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Analysis of Rainfall Prediction in Lampung Province using the Exponential Smoothing Method

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ABSTRACT

This research aims to predict annual rainfall in Lampung Province using the Exponential Smoothing method. The data used in this research is annual rainfall data from January 2010 to December 2022. The 156 months data rainfall is from the Badan Pusat Statistik (BPS) of Lampung Province. The results of data analysis state that annual rainfall in Lampung Province contains a seasonal pattern. The results of this research state that the Triple Exponential Smoothing (TES) Holt-Winter's method is a suitable model for predicting annual rainfall data in Lampung Province because it has a small Sum Square Error (SSE) value 1152255 with the parameters α , β, and γ respectively being 0.2158, 0.0298, and 0.2380. Forecasting using the Triple Exponential Smoothing (TES) Holt-Winter's method shows that rainfall in Lampung Province will increase in the next year.

Keywords: Exponential Smoothing, Rainfall, Seasonal, Sum Square Error

I. INTRODUCTION

Rain is the most critical factor in hydrological analysis. Rain events can be classified into two groups: actual rain and target rain. Rainfall can be classified into daily rainfall, maximum daily rainfall, monthly rainfall, and annual rainfall. Daily rainfall is a record of rainfall that occurs several times at the rainfall observation point every day (24 hours). Maximum daily rainfall is the leading daily rainfall in the observation year at a particular station. Monthly rainfall is the total rainfall from daily rainfall during a month observed at a specific rainfall station. Annual rainfall is the total rainfall from monthly rainfall observed at a particular station of rainfall [1]. In recent years, Lampung Province has experienced erratic weather conditions. Therefore, it is necessary to have precise information regarding the amount of rainfall and the time and duration of rainfall.

One method commonly used to forecast time series data is Exponential Smoothing. The Exponential Smoothing method is a technique for predicting units of time in the future [2]. The Exponential Smoothing method can be carried out using three approaches, namely using the Single Exponential Smoothing (SES) technique, which refers to explicit level (Error) modeling; Holt's Double Exponential Smoothing (DES) technique, which relates to level and trend modeling, and the Triple Exponential technique Holt-Winter's Smoothing (TES) which refers to level, trend and seasonal modelling [3].

In recent years, Lampung Province has experienced weather conditions that tend to be unpredictable and difficult to predict [4]. Therefore, clear information is needed regarding the amount of rainfall and the time/period. Thus, this research aims to predict the amount and period of rainfall using the Exponential Smoothing method. The exponential smoothing method is used in this research because the data used uses time series data with a single variable. So, this research only analyzes the amount of rainfall based on historical monthly rainfall data in Lampung Province.

II. METHODS AND DATA

Exponential Smoothing Method and Sum Square Error

The Exponential Smoothing method is a technique for predicting units of time in the future, namely $t+1$ (if the known past data is X_t), can use a weighted average of past data and has the following general form as follows.

$$S_{t+1} = \sum_{i=0}^{\infty} \beta_i X_{t-i} \qquad (1)$$

In the Exponential Smoothing method, the S_{t+1} is standard smoothing value, the parameter β_i value is given as a geometric weight and trend constant, as follows.

$$\beta_i = \alpha(1-\alpha)^i, \qquad 0 < \alpha < 1 \qquad (2)$$

with the parameter α is level constant.

The Single Exponential Smoothing (SES) method [5] uses the following equation to carry out the forecasting process.

$$F_{t+1} = \alpha X_t + (1-\alpha)F_t \qquad (3)$$

with the F_t is prediction value.

Holt's Double Exponential Smoothing (DES) method [5, 6] uses the following equation in carrying out the forecasting process.

$$L_t = \alpha X_t + (1-\alpha)(L_{t-1} + b_{t-1}) \qquad (4)$$

$$b_t = \beta + (L_t - L_{t-1})(1-\beta)b_{t-1} \qquad (5)$$

$$F_{t+m} = L_t + b_t m \qquad (6)$$

with the L_t is level smoothing value, b_t is trend smoothing value.

Holt-Winter's Triple Exponential Smoothing (TES) method [5-8] is divided into two approaches, the Multiplicative Seasonal model and the Additive Seasonal model, respectively, using the following equations in the forecasting process.

$$X_t = (\beta_1 + \beta_2 t)S_t + \varepsilon_t \qquad (7)$$

$$X_t = \beta_1 + \beta_2 t + S_t + \varepsilon_t \qquad (8)$$

The Sum Square Error (SSE) formula in statistics is used to describe how well the data being modeled is represented by a model. The sum of squares formula is used [9]

$$SSE = \sum_{i=0}^{n} (X_i - \bar{X})^2 \qquad (9)$$

where means of the value

$$\bar{X} = \frac{1}{n}\sum_{i=0}^{n} X_i \qquad (10)$$

Rainfall Data Observations

The annual rainfall data used in this research results from rainfall observations in Lampung Province over 13 years. This rainfall data was taken from the website *Badan Pusat Statistik* (BPS) of the Lampung Province [10]. Using a visual representation, the yearly rainfall in Lampung Province during the period January 2010 to December 2022 is illustrated through a line diagram in Fig. 1.

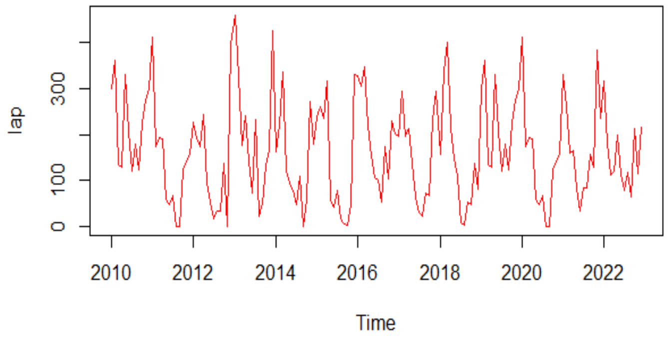

Figure 1: Annual rainfall graph in Lampung province for the period January 2010 to December 2022

It can be seen that the annual rainfall pattern in Lampung Province varies greatly. The highest rainfall occurred in 2013, while the lowest occurred in 2020. The yearly rainfall pattern in Fig. 1 also shows annual fluctuations, with a tendency for high rain to appear in the first trimester of each year, namely from January to March. Meanwhile, in other months, rainfall levels tend to be lower. This pattern repeats itself yearly, indicating seasonal variations in rainfall data in Lampung Province. In Fig. 1, it can be seen that rainfall data for 13 years shows significant fluctuations every year, with a marked increase or decrease. Annual observations show trend patterns are formed in specific years while other years' experience fluctuations. Therefore, indications of trend patterns in rainfall data need to be more robust [11].

TABLE I

STATISTICAL DESCRIPTION OF RAINFALL DATA FOR LAMPUNG PROVINCE FOR THE PERIOD JANUARY 2010 TO DECEMBER 2022

Maximum rainfall (mm)	459.80
Minimum rainfall (mm)	0.00
Average rainfall (mm)	164.59
Standard Deviation rainfall (mm)	77.00

The average monthly rainfall in Lampung Province for the period January 2010 to December 2022 is 164.59, with a standard deviation of 77.0014. This shows that over the last 13 years, monthly rainfall in Lampung Province has had relatively high variations. The highest rainfall was recorded in January 2013, with total rain reaching 459.8 mm, while the lowest rainfall was recorded in August 2011, November 2012, and September 2014, with total rainfall coming 0.00 mm.

TABLE II

STATISTICAL DESCRIPTION OF MONTHLY RAINFALL IN LAMPUNG PROVINCE FOR THE PERIOD JANUARY 2010 TO DECEMBER 2022

Month	Mean (mm)	Maximum (mm)	Minimum (mm)
January	295.631	459.80	158.00
February	265.28	360.50	173.10
March	214.49	399.50	111.10
April	191.49	315.90	120.40
May	145.84	331.10	57.70
June	91.19	207.00	33.40
July	81.35	233.50	9.30
August	63.47	180.40	0.00
September	66.20	173.40	0.00
Oktober	121.94	224.80	1.80
November	186.25	384.20	0.00
December	252.00	426.30	80.50

Table II shows that the average rainfall in January, February, and March is above 200 mm, while in other months, the rainfall is less than 200 mm. This indicates that rainfall in Lampung Province in January, February, and March tends to be higher in the middle category. This confirms the previous explanation, which stated that rainfall in Lampung Province experiences a seasonal pattern. However, the annual rainfall intensity fluctuates (the amount of rainfall is not the same yearly).

III.RESULTS AND DISCUSSION

Level Smoothing Analysis using Single Exponential Smoothing (SES) Technique

Single Exponential Smoothing (SES) modelling, which is a simple linear regression model concerning explicit level (Error) modelling, the optimal α parameter value is 0.6847 with a coefficient of [0,1]. Based on these parameters, the Sum Square Error (SSE) value is 1683526, and the a value is 189.4612, with the graphic display as follows

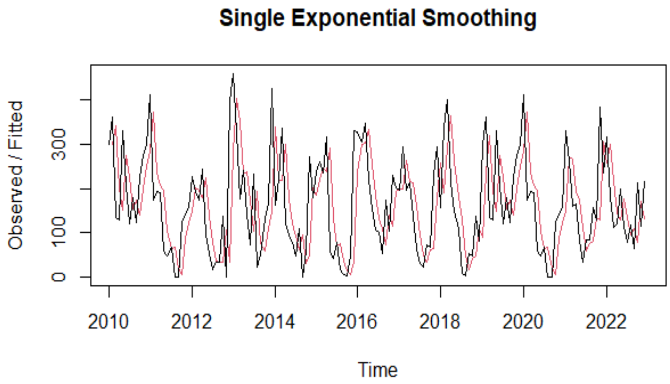

Figure 2: Level smoothing graph (black line: actual data, red line: prediction data) using the single exponential smoothing technique for the period January 2010 to December 2022

Level and Trend Smoothing Analysis using Holt's Double Exponential Smoothing (DES) Technique

Holt's Double Exponential Smoothing (DES) modelling, which is a simple linear regression model concerning explicit level (Error) and trend modelling, the optimal α and β parameter values, respectively, are 0.7561 and 0.0451 with a coefficient of [0,1]. SSE value of 184830 is obtained with a and b values of 194.6878 and 1.7720, respectively, so the graphic display is as follows.

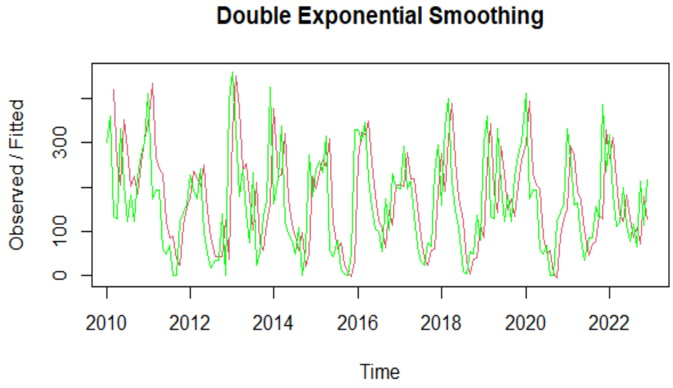

Figure 3: Level and trend smoothing graph (green line: actual data, red line: prediction data) using holt's double exponential smoothing (DES) technique for the period January 2010 to December 2022

Level, Trend, and Seasonal Smoothing Analysis Using Holt-Winter's Triple Exponential Smoothing (TES) Technique

Holt-Winter's Triple Exponential Smoothing (TES) modelling, which is a simple linear regression model concerning explicit level (Error), trend, and seasonal modelling, the optimal α, β, and γ parameter values, respectively, are 0.2158, 0.0298, and 0.2380 with coefficient [0,1]. SSE value of 1152255 is obtained with a and b values, respectively 138.6188 and -0.2435. In addition, seasonal component values were obtained, as in Table III below.

TABLE III
SEASONAL COMPONENTS OF HOLT-WINTER'S TRIPLE EXPONENTIAL SMOOTHING (TES) MODEL

Month	S_t
January	165.3546
February	104.2555
March	57.8446
April	45.1167
May	10.6788
June	-50.1412
July	-66.1495
August	-68.9683
September	-69.0478

Month	S_t
Oktober	10.8852
November	52.3205
December	81.2770

By using Holt-Winter's Triple Exponential Smoothing (TES) technique, the following graphic display is obtained.

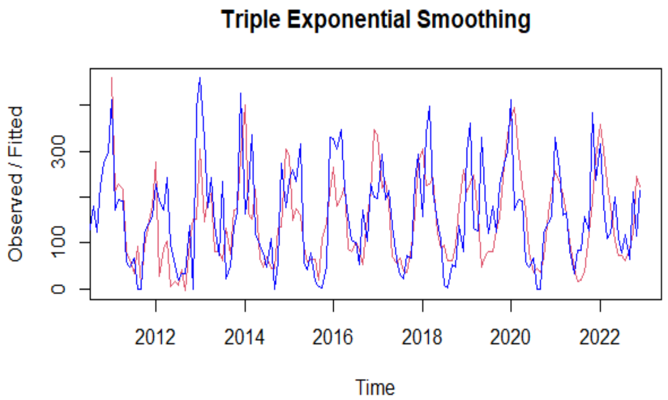

Figure 4: Level, trend and seasonal smoothing graph (blue line: actual data, red line: prediction data) using holt-winter's triple exponential smoothing (TES) technique for the period January 2010 to December 2022

Selection of the Best Model

The selection of the best model is based on prediction accuracy using SSE. A summary of the SSE values for the three models is shown in Table IV below.

TABLE IV
SUMMARY OF SSE VALUES FOR EACH EXPONENTIAL SMOOTHING MODEL

Model Exponential Smoothing	SSE
Single	1683526
Holt's Double	1848380
Holt-Winter's Triple	1152255

Based on the results listed in Table IV, it can be concluded that the SSE value of Holt's Double Exponential Smoothing (DES) Model is higher than the other two models. Therefore, Holt's Double Exponential Smoothing (DES) model could be more optimal.

Furthermore, the results obtained in Table IV state that the Holt-Winter's Triple Exponential Smoothing (TES) model has a smaller SSE than the Single Exponential Smoothing model, so it can be concluded that the Holt-Winter's Triple Exponential Smoothing (TES) method is better than the two models. Others to predict annual rainfall data in Lampung Province.

Rainfall Prediction for the 2023 and 2024

Because Holt-Winter's Triple Exponential Smoothing (TES) model has a Sum of Squared Errors (SSE) value that is smaller than the SSE value in Single Exponential Smoothing (SES) and Holt's Double Exponential Smoothing (DES), Triple Exponential Smoothing (TES) will be used Holt-Winter will predict rainfall data in Lampung Province for the next two years. The following are the results of rainfall predictions in Lampung Province for the next two years (24 months).

TABLE V
RESULTS OF RAINFALL PREDICTION CALCULATIONS IN LAMPUNG PROVINCE FOR THE NEXT 2 YEARS USING THE HOLT-WINTER'S TRIPLE EXPONENTIAL SMOOTHING (TES) MODEL

Months	2023	2024
January	303.7299	300.8076
February	242.3873	839.4650
March	195.7328	192.8106
April	182.7614	179.8391
May	148.0800	145.1578
June	87.0165	84.0942
July	70.7647	67.8424
August	67.7023	64.7801
September	67.3793	64.4570

Months	2023	2024
Oktober	125,2984	122.3761
November	188,2606	185.3383
December	216,9735	214.0513

The Significances of Rainfall Prediction

For the province of Lampung, proper rainfall predictions are important across various fields, including disaster management, tourism planning and management, agriculture, and clean water supply for years. In disaster management contexts, Lampung Province often faces natural geohazards, such as floods, landslides, and droughts. These geohazards are closely related to annual rainfall dynamics [12-15]. Acceptable rainfall predictions enable proactive efforts to reduce disaster risks. Heavy rainfall alerts can initiate early evacuation in flood to landslide-prone areas [16-17]. Simultaneously, forecasts of prolonged next dry seasons allow for farsighted water conservation efforts and sufficient clean water to mitigate the impacts of massive drought and clean water crises.

Guiding regulations on clean water supply, reservoir management, and groundwater management are necessary for Lampung Province, where access to clean water may be limited in several remote areas, particularly during the next annual dry season [18]. By implementing water conservation standards and planning alternative water supplies during low rainfall, local government can save water resources, maintain quality standards, meet essential needs across sectors, and protect critical ecosystems and considerable local economic activities such as agriculture and tourism [19-20]. Recently, Lampung Province also boasts various notable natural tourist attractions, from mountainous landscapes to exotic maritime tourist destinations, supported by its local geodiversity, biodiversity, and cultural diversity [21-25]. Accurate rainfall predictions are essential given tourism considerations, especially in the high appeal of natural attractions. Tour operators, local guides, and tourists depend heavily on these forecasts to plan activities effectively, ensuring safe and enjoyable experiences [26-27]. Tourism operators must always consider hazardous weather conditions, whether traveling on steep mountain terrain or crossing the open sea in Lampung Province.

For agriculture and irrigation, rainfall predictions assist farmers in planning crop cultivation and management more efficiently by adjusting irrigation schedules based on anticipated rainfall patterns to ensure an adequate water supply for crops. Proper rainfall forecast data guide reservoir-filling estimations, flood control, and river flow regulation decisions in water resource management. This ensures sufficient water availability and balanced consumption for industrial needs, agriculture, and natural ecosystems, particularly in drought-prone regions during the dry season [19, 28]. Rainfall predictions play a crucial role in environmental management, aiding in monitoring water quality, mitigating erosion and pollution, and preserving natural ecosystems [21, 28]. By advancing proper rainfall predictions, the local government can optimize planning, minimize risks, and effectively manage resources, contributing to sustainable development and resilience in the Lampung Province for next out coming years.

IV.CONCLUSION

Annual rainfall data in Lampung Province from 2010 to 2022 has a seasonal pattern. Thus, the Exponential Smoothing method suitable for this data is Holt-Winter's Triple Exponential Smoothing (TES) method. The Holt-Winter Exponential Smoothing (TES) method is the best method for forecasting annual rainfall data in Lampung Province because it has the smallest SSE value compared to other methods. Forecasting results for the next few years using Holt-Winter's Triple Exponential Smoothing (TES) method produce better prediction accuracy values, namely with the parameters α, β, and γ respectively being 0.2158, 0.0298, and 0.2380 in 2023 and 2024.

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