}{2} \tag{5}$$

2) If the FLR of A_i, A_h what is formed is a one-to-one relation $(A_i, A_h \rightarrow A_j)$, then the forecasting data at time t is the middle value of the interval j which is formulated as follows:

$$\widehat{F}(t) = m_j \tag{6}$$

3) If the FLR of A_i, A_h what is formed is a relation from one to many $(A_i, A_h \rightarrow A_j, \dots, A_k)$, then the forecasting data at time t is formulated as follows :

$$\widehat{F}(t) = \frac{am_j + \cdots + bm_k}{a + \cdots + b} \quad (7)$$

The data analysis of this research was carried out in the following manner:

1. **Study of literature**

Literature study is studying theories related to fuzzy time series. Then apply it to the data obtained from the field. The case study was conducted at PT. Buana Mudantara.

2. **Data retrieval**

In this stage is data retrieval using secondary data obtained from PT. Buana Mudantara, namely data in the form of palm oil production from January 2017 to October 2019.

3. **Data processing**

Based on the data obtained, data processing will be carried out using the fuzzy time series method. The following is a flow chart used in data processing.

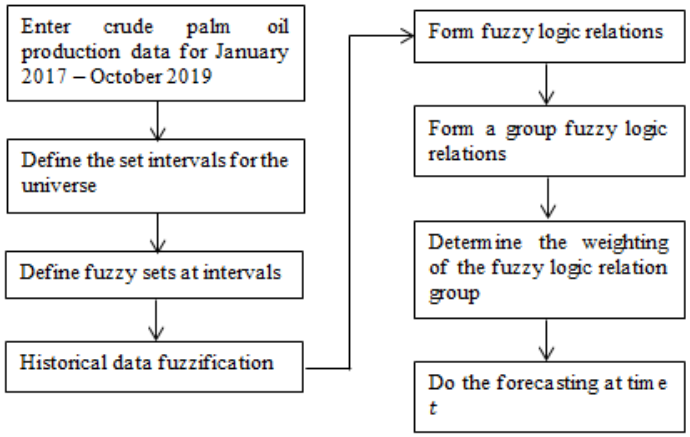

Figure 1. Data Processing Flowchart

4. **Forecasting Results**

After processing the data, the results of forecasting the amount of oil palm production will be obtained.

RESULTS AND DISCUSSION

Forecasting the amount of crude palm oil production in this study uses data from January 2017 to October 2019 which is shown in the following table (in tonnes):

Table 1. Data on the Amount of Crude Palm Oil Production in Tons

No	Month	Production	No	Month	Production
1	Jan 17	90369	18	Jun 18	277534
2	Feb 17	92637	19	Jul 18	285671
3	Mar 17	122391	20	Aug 18	334691
4	Apr 17	132732	21	Sep 18	561331
5	May 17	171412	22	Oct 18	616103
6	Jun 17	125156	23	Nov 18	293744
7	Jul 17	165556	24	Dec 18	521965
8	Aug 17	188777	25	Jan 19	509177
9	Sep 17	183480	26	Feb 19	295593
10	Oct 17	257227	27	Mar 19	485327
11	Nov 17	284894	28	Apr 19	432444
12	Dec 17	235160	29	May 19	470039
13	Jan 18	317302	30	Jun 19	310432
14	Feb 18	223761	31	Jul 19	342962
15	Mar 18	258647	32	Aug 19	484216
16	Apr 18	280583	33	Sep 19	763968
17	May 18	350047	34	Oct 19	761250

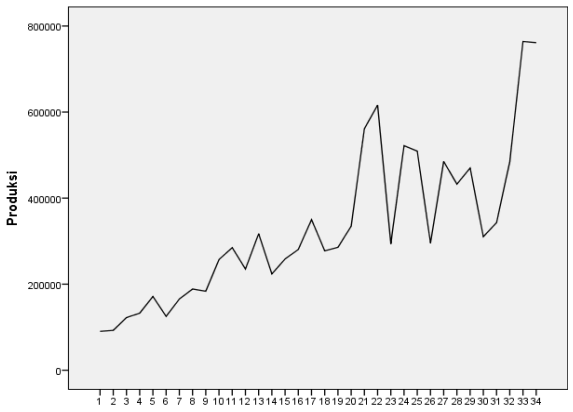

Figure 2. Time Series Plot of Palm Oil Production

1. Fuzzification of Historical Data

a. Defines the Set of the Universe with formulas

$$U = [X_{min}, X_{max}] \tag{8}$$
$$U = [90369, 763968]$$

b. Divides U Into Multiple Intervals

To divide the interval, we will first calculate the number of classes (k) and class lengths (l) using the sturgess rule as follows :

$$k = 1 + 3{,}322 \times \log(N) \tag{9}$$
$$= 1 + 3{,}322 \times \log(34)$$
$$= 6{,}08757 \approx 7$$
$$l = \frac{X_{max} - X_{min}}{k} \tag{10}$$
$$= \frac{763968 - 90369}{6{,}08757}$$
$$= 110651{,}48692$$

The calculation of the mean mean value is as follows:

$$m = \frac{upper\ limit + lower\ limit}{2} \tag{11}$$

Table 2. Mean Intervals and Points

No	Interval (u_i)	Midpoint of Mean (m_i)
1	[90369 ; 201020,44869)	145694,74346
2	[201020,448692 ; 311671,97384)	256346,23038
3	[311671,97384 ; 422323,46076)	366997,71730
4	[422323,46076 ; 532974,94768)	477649,20422
5	[532974,94768 ; 643626,43460)	588300,69115
6	[643626,43460 ; 754277,92152)	698952,17805
7	[754277,92152 ; 864929,40844)	809603,66500

c. Defining Fuzzy Sets

$$A_1 = \{\frac{1}{u_1} + \frac{0{,}5}{u_2} + \frac{0}{u_3} + \frac{0}{u_4} + \frac{0}{u_5} + \frac{0}{u_6} + \frac{0}{u_7}\}$$
$$A_2 = \{\frac{0{,}5}{u_1} + \frac{1}{u_2} + \frac{0{,}5}{u_3} + \frac{0}{u_4} + \frac{0}{u_5} + \frac{0}{u_6} + \frac{0}{u_7}\}$$
$$A_3 = \{\frac{0}{u_1} + \frac{0{,}5}{u_2} + \frac{1}{u_3} + \frac{0{,}5}{u_4} + \frac{0}{u_5} + \frac{0}{u_6} + \frac{0}{u_7}\}$$
$$A_4 = \{\frac{0}{u_1} + \frac{0}{u_2} + \frac{0{,}5}{u_3} + \frac{1}{u_4} + \frac{0{,}5}{u_5} + \frac{0}{u_6} + \frac{0}{u_7}\}$$
$$A_5 = \{\frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \frac{0{,}5}{u_4} + \frac{1}{u_5} + \frac{0{,}5}{u_6} + \frac{0}{u_7}\}$$
$$A_6 = \{\frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \frac{0}{u_4} + \frac{0{,}5}{u_5} + \frac{1}{u_6} + \frac{0{,}5}{u_7}\}$$
$$A_7 = \{\frac{0}{u_1} + \frac{0}{u_2} + \frac{0}{u_3} + \frac{0}{u_4} + \frac{0}{u_5} + \frac{0{,}5}{u_6} + \frac{1}{u_7}\}$$

d. Fuzzification of Historical Data

Table 3. Fuzzy Set Against Interval l

Interval	*Fuzzy Set*
u_1	A_1
u_2	A_2
u_3	A_3
u_4	A_4
u_5	A_5
u_6	A_6
u_7	A_7

Table 4. Fuzzification of Historical Data

No	Period	Fuzzification	No	Period	Fuzzification
1	January 2017	A_1	18	June 2018	A_2
2	February 2017	A_1	19	July 2018	A_2
3	March 2017	A_1	20	August 2018	A_3
4	April 2017	A_1	21	September 2018	A_5
5	May 2017	A_1	22	October 2018	A_5
6	June 2017	A_1	23	November 2018	A_2
7	July 2017	A_1	24	December 2018	A_4
8	August 2017	A_1	25	January 2019	A_4
9	September 2017	A_1	26	February 2019	A_2
10	October 2017	A_2	27	March 2019	A_4
11	November 2017	A_2	28	April 2019	A_4
12	December 2017	A_2	29	May 2019	A_4
13	January 2018	A_3	30	June 2019	A_2
14	February 2018	A_2	31	July 2019	A_3
15	March 2018	A_2	32	August 2019	A_4
16	April 2018	A_2	33	September 2019	A_7
17	May 2018	A_3	34	October 2019	A_7

2. Forming Fuzzy Logic Relations Group Order 1, 2, 3 and 4

a. Forming Fuzzy Linguistic Relations (FLR)

Forming a fuzzy logic relationship by connecting the fuzzy set at time $t-1$ t0 t.

Table 5. Fuzzy Linguistic Relations Order 1, 2, 3 and 4

No	Month	FLR Order 1	FLR Order 2	FLR Order 3	FLR Order 4
1	Jan 17	–	–	–	–
2	Feb 17	$A_1 \rightarrow A_1$	–	–	–
3	Mar 17	$A_1 \rightarrow A_1$	$A_1, A_1 \rightarrow A_1$	–	–
4	Apr 17	$A_1 \rightarrow A_1$	$A_1, A_1 \rightarrow A_1$	$A_1, A_1, A_1 \rightarrow A_1$	–
5	May 17	$A_1 \rightarrow A_1$	$A_1, A_1 \rightarrow A_1$	$A_1, A_1, A_1 \rightarrow A_1$	$A_1, A_1, A_1, A_1 \rightarrow A_1$
6	Jun 17	$A_1 \rightarrow A_1$	$A_1, A_1 \rightarrow A_1$	$A_1, A_1, A_1 \rightarrow A_1$	$A_1, A_1, A_1, A_1 \rightarrow A_1$
7	Jul 17	$A_1 \rightarrow A_1$	$A_1, A_1 \rightarrow A_1$	$A_1, A_1, A_1 \rightarrow A_1$	$A_1, A_1, A_1, A_1 \rightarrow A_1$
8	Aug 17	$A_1 \rightarrow A_1$	$A_1, A_1 \rightarrow A_1$	$A_1, A_1, A_1 \rightarrow A_1$	$A_1, A_1, A_1, A_1 \rightarrow A_1$
9	Sep 17	$A_1 \rightarrow A_1$	$A_1, A_1 \rightarrow A_1$	$A_1, A_1, A_1 \rightarrow A_1$	$A_1, A_1, A_1, A_1 \rightarrow A_1$
10	Oct 17	$A_1 \rightarrow A_2$	$A_1, A_1 \rightarrow A_2$	$A_1, A_1, A_1 \rightarrow A_2$	$A_1, A_1, A_1, A_1 \rightarrow A_2$
11	Nov 17	$A_2 \rightarrow A_2$	$A_1, A_2 \rightarrow A_2$	$A_1, A_1, A_2 \rightarrow A_2$	$A_1, A_1, A_1, A_2 \rightarrow A_2$
12	Dec 17	$A_2 \rightarrow A_2$	$A_2, A_2 \rightarrow A_2$	$A_1, A_2, A_2 \rightarrow A_2$	$A_1, A_1, A_2, A_2 \rightarrow A_2$
13	Jan 18	$A_2 \rightarrow A_3$	$A_2, A_2 \rightarrow A_3$	$A_2, A_2, A_2 \rightarrow A_3$	$A_1, A_2, A_2, A_2 \rightarrow A_3$
14	Feb 18	$A_3 \rightarrow A_2$	$A_2, A_3 \rightarrow A_2$	$A_2, A_2, A_3 \rightarrow A_2$	$A_2, A_2, A_2, A_3 \rightarrow A_2$
15	Mar 18	$A_2 \rightarrow A_2$	$A_3, A_2 \rightarrow A_2$	$A_2, A_3, A_2 \rightarrow A_2$	$A_2, A_2, A_3, A_2 \rightarrow A_2$
16	Apr 18	$A_2 \rightarrow A_2$	$A_2, A_2 \rightarrow A_2$	$A_3, A_2, A_2 \rightarrow A_2$	$A_2, A_3, A_2, A_2 \rightarrow A_2$
17	May 18	$A_2 \rightarrow A_3$	$A_2, A_2 \rightarrow A_3$	$A_2, A_2, A_2 \rightarrow A_3$	$A_3, A_2, A_2, A_2 \rightarrow A_3$
18	Jun 18	$A_3 \rightarrow A_2$	$A_2, A_3 \rightarrow A_2$	$A_2, A_2, A_3 \rightarrow A_2$	$A_2, A_2, A_2, A_3 \rightarrow A_2$
19	Jul 18	$A_2 \rightarrow A_2$	$A_3, A_2 \rightarrow A_2$	$A_2, A_3, A_2 \rightarrow A_2$	$A_2, A_2, A_3, A_2 \rightarrow A_2$
20	Aug 18	$A_2 \rightarrow A_3$	$A_2, A_2 \rightarrow A_3$	$A_3, A_2, A_2 \rightarrow A_3$	$A_2, A_3, A_2, A_2 \rightarrow A_3$
21	Sep 18	$A_3 \rightarrow A_5$	$A_2, A_3 \rightarrow A_5$	$A_2, A_2, A_3 \rightarrow A_5$	$A_3, A_2, A_2, A_3 \rightarrow A_5$

22	Oct 18	$A_5 \rightarrow A_5$	$A_3, A_5 \rightarrow A_5$	$A_2, A_3, A_5 \rightarrow A_5$	$A_2, A_2, A_3, A_5 \rightarrow A_5$
23	Nov 18	$A_5 \rightarrow A_2$	$A_5, A_5 \rightarrow A_2$	$A_3, A_5, A_5 \rightarrow A_2$	$A_2, A_3, A_5, A_5 \rightarrow A_2$
24	Dec 18	$A_2 \rightarrow A_4$	$A_5, A_2 \rightarrow A_4$	$A_5, A_5, A_2 \rightarrow A_4$	$A_3, A_5, A_5, A_2 \rightarrow A_4$

b. Forming Fuzzy Logic Relations Group (FLRG) Order 1, 2, 3 and 4

The formation of fuzzy logic relationship groups and weighting can be seen in the following table:

Table 6. FLRG and Weighted FLRG Order 1

Group	FLRG	Weight ($W_n(t)$)
1	$A_1 \rightarrow A_1, A_1, A_1, A_1, A_1, A_1, A_1, A_1, A_2$	[1,2,3,4,5,6,7,8,1]
2	$A_2 \rightarrow A_2, A_2, , A_2, A_2, A_2, A_3, A_3, , A_3, A_4$	[1,2,3,4,5,1,2,3,1]
3	$A_3 \rightarrow A_2, A_2, A_5$	[1,2,1]
4	$A_5 \rightarrow A_2, A_5$	[1,1]

Table 7. FLRG and Weighting of Order 2 FLRG

Group	FLRG	Weight ($W_n(t)$)
1	$A_1, A_1 \rightarrow A_1, A_1, A_1, A_1, A_1, A_1, A_1, A_2$	[1,2,3,4,5,6,7,1]
2	$A_1, A_2 \rightarrow A_2$	[1]
3	$A_2, A_2 \rightarrow A_2, A_2, A_3, A_3, A_3$	[1,2,1,2,3]
4	$A_2, A_3 \rightarrow A_2, A_2, A_5$	[1,2,1]
5	$A_3, A_2 \rightarrow A_2, A_2$	[1,2]
6	$A_3, A_5 \rightarrow A_5$	[1]
7	$A_5, A_5 \rightarrow A_2$	[1]
8	$A_5, A_2 \rightarrow A_4$	[1]

Table 8. FLRG and Weighting of the Order 3 FLRG

Group	FLRG	Weight ($W_n(t)$)
1	$A_1, A_1, A_1 \rightarrow A_1, A_1, A_1, A_1, A_1, A_1, , A_2$	[1,2,3,4,5,6,1]
2	$A_1, A_1, A_2 \rightarrow A_2$	[1]
3	$A_1, A_2, A_2 \rightarrow A_2$	[1]
4	$A_2, A_2, A_2 \rightarrow A_3, A_3$	[1,2]
5	$A_2, A_2, A_3 \rightarrow A_2, A_2, A_5$	[1,2,1]
6	$A_2, A_3, A_2 \rightarrow A_2, A_2$	[1,2]
7	$A_3, A_2, A_2 \rightarrow A_2, A_3$	[1,1]
8	$A_2, A_3, A_5 \rightarrow A_5$	[1]
9	$A_3, A_5, A_5 \rightarrow A_2$	[1]
10	$A_5, A_5, A_2 \rightarrow A_4$	[1]

Table 9. FLRG and Weighting of the Order 4 FLRG

Group	FLRG	Weight ($W_n(t)$)
1	$A_1, A_1, A_1, A_1 \rightarrow A_1, A_1, A_1, A_1, A_1, A_2$	[1,2,3,4,5,1]
2	$A_1, A_1, A_1, A_2 \rightarrow A_2$	[1]
3	$A_1, A_1, A_2, A_2 \rightarrow A_2$	[1]
4	$A_1, A_2, A_2, A_2 \rightarrow A_3$	[1]
5	$A_2, A_2, A_2, A_3 \rightarrow A_2, A_2$	[1,2]
6	$A_2, A_2, A_3, A_2 \rightarrow A_2, A_2$	[1,2]
7	$A_2, A_3, A_2, A_2 \rightarrow A_2, A_3$	[1,1]
8	$A_3, A_2, A_2, A_2 \rightarrow A_3$	[1]
9	$A_3, A_2, A_2, A_3 \rightarrow A_5$	[1]
10	$A_2, A_2, A_3, A_5 \rightarrow A_5$	[1]
11	$A_2, A_3, A_5, A_5 \rightarrow A_2$	[1]
12	$A_3, A_5, A_5, A_2 \rightarrow A_4$	[1]

c. Defuzzification

After weighting the relationship group, the next step is to do defuzzification which is then used as the result of data forecasting. Historical data for time to -t is the result of defuzzification of one of the following rules:

1. FLRG $(A_i \rightarrow \emptyset)$, $\widehat{F}(t) = m_i$ (12)

2. FLRG $(A_i \rightarrow A_j)$, $\widehat{F}(t) = m_j$ (13)

3. FLRG $(A_i \rightarrow A_j, \dots, A_k)$, $\widehat{F}(t) = \frac{am_j + \cdots + bm_k}{a + \cdots + b}$ (14)

Forecasting results can be seen in the following table:

Table 10. Calculation Results for Data Training Forecast Order 1, 2, 3 and 4

Month	Actual Data ($F(t)$)	Order Forecasting Data 1 ($\widehat{F}(t)$)	Order Data Forecasting 2 ($\widehat{F}(t)$)	Order Forecasting Data 3 ($\widehat{F}(t)$)	Order Forecasting Data 4 ($\widehat{F}(t)$)
Jan 17	90369	–	–	–	–
Feb 17	92637	157989,35312	–	–	–
Mar 17	122391	157989,35312	159526,17933	–	–
Apr 17	132732	157989,35312	159526,17933	161502,09873	–
May 17	171412	157989,35312	159526,17933	161502,09873	164136,65795
Jun 17	125156	157989,35312	159526,17933	161502,09873	164136,65795
Jul 17	165556	157989,35312	159526,17933	161502,09873	164136,65795
Aug 17	188777	157989,35312	159526,17933	161502,09873	164136,65795
Sep 17	183480	157989,35312	159526,17933	161502,09873	164136,65795
Oct 17	257227	157989,35312	159526,17933	161502,09873	164136,65795
Nov 17	284894	317819,27867	256346,23038	256346,23038	256346,23038
Dec 17	235160	317819,27867	322737,12254	256346,23038	256346,23038
Jan 18	317302	317819,27867	322737,12254	366997,71730	366997,71730
Feb 18	223761	366997,71730	366997,71730	366997,71730	256346,23038
Mar 18	258647	317819,27867	256346,23038	256346,23038	256346,23038
Apr 18	280583	317819,27867	322737,12254	311671,97384	311671,97384
May 18	350047	317819,27867	322737,12254	366997,71730	366997,71730
Jun 18	277534	366997,71730	366997,71730	366997,71730	256346,23038
Jul 18	285671	317819,27867	256346,23038	256346,23038	256346,23038
Aug 18	334691	317819,27867	322737,12254	311671,97384	311671,97384
Sep 18	561331	366997,71730	366997,71730	366997,71730	588300,69115
Oct 18	616103	422323,46077	588300,69115	588300,69115	588300,69115
Nov 18	293744	422323,46077	256346,23038	256346,23038	256346,23038
Dec 18	521965	317819,27867	477649,20422	477649,20422	477649,20422

3. Calculating Forecasting Accuracy

After obtaining the Fuzzy Time Series forecasting order 1, order 2, order 3 and order 4 for January 2017 to December 2018, then the level of forecasting accuracy will be calculated against the method. In this study, the authors used the Mean Absolute Percentage Error (MAPE) method to calculate the accuracy level of the Fuzzy Time Series method. The MAPE values for Fuzzy Time Series Order 1, 2, 3 and 4 are obtained by the following calculations:

$$MAPE = \frac{\sum_{t=1}^{24} \left| \frac{F(t) - \widehat{F}(t)}{F(t)} \right| \times 100}{24} \times 100\% \quad (15)$$

The results of the MAPE calculation can be seen in the following table :

Table 11. MAPE Values of Order 1, 2, 3 and 4

Order	MAPE Value
1	24,15845%
2	16,59285%
3	14,49317%
4	9,05895%

4. Forecasting Production on Data Validation

Validation data is data from January 2019 to October 2019. Forecasting in the validation data uses FTS Order 4 which has the smallest accuracy level value. The calculation of validation data is as follows:

a. Determine FLR and Weighting historical data

Table 12. FLR and Weighting Data Validation

No.	Month	FLR	Weight ($W_n(t)$)
1	January 2019	$A_5, A_5, A_2, A_4 \rightarrow \emptyset$	[1,1,1,2]
2	February 2019	$A_5, A_2, A_4, A_4 \rightarrow \emptyset$	[1,1,2,1]
3	March 2019	$A_2, A_4, A_4, A_2 \rightarrow \emptyset$	[1,2,1,2]

4	April 2019	$A_4, A_4, A_2, A_4 \rightarrow \emptyset$	[1,1,2,3]
5	May 2019	$A_4, A_2, A_4, A_4 \rightarrow \emptyset$	[1,1,2,3]
6	June 2019	$A_2, A_4, A_4, A_4 \rightarrow \emptyset$	[1,1,2,3]
7	July 2019	$A_4, A_4, A_4, A_2 \rightarrow \emptyset$	[1,1,2,3]
8	August 2019	$A_4, A_4, A_2, A_3 \rightarrow \emptyset$	[1,1,1,2]
9	September 2019	$A_4, A_2, A_3, A_4 \rightarrow \emptyset$	[1,1,1,2]
10	October 2019	$A_2, A_3, A_4, A_7 \rightarrow \emptyset$	[1,1,1,1]

b. Defuzzification

After weighting, next is the defuzzification process using the following basic rules :

$$\text{FLRG } (A_i, A_h, A_n, A_p \rightarrow \emptyset),\ \hat{F}(t) = \frac{m_i + m_h + m_n + m_p}{4} \quad (16)$$

$$\text{FLRG } (A_i, A_h, A_n, A_p \rightarrow A_j), \hat{F}(t) = m_j \quad (17)$$

$$\text{FLRG } (A_i, A_h, A_n, A_p \rightarrow A_j, \dots, A_k),\ \hat{F}(t) = \frac{am_j + \cdots + bm_k}{a + \cdots + b} \quad (18)$$

The results of forecasting on the validation data are as follows :

Table 13. Results of Forecasting Data for January 2019 - October 2019

No	Month	Actual Data ($\boldsymbol{F(t)}$)	Forecasting Data ($\boldsymbol{\hat{F}(t)}$)
1	Jan 19	509177	477649,20423
2	Feb 19	295593	449986,33250
3	Mar 19	485327	366997,71730
4	Apr 19	432444	422323,46078
5	May 19	470039	422323,46078
6	Jun 19	310432	422323,46078
7	Jul 19	342962	422323,46078
8	Aug 19	484216	394660,58903
9	Sep 19	763968	394660,58903
10	Oct 19	761250	477649,20423

5. Forecasting Data Calculations

Forecasting data calculations are performed using past data patterns. The calculation process in November 2019 - March 2020 starts by determining the FLR and weighting as in the following table:

Table 14. FLR and Weighting Forecasting Data

No	Month	FLR	Weight ($\boldsymbol{W_n(t)}$)
1	November 2019	$A_3, A_4, A_7, A_7 \rightarrow \emptyset$	[1,1,1,2]
2	December 2019	$A_4, A_7, A_7, A_5 \rightarrow \emptyset$	[1,1,1,2]
3	January 2020	$A_7, A_7, A_5, A_6 \rightarrow \emptyset$	[1,2,1,2]
4	February 2020	$A_7, A_5, A_6, A_6 \rightarrow \emptyset$	[1,1,2,1]
5	March 2020	$A_5, A_6, A_6, A_6 \rightarrow \emptyset$	[1,1,2,3]

Forecasting results in November 2019 - March 2020 are as follows :

Table 15. Forecasting Results for November 2019 - March 2020

No	Month	Forecasting ($\boldsymbol{\hat{F}(t)}$)
1	November 2019	615963,56288
2	December 2019	671289,30635
3	January 2020	726615,04980
4	February 2020	698952,17808
5	March 2020	671289,30635

In this study, the calculation of the Fuzzy Time Series starts from order 1, order 2, order 3 and so on. However, because the MAPE value in each order continues to decrease, the forecasting is carried out up to order 4 which already has a very good level of accuracy. The FTS used to calculate validation data and forecast data is order 4 FTS, this is because FTS order 4 already has a MAPE value $< 10\%$ which means that the forecast is very good. The results of the Fuzzy Time Series Forecasting show that the smallest forecast of palm oil production occurs in November 2019 by 615963,56288 tons the largest production occurs in January 2020 by 726615,04980 tons.

CONCLUSION

Based on the research results it can be concluded that:

1. Forecast value of oil palm production at PT. Buana Mudantara November 2019 - March 2020 using the Fuzzy Time Series method successively equal to 615963,56288 tons, 671289,30635 tons, 726615,04980 tons, 698952,17808 tons dan 671289,30635 tons.
2. Forecasting oil palm production using the Fuzzy Time Series method produce a MAPE value of so much that 9,05895% it can be said that the level of forecasting accuracy is very good.

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