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Comparison of Fuzzy Time Series and Double Smoothing Holt Methods for Rainfall Forecasting

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Abstract

This research aims to compare the time series forecasting method, namely the Fuzzy Time Series method, with Double Exponential Smoothing Holt. The data used in this study is the rainfall data of the city of Bandung every month from January 2012 to December 2021. The analysis of the two methods is seen for accuracy according to the measure of error, namely MSE (Mean Square Error) and MAD (Mean Absolute Deviation). The results show that the Fuzzy Time Series method has MSE of 15558.89 and MAD of 108.97. While the Doube Smoothing Holt method has MSE of 23367.79 and MA of 115.94 So the Fuzzy Time Series method is reliable to use for forecasting rainfall in Bandung because the error values is lower than that of the Exponential Smoothing Holt.

Keysword: *Forecasting, Fuzzy Time Series, Double Exponential Smoothing Holt, MSE, MAD.*

1. Introduction

Geographically, Bandung in West Java is an area located at 107°36' east longitude and 6°55' south latitude and has an area of 167.45 sq km. One of the problems in this city is rainfall. High rainfall often causes natural disasters such as floods. Meanwhile, when the rainfall is low, the availability of water is reduced and drought. This problem is influenced by climate change due to air temperature, humidity, rainfall, and other factors that influence it [1]. Rainfall forecasting is very important information. It is used as a reference in planning the activities of several sectors such as agriculture, plantations, fisheries, production, aviation, public services, and so on [2]. In addition, the information is useful for the community and related parties as an early detection as an effort to anticipate disasters that can occur due to extreme rainfall.

The forecasting models are needed to predict the future. Forecasting aims to obtain a pattern of problems based on past data (historical), and obtained periodically in a time series . Forecasting methods based on time series data can be solved using Fuzzy Time Series and Holt's Double Exponential Smoothing method. The Fuzzy Time Series method uses the concept of logic and fuzzy sets. This method accuracy is largely determined by the formation of time intervals to generate linguistic values.[3]. While the Double Exponential Smoothing Holt method is a forecasting method with two smoothing parameters, namely data smoothing parameters (α) and trend smoothing parameters (γ). Both parameters are optimized to produce forecasting accuracy with minimum error size. To measure the accuracy of the forecasting of each method used the value of the difference between the actual value and the value of the forecast results. The difference is the value of Mean Absolute Deviation (MAD) and Mean Square Error (MSE) [4].

The research on the Fuzzy Time Series method has been carried out by [5,6] with the results of forecasting having high accuracy, and research using the Double Exponential Smoothing Holt method by [7,8] with the result that the high accuracy of forecasting is determined by the model parameters and the amount of research data used. The research by [9] that the Exponential Smoothing method has a lower error than the Fuzzy Time Series method. Based on the description above, this study aims to apply the Fuzzy Time

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Series method and the Double Exponential Smoothing Holt method to forecasting rainfall in Bandung. Both methods were evaluated based on MAD and MSE to obtain the right method in producing rainfall forecasts.

2. Research Methodology

The method to analyze the data used is Fuzzy Time Series and Double Smoothing Exponential Holt on time series data. The results of the analysis obtained, then the two methods are compared to find. which is more reliable. method for the level of accuracy.

2.1. Data

The data used is the monthly rainfall data for the city of Bandung from 2012 to 2021 which is sourced from the BPS for the city of Bandung, West Java [10]. The variable is time series data of monthly rainfall.

2.2. Fuzzy Time series

Fuzzy Time Series is a forecasting method based on the concept of fuzzy sets. This method is determined by making appropriate linguistic intervals. Fuzzy concept of average basis (Average Based) in determining the length of the interval is more appropriate to be used for the forecasting process [6].

The stages in forecasting Fuzzy Time Series on an average basis (Chen & Hsu, 2004) [11] are as follows :

1) Determination of the universal set (Universe of Discourse) from historical data, with $U = [X_{min} - D_{1,} X_{mak} + D_2]$, X_{min} : minimum data, X_{mak} : maximum and D_1 dan D_2: positive numbers.
2) Formation of intervals, linguistic distribution of U, and fuzzy set A from set U.
3) Fuzzification of qualitative data, namely the value of the appropriate fuzzy set for each of the actual data,
4) Formation of FLR (Fuzzy Logical Relationship), which is a Fuzzy relation $A_i \rightarrow A_j$ with the enrollment value in step i and the value in step j = i+1. Aj as the current state. If a recurrence relation occurs, it is counted only once.
5) Grouping relations or Logical Relationship Group, namely grouping relations from the current state to a collection of relations next state.
6) Determine defuzzification,; the calculation process to obtain a firm value (crisp) from the fuzzy set. The result of defuzification is the forecasting value. The rules of defuzification and forecasting use Chen's rule [8,11].

2.3. Holt Double Exponential Smoothing

Double Exponential Smoothing Holt is a forecasting method that is exponential smoothing using two parameters (α and), smoothing the exponential value and smoothing the trend value The forecast value is obtained using the following equation [12,13] :

$$A_t = \propto y_t + (1-\alpha)(L_{t-1} + b_{t-1}) \quad (1)$$
$$T_t = \beta(A_t - A_{t-1}) + (1-\beta)T_{t-1} \quad (2)$$
$$F_{t+m} = A_t + T_t m \quad (3)$$

Initialitation :

$$A_1 = y_1 \quad (4)$$
$$T_1 = \frac{(y_2 - y_1) + (y_4 - y_3)}{2} \quad (5)$$

with :

y_t : actual value
At : exponential smoothing valueof time t.
A_{t-1} : exponential smoothing value of time t-1.

T_t : estimated time trend t
T_{t-1} : estimated time trend t-1.
F : prediction result of time t .
m : calculated period
α : data smoothing constant (0 <α < 1)
β : trend smoothing parameter (0 < β< 1)

3. Results And Discussion

The research data are monthly rainfall data for the city of Bandung for 10 years with a total of 120 months for the period January 2012 – December 2021 [10], the data plot is shown in Figure 1.

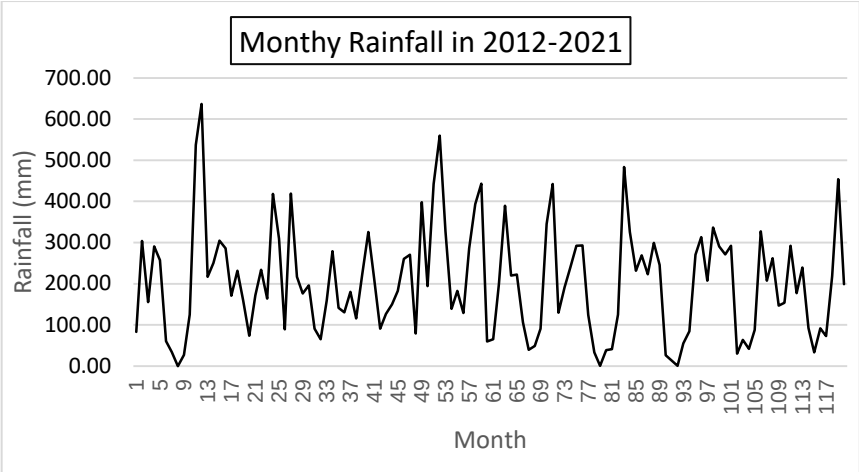

Figure 1. Rainfall (mm) Period January-December 2012-2021

Based on the data plot, the highest rainfall was in December 2012 of 637 mm and the lowest was in August 2012 of 0 mm.

3.1. Fuzzy Time Series Method

With the rainfall data used and the stages of this method, the following results are obtained:

a) The maximum data is 647 and the minimum data is 0, and the universal set is U = [0 ;660]. The average based method produces many classes of 12, length of class 55, the middle value and the set of fuzzy A_i as shown in Table 1.

Table 1. Linguistic Distribution

No.	Linguistic Interval	Middle Value	Fuzzification
1	$u_1 = [0,55]$	27.5	A_1
2	$u_2 = [55,110]$	82.5	A_2
3	$u_3 = [110,165]$	137.5	A_3
4	$u_4 = [165,220]$	192.5	A_4
5	$u_5 = [220,275]$	247.5	A_5
6	$u_6 = [275,330]$	302.5	A_6
7	$u_7 = [330,385]$	357.5	A_6
8	$u_8 = [385,440]$	412.5	A_8
9	$u_9 = [440,495]$	467.5	A_9
10	$u_{10} = [495,550]$	522.5	A_{10}
11	$u_{11} = [550,605]$	577.5	A_{11}
12	$u_{12} = [605,660]$	632.5	A_{12}

b) Fuzzification.
Rainfall data from January 2012 to December 2021 are shown in Table 2.

Table 2. Fuzzification

Month	Rainfall (mm)	Fuzzification	Month	Rainfall (mm)	Fuzzification
1	82.90	A_2	.	…	…
2	303.70	A_6	.	…	…
3	155.50	A_3	….	….	….
4	290.80	A_6	111	292.50	A6
5	257.10	A_5	112	177.30	A4
6	60.50	A2	113	239.00	A5
7	34.20	A1	114	92.40	A2
8	0.00	A1	115	33.20	A_1
9	27.00	A1	117	73.00	A_2
10	125.00	A3	118	218.40	A_4
11	537.00	A10	119	454.30	A_9
12	637.00	A12	120	198.50	A_4

Actual rainfall data for January 2012 is 82.90 mm , and the result of fuzzification is A_2 , and so on.

c) The formed FLR is the fuzzy set relation Ai to be shown in Table 3.

Table 3. FLR

Time Series	FLRG
Jan-12 → feb-12	$A_2 \rightarrow A_6$
Feb-12→ March-12	$A_6 \rightarrow A_3$
March-12 → April-12	$A_3 \rightarrow A_6$
April -12 → May-12	$A_6 \rightarrow A_5$
May-12 → June-12	$A_5 \rightarrow A_2$
……	.....
August.21 → Sept.-21	$A_2 \rightarrow A_2$
Sept-21 → Oct-21	$A_2 \rightarrow A_4$
Oct-21 → Nov-21	$A_4 \rightarrow A_9$
Nov-21 → Dec-21	$A_9 \rightarrow A_4$

d) The formed FLRG are shown in Table 4.

Table 4. FLR Group

No	Fuzzy	FLRG	No.	Fuzzy	FLRG
1	A_1	A_1, A_2, A_3	7	A_7	A_6, A_9
2	A_2	$A_1, A_2, A_4, A_5, A_6, A_7, A_8$	8	A_8	$A_4, A_5 A_6, A_9$
3	A_3	$A_1, A_2, A_3, A_4, A_5, A_6, A_7 A_8, A_9, A_{10}$	9	A_9	A_2, A_3, A_4, A_6
4	A_4	$A_2, A_3, A_4, A_5, A_6, A_7, A_8, A_9$	10	A_{10}	$A_2, A_3, A_4, A_5, A_{11}$
5	A_5	$A_1, A_2, A_3, A_4, A_5, A_7$	11	A_{11}	A_5
6	A_6	$A_1, A_2, A_3, A_4, A_5, A_6, A_7, A_8$	12	A_{12}	A_4

$A_1 \rightarrow A_1, A_2, A_3,$ the meaning A_1 is related to A_1, A_2 and A_3 so on.

e) Defuzzification. Defuzzification and calculation of rainfall forecasting for Bandung City from January 2012 to December 2021 based on forecasting rules. The results of defuzzification are shown in table 5.

Table 5. Forecasting Defuzzification

No	Fuzzy	Defuzzification	No.	Fuzzy	Defuzzification
1	A_1	82.5	7	A_7	385
2	A_2	231.786	8	A_8	302.5
3	A_3	232.222	9	A_9	178.75
4	A_4	275	10	A_{10}	258.5
5	A_5	159.5	11	A_{11}	302.5
6	A_6	200.357	12	A_{12}	192.5

f) Forecast Results. The results of rainfall forecasting for Bandung City from January 2012 to December 2021 re shown in the Table 6. following.

Table 6. Forecasting Value Month Rainfall Forecast Fuzification

Month	Rainfall (mm)	Fuzzification	Forecast Fuzzification (mm)
1	82.90	A_2	231.79
2	303.70	A_6	200.36
3	155.50	A_3	232.22
4	290.80	A_6	200.36
5	257.10	A_5	159.50
…			
116	91.80	A_2	231.79
117	73.00	A_2	231.79
118	218.40	A_4	275.00
119	454.30	A_9	178.75
120	198.50	A_4	275.00

Table 6. shows that the predicted rainfall forecast for December 2021 is 275.00 mm. While the forecast for January 2022 is 275 mm, this results in the fuzzification of FLR process, namely the relation $A_9 \rightarrow A_4$ and the defuzzification of the FLRG namely A_4. The plot of the actual value and the forecast value s shown in the following Figure 2.

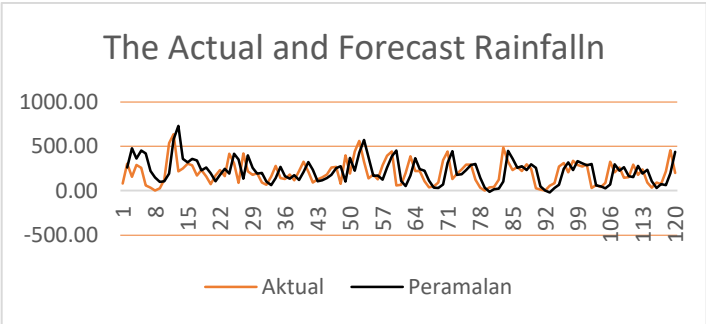

Figure 2. Graph of Actual Value and Fuzzy Time Series Value

The measurement of accuracy of this ethod in the table produces an MAE value of 108.97 and an MSE of 15588.89.

3.2. Holt's Double Smoothing Method

By using equations (1) , (2), (3), (4), (5) and computer-assisted calculations, the forecast value is obtained every month. Optimal forecasting values obtained for parameters $\alpha = 0.84$ and $\beta = 0.1$ are shown in Table 7.

Table 7. Smoothing and Forecasting of the Double Smoothing Method

Month	Rainfall(mm)	At	Tt	Forecast
1	82.90	82.90	178.05	
2	303.70	296.81	181.64	260.95
3	155.50	207.51	154.54	478.45
4	290.80	302.28	148.56	362.06
5	257.10	288.30	132.31	450.84
…				
118	218.40	193.50	3.81	63.81
119	454.30	412.91	25.37	197.31
120	198.50	237.12	5.25	438.28

Based on Table 7. the predicted rainfall forecast for December 2021 is 438.28 mm, while the forecast for January 2022 is 242.37 mm. The plot of the actual value and the forecast value is shown in Figure 3.

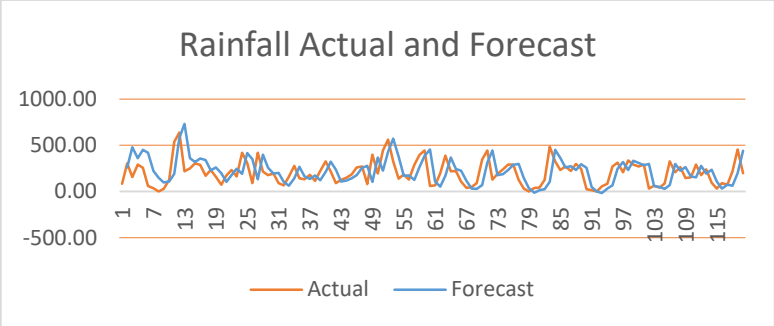

Figure 3. Graph of the Actual Value and Holt . Double Smoothing Value

The measurement accuracy of this method resulted in an MAE of 115.93 and an MSE of 23367.79.

3.3. Forecasting Comparison

Results the two forecasting methods are shown in the following Figure.4.

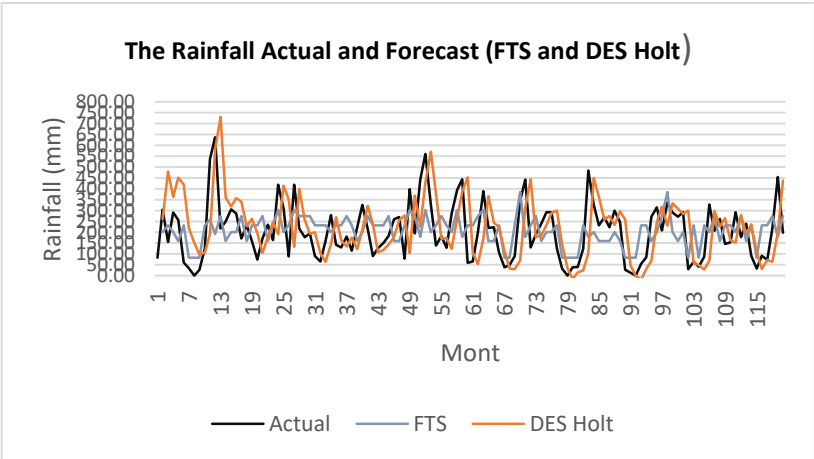

Figure 4. Graph of Actual , FTS, DES Holt Value

Base on Table 6. and Table 7., and Figure 4. , the forecast results for the actual December value of 198.50 mm, the forecast value of the FTS method is 275 mm and the DES Holt method is 438.28 cm.

Method	MAD	MSE
FTS	108.704	15588.89
DES Holt	115.9337	23367.79

Based on Table 9, The forecasting accuracy of the Fuzzy Time Series method is higher than the Double Smoothing method seen from the calculation results of the MAE and MSE values which are smaller than the Double Exponential Smoothing Holt method.

4. Conclussion

The Based on the analysis, the results of monthly rainfall forecasting for the city of Bandung were obtained using the Fuzzy Time Series (Average Based) and Double Exponential Smoothing Holt methods for January 2012 to December 2021. Fuzzy Time Series Prediction results for rainfall forecasts for January 2022 which is 275 mm , and the Double Exponential Smoothing Holt method is 242.37 mm.

The Fuzzy Time Series method based on the average is more appropriate for predicting rainfall in the city of Bandung than the Double Smoothing method, because the MAE and MSE values of the Fuzzy Time Series method are smaller than the value of the Double Exponential Smoothing Holt method.

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