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Comparison of Decomposition and Triple Exponential Smoothing Methods to Improve Rice Production Forecasting in East Java Province

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ABSTRACT

This study forecasts rice production in East Java using Triple Exponential Smoothing (Holt-Winters) and Decomposition. Data includes rice production in dry milled grain (GKG) from January 2018 until December 2023, sourced from the Central Statistics Agency (BPS) of East Java. The analysis identifies the Holt-Winters Multiplicative model as the most effective, with the lowest error values: Mean Absolute Percentage Error (MAPE) of 0.1452, Mean Absolute Deviation (MAD) of 0.1078, and Mean Squared Error (MSE) of 0.0286 during training, and MAPE of 0.1974, MAD of 0.1909, and MSE of 0.0858 during testing. The Holt-Winters Multiplicative model is recommended for future rice production predictions, providing reliable method for accurate forecasting, and aiding in future rice demand planning in East Java.

1. Introduction

Rice is one of the most essential carbohydrate-producing food crops in the world. Rice plants are annual plants with a round and hollow stem shape called Straw, with an elongated leaf shape and internodes in the direction of the leaf stem (Widiyawati et al., 2023). The agricultural sector is a sector that has a vital role in Indonesia's economy, and rice is one of the leading agricultural commodities. It is the main food crop that is a source of income for farmers and communities in Indonesia (Negara et al., 2023). Almost 95% of the Indonesian population

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consumes rice or processed rice as a staple food, so the demand for rice yearly will continue to increase along with population growth (Afiyah et al., 2021).

East Java Province is the largest rice-producing region in Indonesia. Governor Khofifah stated that until 2023, East Java province will continue to maintain its position as the National Food Barn. The possibility that the amount of rice production will continue to decline is caused by the uncertainty of what will happen. Therefore, research on how rice production in the future can be used as a reference for making a policy or strategy to maximize rice production (Zamahzari & Puryantoro, 2023). One of the first steps that can be used to handle fluctuations in rice production in East Java province is to predict or estimate future rice production, which is done so that the government can know the availability of rice in all regions of Indonesia (Nurwahdania & Sulistijanti, 2020).

There are several previous studies relevant to rice production forecasting that are used as reference materials in writing this research, including research conducted by Afiyah et al. (2021) which forecasts rice production in East Java by applying the Double Exponential Smoothing method, research conducted by Kurniawan et al. (2023) which forecasts rice production in Indonesia by applying Generalized M Estimation Robust Regression, then forecasting conducted by Putra et al. (2023) by implementing the Simple Linear Regression and Single Exponential Smoothing methods to predict East Java rice production. In spatial research, Nurdiansyah et al. (2024) showed that rice predictors have varying influences depending on their location in each subdistrict in Bojonegoro Regency.

The forecasting method is used to project, estimate, or predict the level of uncertain events in the future. Several forecasting methods can be used, one of which is the Exponential Smoothing method, which is an exponential weighting method that reduces the value of previous observations. One of the advantages of using this method is that it significantly reduces data storage problems. It means that only the last observation, forecast, and constant value must be stored, not all historical data or only a part of it. Because this method is simple and effective in forecast calculations, easy to adjust to changes in data, and the accuracy of this method is significant, it is widely used in forecasting (Nurdiansyah & Wafa, 2021). There are three models in the Exponential Smoothing method: Single Exponential Smoothing, Double Exponential Smoothing, and Triple Exponential Smoothing. Each part has a different smoothing rate and will be used according to the pattern of historical data. Identifying the data pattern can be done by looking at the curve of the number of cases over a certain period (Islamiati et al., 2020). An example of previous research that applies the Exponential Smoothing method is by Hasanah (2023), where the Single Exponential Smoothing method is applied to rice production in Sumenep district. The results show that the method is already included in the accurate category and can be used to predict rice production in the Sumenep district. In Makridakis et al. (1998), exponential smoothing is simple, efficient, and effective for forecasting data with consistent patterns but lacks the ability to handle complex trends or seasonality. Extensions like Holt-Winters are needed for more advanced patterns.

In addition to the Exponential Smoothing method, analysis with the Decomposition method is also introduced. This method shows the results of various factors, such as trend, cycle, seasonal, and randomness (irregular) (Kristiyanti & Sumarmo, 2020). The advantages of the Decomposition method,

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according to Hendra (2020) explained that the Decomposition method has advantages over other methods, namely that the pattern or component can be broken or decomposed into subpatterns that display each part of a separate periodic series. It often increases the accuracy of a forecast and helps to distinguish the behaviour of the data series better. Some previous research relevant to the decomposition method was conducted by Satyawati et al. (2022), who used decomposition analysis to predict data on the percentage of poor people in Indonesia. The results showed that the additive decomposition model has a lower error value, so it can be interpreted that the additive decomposition model is better than the multiplicative decomposition model. Then, Andriawan and Muflihah (2023) research aims to forecast the demand for UD blessing jaya offset cardboard boxes by comparing the Decomposition, Winter's Exponential Smoothing, and Holt's Exponential Smoothing methods. The results show that the decomposition method is the best, with an error value of MAPE of 19, MAD of 28000, and MSD of 1247419480, indicating a low forecasting error level compared to other approaches. In Hyndman and Athanasopoulos (2018), decomposition models are useful for analyzing time series by separating trend, seasonality, and residuals, making them ideal for data with strong patterns. However, they rely on simplified assumptions and struggle with irregular or highly volatile data.

In this research, Decomposition and Triple Exponential Smoothing methods are used. The novelty of this research lies in using observational data in the form of monthly data on rice production in East Java province by applying the Decomposition and Triple Exponential Smoothing methods that have yet to be widely analyzed. Judging from previous research, the approach with these methods can handle many examples of time series data and provide reasonably accurate results. Thus, proposing a study entitled "Comparison of Decomposition and Triple Exponential Smoothing Methods to Improve Rice Production Forecasting in East Java Province" is necessary. For the implementation of rice production forecasting, the monthly rice production data in East Java from January 2018 to December 2023. The application of this research is implemented using R-based programming, as explained by Nurdiansyah and Sulistiawan (2023).

Based on the problems that have been described, the objectives of this study are to determine the descriptive statistics of rice production in East Java province, to analyze the results of the comparison of Decomposition and Triple Exponential Smoothing methods in forecasting rice production in East Java province, and to obtain the results of forecasting the amount of rice production in East Java province using the best method. This research will likely be a source of reference or information that can be used to determine the level of rice production in East Java province in the future and can be used as a reference in decision-making related to rice production.

2. Method

2.1. Research Design

The research conducted used quantitative methods. A quantitative method is research that finds knowledge by using numbers to analyze information about what you want to know. The numbers used come from secondary data, which is

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obtained from other parties for research purposes or others (Ilmiah et al., 2020). The data used in this study is secondary data in the form of monthly data on rice production in East Java province from January 2018 to December 2023 obtained from the website of the Central Bureau of Statistics of East Java province.

2.2. Research Variables

This study used variables, namely rice production variables in East Java province. In the form of monthly data from January 2018 to December 2023. An explanation of the variables to be used is described in Table 1 below:

Table 1. Variable Definition

No.	Variable	Operational Definition	Unit	Scale
1.	Rice production in East Java province	Total rice production in the form of milled dry grain (MDG)	Ton	Ratio

The time series data variable in this study is denoted by Y, which stands for rice production, and t, which stands for time or period.

2.3. Analysis Steps

This research uses two methods: Decomposition and triple exponential smoothing. The two methods will be compared to determine the best method for rice production data in East Java province by looking at the minor error value in each method and forecasting results for the next period. The steps in analyzing rice production data in East Java province for the period 2018 - 2023 using the Decomposition and Triple Exponential Smoothing method comparison are as follows:

1. Perform descriptive statistical analysis and see whether the pattern of time series data forms a seasonal pattern or not. For rice production data in East Java province for the period 2018 - 2023, find out the general description of the data.
2. Perform data division into training data and testing data. This study used a training data composition of 70% and testing data of 30%. Then, the training and testing will be conducted to determine the results of comparing the Decomposition Triple Exponential Smoothing methods. The training and testing process is carried out with the same steps as in the following:

   a. Testing with the Triple Exponential Smoothing method Additive model and Triple Exponential Smoothing Multiplicative model with the following procedure:
      i. Determine the parameter values of alpha (α), beta (β), and gamma (γ), where the parameter values are in the range of 0 to 1 to get the optimum value.
      ii. Before performing the smoothing calculation, it is necessary to initialize the level, trend, and seasonality.
      iii. Perform level, trend, and seasonal smoothing processes on the estimated parameters.
      iv. Forecasting Calculation.

   b. Testing with the Additive model Decomposition and Multiplicative

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model Decomposition methods with the following procedures:

i. The first step is to determine the 12-month moving average because the time series data is monthly to estimate the influence of the trend (Tx) and cyclic (Cx).
ii. Calculate the effect of seasonality (Ix).
iii. Identify the trend effect that fits the data (linear, exponential, quadratic, etc.) using the least squares method as in the regression model.
iv. Calculate the cycle effect (Cx) by separating the combined value of the trend component and the cycle component to obtain the cycle factor by dividing the moving average value by the value of the trend component.
v. Then forecasting is done

c. Calculating model error, MAPE, MSE, and MAD values for Triple Exponential Smoothing Additive model, Triple Exponential Smoothing Multiplicative model, Decompocition Additive model, and Decompocition Multiplicative model.
d. Conduct a comparison study between the four models based on the smallest MAPE, MSE, and MAD criteria to determine the best model.

3. Forecast rice production with the original data using the best model and interpret the forecasting results.

2.4. *Flowchart*

The research used research steps following the Mursidah flow chart (Mursidah et al., 2021) as in Figure 1 below

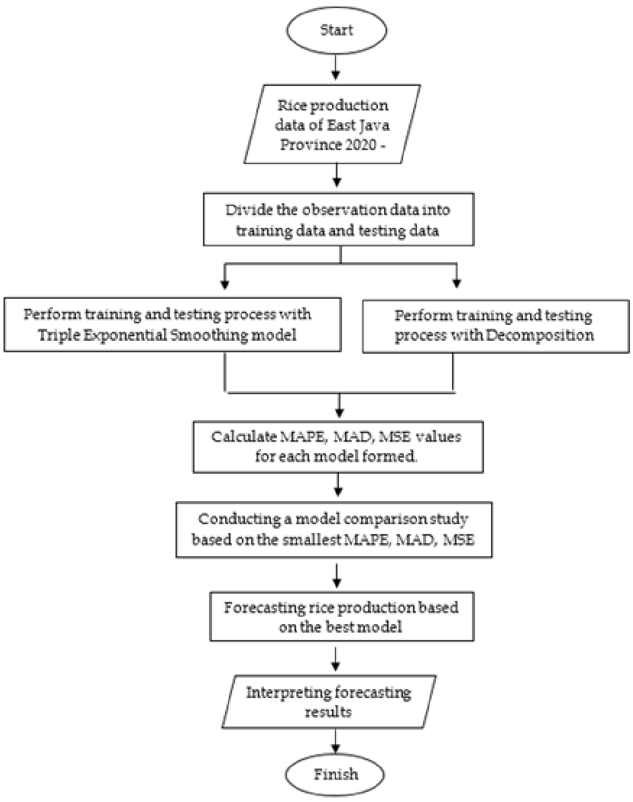

Figure 1. Research Flowchart

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3. Results and Discussion

3.1. Results

The data used in this study are monthly data on rice production in East Java province from January 2018 to December 2023. As much as 72 data were obtained through the website of the Central Bureau of Statistics of East Java Province. The data was divided into two parts, namely 70% training data and 30% testing data. The following data descriptive statistics are presented in Table 2 below:

Table 2. Descriptive Analysis of Rice Production

Statistic	Full Data	Training Data	Testing Data
Minimum	0.2100	0.2100	0.3200
Q1	0.4875	0.4825	0.4900
Median	0.6200	0.6200	0.6350
Mean	0.8160	0.8086	0.8327
Q3	0.9825	0.9825	0.9700
Maximum	2.2900	2.2900	2.2900

Before conducting a forecasting analysis, it is necessary to analyze data patterns to make it easier to determine the proper forecasting method. The following is the monthly data pattern of rice production in East Java province in the period January 2018 to December 2023, shown in Figure 2 below:

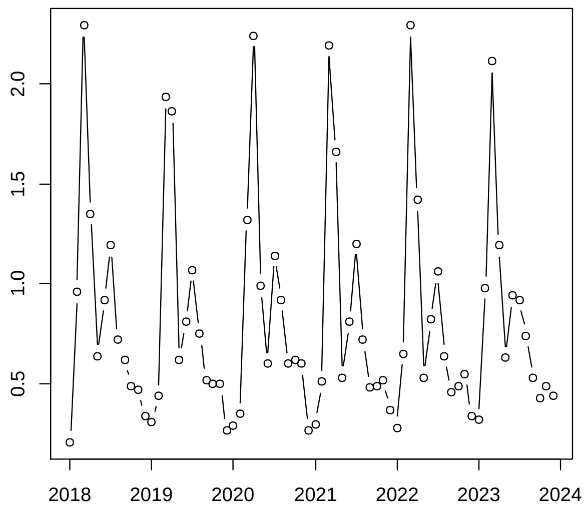

Figure 2. Time Series Plot of Rice Production Data

The data plot in Figure 2 shows that the rice production in East Java province from January 2018 to December 2023 experienced periodic fluctuations each year, with peak production in certain months and valley production in other months.

The first step to calculating forecasting with the Triple Exponential Smoothing method (Holt-Winters method) is required to determine the parameter values of alpha (α), beta (β), and gamma (γ), where the parameter values are in the range of 0 to 1 to get the optimum value. The following results calculate the three parameters to get the optimum value. The optimal parameters on monthly data of rice production in East Java province from January 2018 to

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December 2023, obtained from R software, are shown in Table 3 below:

Table 3. Parameter Estimation in Triple Exponential Smoothing method

Method	Parameter	Estimate
Holt-Winters Additive	α	0.0197
	β	0.4942
	γ	0.0000
Holt-Winters Multiplicative	α	0.0279
	β	0.2770
	γ	0.0000

After obtaining the parameter values of alpha (α), beta (β), and gamma (γ), these parameter values are used to find the initial values of level smoothing, trend smoothing, and seasonal smoothing. After obtaining the initial value, find the smoothing value for level, trend, and seasonal. Then, calculate the forecasting value for the next period. After receiving the forecasting value, the next step is to see the extent of the applied model's accuracy or accuracy. In this study, to determine the accuracy of forecasting, it was carried out by looking at the MAPE, MAD, and MSE values with the help of R software, and the results obtained are shown in Table 5 and Table 6.

To perform a forecasting analysis using the Decomposition method, it is first necessary to determine a 12-month moving average since the time series data is monthly in nature to obtain an estimate of the trend (Tx) and cyclic (Cx) effects. The least squares method is used in regression models to identify the trend effect that fits the data (linear, exponential, quadratic, or otherwise). After that, calculate the influence of the cycle (Cx) by separating the combined value of the trend component and the cycle component to obtain the cycle factor, namely by dividing the moving average value by the value of the trend component. Then, the forecasting calculation is carried out for the next period.

After the model training process (training) and the model evaluation process (testing), the model comparison results with forecasting or forecasting for the next period are obtained. The accuracy value of the model can be seen by calculating the MAPE, MAD, and MSE values. For the accuracy value of the Additive Decomposition model method, the accuracy value of the model is shown in Table 4 and Table 5.

Table 4. Accuracy Value of Training Process

Training	MAPE	MAD	MSE
Holt-Winters Additive	0.1553	0.1097	0.0296
Holt-Winters Multiplicative	0.1452	0.1078	0.0286
Decomposition Additive	**0.0759**	**0.0684**	**0.0152**
Decomposition Multiplicative	0.4569	0.7590	0.7703

Table 5. Accuracy Value of Testing Process

Testing	MAPE	MAD	MSE
Holt-Winters Additive	0.2135	0.1978	0.0731
Holt-Winters Multiplicative	**0.1974**	**0.1909**	**0.0858**
Decomposition Additive	4.8738	0.7920	0.7006
Decomposition Multiplicative	0.2616	0.2736	0.1544

In Table 4 and Table 5, it can see the results of the model error comparison

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by looking at the MAPE, MAD, and MSE values. The accuracy value of training data is used to assess the accuracy of model estimation. In contrast, the accuracy value of the testing data illustrates the accuracy of the model forecast.

The Additive Decomposition model method has the lowest MAPE, MAD, and MSE values in the training process but performs poorly in the testing process. It indicates that the model is overfitting. For the Triple Exponential Smoothing method, the Multiplicative model, although it has slightly higher MAPE, MAD, and MSE values in the training process than the Additive model Decomposition method, has better and consistent performance on testing data in training and testing data.

Based on the results of the above analysis, with a MAPE value of 0.1452, MAD of 0.1078, MSE of 0.0286 in the training process, and a MAPE value of 0.1974, MAD of 0.1909, MSE of 0.0858 in the testing process, the Triple Exponential Smoothing method Multiplicative model is the best method overall, because it has excellent and consistent performance on training and testing data, which means that of the four models above, the Triple Exponential Smoothing Multiplicative model is more appropriate to use to forecast rice production in East Java province. So, forecasting is carried out with monthly data on rice production in East Java from January 2018 to December 2023 to forecast rice production in the future. In this study, rice paddy production in 2024 will be forecasted using the selected method, namely the Triple Exponential Smoothing method of the Multiplicative model.

After determining the best forecasting method, the forecasting process will be carried out using the original rice production data with the selected model, namely the Triple Exponential Smoothing method Multiplicative model. Forecasting is carried out with the Triple Exponential Smoothing method Multiplicative model using R software, and the results are obtained in Figure 3.2 below:

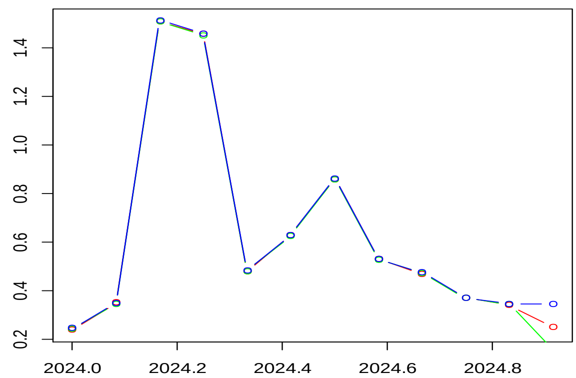

Figure 3. Plot of Rice Production Forecasting Results in 2024

Based on Figure 3, the forecasting results using the Triple Exponential Smoothing Multiplicative model method can be seen. The red graph is the forecasting result, the green graph is the lower limit value with 95% confidence, and the blue graph is the upper limit value with 95% confidence. In addition, the results of rice production forecasting in East Java province in 2024 are presented in Table 6 below:

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Table 6. Forecasting Results of Rice Production in 2024

No.	Period	Point Forecast	Lo 95	Hi 95
1.	January 2024	0.2434	0.2427	0.2442
2.	February 2024	0.3460	0.3451	0.3470
3.	March 2024	1.5128	1.5098	1.5159
4.	April 2024	1.4561	1.4531	1.4591
5.	May 2024	0.4823	0.4810	0.4835
6.	June 2024	0.6278	0.6262	0.6294
7.	July 2024	0.8605	0.8584	0.8626
8.	August 2024	0.5290	0.5276	0.5306
9.	September 2024	0.4733	0.4719	0.4747
10.	October 2024	0.3696	0.3683	0.3708
11.	November 2024	0.3441	0.3429	0.3454
12.	December 2024	0.2490	0.1529	0.3451

Table 6 shows the results of rice paddy production forecasting in 2024 using the selected method, namely the Triple Exponential Smoothing method Multiplicative model. Rice production in the year tends to decrease, with the highest amount of rice production being 1.51 million tons, which occurred in March 2024. The results of forecasting future rice production can provide an overview to the government and the community regarding future conditions so that the government and the community can prepare strategies to overcome the situations that occur in the future.

3.2. Discussion

The findings indicate that rice production in East Java exhibits a pattern of periodic fluctuations each year, with clear peaks and valleys in output across different months. The use of the Additive Decomposition model in the analysis initially showed promising results in terms of low error metrics, such as MAPE, MAD, and MSE, during the training phase. However, this model struggled in the testing phase, suggesting that it might be overfitting the training data. On the other hand, the Triple Exponential Smoothing method with a Multiplicative model, despite slightly higher error values in training, provided more stable and reliable performance on testing data. This indicates a stronger ability to generalize and accurately predict rice production trends outside the training dataset.

For 2024, the Triple Exponential Smoothing Multiplicative model forecasts a general decline in rice production, with the highest production level anticipated at 1.51 million tons in March. This projection provides valuable insight for both the government and local communities, allowing them to anticipate future rice production trends and implement proactive strategies. By understanding the likely decreases in production, authorities can better prepare for potential shortfalls, possibly developing policies to stabilize rice supplies and support affected farmers. This foresight highlights the importance of robust forecasting models in agricultural planning, particularly in regions where production fluctuations can impact food security and economic stability.

4. Conclusions

This study demonstrates that the Triple Exponential Smoothing Multiplicative method is the most effective approach for forecasting rice

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production in East Java Province, based on monthly data from January 2018 to December 2023. With a MAPE value of 0.1452 for training data and 0.1974 for testing data, this method proved to deliver accurate and consistent predictions compared to other models. The periodic fluctuations in rice production each year, with peak production in certain months, were effectively captured by the model. Forecasting results for 2024 indicate a general decline in rice production, with the highest production level estimated at 1.51 million tons in March. These findings provide valuable insights for the government and stakeholders to design proactive policies to manage rice production and ensure food security.

Author Contributions

The first author is a student who worked on the scientific article as the output of the final project, the second author is the primary advisor who assisted with the research material, and the third author is the second advisor who provided support in the writing process.

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Declaration of Competing Interest

The authors affirm that no conflicts of interest exist in relation to the development of this scientific article.

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