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A comparative analysis of the accuracy of forecasting methods in predicting strategic food production in East Java

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ABSTRACT

Food security is one of the main pillars of sustainable national development, especially in East Java, a region that contributes significantly to the national rice production. However, data from 2016 to 2024 show a downward trend in rice production. This contrasts with the relatively stable consumption demand and poses a risk to future food stability. This study aims to predict future food needs and determine the most accurate forecasting method by comparing the naive method, moving average, single exponential smoothing (SES), and double exponential smoothing (DES) methods. The research data includes annual rice production and consumption volumes in East Java over a nine-year period. We evaluated the forecasting accuracy using the mean absolute deviation (MAD), mean squared error (MSE), and mean absolute percentage error (MAPE). The results of the analysis show that the double exponential smoothing method (with $\alpha = 0.9$ and $\beta = 0.1$) provides the best performance, with the lowest error rate (MAPE) of 1.020%. This value is much more accurate than those of the naive method (6.397%), moving average method (6.359%), and single exponential smoothing method (6.530%), which are less responsive to downward trends in the data. Therefore, the DES method is recommended as the most appropriate forecasting model to assist the government of East Java with strategic planning and food security policies.

Keywords: Food Security, Rice Production Forecasting, Double Exponential Smoothing, MAPE

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RESEARCH & PUBLISHING

1. INTRODUCTION

Food security is a pillar of sustainable national development. Strategic foods, such as rice, corn, soybeans, sugar, and chicken meat, are vital to national food security, especially in East Java (Rusono, 2019). This commodity determines the prices and socioeconomic stability of farmers and consumers (Nuryanti, 2017). East Java Province contributes more than 15% to the national rice production. In contrast, corn production has increased rapidly from 2013 to 2019, almost doubling from previous levels (BPS, 2025).

Rice remains the primary staple food in Indonesia, making its availability a critical determinant of food security and regional economic stability. East Java plays a strategic role as one of the largest contributors to national rice production; however, recent statistics indicate a gradual decline in output alongside continued population growth. This condition increases the pressure on regional food systems and heightens the risk of supplydemand imbalances. At the policy level, the Indonesian government has intensified food security programs and strengthened national reserve strategies in response to climate variability and production uncertainties. These developments highlight the urgency of improving forecasting accuracy to support evidence-based planning and prevent potential food shortages in the future.

Existing studies predominantly focus on food systems in developed economies characterized by just-in-time supply chains and a strong dependence on imports rather than domestic production, often externalizing environmental impacts to exporting regions. Although such supply chains may rapidly recover from short-term disruptions, their apparent resilience does not guarantee long-term stability. Consequently, policy discussions increasingly emphasize the need for long-term resilience and environmental sustainability of food systems. However, the literature remains largely concentrated on crisis-specific responses, particularly those related to COVID-19, favoring shallow, non-systemic adaptation measures over deeper structural transformations (Hirth et al., 2025).

This study uses data from the East Java Provincial Statistics Agency for the last two years, 2023-2024. Rice production data for food consumption reached 5.35 million tons in 2024, down approximately 4.53% compared to the previous year (BPS, 2025). Similar phenomena occur in the production of sugar and broiler chicken meat products. Both are affected by distribution and feeding factors. Food demand in East Java is subject to complex dynamics owing to frequent mismatches between demand and supply in several regions, primarily caused by uneven distribution and inaccurate forecasting. This situation poses a risk to price stability and inflation in the food industry.

Accurate food demand forecasts are essential for food policy planning, distribution, and inflation control. Inaccurate forecasts can lead to food surpluses or shortages, which affect economic stability and public welfare. Data volatility and inaccuracies hinder fertilizer allocation, reserve stock planning (in the absence of an official optimal benchmark), and price forecasting, contributing to food inflation. Production optimization policies, including increasing the cropping intensity to 2.8, are constrained, leading to imports despite local surpluses. Therefore, predictive modeling is essential for price stabilization and evidence-based policymaking (Mahariani & Arifianti, 2025). Therefore, an appropriate and accurate method is needed to strategically forecast food demand. One approach is to use time-series methods, such as exponential smoothing, for forecasting analysis. This method has been proven to produce relatively accurate forecasts in various fields, including agricultural production (Safitri et al., 2025).

Several previous studies have served as important references for developing methods to forecast strategic food needs in Indonesia, particularly in East Java Province. Researchers have used double exponential smoothing to predict food crop production yields. The research dataset was collected over a 20-year period from 1994 to 2014. The prediction results of this study produced an error rate of only 2.22% (Ariyanto et al., 2017). The next study used Holt-Winters exponential smoothing and ARIMA to predict rice production in Gorontalo. The research dataset included rice production data from 2009–2018. The ARIMA (3, 1, 3) method produced the best forecast, yielding a smaller root mean square error (RMSE) value than the Holt-Winters exponential smoothing method (Akolo, 2019). The research on rice production forecasting in Lamongan used the naive method, moving average, exponential smoothing, and linear regression/least squares. The results of the forecasts in this study indicate that Linear Regression/Least Squares is the best method, with an error value of 8.259%. Therefore, linear regression can be used to forecast rice production in Lamongan in the future (Safitri et al., 2025). On the other hand, there has not been much research that specifically conducts a systematic comparative analysis of the exponential smoothing method for strategic food needs in rice commodities that links rice production and rice consumption in East Java Province.

Recent forecasting studies emphasize global, model-based time series clustering approaches that exploit cross-series similarities to enhance predictive accuracy and robustness, often outperforming traditional local models(López-Oriona et al., 2025). However, existing studies have not sufficiently conducted systematic comparisons between these emerging approaches and classical forecasting methods, such as ARIMA, Holt–Winters, exponential smoothing, and naïve models, particularly in applied policy-relevant contexts.

Although prior studies have examined rice production forecasting using individual statistical models, limited research has conducted a structured comparison of classical time-series approaches within a policy-relevant regional context that simultaneously considers production dynamics and consumption needs. Furthermore, empirical evidence assessing forecasting performance using recent post-pandemic data remains scarce. This study addresses these gaps by providing a comparative evaluation of multiple forecasting models using updated data from East Java, thereby offering a more robust empirical basis for regional food security planning.

Based on the background information provided, the objective of this study is to forecast the strategic food needs of East Java using the naive method, moving average, exponential smoothing and double exponential smoothing method. The results are expected to inform the East Java Provincial Government's evaluation of policies related to the food sector.

2. METHOD

This study uses annual rice production and population data for East Java Province spanning the period 2016–2024 as compiled by the Central Statistics Agency (BPS) of East Java. In 2024, the harvested area of paddy in East Java reached approximately 1.62 million hectares, with rice production equivalent to about 9.27 million tons of dry milled grain (GKG) and approximately 5.35 million tons of rice allocated for resident food consumption. In terms of demographic context, the province's total mid-year population estimate increased steadily over recent years, reaching roughly 41.81 million people by mid-2024, providing a comprehensive baseline for analysis of rice supply relative to potential consumer demand. All production and population data are aggregated at the annual level, with rice production and consumption measured in metric tons. These annual series from 2016 through 2024 serve as the empirical foundation for the study. However, it should be noted that the analytical scope deliberately excludes external explanatory variables, such as commodity price variations, rainfall patterns, paddy harvest area changes, and fertilizer usage, which have been demonstrated in agronomic and economic studies to influence total production volume but are beyond the descriptive focus of the present dataset.

Time-series forecasting techniques were selected because the research objective focuses on predicting future production based on historical patterns rather than explaining causal relationships. Exponential smoothing models are particularly suitable for short- to medium-term forecasting due to their ability to capture level and trend components while requiring relatively few assumptions.

This study employs a quantitative comparative research design focused on evaluating the forecasting accuracy of selected time series methods in predicting food production. The research review procedure uses several forecasting methods, including naive method, moving average method, single exponential smoothing (SES), double exponential smoothing (DES). Various studies will be analyzed to determine the threshold values that provide the greatest forecasting accuracy. Forecasting accuracy is reflected in values such as MAD (mean absolute deviation), MSE (mean squared error), and MAPE (mean absolute percentage error). These forecasting methods are selected for comparison because they represent established benchmark approaches in time series analysis, each capturing different characteristics of trend and seasonality commonly observed in food production data, thereby enabling a comprehensive evaluation of forecasting performance.

2.1. Mean Absolute Deviation (MAD)

The mean absolute deviation (MAD) is used to calculate the mean absolute error of various forecasting methods, which is considered the most accurate measure of accuracy (Kim & Kim, 2016). The formula for calculating MAD follows these rules:

$$MAD = \sum_{t=1}^{n} \left| \frac{A_t - F_t}{n} \right|$$

2.2. Mean Squared Error (MSE)

Another way to measure the accuracy of a forecasting method is to use mean squared error (MSE). Unlike MAD, MSE squares each forecasting error before combining them. This method takes larger forecasting errors into account (Hodson, 2022). The formula for calculating MSE follows these rules:

$$MSE = \sum_{t=1}^{n} \frac{(A_t - F_t)^2}{n}$$

2.3. Mean Absolute Percentage Error (MAPE)

MAPE helps select the most suitable forecasting model in situations where the size of the forecast variable is important. Models with the lowest MAPE are the most effective at predicting relative data values (Chicco et al., 2021). The formula for calculating MAPE follows these rules:

$$MAPE = \frac{1}{n} \sum_{t=1}^{n} \left| \frac{A_t - F_t}{A_t} \right| \times 100\%$$

The criteria for MAPE accuracy are as follows: (1) Forecast accuracy is considered excellent if MAPE is less than 10%; (2) Forecast accuracy is considered good if the MAPE is between 10% and 20%; (3) Forecast accuracy is adequate if MAPE is between 20% and 50%; (4) Forecast accuracy is considered inaccurate if MAPE is greater than 50%.

3. RESULT AND DISCUSSION

3.1. Data Analysis

The data was obtained from the Central Statistics Agency and includes rice production and consumption figures in East Java from 2016 to 2024. Data from nine years of this period was obtained, with results detailed in tons. Initial data processing involved analyzing the available data. An important aspect of data forecasting is considering the characteristics of the data pattern type to find a suitable calculation method. Selecting a suitable method according to the characteristics of the data will affect the interpretation of the data testing results. The research data is presented in Table 1 and graphically displayed in Figure 1.

Table 1. Rice Production Data, Rice Production Yield, and Food Requirements

Year	Rice Grain Production (Tons)	Rice Production (Tons)	Food Demand (Tons)
2016	12.726.463	7.310.662	3.389.235
2017	13.060.464	7.502.528	3.197.826
2018	10.203.213	5.861.192	3.186.719
2019	9.580.934	5.503.726	3.104.981
2020	9.944.538	5.712.597	3.191.729

2021	9.789.588	5.652.705	3.332.358
2022	9.526.516	5.500.802	3.334.961
2023	9.710.661	5.607.132	3.359.815
2024	9.270.435	5.352.936	3.306.565

Figure 1 shows the data on rice production and food requirements plotted to obtain an overview of the data pattern. As can be seen, the data did not show a significant trend; therefore, an analysis using the exponential smoothing model was performed.

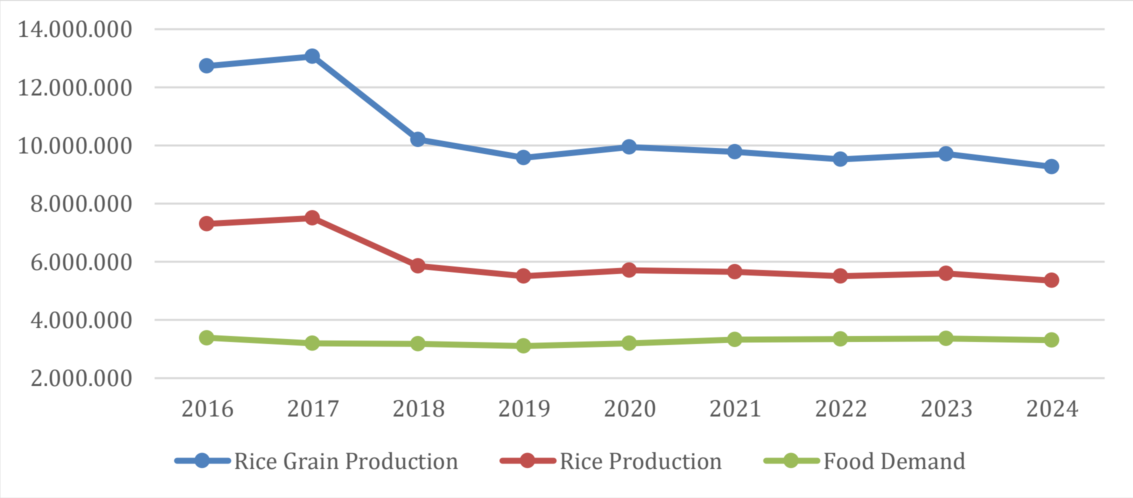

Figure 1. Rice Grain Production, Rice Production and Food Demand from 2016 to 2024

Source: Processed from primary data (2025)

Figure 1 illustrates the evolution of rice grain production, rice production, and demand in East Java from 2016 to 2024. Generally, production and food demand trends are different. Rice grain production (blue line) fluctuates with an overall downward trend. From 2016 to 2017, production was at its highest level, around 12.6 to 13 million tons. Since 2018, however, there has been a sharp decline to around 10 million tons. Despite slight improvements in 2020 and 2023, the downward trend continued until 2024, with production reaching only around 9.3 million tons.

Rice production (red line) follows the same pattern as rice grain production because rice is derived from milled dry grain. Rice production reached around 7.2–7.5 million tons in 2016–2017 but experienced a significant decline to around 5.9 million tons in 2018. Since then, rice production has stabilized at approximately 5.3–5.8 million tons. This indicates a limitation in the supply of rice as a raw material, which directly impacts the availability of rice as a main food source for the community.

In contrast, food demand (green line) remained relatively stable throughout the observation period. It fluctuated only slightly, ranging from 3.1 to 3.4 million tons, and did not experience any significant spikes. This can be explained by the population's relatively constant growth and unchanged rice consumption patterns.

A comparison of rice production and food demand indicates that East Java will remain in a surplus position from 2016 to 2024. However, the surplus margin will decline from approximately 4.2 million tons in 2017 to around 2 million tons in 2024. This decline indicates potential vulnerability to food insecurity if the downward production trend continues. Figure 1 shows that, while the current situation is relatively secure, the government must take strategic measures to stabilize rice production and ensure future food security.

3.2. Naive Method

The naïve forecasting method is employed due to its minimal model assumptions and its effectiveness in detecting systematic prediction errors that signal structural changes preceding an inverted yield curve (Ouyang et al., 2025).

The following are the results of the data analysis for the naive method. The most accurate predictions of rice production are characterized by a small difference between the actual and predicted results. Conversely, poor accuracy is characterized by a high level of difference. The greater the difference between the actual values and the predicted results, the poorer the accuracy.

Table 2. Naive Method Forecasting in Rice Production

Period	A_t	F_t	MAD	MSE	MAPE
2016	7.310.662	-	-	-	-
2017	7.502.528	7.310.662	191.866	36.812.560.000	2,557%
2018	5.861.192	7.502.528	1.641.336	2.693.984.000.000	28,003%
2019	5.503.726	5.861.192	357.466	127.781.900.000	6,495%
2020	5.712.597	5.503.726	208.871	43.627.090.000	3,656%
2021	5.652.705	5.712.597	59.892	3.587.052.000	1,06%
2022	5.500.802	5.652.705	151.903	23.074.520.000	2,761%
2023	5.607.132	5.500.802	106.330	11.306.070.000	1,896%
2024	5.352.936	5.607.132	254.196	64.615.610.000	4,749%
		Average	371.482	375.598.600.000	6,397%

Source: Processed from primary data

According to Table 2, the naive method is simple to calculate but produces fluctuating levels of accuracy throughout the 2017–2024 period. This method can produce relatively small errors in certain years. For example, in 2021, the MAPE was 1.06%, indicating a fairly good level of forecasting accuracy, and in 2023, the MAPE was 1.896%. However, in 2018, there was a significant spike in error, with a MAPE of 28.003%. This reflects the Naive method's limited ability to capture sharp changes in production patterns. The MAD and MSE values show a similar pattern: in some periods, the error is low; in others, it increases significantly. The average MAPE of 6.397% suggests that this method is feasible for short-term forecasting but has limitations when faced with unstable production dynamics. These results confirm that the naive method is practical and fast but less adaptive to extreme changes in production trends.

3.3. Moving Average Method

The moving average method is applied because the time series exhibits no seasonal component, allowing the trend-cycle to be effectively estimated by smoothing random fluctuations in the data (Makridakis et al., 1998). The following are the results of the data analysis for the moving average method.

Table 3. Moving Average Method Forecasting in Rice Production with n as 4

Period	A_t	F_t	MAD	MSE	MAPE
2016	7.310.662	-	-	-	-
2017	7.502.528	-	-	-	-
2018	5.861.192	-	-	-	-
2019	5.503.726	-	-	-	-
2020	5.712.597	6.544.527	831.930	692.107.500.000	14,563%
2021	5.652.705	6.145.011	492.306	242.365.200.000	8,709%
2022	5.500.802	5.682.555	181.753	33.034.150.000	3,304%
2023	5.607.132	5.592.458	14.674,5	215.340.900	0,262%
2024	5.352.936	5.618.309	265.373	70.422.830.000	4,958%
		Average	357.207,3	207.629.000.000	6,359%

Source: Processed from primary data

According to Table 3, the moving average method (n = 4) demonstrates consistent performance during the final period but is suboptimal during the initial phase. This method did not produce forecasts for 2016–2019 due to data limitations but has provided measurable results since 2020. Initially quite high in 2020 at 14.563%, the MAPE value decreased sharply to 0.262% in 2023, then increased again in 2024. Although the average MAPE of 6.359% indicates good accuracy, it still shows limitations in responding to rapid changes in production.

3.4. Single Exponential Smoothing (SES)

Single Exponential Smoothing is employed because it assigns exponentially decreasing weights to past observations, allowing recent data to have greater influence on forecasts while efficiently correcting prediction errors with minimal data storage requirements (Makridakis et al., 1998). The following are the results of the data analysis for the single exponential smoothing (SES).

Table 4. Single Exponential Smoothing Method in Rice Production with α =0,9

Period	A_t	F_t	MAD	MSE	MAPE
2016	7.310.662				
2017	7.502.528	7.310.662	191.866	36.812.560.000	2,557%
2018	5.861.192	7.483.342	1.622.150	2.631.369.000.000	27,676%
2019	5.503.726	6.023.407	519.681	270.068.300.000	9,442%
2020	5.712.597	5.555.694	156.903	24.618.550.000	2,747%
2021	5.652.705	5.696.907	44.201,5	1.953.773.000	0,782%
2022	5.500.802	5.657.125	156.323	24.436.880.000	2,842%
2023	5.607.132	5.516.435	90.697,5	8.226.037.000	1,618%
2024	5.352.936	5.598.062	245.126	60.086.760.000	4,579%
		Average	378.368,4	382.196.500.000	6,530%

Source: Processed from primary data

According to Table 4, the Single Exponential Smoothing method with α = 0.9 excels at responding quickly to data changes but struggles to maintain stable accuracy. This method can produce very low error rates in certain periods. For example, in 2021, the MAPE was 0.782%, reflecting high forecasting accuracy, and in 2023, the MAPE was 1.618%. However, there was a spike in MAPE to 27.676% in 2018, indicating the method's weakness in dealing with extreme changes in production. While the average MAPE value of 6.53% indicates reliability, the method has limitations when faced with sharp and unexpected data fluctuations.

3.5. Double Exponential Smoothing (DES)

Holt's double exponential smoothing is applied because it extends simple exponential smoothing by explicitly modeling both the level and the trend of the time series, thereby reducing forecast lag and improving accuracy for data exhibiting a linear trend (Makridakis et al., 1998). The following are the results of the data analysis for the double exponential smoothing (DES).

Table 5. Double Exponential Smoothing Method in Rice Production with α =0,9

Period	A_t	F_t	MAD	MSE	MAPE
2016	7.310.662	-	-	-	-
2017	7.502.528	7.694.394	191.866	36.812.560.000	2,557%
2018	5.861.192	6.071.390	210.198	44.182.940.000	3,585%
2019	5.503.726	5.536.280	32.554	1.060.000.000	0,591%
2020	5.712.597	5.686.622	25.975	674. 700.000	0,455%
2021	5.652.705	5.644.701	8.004	64.064.000	0,142%
2022	5.500.802	5.490.845	9.957	99.141.000	0,181%
2023	5.607.132	5.581.622	25.510	651.000.000	0,455%
2024	5.352.936	5.341.342	11.594	134.400.000	0,217%
		Average	57.520	10.647.600.000	1,020%

Source: Processed from primary data

According to Table 5, the Double Exponential Smoothing forecast with α = 0.9 and β = 0.1 is highly accurate. However, there are differences in several periods. The average MAPE value of 1.02% indicates that the model accurately follows the rice production pattern. The low error rate from 2020 to 2024 demonstrates the stability of the forecast results. However, at the beginning of the forecasting period, relatively large differences still exist, particularly in 2017 and 2018. This demonstrates that, although DES is responsive to trends, it requires adaptation during the initial phase of data changes. Thus, DES is highly accurate and adaptive but has limitations during the transition period of production trends.

3.6. A Comparative Analysis

We will compare the overall method numerically using forecasting accuracy. The accuracy measures used are Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE).

Table 6. Forecast Accuracy Values For Each of the Methods

Method	MAD	MSE	MAPE	Accuracy rate of MAPE
Naive Method	371.482	375.598.600.000	6,397%	excellent
Moving Average	357.207,3	207.629.000.000	6,359%	excellent
SES	378.368,4	382.196.500.000	6,530%	excellent
DES	57.520	10.647.600.000	1,020%	excellent

Source: Processed from primary data

According to Table 6, Based on the average MAPE value, the naive method is simple to calculate but produces a fairly fluctuating error rate averaging around 6.397%. This method is practical to use, but it is less effective at capturing sharp changes in production trends. The moving average method (n = 4) produces a relatively stable MAPE average of 6.359%. However, although it can smooth data, this method is less responsive to sudden changes. Single exponential smoothing with α = 0.9 produces an average MAPE of 6.53%, showing a quick response to the latest data. However, it is prone to error spikes in certain periods. Unlike the previous three methods, double exponential smoothing with α = 0.9 and β = 0.1 produces the lowest average MAPE of 1.02%, reflecting a high level of accuracy. However, it still requires the assumption of a consistent trend.

The results of this study align with those of Ariyanto, who used the Double Exponential Smoothing method to predict food crop production. Ariyanto's study recorded an error rate of 2.22% (Ariyanto et al., 2017). These results reinforce the argument that the DES method is highly effective for agricultural data with trend components. In fact, this study achieved greater accuracy, with a mean absolute percentage error (MAPE) of 1.02%, compared to Ariyanto's study.

The superior performance of the double exponential smoothing model can be explained by its capacity to explicitly model trend behavior, which is evident in the gradual decline of rice production over the observation period. This finding is consistent with forecasting theory suggesting that models incorporating trend components outperform simpler approaches when structural movement exists in the data.

However, these results differ from those of Safitri et al. in Lamongan. In that study, the linear regression or least squares method was found to be the best method, with an error value of 8.259%. The exponential smoothing method was also tested, but it was not the best method (Safitri et al., 2025). This difference is likely due to the characteristics of the data; the East Java rice production data in this study shows a fluctuating downward trend. The DES method has proven to be more adaptive to this type of trend than the Naive or Moving Average methods.

Of all the methods, Double Exponential Smoothing is the best because it produces the lowest error rate, making it the most accurate method for predicting rice production trends. Beyond methodological contributions, this study underscores the relevance of forecasting accuracy for food security governance. Reliable production forecasts provide an evidence base for anticipatory policy actions, enabling governments to respond proactively to potential food shortages and strengthen public trust in food security management. The provincial government should integrate DES-based forecasts into annual food balance planning, prioritize buffer stock adjustments when projected surplus falls below safe thresholds, and strengthen inter-regional distribution mechanisms. In the short term, forecasting outputs should inform planting calendar coordination and fertilizer allocation.

4. CONCLUSION

The results of the analysis of rice production forecasts and strategic food requirements in East Java, using data from 2016 to 2024, reveals the following: rice production in East Java has generally declined since 2018. In contrast, food demand has remained relatively stable and has not experienced a significant increase. Although there is still a surplus, the margin continues to decline, indicating potential future vulnerability to food insecurity. Double exponential smoothing (with $\alpha = 0.9$ and $\beta = 0.1$) is the best method for forecasting rice production in East Java. This method yields the lowest error values: MAPE of 1.02%, MAD of 57.52, and MSE of 10,647,600,000. Due to its high level of accuracy, the Double Exponential Smoothing method is recommended as a reference for formulating strategic policies, especially for anticipating declining production trends and maintaining regional food security.

Ethical Approval

This research did not require ethical approval.

Informed Consent Statement

This research did not require informed consent.

Authors' Contributions

PS contributed to the research conceptualization, data collection, and preparation of the manuscript. DJ supervised the study, provided theoretical and methodological guidance. YRM contributed to data analysis.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data Availability Statement

The data presented in this study are available on request from the corresponding author due to privacy reasons.

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