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Rainfall Forecasting in the City of Pekanbaru Using the Exponential Smoothing Method

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Abstract - *Rainfall is one of the main components in the climate system that has a major influence on various sectors, such as agriculture, transportation, and disaster management. The city of Pekanbaru in Riau Province has tropical climate characteristics with varying levels of rainfall throughout the year. Therefore, a forecasting method is needed that is able to accurately predict rainfall. This study aims to identify the most suitable forecasting model for rainfall data in the region. The two methods used in this study are Single Exponential Smoothing (SES) and Holt's Double Exponential Smoothing (DES). The results of the analysis showed that the SES method provided a higher level of accuracy compared to the DES Holt method, with a MAPE value of 33.37%. Thus, the SES model is considered the best method in predicting rainfall in the city of Pekanbaru.*

Keywords: *Rainfall, Exponential Smoothing, Forecasting.*

1. Introduction

Climate reflects the average of conditions such as air temperature, precipitation, air pressure, wind direction, humidity, and other climatic elements over a long period of time. Rainfall is a natural phenomenon that has a great influence on daily life [1]. The Indonesian Maritime Continent is the largest contributor to rainfall in the world, as shown by the mass of water vapor present in the atmosphere at an altitude of 500 millibars of about 50 grams/. One of the factors that affect the weather and climate in this region is the monsoon. Among the various monsoon cycles in the world, the Asian and Australian monsoons are the most dominant 〖cm〗^2[2]. Countries with tropical climates, such as Indonesia, rely heavily on rainfall predictions for many sectors such as agriculture, aviation, and shipping [3].

This climatic condition is also clearly seen on the island of Sumatra itself, Riau province is mostly tropical in the city of Pekanbaru, with a maximum air temperature of 34.1-35.C and a minimum air temperature of 20.2-23 C. Annual rainfall that occurs ranges from 38.6-435.0 mm, and the rainy season lasts from January to April and the dry season lasts from May to August. The highest humidity reaches 96-100% and the lowest humidity touches 46-62%6^° 0^° [4]. Climate characteristics like this show how important it is to understand weather forecasting in order to reduce the risk of natural disasters that will occur.

Rainfall forecasting can be done using a variety of methods time series, one of which is the Exponential smoothing. This method is one of the advanced forecasting methods of moving averages and is easy to use [5]. Method Exponential Smoothing divided into 3 namely Single Exponential Smoothing, Double Exponential Smoothing, and Triple Exponential Smoothing [6]. However, in this study, we will only discuss 2 methods, namely the Single and Double Exponensial Smoothing just.

Several studies related to forecasting with the Exponential Smoothing has been done by Humairo' Dyah Puji Habsari et al [7] In 2020 this study aims to determine the forecasting method Double Exponential Smoothing best based on the smallest MAPE value and verification of the best forecasting method based on the tracking signal controller graph. Based on the forecasting results using the Double Exponential Smoothing with the parameters $\alpha = 0.9$ and $\beta = 0.1$ in March was 139,574, April was 139,914, and for May was 140,254.

In 2023, Hasina Tazkiyya Fitriani et al [8] conducting research on Analysis of Forecasting the Amount of Rice Production in West Java Using the Method Single Exponential Smoothing. The purpose of this study is to determine the best forecasting model using the SES method and estimate rice production in West Java for the next 5 periods. The results of the study showed that the best parameter used was alpha of 0.9 with a MAPE of 5.42%. So the estimated rice production in 2024-2028 is 9,126,433 tons.

According to Raden Mohammad Reski Imam Dwiyanto et al [9] in 2024. This study aims to compare the accuracy of the two

models in forecasting data time series, especially rainfall data in Kendari City using the exponential smoothing. Based on the RSME, MAE, and BIC secretariats, it shows that the Winter's Exponensial Smoothing The best with an alpha of 0.85, gamma of 0.05 and delta of 0.001. Based on the literature and relevant studies above, the author is interested in conducting a research study entitled Title of Rainfall Forecast in Pekanbaru Using the Method Exponential Smoothing.

2. Theoretical Foundations

2.1. *Rainfall*

Rain is the precipitation of liquid falling from the atmosphere in liquid or frozen form to the earth's surface in liquid form. For rain to occur, a thick enough layer of atmosphere is needed so that the air temperature above the earth's surface is above the melting point of ice. This process starts from condensation, which is the change of water vapor in the air into water droplets that are heavy enough to fall to the ground. Before it rains, the air usually becomes saturated due to cooling or due to an increase in water vapor in the atmosphere. Raindrops that fall vary in size, ranging from large to very small [10].

Rainfall it is the amount of water that falls to the surface of the ground in a certain period of time, for example per day, per week, per month, or in a year. The unit used to measure it is millimeters (mm), which indicates the height of water on a flat surface. In simple terms, rainfall shows how much water falls and collects in a flat area, without evaporation, absorption into the soil, or flow elsewhere [11].

Increased rainfall, as happened in the city of Pekanbaru, will have the potential to cause various problems, such as flooding on a number of roads and certain areas. In addition, other unexpected disasters can also occur, so that they can hinder the activities of the people affected by the flood. Therefore, it is important to know disaster prevention efforts from an early age, so that the people in Pekanbaru City can handle emergency situations quickly and appropriately [4].

2.2. *Forecasting*

Forecasting is the process of estimating future needs, both in terms of quantity, quality, time, and location needed to meet the demand for goods or services. This activity is carried out to predict future events by making a plan in advance. The plan is prepared based on the capacity and ability of demand or production that has been carried out previously [12]. In the forecasting method, there are several quantitative categories, especially the time series model *(timeseries)* There are several methods, namely the *Naïve*, moving average *(moving average)* and exponential smoothing *(exponential smoothing)*.

Method *exponential smoothing* is an evaluation of the *Moving Average* which are generally used to solve time series problems [13]. Based on the number of smoothings, the *exponential smoothing* can be divided into several types, namely the *Single Exponential Smoothing (SES), Double Exponential Smoothing (DES), dan Triple Exponential Smoothing (TES)*. The SES method can be used on data that has a stationary pattern. The DES Holt and DES Brown methods can be used on data that have a trend pattern. TEST Method *Holt-Winter* can be used on data that shows trend patterns as well as seasonality [14]. The method used to determine the best parameters usually uses trial and error [15]. However, in this study, only the *single exponential smoothing* (SES) only.

SES is an exponential smoothing method using a single stationary value smoothing parameter. Forecasting using the SES method is obtained with the following equation:

$$Y_{t+1} = \alpha X_t + (1 - \alpha) Y_t \quad (1)$$

with:

Y_{t+1} : Forecast value in the next period

α : Smoothing parameters

X_t : Actual value in period t

Y_t : Forecast value in period t

This SES method is very suitable for data that does not experience significant pattern changes, because the forecast is calculated from the combination of previous data and the latest data.

2.3. *Calculation of Forecasting Accuracy*

There are various methods that can be used in forecasting. However, not all methods are suitable for every type of data. The suitability of forecasting methods is usually determined by the degree of accuracy produced. In general, there are three types of calculations used to measure the error rate in the forecasting process, namely:

1. MAD *(Mean Absolute Deviation)*

   MAD is a calculation used to calculate the absolute average error [16], with the formula [17]:

$$MAD = \frac{\sum |Actual - Forecasting|}{n} \quad (2)$$

Based on formula (2.2), it can be interpreted that it is the result of a subtraction between the actual value and the forecast of each period which is then in the $\sum |Actual - Forecasting|$*absolute*-right, and then the summation of the results of the reduction is carried out. And *n* is the number of periods used for the calculation [18].

2. MSE *(Mean Square Error)*
   MSE is a calculation used to calculate the average of the rank error[16], with the formula [17]:

$$MSE = \frac{\sum|Actual-Forecasting|^2}{n} \quad (3)$$

Based on formula (2.3), it can be interpreted that it is the result of subtraction between the actual value and the forecast that has been squared, then the sum of these results is added. And $\sum|Actual - Forecasting|^2 n$ is the number of periods used for the calculation [18].

3. MAPE *(Mean Absolute Percent Error)*
   MAPE is a calculation used to calculate the average percentage of absolute error [16], with the formula [17]:

$$MAPE = \sum\left(\frac{|Actual-Forecasting|}{actual}\right) \times \frac{100}{n} \quad (4)$$

Based on formula (2.4), it can be interpreted that it is the result of subtraction between the actual value and the forecast that has been $\sum\left(\frac{|Actual-Forecasting|}{actual}\right)$*absoluted*, then divided by the actual value per respective period, then the sum of these results is added. And *n* is the number of periods used for the calculation. The lower the MAPE value, the ability of the forecasting model used can be said to be good, and for MAPE there is a range of values that can be used as a measurement material regarding the ability of a forecasting model, the range of values can be seen in table 1

Table 1. *MAPE Value* Range

Range	Information
$< 10\%$	Excellent forecasting model capabilities
10-20%	Good forecasting model capabilities
20-50%	Feasibility of the forecasting model
$< 50\%$	Poor forecasting model capabilities

Based on Table 2.1, the MAPE value can be classified after the feasibility category of a method used in forecasting. MAPE is used if the size of the forecasting variable is an important factor in evaluating the accuracy of the forecast. MAPE provides clues to how much of the forecasting error is compared to the actual value of the series [18].

3. Research Methodology

The following are the stages that will be carried out in forecasting rainfall in the city of Pekanbaru using the exponential smoothing method:

1. Data collection
   The data used is rainfall data in the city of Pekanbaru in 2022-2024.
2. Testing the parameters
   Parameter testing of single exponential smoothing and double exponential smoothing methods was carried out by trial and error with the help of the minitab for windows application.
3. Choosing a parameter
   The selection of parameters for each type of exponential smoothing method is carried out by selecting the parameters that meet the smallest MAPE (Mean Absolute Percentage Error) accuracy test.
4. Choosing the best method
   The selection of the best method was carried out by comparing the results of rainfall forecasting and the method that had the smallest accuracy of MAD, MSD, and MAPE was selected.

4. Results and Discussion

4.1. Statistics Descriptive

The data used are secondary data on rainfall results at the SSK II Pekanbaru Meteorological Station in 2022 – 2024 which is presented in 2 table below:

Table 2. Rainfall Data at Stamet SSK II Pekanbaru.

Rainfall (mm)			
Moon	**Year**		
	2022	**2023**	**2024**
January	299	184	286

February	291	271	307
March	214	251	183
April	417	176	287
May	274	193	378
June	268	201	355
July	91	94	51
August	199	184	160
September	311	205	79
October	343	154	207
November	342	385	476
December	206	508	268
Sum	**3255**	**2806**	**3037**

Source: Sultan Syarif Kasim II Meteorological Station Pekanbaru

The first stage in this study is to observe the data patterns. This can be done visually by paying attention to the time sequence graph in Figure 1 below:

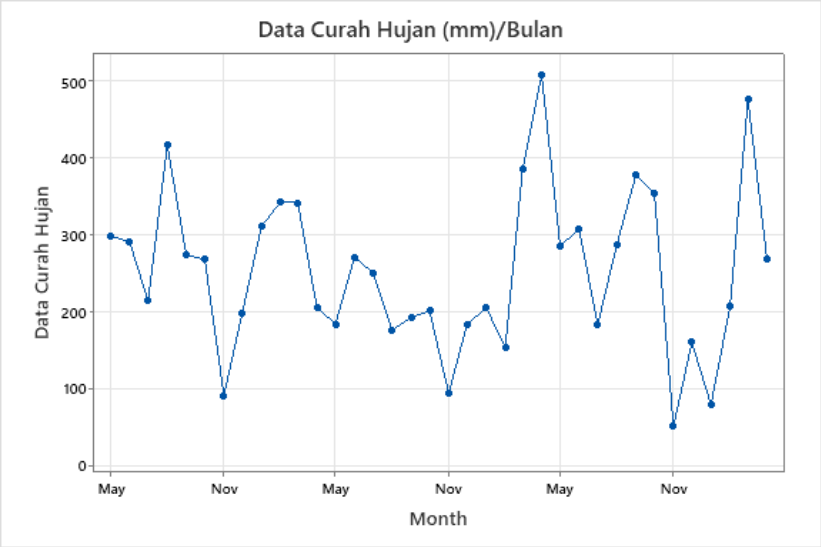

Figure 1. Rainfall Time Graph

Based on rainfall data in Pekanbaru during 2022–2024, there is a trend pattern with the highest increase in 2022, a decrease in 2023, and a slight increase in 2024. Seasonally, rainfall tends to be higher at the end of the year, especially December, with the peak occurring in December 2023. Meanwhile, the lowest rainfall was recorded in September and October 2024. This pattern shows strong seasonal trends and variations, with rainfall intensity higher at the end of the year and less in the middle of the year.

4.2. Forecast Results

Forecasting is carried out using *the Single Exponential Smoothing method with*the help of *Minitab for windows software.* In the *Exponential smoothing* method, the best parameter smoothing value will first be determined to calculate the magnitude of the error in the forecast. The parameter values in this study were selected based on the smallest MAD, MSD and MAPE values. Before forecasting using *the Single Exponential Smoothing method*, parameter testing is first carried out with the help of the Minitab application. After the testing process, the value of the best alpha parameter will be determined to calculate the error rate in the forecast results. The calculation results for each of these alpha values will then be summarized in the following Table 3.

Based on Table 3, it can be seen that different α values give different results for each evaluation metric. At giving a MAD value of 83.01, MSD of 12807.35 and MAPE of 33.37% and being the best $\alpha = 0{,}2$ parameter value α because it produces the smallest error accuracy rate. After the value is selected, then Single Exponential Smoothing forecasting is carried out at the rainfall

level in the form of a model as follows:$\alpha = 0{,}2$

$$Y_{t+1} = 0{,}5X_t + (1 - 0{,}5)Y_t$$

Table 3. Recapitulation of Accuracy Values of SES Forecasting Method Parameters

A	MAD Value	MSD Value	MAPE value (%)
0,1	86,65	12359,70	33,59
0,2	**83,01**	**12807,35**	**33,37**
0,3	83,78	13216,24	34,60
0,4	86,69	13570,71	36,47
0,5	89,20	13908,11	37,97
0,6	91,36	14260,95	39,26
0,7	93,48	14657,48	40,74
0,8	95,61	15129,09	42,76
0,9	98,01	15713,25	45,80

With this model, a rainfall level forecast is produced which is presented in figure 4.2

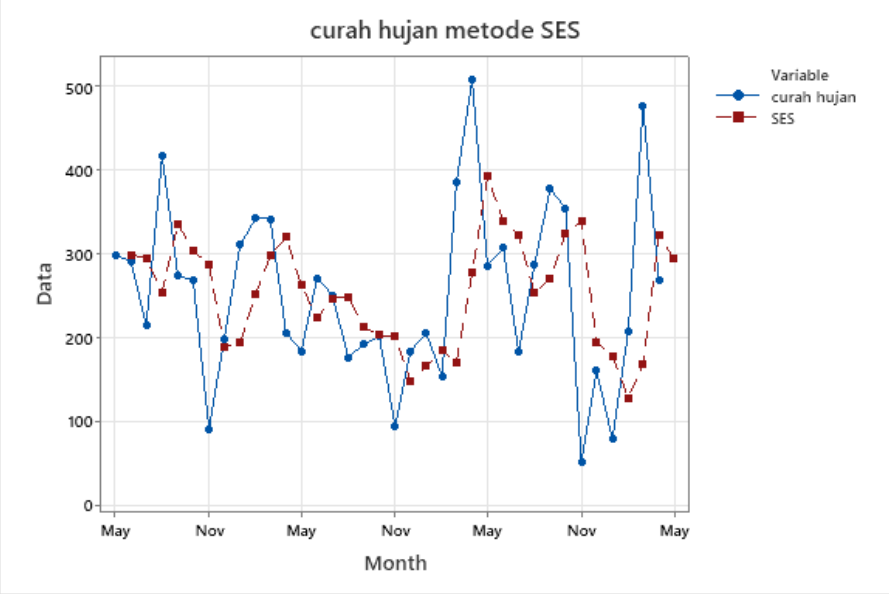

Figure 2. SES Forecast Results Graph

Based on Figure 2, it can be seen that the results of the forecasting calculation using the SES method follow the model of the movement of the actual value of rainfall. In addition, the distance between the forecast movement and the actual data movement is not too much different. So that through the image it is known that the SES method has a decent forecasting model capability After it is known that *the Single Exponential Smoothing (SES) method* is suitable for rainfall forecasting, the forecasting results using this method with the parameter α = 0.2 are presented in Table 4.

Table 4. SES Method Forecasting Results

Year	Rainfall Data		Forecasting
2022	January	299	
	February	291	299
	March	214	297,4
	April	417	280,72
	May	274	307,98

	June	268	301,18
	July	91	294,54
	August	199	253,84
	September	311	242,87
	October	343	256,49
	November	342	273,80
	December	206	287,44
2023	January	184	271,15
	February	271	253,72
	March	251	257,18
	April	176	255,94
	May	193	239,95
	June	201	230,56
	July	94	224,65
	August	184	198,52
	September	205	195,62
	October	154	197,49
	November	385	188,79
	December	508	228,04
2024	January	286	284,03
	February	307	284,42
	March	183	288,94
	April	287	267,75
	May	378	271,60
	June	355	292,88
	July	51	305,30
	August	160	254,44
	September	79	235,55
	October	207	204,24
	November	476	204,80
	December	268	259,04

From the results of the forecasting, it can be seen that the forecasting carried out is not much different from the actual data, so it is true that this method is worth using.

5. Conclusion

Based on the forecasting results using *the Single Exponential Smoothing* (SES) method with the best alpha parameter of 0.2, it can be concluded that this method is able to produce rainfall forecast results that are quite accurate and close to the actual data value. This can be seen from the low error evaluation values (MAD, MSD, and MAPE) as well as the graph of forecasting results that follow the actual data movement pattern. In addition, the distance between the forecast value and the actual value is not too much different, which suggests that the SES method is very feasible to use to forecast future rainfall data

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