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# Application of the Holt-Winters Multiplicative Method to Predict Cayenne Pepper Production in 2025 in Riau Province

Elfira Safitri*[1], Isfi Zainul Karimah[2], Rahmadeni[3], Ahmad Faizal[4]

[1,2,3]*Department of Mathematics, Faculty of Science & Technology, Universitas Islam Negeri Sultan Syarif Kasim Riau*
[4]*Department of Electrical Engineering, Faculty of Science & Technology, Universitas Islam Negeri Sultan Syarif Kasim Riau*
*Email: elfira.safitri@uin-suska.ac.id*

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**Abstract** - *Production forecasting in the agricultural sector is an important component in the planning and decision-making process, especially for commodities with high levels of demand, such as cayenne pepper. This study aims to predict the amount of cayenne pepper production in Riau Province by applying the Holt-Winters Multiplicative method. The selection of this method is based on its ability to process time series data that has seasonal patterns and trends that change proportionally to the data level. The data used in this study is secondary data sourced from the Riau Province Food, Food Crops, and Horticulture Office for the period from 2022 to 2024. The analysis stage includes data exploration, determination of the initial smoothing value for levels, trends, and seasonality, adjustment of smoothing parameters (α, β, γ), and evaluation of model performance using MAPE, MAD, and MSE error measures. Based on the results of the analysis, it shows that the Holt-Winters Multiplicative model produces a MAPE value of 11%, which indicates that the model has a good level of accuracy. Therefore, this method can be used as a supporting tool in planning the production and distribution of cayenne pepper in Riau Province.*

**Keywords:** *Cayenne Pepper, Holt-Winter Multiplicative, MAPE, Forecasting, Time Series.*

## 1. Introduction

Indonesia is known as an agrarian country, where most of the population makes a living in the agricultural sector. This condition is supported by the availability of large and fertile land, as well as good soil nutrient content, thus supporting the optimal growth of various types of plants [1]. As an agrarian country, the agricultural sector has a very important role in supporting the national economy. Supported by abundant natural resources and supportive climate variations, Indonesia has great potential to improve both the quality and quantity of its agricultural commodities [2]. One of the leading commodities that has high economic value and wide adaptability to various environmental conditions is cayenne pepper.

Cayenne pepper (*Capsicum frutescens* L.) is one of the main food commodities that has an important role in the consumption of the Indonesian people, considering the habits of people who like to consume spicy food. In the cultivation process, various obstacles are often faced, such as limited planting land, uncertain weather conditions, and pest and plant disease attacks. The demand for cayenne pepper tends to increase all the time, especially in certain periods. However, the trading activity of this commodity is greatly influenced by its production level [3]. The demand for cayenne pepper is very high among the public, especially in Riau Province [5].

Riau Province is one of the regions that has considerable potential in the development of the horticultural agricultural sector, especially for cayenne pepper commodities. Cayenne pepper production in this region shows fluctuations from year to year which are influenced by various factors, such as climatic conditions, the application of cultivation techniques, and market demand dynamics. Based on data from the Riau Province Food, Crops, and Horticulture Office, it is known that cayenne pepper production in 2022 reached 74,287 tons, an increase of about 10% compared to the previous year. However, there is also a period of decline in production, namely in 2023 which decreased by 11%, and in 2024 it decreased by around 4.8%.

Cayenne pepper production shows a fairly clear seasonal pattern, while the demand for this commodity continues to increase along with population growth. This condition makes forecasting the production of cayenne pepper very important to ensure the availability of supply and maintain price stability in the market. One of the forecasting methods that is considered effective for analyzing data with proportionally changing seasonal patterns and trends is the Holt-Winters Multiplicative method.

The Holt-Winters Multiplicative method is a time series forecasting technique used to analyze data with trend and seasonal patterns, where seasonal variations change proportionally to the level of data. This model combines three main components, namely level, trend, and seasonality, and is ideally applied to data that shows an increase in seasonal fluctuations as observation values increase. The application of the Holt-Winters Multiplicative method in forecasting cayenne pepper production has an important role, not only for farmers in determining optimal planting and harvest times, but also for the government and stakeholders in formulating policies related to the agricultural sector and yield distribution. Through accurate forecasting, it is hoped that it can minimize potential losses for farmers while supporting the improvement of national food security [6].

Some research related to the *Holt-Winter* i.e. done by [6] with the title *"*Testing of Holt-Winter's Exponential Smoothing Multiplicative Model in Forecasting Time-Series Data Affected by Covid-19*."* The study used the smoothing parameters α = 0.97, β = 0.03, and γ = 1. The test results show that at the *Testing Data*, the Multiplicative Holt-Winters Exponential Smoothing model has not been able to keep up with the trend changes significantly. Nevertheless, the level of prediction accuracy obtained is quite good, with a MAPE value of 9.98%, which indicates that this model is effective in predicting data with clear and significant trends.

The next research was conducted by [2] with the title *"*Forecasting the Production of Shallots, Large Chilies, and Cayenne Peppers in Riau Province with the Holt-Winters Multiplicative Method" The results of the study show that the amount of production of the three commodities has fluctuated in the form of increases and decreases in certain months throughout 2024. Based on the results of the accuracy test using MAPE values, it was obtained that the forecasting of the amount of production of large chili peppers and cayenne peppers was quite accurate with the MAPE value in the range of 10-20%. On the other hand, the forecasting results for shallots are considered less accurate because they have a MAPE value that exceeds 50%. Furthermore, a study conducted by [7] entitled "Implementation of the Holt-Winters Multiplicative Method on the Visitor Forecasting System of Ijen Crater Tourist Attractions, Bondowoso Regency" showed that the application of the Holt-Winters Multiplicative method produced an excellent level of accuracy. The results of the analysis showed that the calculation without including 2020 data resulted in a MAPE value of 9.03%, which is classified as very low because it is below the 10% threshold, so the model is considered to have very accurate forecasting performance.

Based on the results of the research conducted by [6] and [7], the author wants to conduct further research on the Holt-Winters Multiplicative method with different cases. Therefore, the author raises the title of the research "Forecasting the Number of Cayenne Pepper Production in Riau Province Using the Holt-Winters Multiplicative Method". This study aims to find out the results of the forecast of the amount of production for 2025 and its fluctuation patterns, as well as measure the accuracy of the forecasting results using MAPE values

## 2. Materials and Methods

### 2.1. *Forecasting*

Forecasting is the process of estimating future needs that include aspects of quantity, quality, time, and location to meet the demand for goods or services. This activity aims to predict future conditions through the preparation of plans based on capacity and production capabilities or demand that have occurred before [9]. Subjective forecasting methods are generally qualitative, while objective forecasting methods consist of two main approaches, namely time series models and causal models. Time series models are used to predict future conditions based on historical data patterns. In other words, this approach analyzes trends that occur over a given period of time and leverages past information to generate accurate predictions. Some examples of methods included in the time series model include Moving Average, Exponential Smoothing, and Holt-Winters [10].

### 2.2. *Holt-Winters Method*

The Holt-Winters method is a quantitative forecasting technique used to analyze data with trend and seasonal patterns. This method was first developed by Charles C. Holt and later refined by his student, Peter Winters. Also known as the triple exponential smoothing model, this method includes an adaptive model that is widely used in time series analysis with the characteristics of seasonal trends and variations. There are several variants of this method, namely Holt-Winters Additive, Holt-Winters Multiplicative, and Double Seasonal Holt-Winters. The Additive model is used when seasonal variation is relatively constant, while the Multiplicative model is more suitable when seasonal fluctuations increase as data levels change [11].

The Holt-Winters Multiplicative method is used to analyze time series data that show seasonal patterns with fluctuations that increase or decrease proportionally to the data level. This method is a development of a combination of the Holt and Winters methods, which are designed to forecast data that has both trend and seasonal components. This approach is based on three main elements, namely level (stationary), trend (trend), and seasonal, with each element weighted through three smoothing parameters, namely α (alpha), β (beta), and γ (gamma). The alpha parameter (α) serves to set the level of smoothing to the most recent observed value on the level component. The beta parameter (β) is used to control the smoothing process in estimating the trend or trend components of the data, while gamma (γ) plays a role in smoothing the seasonal component based on recent observations. All three parameters have values ranging from 0 to 1, which can be determined subjectively or through an optimization process by minimizing the value of forecast errors.

In the application of this forecasting method, an initialization process is required which includes determining the initial values for the level (Ll), trend (bl), and seasonal (Sl) components. Preliminary estimates of seasonal indices are obtained using complete data in a single seasonal cycle. Thus, the initial values for the trend and level components are set in the lth period as the basis for the calculation of the next forecast.

The initial value of the level smoothing constant is obtained by using the average of the first season, namely:

$$L_l = \left(\frac{1}{l}\right)(y_1 + y_2 + \cdots + y_l) \quad (1)$$

To initialize *Trend* It would be better to use the whole data for two seasons, namely:

$$b_l = \frac{1}{l}\left(\frac{y_{l+1}-y_1}{l} + \frac{y_{l+2}-y_2}{l} + \cdots + \frac{y_{l+l}-y_l}{l}\right) \quad (2)$$

Then to initialize the seasonal index of the *multiplicative model*, namely:

$$S_l = \frac{y_l}{L_l} \quad (3)$$

Information:

$b_l$ : Initial value *of smoothing* trend *patterns;*
$L_l$ : Initial value *of smoothing level*;
$S_l$ : Seasonal *smoothing* starting value;
$l$ : Seasonal length;
$y_l$ : The $l$ data.

There are several functions of the multiplicative model equation in *holt-winters* are as follows:

$$L_t = \alpha \frac{Y_t}{S_{t-s}} + (1-\alpha)(L_{t-1} + b_{t-1}) \quad (4)$$

$$b_t = \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1} \quad (5)$$

$$S_t = \gamma \frac{Y_t}{L_t} + (1-\gamma)S_{t-s} \quad (6)$$

$$Y_{t+m} = (L_t + b_t m)S_{t-s+m} \quad (7)$$

Where:

$L_t$ : Period level at *t*;
$\alpha$ : Level smoothing parameters;
$\beta$ : Trend smoothing parameters;
$\gamma$ : Seasonal smoothing parameters;
$X_t$ : Actual data on the period *t*;
$S_t$ : Seasonal in the period *t*;
$b_t$ : Trend in the period *t*;
$s$ : Seasonal length;
$Y_{t+m}$ : Forecasting on the period *t* + *m*;

### 2.3. *Forecasting Accuracy Calculation*

In general, there are three types of calculations that can be used to see how much error in forecasting is:

a. MAD (*Mean Absolute Deviation*)

MAD is a calculation used to calculate the absolute mean of error, with the formula:

$$MAD = \frac{\sum|Aktual - Forecast|}{n} \quad (8)$$

MAD is used to assess the magnitude of forecasting errors in units equivalent to actual data.

b. MSE (*Mean Square Error*)

MSE is a calculation used to calculate the average ranked error [12], with the formula [13]:

$$MSE = \frac{\sum(Aktual - Forecast)^2}{n} \quad (9)$$

MAPE (Mean Absolute Percentage Error) is used when the magnitude of the forecasting variable becomes an important factor in assessing the accuracy level of a model. The smaller the MAPE value obtained, the better the performance of the forecasting model [14]. In addition, there is a range of MAPE values that can be used as a reference in assessing the accuracy of the forecasting model, as shown in Table 1 below:

**Table 1**. **MAPE value range**

| *Range* | **Information** |
|---|---|
| <10% | Excellent forecasting model capabilities |
| 10 - 20% | Good forecasting model capabilities |
| 20 - 50% | Feasibility of the forecasting model |
| >50% | Poor forecasting model capabilities |

Based on Table 1, the MAPE value can be classified into several categories that describe the feasibility level of a method in conducting forecasting. This measure is used when the magnitude of the forecasting variable is an important aspect in evaluating the accuracy level of the model. Value MAP It provides an overview of how much the forecast results differ from the actual value of the analyzed time series data.

The following are the stages used in the study using *the Multiplicative Holt-Winters* method:

1. Data Exploration.

At this stage, an examination of cayenne pepper production data is carried out to ensure its completeness and consistency. The data is then analyzed descriptively to find out the patterns, trends and seasons. In addition, visualization is carried out in the form of a time series graph to support an initial understanding of the characteristics of the data to be used in the modeling.

2. Specify the initialization value:
   a. Calculating the initial value *of the smoothing level* ($L_l$) using the complete data of one season;
   b. Calculates the initial value *of the smoothing trend* ($b_l$);
   c. Calculates the *seasonal* smoothing initial value ($S_l$).
3. Sets the values of *the alpha*(α), *beta*(β) and *gamma*(γ) parameters where the values of these parameters are between 0 and 1, based on *the smallest* error;
4. Calculating the *value of the smoothing level* ($L_t$);
5. Calculating *the value of the smoothing trend* ($b_t$);
6. Calculate the *seasonal smoothing* value ($S_t$);
7. Calculate the forecast value for *n* subsequent periods;
8. Calculates the accuracy of the model with MAE, MSE and MAPE values.

## 3. Results and Discussion

### *3.1. Data Description*

The data used in this study is in the form of the number of cayenne pepper production in Riau Province for the period 2022 to 2024, which was obtained from the Riau Province Food, Food Crops and Horticulture Office. Data on the amount of cayenne pepper production can be seen in Table 2 below:

**Table 2. Data on the Number of Cayenne Pepper Production in Riau Province in 2022-2024**

| **Moon** | **Year (Quintal)** | | |
|---|---|---|---|
| | **2022** | **2023** | **2024** |
| January | 6.265,19 | 4.706,73 | 6.106,15 |
| February | 6.729,83 | 4.918,24 | 4.256,95 |
| March | 5.596,84 | 6.058,21 | 4.384,02 |
| April | 5.434,50 | 5.749,50 | 4.087,12 |
| May | 5.755,55 | 5.109,89 | 5.423,10 |
| June | 5.813,33 | 5.554,17 | 4.900,67 |
| July | 5.173,41 | 6.143,34 | 5.134,26 |
| August | 6.197,60 | 5.178,77 | 6.424,53 |
| September | 6.481,86 | 5.284,97 | 5.132,55 |
| October | 6.782,88 | 6.100,98 | 5.338,04 |
| November | 6.751,24 | 5.677,30 | 5.788,71 |
| December | 7.304,85 | 5.585,58 | 5.880,28 |
| **Sum** | **74.287,58** | **66.067,68** | **62.856,38** |

Source: (Riau Province Food, Food Crops and Horticulture Office in 2024)

The multiplicative Holt-Winters method can be used for seasonal data with an observation period of 3 years, as long as the data shows a consistent seasonal pattern and is proportional to the data level. Even though the amount of data meets the minimum requirements for applying the method, increasing the observation period will increase the stability and accuracy of the forecasting results

***3.2. Settlement Method Holt-Winters Multiplicative in Forecasting the Production of Cayenne Pepper***

3.2.1 Data Exploration

This data exploration was carried out to find out an overview of the amount of cayenne pepper production from January 2022 to December 2024.

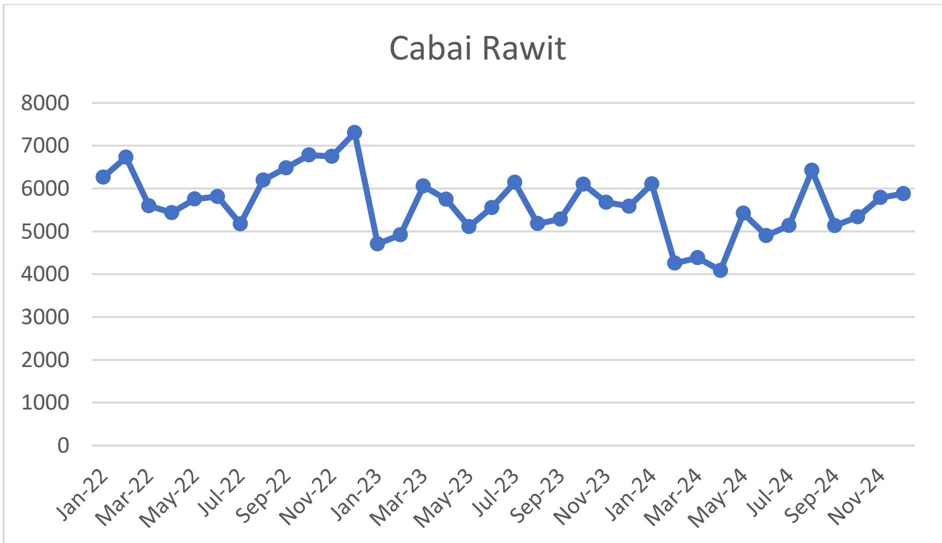


**Fig. 2 *Time Series Plot* of Cayenne Pepper Data**

Based on Figure 2, it can be seen that the data on the amount of cayenne pepper production shows a seasonal pattern with an increasing trend in certain months that recur every year. Therefore, the forecasting method used is the Holt-Winters Multiplicative method.

3.2.2 Initialization Process

The initial stage in the initialization process is done by determining the initial value first. At this stage, the initial value of smoothing for level, trend, and seasonal components is determined in the data on the amount of cayenne pepper production in 2022–2024.

a. Calculating the *Starting Value of the Smoothing Level* (Ll)

Based on Equation (1) and the data in Table 2, the initial value *of the smoothing level* was obtained as follows:

$$L_l = \left(\frac{1}{l}\right)(y_1 + y_2 + \cdots + y_t)$$

$$L_{12} = \left(\frac{1}{12}\right)(6.265{,}19 + 6.729{,}83 + 5.596{,}84 + 5.434{,}5 + 5.755{,}55 + 5.813{,}33 + 5.173{,}41 + 6.197{,}6 + 6.481{,}86 + 6.782{,}88 + 6.751{,}24 + 7.304{,}85)$$

$$L_{12} = \left(\frac{1}{12}\right)(74.287{,}58)$$

$$L_{12} = 6.190{,}59$$

Thus, the initial value of the smoothing level ($L_1$) used was 6,190.59 quintals. These values are then used together with trend and seasonal components in the forecasting process of the next period using the *Holt-Winters Multiplicative*.

b. Calculating the Initial *Value of the Smoothing Trend* ($b_t$)

Based on Equation (2) and the data in Table 2, the initial value of *the smoothing trend* is obtained as follows:

$$b_l = \frac{1}{l}\left(\frac{y_{l+1} - y_1}{l} + \frac{y_{l+2} - y_2}{l} + \cdots + \frac{y_{l+l} - y_l}{l}\right)$$

$$b_{12} = \frac{1}{12}\left(\frac{y_{13} - y_1}{12} + \frac{y_{14} - y_2}{12} + \frac{y_{15} - y_3}{12} + \frac{y_{16} - y_4}{12} + \frac{y_{17} - y_5}{12} + \frac{y_{18} - y_6}{12} + \frac{y_{19} - y_7}{12} + \frac{y_{20} - y_8}{12} + \frac{y_{21} - y_9}{12} + \frac{y_{22} - y_{10}}{12} + \frac{y_{23} - y_{11}}{12} + \frac{y_{24} - y_{12}}{12}\right)$$

$$b_{12} = \frac{1}{12}\left(\begin{array}{c} \frac{-1.558,46}{12} + \frac{-1.811,59}{12} + \frac{461,37}{12} + \frac{315}{12} + \frac{-645,66}{12} + \frac{-259,16}{12} \\ + \frac{969,93}{12} + \frac{-1.018,83}{12} + \frac{-1.196,89}{12} + \frac{-681,9}{12} + \frac{-1.073,94}{12} + \frac{-1.719,27}{12} \end{array}\right)$$

$$b_{12} = \frac{1}{12}(-684,95)$$

$$b_{12} = -57,08.$$

So, the initial value of the smoothing trend is -57.08 which shows that on average, production has decreased by 57.08 quintals per month from 2022 to 2024.($b_l$)

c. Calculating the Seasonal *Smoothing* Starting Value ($S_l$)

Based on Equation (3) and Table 2 data, Initial value is obtained *smoothing trend* For each period (month) as follows:

Known: $L_{12} = 6.190,59$

$$S_1 = \frac{y_1}{L_{12}} = \frac{6.265,19}{6.190,59} = 1,01;$$

$$S_2 = \frac{y_2}{L_{12}} = \frac{6.729,83}{6.190,59} = 1,09;$$

$$S_3 = \frac{y_3}{L_{12}} = \frac{5.596,84}{6.190,59} = 0,90\ ;$$

By doing the same calculation, the initial value *of the smoothing trend* can be seen in the following Table 3:

**Table 3. Initial Value *of Seasonal* Smoothing**

| $S_l$ | *Multiplicative* $(\frac{y_l}{L_l})$ |
|---|---|
| $S_1$ | 1,01 |
| $S_2$ | 1,09 |
| $S_3$ | 0.90 |
| $S_4$ | 0.88 |
| $S_5$ | 0.93 |
| $S_6$ | 0,94 |
| $S_7$ | 0,84 |
| $S_8$ | 1,00 |
| $S_9$ | 1,05 |
| $S_{10}$ | 1,10 |
| $S_{11}$ | 1,09 |
| $S_{12}$ | 1,18 |

3.2.3 Setting Parameter Values alpha (α),beta (β) and gamma (γ)

Based on cayenne pepper data in 2022-2024 with the help of *Minitab software*, three parameter values α, β and γ were obtained for *the Holt-Winters Multiplicative* method, namely α = 0.1; β = 0.2 and γ = 0.1. This value indicates that the model is more stable to changes in levels and seasonality, and is sufficiently responsive to trends, making it suitable for data with consistent seasonal patterns and trend changes.

3.2.4 Calculating the Value of the Smoothing Level ( Lt )

The calculation of the new smoothing level can be started from the 13th period ($L_{13}$)because the Holt-Winter method requires one full season (12 months) of seasonal data to calculate the seasonal index.The following will be calculated the value of the smoothing level with a multiplicative model using the formula of Equation (3.4) and the value of the parameter α = 0.1.

$$L_t = \alpha\left(\frac{Y_t}{S_{t-s}}\right) + (1-\alpha)(L_{t-1} + b_{t-1})$$

$$L_{13} = \alpha\left(\frac{Y_{13}}{S_1}\right) + (1-\alpha)(L_{12} + b_{12})$$

- $L_{13} = 0,1\left(\frac{4.706,73}{1,01}\right) + (1-0,1)\big(6.190,59 + (-57,08)\big)$

$$L_{13} = 0,1(4.650,69) + (0,9)(6.133,51)$$

$L_{13} = 5.985{,}23;$

$L_{14} = \alpha\left(\frac{Y_{14}}{S_2}\right) + (1-\alpha)(L_{13} + b_{13})$

- $L_{14} = 0{,}1\left(\frac{4.918{,}24}{1{,}09}\right) + (1-0{,}1)\big(5.985{,}23 + (-86{,}74)\big)$

  $L_{14} = 0{,}1(4.524{,}16) + (0{,}9)(5.898{,}49)$

  $L_{14} = 5.761{,}06;$

  ⋮

- $L_{36} = \alpha\left(\frac{Y_{36}}{S_{24}}\right) + (1-\alpha)(L_{35} + b_{35})$

  $L_{36} = 0{,}1\left(\frac{5.880{,}28}{1{,}17}\right) + (1-0{,}1)\big(5.028{,}55 + (-7{,}07)\big)$

  $L_{36} = 0{,}1(5.025{,}88) + (0{,}9)(5.021{,}48)$

  $L_{36} = 5.022{,}93.$

So that a value is obtained for *Smooting level* The 13th month is 5,985.23, the 14th month is 5,761.06 to the 36th month level is 5,022.93.

3.2.5 Calculating the Value *of Smoothing Trend* ( bt )

Next, the value *of the smoothing trend* will be calculated using *the multiplicative model* using the formula of Equation (5) and the value of the parameter β = 0.2.

$b_t = \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1}$

- $b_{13} = \beta(L_{13} - L_{12}) + (1-\beta)b_{12}$

  $b_{13} = 0{,}2(5.985{,}23 - 6.190{,}59) + (1-0{,}2)(-57{,}08)$

  $b_{13} = 0{,}2(-205{,}36) + (0{,}8)(-57{,}08)$

  $b_{13} = -86{,}74;$

- $b_{14} = \beta(L_{14} - L_{13}) + (1-\beta)b_{13}$

  $b_{14} = 0{,}2(5.761{,}06 - 5.985{,}23) + (1-0{,}2)(-86{,}74)$

  $b_{14} = 0{,}2(-224{,}22) + (0{,}8)(-86{,}74)$

  $b_{14} = -114{,}24;$

  ⋮

- $b_{36} = \beta(L_{36} - L_{35}) + (1-\beta)b_{35}$

  $b_{36} = 0{,}2(5.021{,}91 - 5.028{,}55) + (1-0{,}2)(-7{,}07)$

  $b_{36} = 0{,}2(-6{,}64) + (0{,}8)(-7{,}07)$

  $b_{36} = -6{,}78.$

So that the value is obtained *smoothing trend* For the 13th month was -86.74 which means there was a decrease in the amount of cayenne pepper production by 86.74, the 14th month was -114.24 which means there was a decrease in the amount of cayenne pepper production by 114.24 until in the 36th month it was -6.78 which means there was a decrease in the amount of cayenne pepper production by 6.78.

3.2.6 Calculating the *Seasonal Smoothing* Value ( St)

The following will be calculated the *value of seasonal smoothing* with *a multiplicative* model using the formula of Equation (6) and the value of the parameter γ = 0.1.

$S_t = \gamma\left(\frac{Y_t}{L_t}\right) + (1-\gamma)S_{t-s}$

- $S_{13} = \gamma\left(\frac{Y_{13}}{L_{13}}\right) + (1-\gamma)S_1$

  $S_{13} = 0{,}1\left(\frac{4.706{,}73}{5.985{,}23}\right) + (1-0{,}1)(1{,}01)$

  $S_{13} = 0{,}1(0{,}78) + (0{,}9)(1{,}01)$

  $S_{13} = 0{,}99;$

- $S_{14} = \gamma\left(\frac{Y_{14}}{L_{14}}\right) + (1-\gamma)S_2$

  $S_{14} = 0{,}1\left(\frac{4.918{,}24}{5.761{,}06}\right) + (1-0{,}1)(1{,}09)$

  $S_{14} = 0{,}1(0{,}85) + (0{,}9)(1{,}09)$

  $S_{14} = 1{,}06;$

  ⋮

$$S_{36} = \gamma\left(\frac{Y_{36}}{L_{36}}\right) + (1-\gamma)S_{24}$$
$$S_{36} = 0{,}1\left(\frac{5.880{,}28}{5.022{,}93}\right) + (1-0{,}1)(1{,}17)$$
$$S_{36} = 0{,}1(1{,}17) + (0{,}9)(1{,}17)$$
$$S_{36} = 0{,}12 + 1{,}05$$
$$S_{36} = 1{,}17.$$

So that the value is obtained *seasonal smoothing* The 13th month is 0.99, the 14th month is 1.06 and the 36th month is 1.17.

3.2.7 Calculating the Forecast Value for n in the Next Period

Next, the calculation of f*orecast will be carried out* using the Equation function (7) and the results of the calculation are obtained as follows:

$$Y_{t+m} = (L_t + b_t m)S_{t-s+m}$$

- $Y_{37} = \big(5.022{,}93 + (1(-6{,}78)\big)1{,}01$
  $Y_{37} = 5.043{,}84;$
- $Y_{38} = \big(5.022{,}93 + (2(-6{,}78)\big)1{,}04$
  $Y_{38} = 5.211{,}53;$
- $Y_{39} = \big(5.022{,}93 + (3(-6{,}78)\big)0{,}91$
  $Y_{39} = 4.574;$
  $\vdots$
- $Y_{48} = \big(5.022{,}93 + (12(-6{,}78)\big)1.17$
  $Y_{48} = 5.771{,}58$

Based on the calculation above, for the prediction obtained the prediction result in the 37th month is 5,043.84, the 38th month is 5,211.53, the 39th month is 4,574 and the 48th month is 5,771.58.

So that the prediction value for the amount of cayenne pepper production in Riau province in January 2025-December 2025 is as follows:

**Table 4. Forecast Results of Production Quantity (Quintal)**

| Moon | Actual date 2024 | Forecast Results 2025 |
|---|---|---|
| January | 6.106,15 | 5.043,84 |
| February | 4.256,95 | 5.211,43 |
| March | 4.384,02 | 4.574 |
| April | 4.087,12 | 4.418,18 |
| May | 5.423,10 | 4.712,75 |
| June | 4.900,67 | 4.733,51 |
| July | 5.134,26 | 4.366,41 |
| August | 6.424,53 | 5.071,99 |
| September | 5.132,55 | 5.140,63 |
| October | 5.338,04 | 5.421,83 |
| November | 5.788,71 | 5.408,42 |
| December | 5.880,28 | 5.771,58 |

Based on Table 4, it can be seen that the forecasting results of cayenne pepper have decreased in the amount of production. Furthermore, an actual data graph for 2022-2024 is presented with forecasting results, with the help of *Minitab software* which can be seen in Figure 3 below:

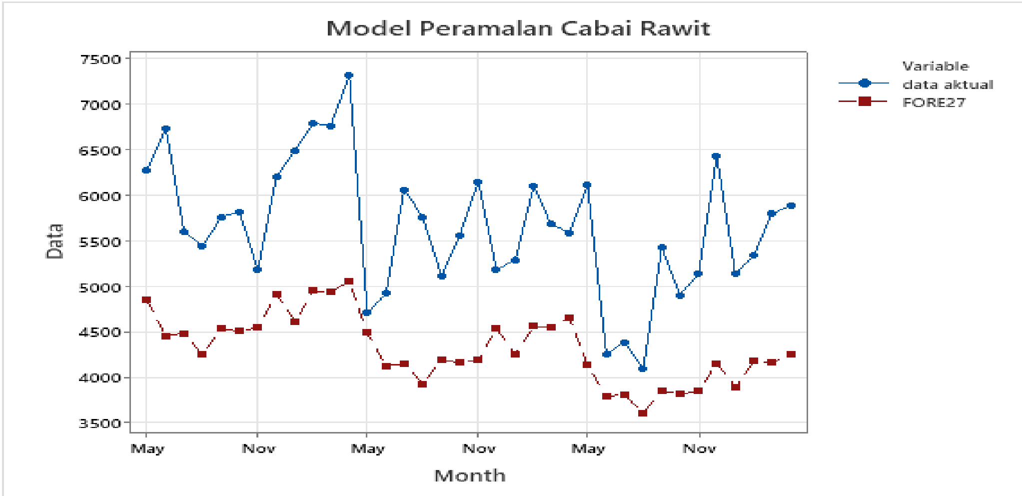


**Fig. 3 Graph of forecast results of the amount of cayenne pepper production in the next period.**

Based on Figure 3, it shows that the forecasting model is able to follow the general pattern of actual data movements, although not perfectly. Forecast values tend to be more stable and refined compared to actual data that show sharper fluctuations, especially in certain months that experience significant spikes or decreases in the number of production. Although there is a discrepancy between the actual value and the forecast results, overall this model can still provide a fairly good picture of production trends. This shows that the FORE27 model has the potential to be used in projecting cayenne pepper production in the next period.

3.2.8 Calculating Model Accuracy with MAD, MSE, and MAPE Values

After smoothing calculations are carried out using *the Holt – Winter exponential smoothing multiplicative* model, the next step is to calculate *the forecast* error or error in the forecast results. *Forecast* errors are calculated using MAD, MSE and MAPE and the results are as follows:

$$MAD = \frac{\sum|Aktual - Forecast|}{n}$$

$$\text{MAD} = \frac{(|4.918{,}24 - 6.412{,}29| + \cdots + |5.880{,}28 - 5.863{,}32|)}{24}$$

$$\text{MAD} = \frac{14.717}{24}$$

$$\text{MAD} = 613$$

For the MSE values as follows:

$$MSE = \frac{\sum(Aktual - Forecast)^2}{n-1}$$

$$MSE = \frac{(4.918{,}24 - 6.412{,}29)^2 + \cdots + (5.880{,}28 - 5.863{,}32)^2}{24}$$

$$MSE = \frac{(14.809.221{,}1)}{24}$$

$$MSE = 617.051.$$

Furthermore, the MAPE score can be obtained as follows:

$$MAPE = \frac{1}{n}\sum\left(\frac{|Aktual - Forecast|}{Aktual}\right) \times 100$$

$$MAPE = \frac{1}{24}\left(\frac{|4.918{,}24 - 6.412{,}29|}{4.918{,}24} + \cdots + \frac{|5.880{,}28 - 5.863{,}32|}{5.880{,}28}\right) \times 100$$

$$MAPE = 11\ \%.$$

With the MAPE value of 11%, it can be concluded that the forecasting model has a good level of accuracy. In addition to MAPE, MAD and MSE values are also calculated as a complement to the evaluation to see the absolute average error and identify the presence of extreme errors. However, MAPE is used as the primary measure in accuracy assessment because it is in the form of a percentage, does not depend on a data unit, and has clear interpretation guidelines. These three measures together provide a comprehensive picture of the performance of the Holt-Winter Multiplicative model in forecasting cayenne pepper production

## 4. Conclusion

Based on the results of the discussion, it can be concluded as follows: The results of the forecast of cayenne pepper production in Riau Province for 2025 show a decrease and increase in production in certain months. For example, there was a decrease in production in January (from 6,106.15 to 5,043.84 quintals) and July (from 5,134.26 to 4,366.41 quintals), as well as an increase in October (from 5,338.04 to 5,421.83 quintals). This indicates that production is unstable and is still affected by seasonal factors; The forecasting accuracy test using the MAPE value was obtained at 11%**,** which means that the model has a good accuracy rate (in the range of 10–20%). Thus, this method is suitable for use as a tool for planning the production and distribution of cayenne pepper in Riau Province

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