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Comparison of Double and Triple Exponential Smoothing Methods for Rainfall Prediction

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Abstract

Rainfall is water that falls to the ground surface over a certain period and is measured in millimeters (mm). Rainfall is essential for the life of living things. Forecasting plays a significant role in decision-making in modern times, with two main methods: causal models and time series. Time series models have five types of data patterns: random, constant, seasonal, cyclical, and trend. For rainfall forecasting, the Double Exponential Smoothing and Triple Exponential Smoothing methods are used for trend pattern data. This research compares the two approaches based on error values using average rainfall data in Bojonegoro. The results show that Double Exponential Smoothing has a Mean Absolute Percentage Error (MAPE) of 0.6996%, while Triple Exponential Smoothing has a MAPE of 119.1497%. So, Double Exponential Smoothing is more accurate.

Keywords: Forecasting, Double Exponential Smoothing (DES), Triple Exponential Smoothing (TES), Mean Absolute Percentage Error (MAPE)

Abstrak

Curah hujan adalah air yang turun ke permukaan tanah selama jangka waktu tertentu dan diukur dalam milimeter (mm). Curah hujan penting bagi kehidupan makhluk hidup. Di era modern, peramalan berperan besar dalam pengambilan keputusan, dengan dua metode utama: model kausal dan time series. Model time series memiliki lima jenis pola data: acak, konstan, musiman, siklis, dan tren. Untuk peramalan curah hujan, metode Double Exponential Smoothing dan Triple Exponential Smoothing digunakan untuk data berpola tren. Penelitian ini membandingkan kedua metode berdasarkan nilai error, menggunakan data rata-rata curah hujan di Bojonegoro. Hasil menunjukkan bahwa Double Exponential Smoothing memiliki Mean Absolute Percentage Error (MAPE) sebesar 0,6996%, sedangkan Triple Exponential Smoothing memiliki MAPE 119,1497%. Jadi, Double Exponential Smoothing lebih akurat.

***Kata-kata kunci**: Peramalan, Double Exponential Smoothing (DES), Triple Exponential Smoothing (TES), Mean Absolute Percentage Error (MAPE)*

1. Introduction

Indonesia is located on the equator, so there are two seasons: rainy and dry. These two seasons significantly influence people's lives, so they are forced to understand the factors that cause these seasons to be able to predict the activities that will be carried out during those seasons. Both seasons are caused by rainfall. Rainfall is water that drips onto a flat ground surface over a certain period and is measured in mm on a flat surface. Rain is defined as the height of water that drips from the sky and collects in a flat place, does not experience evaporation, and does not infiltrate or does not flow [1].

Rainfall data is processed by an institution called BMKG and is intended for the public, especially farmers. BMKG is a non-departmental government agency that works on meteorology, climatology, and geophysics. BMKG is tasked with running various divisions, such as the communications network center [2]. BMKG processes rainfall data using one method, namely ARIMA, a statistical model used to analyze time series and forecasting [3]. BMKG also uses the Double Exponential Smoothing and Triple Exponential Smoothing methods.

Double exponential smoothing (DES) is a quantitative time series data method with trend patterns. CC Holt introduced it in 1958. This method has advantages: It can be used on quite a small amount of data, uses fewer parameters, and can be applied quickly because it does not require changes when the data is non-stationary [4].

Triple Exponential Smoothing (TES) is a forecasting algorithm using seasonal trend data; like the previous method, this method has an additional gamma constant value to obtain smaller smoothing values and more precise forecast results [5]. The total crime rate can be predicted by comparing the two methods and obtaining the results that using the DES method produces a MAPE value of 20.69552% while forecasting using the TES method produces a MAPE value of 30.48323%, so it is stated that the MAPE value of this method is greater than the previous method. So, the DES method is more accurate in estimating crime rates [6].

The total price of eggs for producers in Sukabumi Regency was predicted by comparing the same 2 methods as previous research and obtained the results that using the DES method produced a MAPE value of 8.77002%. In contrast, the figure for the TES method was 3.584268%, so it was stated that the Triple Exponential Smoothing method produced a value smaller than the DES method. So methods with larger numbers are said to be better used to estimate egg prices [7].

Although both methods have been proven effective in various prediction contexts, there needs to be a clear consensus regarding which method is best for estimating rainfall. Therefore, comparing the two is necessary to evaluate their relative superiority in the context of rainfall prediction. By carrying out this comparison, a more effective and accurate method can be found in modeling and predicting rainfall to positively contribute to decision-making in various sectors related to water resource management and flood disaster risk mitigation.

2. Method

This research uses secondary data that was obtained from the National Aeronautics and Space Administration. The data used is in the form of monthly rainfall data at time intervals for 2019 - 2023. The variable used is rainfall. The methods used for analysis are the Double Exponential Smoothing (DES) and Triple Exponential Smoothing (TES) methods. The criteria used to determine the best model is the smallest MAPE value.

2.1 Data Mining

Data mining includes the Knowledge Discovery in Database (KDD) process stage. Through data mining, we can classify, estimate, and obtain other useful information from large data sets [8]. An example of data in data mining that is used in this research is the forecasting method because this method is quite well-known and is often used in data mining.

2.2 Time Series

Time series is a method for predicting based on previous data on a variable or errors that have occurred sequentially, for example, days, weeks, months, and years **[9]**. This data is usually found in everyday life because it is combined over time at intervals ranging from daily to monthly. From the data that has been collected, you can find out if there is a pattern. The time series pattern is then divided into trend, cyclical, and seasonal patterns **[10]**. Seasonal patterns occur in the same way and repeatedly during specific intervals. Two tools are used to analyze using the time series method: smoothing and decomposition.

Smoothing estimates something based on the principle of averaging the errors that occurred previously by adding the percentage of previous prediction error, which is obtained from the difference between the actual value and the predicted value.

Decomposition estimates something by dividing time series data into several components, such as trend, cycle, seasonality, and random influence; then, it combines predictions from these components except random effects **[9]**.

2.3 Forecast

Forecasting includes methods to plan and control production to deal with something that cannot be determined. These methods are qualitative and quantitative. The qualitative method is based on opinions and descriptive analysis, while the quantitative method is based on mathematical calculations **[10]**.

2.4 Gradient Descent

The gradient descent algorithm is a method for finding the minimum value of a function that will be maximized to represent model errors in the context of machine learning or value functions in various optimization problems. This algorithm uses the basic principle of iteratively descending the "valley" of the function towards the minimum value in the direction of the function's derivative **[11]**.

2.5 Double Exponential Smoothing

The DES method is a forecasting method introduced by CC Holt around 1958 **[12]**. It predicts downwards using new data and requires a parameter α with a value range of 0 - 1. This method often carries out smoothing calculations twice, so it is called Double Exponential Smoothing. The DES method is divided into 2, namely one parameter and two. This research was carried out using the two-parameter DES method. So, the steps that will be carried out to predict the DES method are two parameters, namely **[13]**.

Level formulation:

$$L_t = \alpha X_t + (1 - \alpha) \times (L_{t-1} + T_{t-1}) \quad (1)$$

Trend Formulation:

$$T_t = \beta (S_t - S_{t-1}) + (1 - \beta)\ T_{t-1} \quad (2)$$

Forecasting / Forecasting:

$$F_{t+1} = S_t + T_t \quad (3)$$

Where:

L_t = Standard smoothing value
T_t = Trend smoothing value
X_t = Actual data
F_{t+1} = Forecasting value
α = Alpha parameters
β = Beta parameters

In carrying out predictions using Holt-Winters Exponential Smoothing, the initial smoothing value must be determined and considered in the Additive Holt-Winters and Multiplicative Holt-Winters models. These models use the same method; the difference is in the initial calculation of seasonal smoothing.

The following are the stages in the Holt-Winters Exponential Smoothing calculation, namely:

a. Determine the initial data smoothing value through the use of equations (4), (5), and (6) in the Additive model and (4), (5), and (7) in the Multiplicative model.

1. Initial value of exponential smoothing (SL)

$$S_L = \frac{1}{L}\,(X_1 + X_2 + X_3 + \cdots + X_L \tag{4}$$

L = 1,2,3,..., L where L is the seasonal length.

2. Initial value of trend smoothing (TL)

$$T_L = \frac{1}{L}\,(\frac{X_{L+1} + X_1}{L} + \frac{X_{L+2} + X_2}{L} + \cdots + \frac{X_{L+L} + X_L}{L} \tag{5}$$

3. Initial value of seasonal smoothing (It)

Holt–Winters Additive Model

$$I_t = X_t - S_L \tag{6}$$

Holt–Winters Multiplicative Model

$$I_t = \frac{X_t}{S_L} \tag{7}$$

b. Determine the parameters α, β, and γ. To determine the values of α, β, and γ, use a solver table to obtain the maximum value. The values are 0≤α, β, and γ≤1

c. Calculate the initial smoothing value

Equations (5), (6), and (7) can calculate the initial smoothing value in the Additive model, while equations (9), (10), and (11) are used in the multiplicative model.

The Additive Holt-Winters model is a constant method appropriate for periodic calculations. The basic equation for using this model is:

1. Exponential smoothing

$$S_t = \alpha\,(X_t - I_{t-L}) + (1-\alpha)(S_{t-1} + T_{t-1} \tag{8}$$

2. Trend smoothing

$$T_t = \beta\,(S_t - S_{t-1}) + (1-\beta)T_{t-1} \tag{9}$$

3. Seasonal smoothing

$$I_t = \gamma (X_t - S_t) + (1-\gamma) I_{t-1} \quad (10)$$

4. Period forecasting

$$F_{t+m} = S_t + mT_t + I_{t-L+m} \quad (11)$$

The Multiplicative Holt-Winters model is used on data with constant seasonal variations. The basic equation in using this model is:

1. Exponential smoothing

$$S_t = \alpha \frac{X_t}{I_{t-L}} + (1-\alpha)(S_{t-1} + T_{t-1}) \quad (12)$$

2. Trend smoothing

$$T_t = \beta (S_t - S_{t-1}) + (1-\beta) T_{t-1} \quad (13)$$

3. Seasonal smoothing

$$I_t = \gamma \frac{X_t}{S_t} + (1-\gamma) I_{t-1} \quad (14)$$

4. Period forecasting

$$F_{t+m} = (S_t + mT_t) + I_{t-L+m} \quad (15)$$

Where :

α = Actual data smoothing constant

β = Smoothing constant for trend patterns

γ = Smoothing constant for seasonal patterns

X_t = Actual value/data in period t

S_t = Exponential smoothing value of data in period t

l_t = Seasonal value in period t

T_t = Trend value in period t

m = The number of future periods that will be forecast

F_{t+m} = Forecast value for period t + m

d. Calculate predicted values F_{t+m}

Equation (11) can calculate the predicted value for the Additive model, while equation (15) can be used for the multiplicative model. In the training data, m = 1 is used, and in the testing data, m = 1,2,3,..,12 because the data used is monthly data for one year.

After obtaining the forecast value, the next step is to test the accuracy of the forecast results using MAPE, which is calculated from the difference between the forecast value and the actual value. MAPE is a method that can be used to calculate the accuracy value of the forecasting method and relative determination to determine the deviation of the error results from the predicted data from the actual data. The following is the formula used to calculate MAPE.[14].

$$MAPE = \left(\frac{100\%}{n}\right) \sum_{t=1}^{n} \left|\frac{X_t - F_t}{X_t}\right| \quad (16)$$

Where :

X_t= Actual value in period t

F_t= Forecast value in period t

n = Number of data

The equation above is used to find the MAPE value. Calculating MAPE lets you learn about the method's performance in estimating rainfall, which is presented in **Table 1** [15].

Table 1. MAPE Value Terms

MAPE	Criteria
<10%	Very Good
10% - 20%	Good
20% - 50%	Enough
>50%	Bad

3. Results and Discussion

3.1 Double Exponential Smoothing

The aim of using DES in this research is to combine level smoothing and trend smoothing in calculating average values and trends in past data. Figure 1 shows a graph of the results of rainfall calculations using the DES method. The graph shows the up-and-down movement of data. The graph shows the highest average rainfall pattern in Bojonegoro in 2021. A comparison graph of average rainfall with forecast using the des method is in **Figure 1.**

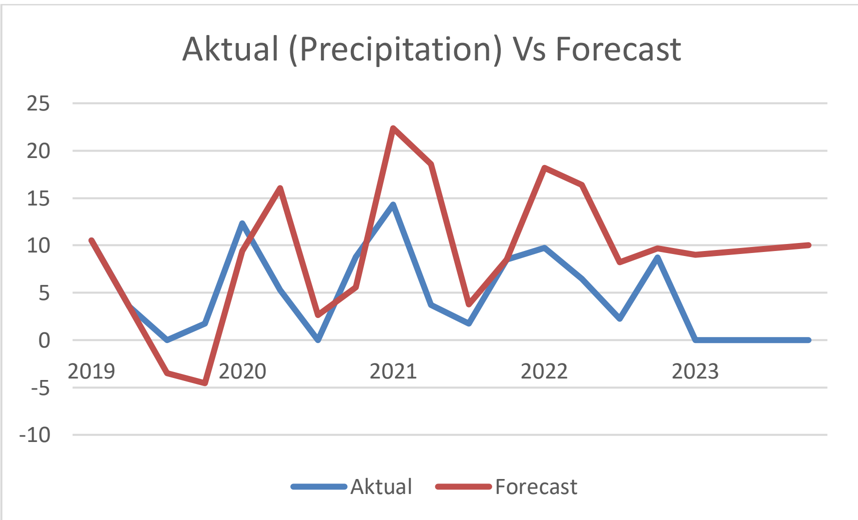

Figure 1. Comparison Graph of Average Rainfall with Forecast Using the DES Method

In the DES method, the error value (MAPE), alpha value, and beta value are needed because, through these three values, the calculation is determined according to the smallest value. Excel software is used to determine the correct alpha through the Solver tool to obtain an accurate alpha for forecasting calculations. The average monthly rainfall data can be seen in **Table 2**.

Table 2. Double Exponential Smoothing for Rainfall Prediction

Year	Quarter	Actual	Levels	Trends	Forecast	Error	APE
2019	1	11.22					1.00
	2	3.67	3.67	-7.56			1.00
	3	0.37	0.37	-6.68	-3.89	4.26	11.57
	4	2.84	2.84	-4.80	-6.31	9.16	3.22
2020	1	11.35	11.35	-2.06	-1.95	13.31	1.17
	2	5.97	5.97	-2.74	9.29	-3.32	0.56
	3	1.76	1.76	-3.04	3.23	-1.47	0.83
	4	8.25	8.25	-1.08	-1.28	9.53	1.16
2021	1	14.33	14.33	0.39	7.16	7.17	0.50
	2	3.79	3.79	-1.86	14.72	-10.93	2.88
	3	1.75	1.75	-1.90	1.93	-0.19	0.11
	4	8.41	8.41	-0.14	-0.15	8.56	1.02
2022	1	9.76	9.76	0.17	8.27	1.49	0.15
	2	6.50	6.50	-0.54	9.94	-3.44	0.53
	3	2.24	2.24	-1.30	5.96	-3.72	1.66
	4	8.55	8.55	0.26	0.94	7.61	0.89
2023	1	10.82	10.82	0.68	8.82	2.00	0.18
	2	3.78	3.78	-0.91	11.49	-7.71	2.04
	3	0.93	0.93	-1.31	2.87	-1.94	2.07
	4	8.90	8.90	0.60	-0.37	9.27	1.04
2024	1				9.50		
	2				10,10		
	3				10.70		
	4				11.30		

Then, carry out the calculation of the error value from the predictions that have been implemented using MAPE according to equation (16)

$$MAPE = \left(\frac{100\%}{n}\right) \int_{t=1}^{n} \left|\frac{X_{t-F_t}}{X_t}\right|$$

$$= \left(\frac{100\%}{48}\right) * (33{,}58)$$

$$= 0{,}6996$$

Based on the formula above, the error result obtained from calculating the prediction of Average Rainfall in Bojonegoro in 2019 - 2023 using the Double Exponential Smoothing method is 0.6996%, so that it can be interpreted as very good. Meanwhile, the MAPE value for the wind speed parameter is 0.1001%, temperature is 0.0530%, and surface pressure is 0.0557%.

3.2 Triple Exponential Smoothing

Figure 2 shows that the average rainfall pattern in Bojonegoro is very diverse. The highest average occurred in February 2021, and the lowest in May to November 2019 and June to September 2020. A comparison chart of average rainfall with forecast using (TES) is presented in **Figure 2**.

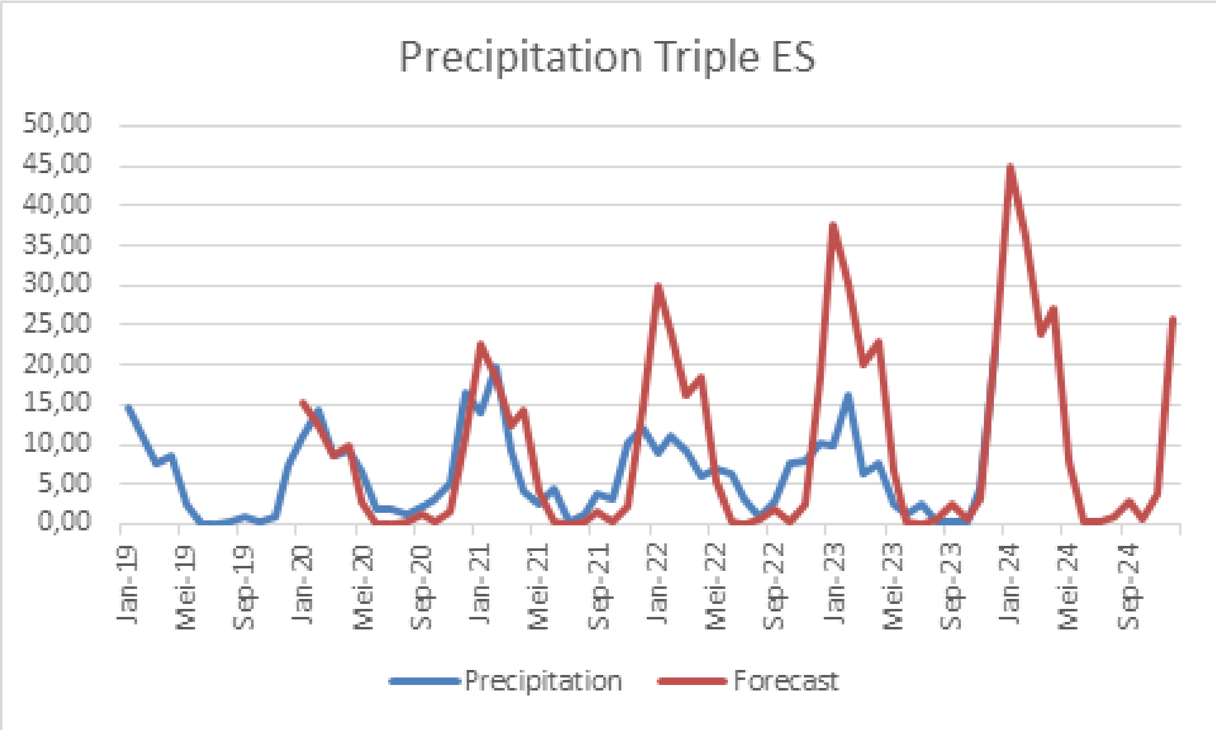

Figure 2. Comparison Chart of Average Rainfall with Forecast Using (TES)

The average rainfall pattern in the figure shows fluctuations yearly, with an increase in rainfall in September and November, while in other months, it tends to decrease. This occurs several times each year, thus showing indications of a seasonal pattern in average rainfall. The figure shows the increase or decrease that happens every year. Observations every month indicate that trend patterns are created in some months, and fluctuations occur in others. **Figure 2** shows that the average rainfall data pattern tends to fluctuate, so the average calculation uses the Multiplicative Model in Holt-Winters Exponential Smoothing. The calculation is that the length of the season (L) is 48 because what is used is per month for one year. Then, the initial value of data smoothing will be calculated using equations (4), (5), and (7), and the following results will be obtained in **Table 3.**

Table 3. Initial Value of Data Smoothing

Year	Month	Rainfall	Level (SL	Trend (TL)	Seasonal (lt)
2019	January	14.58			3.22
2019	February	11.51			2.54
2019	March	7.58			1.67
2019	April	8.46			1.87
2019	May	2.44			0.54
2019	June	0.09			0.02
2019	July	0.04			0.01
2019	August	0.24			0.05
2019	September	0.82			0.18
2019	October	0.17			0.04
2019	November	1.07			0.24
2019	December	7.28	4.52	0.19	1.61

And use a table solver to obtain maximum parameter values for the variables α, β, and γ where the values of α=0, β=0, and γ = 0 and carry out calculations using the Holt-Winters Exponential Smoothing method and using the Multiplicative Model with appropriate. So, the calculation results are obtained in **Table 4.**

Table 4. Comparison of Actual and Predicted Data

Year	Month	Actual Data	Prediction	Difference	Absolute Error (AE)	Squared Error (SE)	Absolute Percent Error (APE)
2020	January	11.08	15.20	-4.12	4.12	16.93	37.13
2020	February	14.38	12.49	1.89	1.89	3.58	13,16
2020	March	8.59	8.55	0.04	0.04	0	0.5
2020	April	9.24	9.9	-0.66	0.66	0.44	7.17
2020	May	6.81	2.96	3.85	3.85	14.80	56.49
2020	June	1.87	0.11	1.76	1.76	3.08	93.96
2020	July	1.76	0.06	1.7	1.7	2.89	96.76
2020	August	1.28	0.32	0.97	0.97	0.93	75.33
2020	September	2.24	1.14	1.10	1.10	1.22	49.18
2020	October	3.31	0.25	3.07	3.07	9.40	92.56
2020	November	4.97	1.58	3.40	3.40	11.54	68.31
2020	December	16.45	11	5.46	5.46	29.90	33.17
2021	January	...	...	...	...	...	...
2022	December	...	...	...	...	...	...
2023	January	9.86	37.51	-27.64	27.64	764.18	280.25
2023	February	16,18	30.10	-13.93	13.93	193.98	86.10
2023	March	6.41	20.14	-13.74	13.74	188.69	214.42
2023	April	7.58	22.85	-15.27	15.27	233.32	201.51
2023	May	2.41	6,7	-4.29	4.29	18.44	178.39
2023	June	1.35	0.25	1.10	1.10	1.22	81.49
2023	July	2.42	0.12	2.30	2.30	5.29	94.88
2023	August	0.24	0.68	-0.43	0.43	0.19	177.91
2023	September	0.14	2.40	-2.26	2.26	5.12	1648.36
2023	October	0.32	0.51	-0.19	0.19	0.04	58.56
2023	November	4.5	3.22	1.28	1.28	1.64	28.45
2023	December	21.88	22.14	-0.26	0.26	0.07	1.19
							5719.19

Forecasting rainfall data for 2024 is presented in **Table 5**.

Table 5. Forecasting Rainfall Data for 2024

Month	Prediction	Difference	Absolute Error (AE)	Square Error (SE)
January	44.94	-44.94	44.94	2019,96
February	35.98	-35.98	35.98	1294.31
March	24.01	-24.01	24.01	576.42
April	27.17	-27.17	27.17	738.31
May	7.95	-7.95	7.95	63.16
June	0.30	-0.30	0.30	0.09
July	0.15	-0.15	0.15	0.02
August	0.80	-0.80	0.80	0.64
September	2.82	-2.82	2.82	7.96
October	0.60	-0.60	0.60	0.36
November	3.77	-3.77	3.77	14,19
December	25.85	-25.85	25.85	668.40

Then, carry out the calculation of error values and predictions that have been carried out using MAPE via equation (16)

$$MAPE = \left(\frac{100\%}{n}\right) \int_{t=1}^{n} \left|\frac{X_t - F_t}{X_t}\right|$$

$$= \left(\frac{100\%}{48}\right) * (5719{,}19)$$

$$= 119{,}1497$$

Based on the formula above, the error result obtained from calculating the prediction of Average Rainfall in Bojonegoro in 2019 - 2023 using the Holt-Winters Exponential Smoothing method using the Multiplicative Model is 119.1497%, which can be interpreted as bad. Meanwhile, the MAPE value for the wind speed parameter is 13.3569%, temperature is 2.7842%, and surface pressure is 0.0602%.

4. Conclusion

Based on the results and discussion, it can be concluded that:

a. Based on the analysis results in estimating average rainfall using the DES method, parameter values are obtained with withα=1, β=0.2. Meanwhile, the results of the analysis in predicting average rainfall use the TES method withα=0, β=0.

b. The results of comparing the DES and TES methods for estimating average rainfall show that the MAPE value for the DES method is 0.6996%, and the TES method is 119.1497%. The MAPE value for the DES method is smaller, so the process is more accurate for estimating average rainfall.

c. After making predictions using these two methods, the best method for this data is the DES method. The resulting MAPE value is smaller than the TES method, and the forecast is experiencing an upward trend.

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