

## **Analysis of Rainfall Forecasting Using the Holt-Winters Approach: Additive and Multiplicative in Pekanbaru**

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| ARTICLE INFO                                                           | ABSTRACT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
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| <b>Published Online:</b><br><b>15 January 2026</b>                     | Rainfall plays an important role in various sectors, such as agriculture, water resource management, and disaster mitigation. However, rainfall patterns in many regions of Indonesia tend to fluctuate and change from year to year, making accurate forecasting increasingly necessary. Several previous studies conducted in Sumbawa Regency, North Padang Lawas Regency, Ambon City, and Pasuruan have shown that the Holt–Winters Exponential Smoothing method is effective in forecasting monthly rainfall because it is able to capture trend and seasonal patterns in the data, resulting in forecasts that are closer to actual conditions. This study aims to analyze and forecast monthly rainfall in Pekanbaru City using the Holt–Winters Exponential Smoothing method for the 2019–2024 period. The data used consist of monthly rainfall data analyzed using additive and multiplicative Holt–Winters models. The analysis results show that the rainfall data exhibit a clear and relatively stable seasonal pattern from year to year, indicating that the Holt–Winters method is appropriate for use. Model performance evaluation using Mean Absolute Error (MAE) shows that the additive Holt–Winters model produces a smaller MAE value than the multiplicative model. |
| <b>Corresponding Author:</b><br><b>Rado Yendra</b>                     | This indicates that the additive model provides better forecasting accuracy in modeling monthly rainfall in Pekanbaru City.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>KEYWORDS:</b> rainfall, forecasting, Holt-Winters, seasonal pattern |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

### **1. INTRODUCTION**

Rainfall is one of the climatic elements that has a significant influence on various sectors of life, such as agriculture, water resources, disaster mitigation, and development planning. The high variability of rainfall in Indonesia often leads to various problems, ranging from droughts during the dry season to floods during the rainy season. Therefore, the availability of information regarding rainfall patterns and predictions is very important to support more accurate decision-making, especially in regions that are vulnerable to climate change.

Various previous studies have utilized time series methods to forecast rainfall in different regions of Indonesia. Research on rainfall prediction in Sumbawa Regency shows that the Holt–Winters method is able to capture strong seasonal patterns, thereby providing more stable estimates of monthly rainfall conditions [1]. Another study conducted in North Padang Lawas Regency also applied the Holt–

Winters Exponential Smoothing approach and demonstrated that this method is capable of accommodating trend and seasonal components present in regional rainfall data [2].

Furthermore, a study on rainfall forecasting in Malang City indicates that the Holt–Winters method is effective for regions with wet climatic patterns and significant seasonal variations [3]. Meanwhile, a study on the prediction of average monthly rainfall in Pasuruan confirms that the Holt–Winters Exponential Smoothing approach provides a good level of accuracy, particularly when the seasonal pattern of rainfall data fluctuates from year to year [4].

Based on the findings of these studies, it can be concluded that the Holt–Winters method, both in its additive and multiplicative forms, is one of the most reliable forecasting methods for rainfall data that exhibit clear seasonal patterns and trends. This model is able to produce more accurate predictions compared to simple forecasting

methods because it takes into account three main components of time series data, namely level, trend, and seasonality. Therefore, research on rainfall forecasting using the Holt-Winters method is important to be conducted in different study areas in order to obtain more accurate climate information and to support planning and risk mitigation related to future rainfall conditions.

## 2. RESEARCH METHODS

This study uses secondary data. The data employed in this research consist of rainfall data from January 2019 to December 2024, obtained from the Central Bureau of Statistics (Badan Pusat Statistik) of Riau Province.

### 2.1 Research Procedures

The research procedures include:

- Data management and exploration of rainfall data
- Implementation of the Holt-Winters method in R using the forecast package
- Model evaluation using error metrics such as Mean Absolute Error (MAE)

### 2.2 Holt Winter

Holt-Winters is a simple exponential smoothing method that has three constant variables, namely trend, level, and seasonal. Holt-Winters' forecasting method is divided into two models, namely additive and multiplicative models. In the Holt-Winters method, the additive model is used on constant time sequence data that has seasonal data variations with the t-end period [5]. The three equations used in the Holt-Winters additive method are [6]:

Overall smoothing

$$S_t = \alpha (X_t - I_t - 1) + (1 - \alpha) (S_t - 1 - b_t - 1)$$

Trend smoothing

$$b_t = \beta (S_t - S_t - 1) + (1 - \beta) b_t - 1$$

Seasonal smoothing

$$I_t = \gamma (X_t - S_t) + (1 - \gamma) I_t - 1$$

Divination

$$Y_{t+m} = S_t + mb_t + I_t - L + m$$

Where:

- $S_t$  : Forecasting smoothing value for period t;  $Y_t$  : Actual value in period t;  
 $X_t$  : Actual value in period t;  
 $B_t$  : Trend smoothing value;  
 $I_t$  : Seasonal component in the t-period;  
 $Y_{t+m}$  : Forecast for m future period of t;  
 $m$  : The number of periods that will be forecast in the future;  
 $\alpha$  : Refinement parameter for trend ( $0 < \alpha < 1$ );  
 $\gamma$  : Refinement parameter for trend ( $0 < \gamma < 1$ );  
 $\beta$  : Refinement parameter for trend ( $0 < \beta < 1$ );

$L$  : Seasonal length.

In the Holt-Winters method, the multiplicative model is used on data patterns of varying seasonal fluctuations. The three equations used in the Holt-Winters additive method are [7]:

Overall smoothing

$$S_t = \alpha \frac{X_t}{I_{t-1}} + (1 - \alpha) (S_t - 1 - b_t - 1)$$

Trend smoothing

$$b_t = \beta (S_t - S_t - 1) + (1 - \beta) b_t - 1$$

Seasonal smoothing

$$I_t = \gamma \frac{X_t}{S_{t-1}} + (1 - \gamma) I_t - 1$$

Divination

$$Y_t + m = (S_t + mb_t) I_t - L + m$$

Information:

- $S_t$  : Forecasting smoothing value for period t;  
 $X_t$  : Actual value in period t;  
 $B_t$  : Trend smoothing value;  
 $I_t$  : Seasonal component in the t-period;  
 $Y_{t+m}$  : Forecast for m future period of t;  
 $m$  : The number of periods that will be forecast in the future;  
 $\alpha$  : Refinement parameter for trend ( $0 < \alpha < 1$ );  
 $\gamma$  : Refinement parameter for trend ( $0 < \gamma < 1$ );  
 $\beta$  : Refinement parameter for trend ( $0 < \beta < 1$ );  
 $L$  : Seasonal length.

### 2.3 Mean Absolute Error (MAE)

Mean Absolute Error (MAE) is a method used to measure the accuracy of a forecasting model. The Mean Absolute Error (MAE) result shows the average value of the absolute error from the actual value to the forecast value. The Mean Absolute Error (MAE) equation is as follows [8]:

$$MAE = \frac{\sum_{i=1}^n |X_t - Y_t|}{n}$$

Information:

- $X_t$  : Actual data in period t;  
 $Y_t$  : Forecasting value in period t;  
 $n$  : Amount of data.

## 3. RESULTS AND DISCUSSION

### 3.1 Data Management and Exploration of Rainfall Data

Rainfall data from 2019 to 2024 were obtained from the Central Bureau of Statistics (Badan Pusat Statistik/BPS) of Riau Province. These data were displayed using the R software, as shown in Figure 1.

|      | Jan   | Feb   | Mar   | Apr   | May   | Jun   | Jul   | Aug   | Sep   | Oct   | Nov   | Dec   |
|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 2019 | 163.0 | 105.0 | 96.0  | 282.0 | 163.0 | 323.0 | 74.0  | 43.0  | 55.0  | 208.0 | 316.0 | 178.0 |
| 2020 | 161.7 | 30.2  | 96.7  | 341.6 | 246.0 | 196.8 | 109.2 | 198.3 | 53.5  | 195.3 | 432.8 | 104.8 |
| 2021 | 326.1 | 96.9  | 357.2 | 409.9 | 256.8 | 207.0 | 91.3  | 199.1 | 310.8 | 343.2 | 342.2 | 206.3 |
| 2022 | 299.0 | 291.0 | 214.0 | 496.0 | 293.0 | 268.0 | 285.0 | 184.0 | 179.0 | 473.0 | 190.0 | 343.0 |
| 2023 | 184.0 | 271.0 | 251.0 | 176.0 | 193.0 | 201.0 | 94.0  | 184.0 | 205.0 | 154.0 | 385.0 | 508.0 |
| 2024 | 286.2 | 306.7 | 183.4 | 287.3 | 378.2 | 355.3 | 50.7  | 160.2 | 79.2  | 296.7 | 476.4 | 268.4 |

Figure 1. Rainfall Dataset

The data used in this study are secondary data in the form of monthly rainfall in Pekanbaru City obtained from the Central Bureau of Statistics (Badan Pusat Statistik/BPS) and organized in an Excel file. The data cover an observation period of five years, from January 2019 to December 2024, consisting of 60 monthly observations. Each observation represents the amount of rainfall in one month measured in millimeters (mm), arranged chronologically by year and month of observation.

Based on the results of the initial exploration, the rainfall data exhibit a fairly clear pattern of fluctuation from month to month. During certain periods, rainfall tends to increase, while in other months it decreases. This pattern repeats from year to year, indicating the presence of a seasonal component in the data. In addition, the variation in rainfall values is not extreme and remains relatively stable across periods, suggesting that seasonal changes are more systematic rather than random.

These characteristics indicate that the rainfall data have a time series structure consisting of level and seasonal components. With the number of observations covering more than two complete seasonal cycles, the data meet the requirements to be analyzed using seasonal time series forecasting methods. Therefore, the Holt–Winters Exponential Smoothing method, both in its additive and multiplicative forms, is considered appropriate for modeling and forecasting rainfall in Pekanbaru City.

The parameter estimation results for the Holt–Winters models, both additive and multiplicative, are presented in Table 3.1. The table shows the values of the level smoothing parameter ( $\alpha$ ), trend smoothing parameter ( $\beta$ ), and seasonal smoothing parameter ( $\gamma$ ) obtained from the estimation process based on monthly rainfall data in Pekanbaru City for the 2019–2024 period. These parameter values describe how each model responds to changes in historical data during the forecasting process.

Table 3.1 Parameter Values of Additive and Multiplicative Models

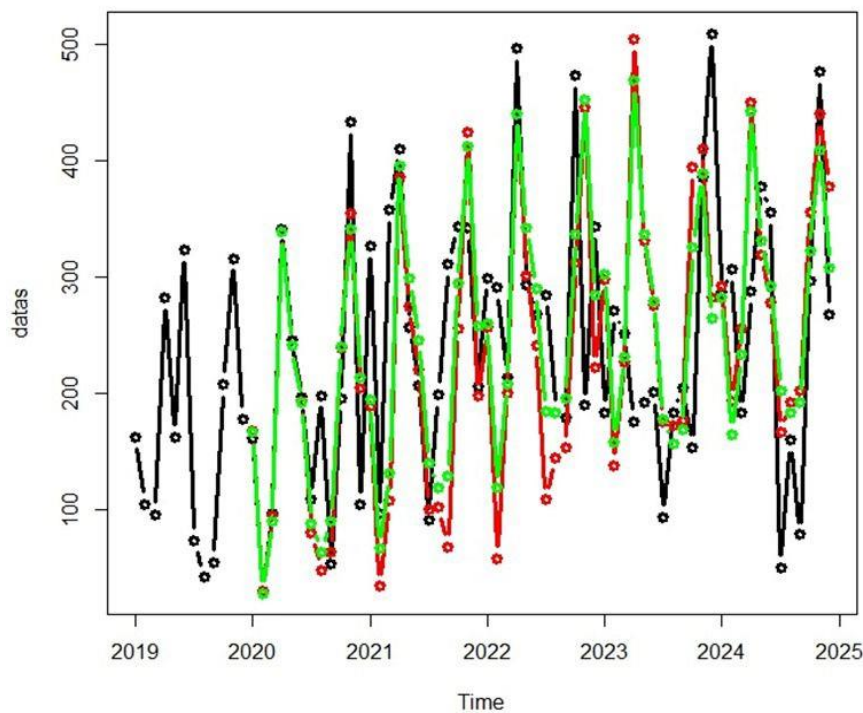
| Model          | $\alpha$ | $\beta$ | $\gamma$ |
|----------------|----------|---------|----------|
| Additive       | 0.310    | 0.086   | 0.214    |
| Multiplicative | 0.298    | 0.092   | 0.201    |

Based on Table 3.1, the additive Holt–Winters model produces an  $\alpha$  value of 0.310,  $\beta$  value of 0.086, and a  $\gamma$  value of 0.214. The relatively larger  $\alpha$  value compared to the other parameters indicates that level updating in the additive model is strongly influenced by recent data while still maintaining contributions from historical data. The small  $\beta$  value suggests that the trend component of the rainfall data does not change significantly over time, resulting in relatively stable forecasts. Meanwhile, the moderate  $\gamma$  value indicates that the seasonal pattern has a considerable influence on the model formation, which is consistent with the annual repetition characteristics of rainfall.

In the multiplicative Holt–Winters model, the parameter values are  $\alpha = 0.298$ ,  $\beta = 0.092$ , and  $\gamma = 0.201$ . The slightly smaller  $\alpha$  value compared to the additive model indicates that level updating in the multiplicative model is relatively more conservative in responding to recent data changes. The slightly larger  $\beta$  value suggests that the multiplicative model assigns a slightly higher weight to trend changes, although overall the rainfall trend remains relatively weak. The  $\gamma$  value, which is close to that of the additive model, indicates that the seasonal component continues to play an important role; however, the amplitude of seasonal variation in the multiplicative model is influenced by the magnitude of the data level.

This section presents the results of time series analysis using several modeling approaches, particularly the Holt–Winters method with two types of seasonal components, namely additive and multiplicative. The displayed graphs are used to compare actual data patterns with modeled values, evaluate model fit using error measures such as Mean Absolute Error (MAE), and assess the forecasting capability of each model for subsequent periods.

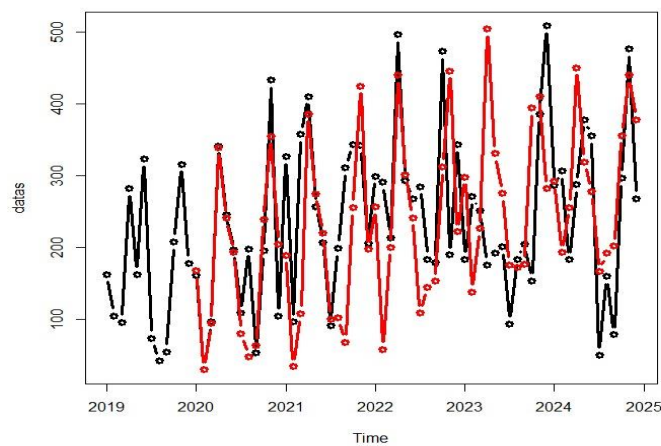
Additive Holt Winter time series model



The first graph shows a comparison between the actual data (displayed by the black line) and the results of two time series models, namely the Holt–Winters additive model (green line) and the Holt–Winters multiplicative model (red line). Visually, both models follow the seasonal pattern of the data; however, differences in model sensitivity can be

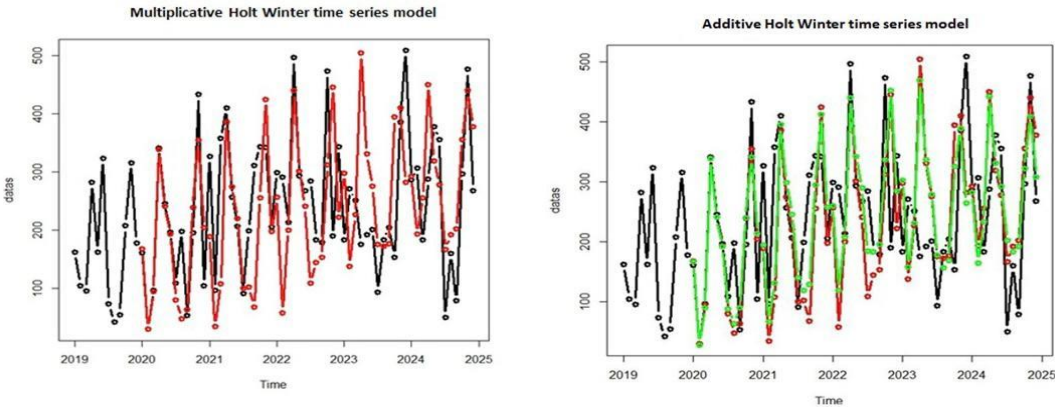
observed. The multiplicative model tends to produce sharper fluctuations in accordance with changes in the magnitude of the data values, whereas the additive model exhibits a smoother and more stable pattern. This graph provides an initial overview of which model more closely represents the actual data movement.

Multiplicative Holt Winter time series model



This graph presents a comparison between the actual data and the modeling results obtained using the Holt–Winters multiplicative method. It can be observed that this model is able to follow the seasonal pattern well, particularly during periods when the data values are high or

low. Because a multiplicative approach is used, the magnitude of seasonal variation changes according to the data level, resulting in larger fluctuations as the data values increase. Nevertheless, several deviations between the actual data and the model results are still observed at certain points.



This graph displays two panels. The left panel shows the Holt–Winters multiplicative model, while the right panel presents the Holt–Winters additive model. With this side-by-side presentation, it can be observed that the additive model produces a relatively constant seasonal pattern over time, as the seasonal component is additive in nature. In contrast, the multiplicative model shows changes in seasonal amplitude that follow variations in the data level. This comparison clarifies the characteristics and fundamental differences between the two approaches.

The results of the forecasting model performance evaluation using the Mean Absolute Error (MAE) measure are presented in Table 3.2. The MAE value is used to measure the average absolute difference between the actual values and the forecasted values; therefore, a smaller MAE indicates better model accuracy in representing rainfall data.

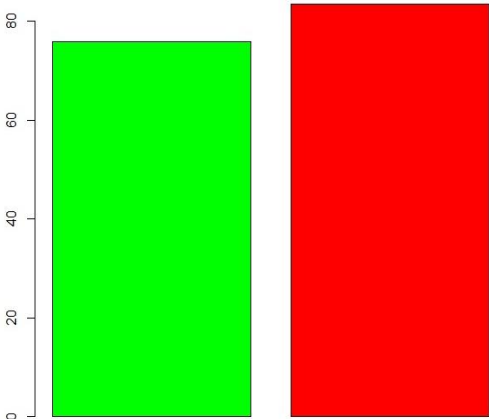
**Table 3.2 MAE Values of Additive and Multiplicative Models**

| Model                       | MAE   |
|-----------------------------|-------|
| Holt–Winters Additive       | 67.28 |
| Holt–Winters Multiplicative | 68.92 |

Based on Table 3.2, the additive Holt–Winters model produces an MAE value of 67.28, while the multiplicative Holt–Winters model produces an MAE value of 68.92. The difference in MAE values indicates that the additive model has a lower forecasting error than the multiplicative model. This suggests that the additive approach is better able to capture the pattern of monthly rainfall data in Pekanbaru City, particularly for data with relatively stable seasonal variation.

The smaller MAE value obtained by the additive model also reflects that this model generates estimates that are closer to the actual values, thereby providing higher accuracy in the forecasting process. Therefore, based on the MAE evaluation, the additive Holt–Winters model can be considered superior to the multiplicative Holt–Winters model for the analyzed rainfall data.

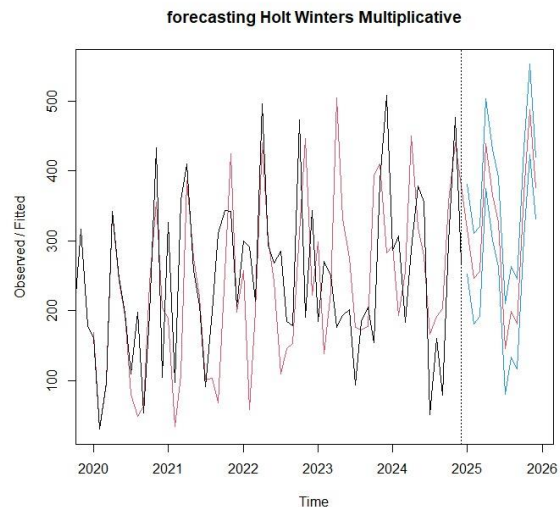
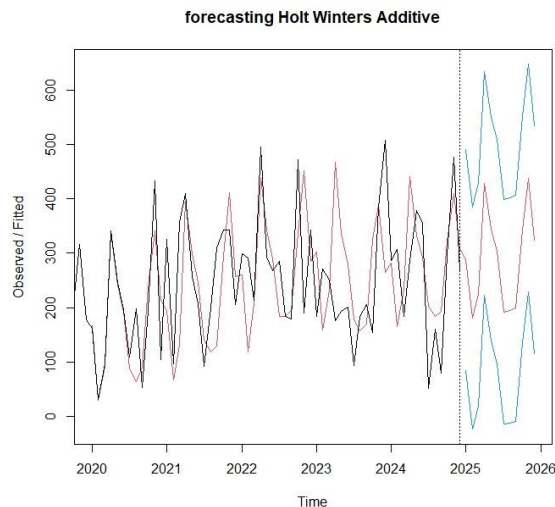
**MAE comparison**



Goodness-of-fit test

The MAE bar chart is used to evaluate the error level of each model. A smaller MAE value indicates that the model has a lower error and is more accurate in approximating the actual data. The chart shows that the Holt–Winters additive

model has a smaller MAE value than the multiplicative model. This means that, statistically, the additive model performs better in modeling the data in this case.



The final graph presents the forecasting results obtained using both models. The left panel shows the forecasts generated by the additive model, while the right panel shows the forecasts produced by the multiplicative model. The dashed line marks the boundary between the historical data and the forecasted results. It can be observed that both models preserve the seasonal pattern of the previous data and generate estimated values for future periods. However, consistent with the previous MAE results, the additive model appears to produce smoother and more stable forecasts.

Based on the overall visualization and evaluation results, both Holt–Winters models are able to capture the trend and seasonal patterns of the time series data. However, the additive Holt–Winters model demonstrates better performance, as it has a smaller MAE value and produces modeling results that are closer to the actual data. Therefore, this model can be recommended as the most appropriate model to be used for forecasting in this dataset.

#### 4. CONCLUSION

Based on the results of the monthly rainfall forecasting analysis in Pekanbaru City using the Holt–Winters method, it can be concluded that the rainfall data for the 2019–2024 period exhibit a clear and relatively stable seasonal pattern from year to year. These data characteristics make the Holt–Winters method an appropriate approach for modeling and forecasting rainfall. The parameter estimation results indicate that both the additive and multiplicative Holt–Winters models are able to capture the level, trend, and seasonal components of the rainfall data.

However, differences in parameter values and model performance evaluation results show that the additive Holt–Winters model is more responsive to changes in the data level and produces a more stable forecasting pattern. The evaluation using Mean Absolute Error (MAE) further

supports this finding, as the additive Holt–Winters model yields a smaller MAE value than the multiplicative model. This indicates that the additive model has higher accuracy in predicting monthly rainfall in Pekanbaru City. Therefore, the additive Holt–Winters model is recommended as the best model to be used for rainfall forecasting in this dataset.

Overall, the forecasting results obtained are expected to provide useful information as a basis for decision-making in various sectors, such as agriculture, water resource management, and disaster risk mitigation, particularly those related to rainfall conditions in Pekanbaru City in the upcoming periods.

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