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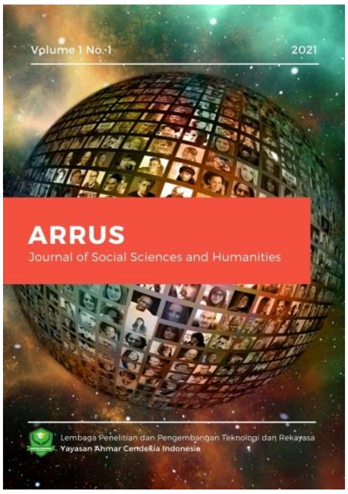

RESEARCH ARTICLE

Rainfall Forecasting in Makassar City Using Triple Exponential Smoothing Method

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Abstract: The purpose of this study is to determine the appropriate forecasting method for predicting rainfall in Makassar City in 2022. This research is based on the problems that are often experienced by the people of Makassar City, namely the occurrence of flooding which results in traffic jams due to high x rainfall which continuously occurs. for several days in a row. With this research, people can see the prediction of rainfall and anticipate flooding in Makassar City. The results of the Makassar city rainfall data plot experience increases and decreases (fluctuations), which tend to repeat every year. This shows that Makassar City's rainfall contains seasonal factors. Therefore the method used is one-parameter Brown triple exponential smoothing, three-parameter Holt-Winters additive and Holt-Winters multiplicative. The forecasting results show that the correct method to use is the Holt-Winters multiplicative method with a parameter value of a=0.001 β=0.15 γ=0.002 which produces a minimum value of MAPE = 1.18 MAD = 136.23 compared to the Brown and Holt-Winters methods additive. Forecasting results using the Holt-Winters multiplicative method show that the highest rainfall occurs from December to April 2022.

Keywords: ainfall, triple exponential smoothing Brown, Holt-Winters additive, Holt-Winters multiplicative

1. Introduction

Rainfall is defined as the amount of water that falls on a flat surface over a specific time period and is measured in millimeters (mm) above a horizontal surface (Suroso, 2006). One of the most common concerns in Makassar City is flooding produced by heavy rain that lasts for several days, causing traffic gridlock. To forecast rainfall, a forecasting system is required. It is impossible to anticipate when rainfall will occur in the absence of a specific method. Forecasting refers to the action of predicting what will happen in the future (forecasting) (Fatimah, 2015; Sudjana, 1989)

Exponential smoothing is a method of forecasting using exponential or tiered weighting on the most recent data, resulting in a moving average that gives the most recent data more weight in the calculation (Biri et al., 2013; Mardiansyah et al., 2016). There are three kinds of exponential smoothing methods: single, double, and triple. Single exponential smoothing is used for data with a steady fluctuation pattern, double exponential smoothing is used for data with a trend pattern, and triple exponential smoothing is used for data with both a trend and a seasonal pattern. Additionally, a triple exponential smoothing method is

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presented in two different types: Brown one-parameter triple exponential smoothing and Holt-Winters three-parameter triple exponential smoothing. The sort of data pattern demonstrates the usage of triple exponential smoothing methods developed by Brown and Holt-Winters. Brown one-parameter method is used for data with quadratic trend patterns, whereas Holt-Winters three-parameter method is utilized for data with seasonal patterns. The Holt-Winters method has two calculations, additive and multiplicative (Kalekar, 2004). When the seasonal data is constant, the additive method is employed, in contrast to the multiplicative computation works for data with variable seasonal impacts (Christnatalis et al., 2019) Essentially, both methods have the same goal: to estimate future events by using past data as a reference in their calculation (Tamasoleng & Iswara, 2020).

The simpler computation method of triple exponential smoothing over other methods is one of its advantages. Furthermore, the triple exponential smoothing analysis is carried out using three smoothing processes and three parameters, yielding higher forecasting results (Gurianto et al., 2016). Another study comparing ARIMA and triple exponential smoothing methods on non-oil and gas export data in East Kalimantan found that triple exponential smoothing was more effective in terms of lower error rates than the ARIMA method (Nurlaily et al., 2022). Rainfall data incorporates seasonal trends. When there is seasonal data, the triple exponential smoothing method can be used to forecast data that contains seasonal elements (Iqbal et al., 2016).

Previous researchers have extensively studied forecasting using the triple exponential smoothing method, such as Sinay, L. J., Pentury, Thomas., and Anakotta, D. (2017) who forecasted rainfall in Ambon city using the triple exponential smoothing method of Holt-Winters with three parameters, and Joshua Dwi Putra and Ida Bagus Ary (2020), who compared the one-parameter Brown triple exponential smoothing method and the three-parameter Holt-Winters method to forecast the occupancy rate of Aston Denpasar Hotel.

2. Research Method

This study was based on secondary data, specifically Makassar City Central Statistics Agency monthly rainfall data from 2018 to 2021. The method applied was triple exponential smoothing, which included the one-parameter Brown method, the three-parameter Holt-Winters additive method, and the three-parameter Holt-Winters multiplicative method.

2.1. Brown Method: one parameter

This method, similar to linear exponential smoothing, can be used to forecast data with a single basic trend pattern. A higher-order smoothing form, on the other hand, can be utilized if the fundamental pattern is quadratic, cubic, or of higher order. This strategy is better suited for forecasting something that varies or experiences waves, which means that changes in the amount of data frequently come suddenly and are difficult to predict.

Single Smoothing : $$S'_t = \alpha Y_t + (1-\alpha)S'_{t-1} \quad (1)$$

Double Smoothing : $$S''_t = \alpha S'_t + (1-\alpha)S''_{t-1} \quad (2)$$

Triple Smoothing : $$S'''_t = \alpha S''_t + (1-\alpha)S'''_{t-1} \quad (3)$$

Total Smoothing : $$\hat{b}_1(t) = 3S'_t - 3S''_t + S'''_t \quad (4)$$

Trend Smoothing : $$\hat{b}_2(t) = \frac{\alpha}{2(1-a)^2}[(6-5a)S'_t - (10-8a)S''_t + (4-3a)S'''_t] \quad (5)$$

Seasonal Smoothing : $$\hat{b}_3(t) = \frac{a^2}{(1-a)^2}(S'_t - 2S''_t + S'''_t) \quad (6)$$

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Forecasting : $F_{t+m} = \hat{b}_1(t) + \hat{b}_2(t).m + \frac{1}{2}\hat{b}_3(t).m^2$ (7)

2.2. Holt-Winters Method: three parameter

The Holt-Winters method consists of the additive and multiplicative Holt-Winters methods. The difference between these two methods is that the Holt-Winters additive method is used for seasonal data variations of time series data that are constant, whereas the Holt-Winters multiplicative method is used for seasonal data variations of time series data that experience fluctuations in increase and decrease (fluctuation) (Christnatalis et al., 2019; Kristianti, 2020).

- Holt-Winters *additive*

Total smoothing :

$$S_t = a(Y_t - I_{t-L}) + (1-a)(S_{t-1} + b_{t-1}) \quad (8)$$

Trend smoothing :

$$b_t = \beta(S_t - S_{t-1}) + (1-\beta)b_{t-1} \quad (9)$$

Seasonal Smoothing :

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

Forecasting :

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

- Holt-Winters multiplicative

Total smoothing :

$$S_t = a\frac{Y_t}{I_{t-L}} + (1-a)(S_{t-1} + b_{t-1}) \quad (12)$$

Trend smoothing :

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

Seasonal Smoothing :

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

Forecasting :

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

3. Results and Discussion

The plot of the rainfall data for the years 2018-2021 can be seen in Figure 1. When data rises and falls in specific periods and has a cyclical or recurrent nature, the data is considered to have a seasonal pattern (Ruhiat & Suwanda, 2019; Sinay et al., 2017). As a result, the graph in Figure 1 visually illustrates a form of seasonal data pattern. The data can then be directly evaluated using the Brown triple exponential smoothing method, Holt-Winters additive and Holt-Winters multiplicative, to establish the best method for

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forecasting rainfall in Makassar in 2022. The best method is the one that minimizes the forecast error value, as measured by the Mean Absolute Percentage Error (MAPE) and Mean Absolute Deviation (MAD) values.

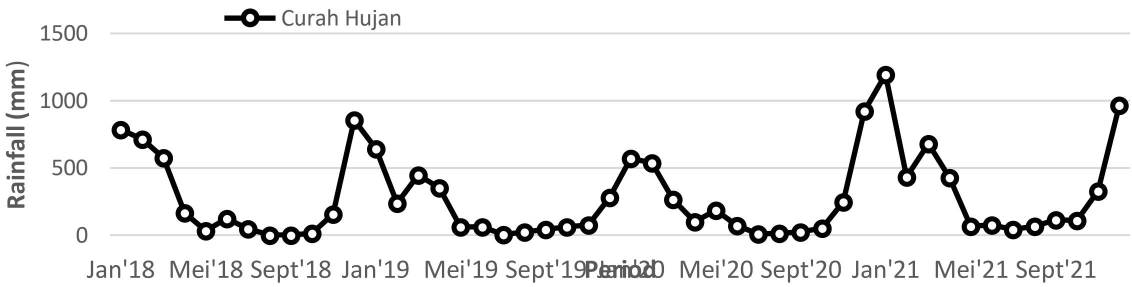

Figure 1. Graph of Rainfall in Makassar City from 2018 to 2021.

2.3. Brown Triple Exponential Smoothing Method

The parameter used in this study is the parameter. According to MAPE and MAD, the ideal parameter selection is based on the minimum error value.

Table 1. MAPE Value and MAD Values of Brown's Method.

***a* Parameter**	**MAPE**	**MAD**
0,1	7,76	250,64
0,2	9,83	259,51
0,3	8,61	246,46
0,4	6,41	223,94
0, 5	**3,45**	**219,56**
0,6	3,68	228,33
0,7	3,54	249,06
0,8	4,21	273,48
0,9	7,21	309,34

The used parameter values vary from 0.1 to 0.9. The lower the error value, the more accurate the forecasting. If the resulting error value is greater, the forecasting outcome is less ideal (Sudiatmika et al., 2022). According to Table 1, the parameter value of $a = 0{,}5$ is the one that minimizes predicting error. Therefore, the parameter value of $a = 0{,}5$ will be used in the Brown method to forecast rainfall in Makassar city in 2022.

$$F_{t+m} = \hat{b}_1(t) + \hat{b}_2(t).1 + \frac{1}{2}\hat{b}_3(t).m^2 \quad (16)$$

$$F_{48+1} = \hat{b}_1(48) + \hat{b}_2(48).1 + \frac{1}{2}\hat{b}_3(48).1^2 \quad (17)$$

$$F_{49} = 903{,}72 + 465{,}83.(1) + \frac{1}{2}(101{,}63).(1^2) \quad (18)$$

$$= 1420{,}36 \quad (19)$$

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$$F_{48+12} = \hat{b}_1(48) + \hat{b}_2(48).12 + \frac{1}{2}\hat{b}_3(48).12 \quad (20)$$

$$F_{60} = 903{,}72 + 465{,}83.(12) + \frac{1}{2}(101{,}63).(12^2) \quad (21)$$

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$$= \quad 13810,97 \tag{22}$$

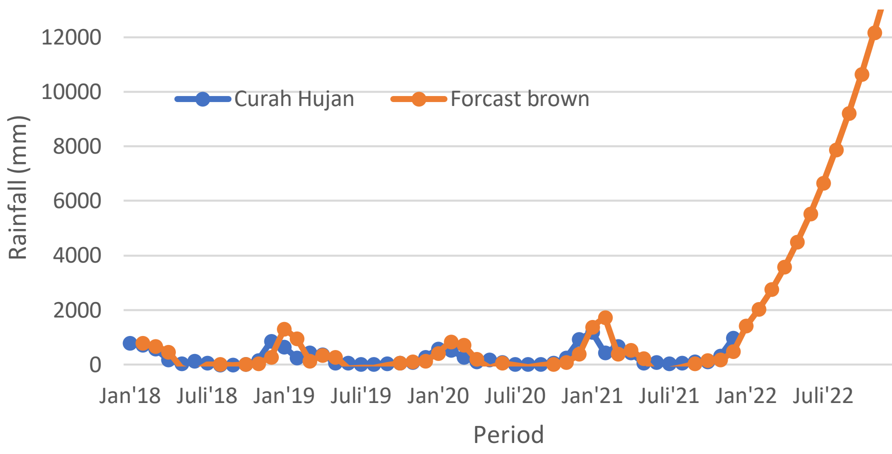

Figure 2. Graph of Rainfall Forecasting Results for Makassar City in 2022 using Brown Method.

Figure 2 demonstrates that the Brown method forecast results are poor. The maximum recorded rainfall is 12,000 mm. When compared to previous data from 2018 to 2021, the highest rainfall figure was only 1000 mm. This shows that the projected number in the Brown method is too far off from the actual data. Consequently, the Brown method is not appropriate for forecasting rainfall in Makassar in 2022.

2.4. Triple Exponential Smoothing Holt-Winters Method

In this study, the values of parameters α, β, and γ and are required, as shown in Table 2.

Table 2. Parameter Values for Holt-Winters Method.

Method	$\boldsymbol{\alpha}$	$\boldsymbol{\beta}$	$\boldsymbol{\gamma}$
Holt-Winters Additive	0,0001	0,1125	0,7423
Holt-Winters Multiplicative	0,001	0,15	0,002

Table 2 compares the values of α, β, γ parameters from both Holt-Winters method (additive and multiplicative). The parameters were chosen through trial and error.

By using the parameters in Table 2, the rainfall forecast results for Makassar city are obtained in Figure 3.
Figure 3 compares the additive and multiplicative rainfall forecast plots. Visually, the Holt-Winters method forecast outputs are very close to the actual data (rainfall). This suggests that the Holt-Winters method produces accurate forecasts.
Table 3 shows the error value of the rainfall forecast in Makassar City in 2022 based on the data that was evaluated using the triple exponential smoothing method.
Table 3 indicates that the Holt-Winters multiplicative method has lower MAPE and MAD values than the Holt-Winters additive method and the Brown method. Accordingly, it suggests that the Holt-Winters multiplicative method is more accurate than the Holt-Winters additive method and the Brown method for forecasting rainfall in Makassar. Table 4 shows the predicted rainfall in Makassar in 2022 using the Holt-Winters multiplicative method.

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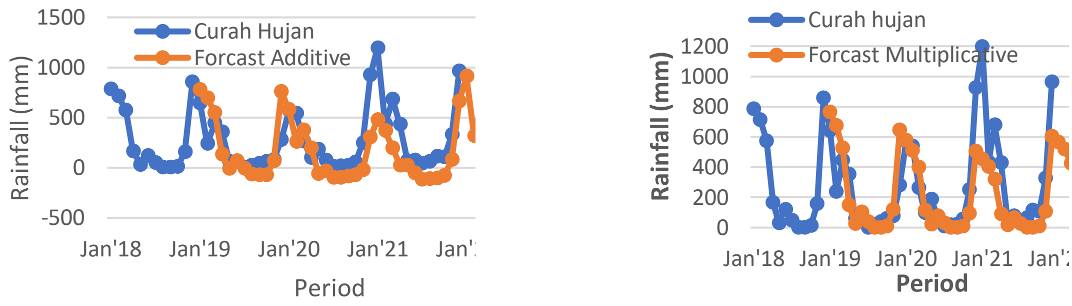

(a) Additive (b) Multiplicative

Figure 3. Forecast Result of Makassar City's Rainfall in 2022 using Holt-Winters Method.

Table 3. Error Values of Rainfall Forecasting in Makassar City for 2022.

Method	MAPE	MAD
Brown	3,45	219,56
Holt-Winters Additive	1,94	199,07
Holt-Winters Multiplicative	1,18	136,23

Table 4. Forecasting of Rainfall in Makassar City for 2022.

Year	Month	Period (t)	Forcasting
2022	January	49	564,35
	February	50	519,46
	March	51	426,20
	April	52	127,31
	May	53	25,16
	June	54	94,49
	July	55	38,86
	August	56	1,07
	September	57	1,25
	October	58	10,49
	November	59	133,13
	December	60	739,98
MAPE			**1,18**
MAD			**136,23**

The forecast findings in Table 4 demonstrate that the rainfall amount is fairly high in the first four months of the period, namely January to April, while it declines from May to October. Then, at the end of the period, in November 2022, the rainfall amount increased significantly from the previous period until December 2022, with December has the highest rainfall amount in 2022 and August has the lowest rainfall amount.

4. Conclusion

Based on the error values obtained, the Holt-Winters multiplicative triple exponential smoothing method is appropriate for forecasting rainfall in Makassar City considering that the Holt-Winters multiplicative method results in lower MAPE and MAD values compared to the Holt-Winters additive and Brown methods. The results of the Holt-Winters

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multiplicative method for predicting rainfall in Makassar City in 2022 suggest that the probability of floods in Makassar City is high between December and the beginning of the year (January-April). Meanwhile, in August, the likelihood of flooding is low because of the low rainfall.

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