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Rainfall analysis using frequency analysis approach and seasonal time series in Nusawungu District

Analisis Curah Hujan Menggunakan Pendekatan Analisis Frekuensi Dan Deret Waktu Musiman Pada Kecamatan Nusawungu

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ABSTRACT

High rainfall can cause floods that damage the environment. To deal with potential extreme rainfall, an estimation of the frequency and intensity of rainfall at certain time intervals in the future is required. Analysis of the frequency of rainfall is also important in calculating the risk of flooding in an area and developing appropriate risk mitigation and management strategies. The purpose of this study was to analyze the frequency of rainfall in the Nusawungu sub-district using the Pearson Log Type III distribution method and forecasting using the moving average method. Daily maximum rainfall data for 20 years were obtained from the Google Earth Engine with the CHIRPS satellite in the Nusawungu sub-district and analyzed with the Smirnov-Kolmogorov distribution fit test and the Pearson Log Type III distribution method to estimate the frequency and intensity of rainfall in plan years 2, 5, 10, 25, 50, and 100. The results showed that the Pearson Log Type III distribution was suitable for analyzing the frequency of rainfall in the Nusawungu sub-district and the highest rainfall intensity occurred in the 100-year plan with a value of 207,22 mm/day. The moving average method is used to predict monthly rainfall in the following year, but the error test using the Mean Absolute Percentage Error (MAPE) shows that the forecasting model still needs to improve its accuracy. Analysis of the frequency of rainfall and forecasting can be an important reference in the planning and risk management of floods in the Nusawungu sub-district area.
Keywords: rainfall, frequency analysis, pearson log, time series

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ABSTRAK

Bencana banjir yang terjadi akibat curah hujan yang tinggi dapat merusak lingkungan dan membahayakan kehidupan manusia. Oleh karena itu, penting dilakukan estimasi frekuensi dan intensitas curah hujan pada interval waktu tertentu di masa yang akan datang untuk mengantisipasi potensi curah hujan yang ekstrim. Selain itu, analisis frekuensi curah hujan juga penting untuk menghitung risiko banjir di suatu wilayah dan menyusun strategi mitigasi dan pengelolaan risiko yang tepat. Tujuan dari penelitian ini adalah menganalisis frekuensi curah hujan di kecamatan Nusawungu menggunakan metode distribusi Log Pearson Type III dan peramalan curah hujan menggunakan deret waktu musiman. Data curah hujan maksimum harian selama 20 tahun diperoleh dari Google Earth Engine dengan satelit CHIRPS di kecamatan Nusawungu dan dianalisis dengan uji kecocokan distribusi Smirnov-Kolmogorof dan metode distribusi Log Pearson Tipe III untuk memperkirakan frekuensi dan intensitas curah hujan pada periode ulang 2, 5, 10, 25, 50, dan 100. Hasil penelitian menunjukkan distribusi Log Pearson Tipe III cocok untuk menganalisis frekuensi curah hujan di kecamatan Nusawungu dan intensitas curah hujan tertinggi terjadi pada tahun ke-100 rencana dengan nilai 207,22 mm/hari. Analisis deret waktu musiman dengan metode Moving Average dan Seasonal Exponential Smoothing digunakan untuk meramalkan curah hujan bulanan pada bulan berikutnya. Uji error menggunakan Mean Absolute Percentage Error (MAPE) menunjukkan bahwa model peramalan menunjukan relatif baik akurasinya. Analisis frekuensi curah hujan dan peramalan dapat menjadi acuan penting dalam perencanaan dan penanggulangan bencana banjir di wilayah kecamatan Nusawungu. Penelitian ini dapat memberikan kontribusi yang signifikan bagi para pengambil keputusan dan pemangku kepentingan yang terlibat dalam penanggulangan bencana banjir di wilayahnya.
Kata Kunci: *curah hujan, analisis frekuensi, time series*

1. Introduction

Rainfall is one of the most influential elements on the climate and natural resources that can meet needs but can also be a source of disaster (Widyawati et al., 2020). The disaster caused is usually in the form of floods caused by high rainfall, Rainfall can be predicted with a time series analysis approach (Sidiq, 2018). Seasonal time series analysis is a statistical method used to analyze and predict data that varies over time and has seasonal patterns (He et al., 2022). Seasonal time series have characteristics indicated by a strong sequential correlation at seasonal distances (seasonal periods), which is time-related to many observations in the seasonal period (Sitepu, 2009). Rainfall prediction is one application of seasonal time series analysis (Wahyuni et al., 2016). Seasonal frequency and time series analysis approaches are effective tools for studying rainfall characteristics(Marín-García et al., 2019). Frequency analysis is used to estimate the probability of a particular rainfall event over a period (Handajani, 2005). Seasonal time series analysis is used to identify seasonal patterns and short-term trends in rainfall data (Manik, 2009).

The flood problem in Nusawungu District, located in Cilacap Regency, has indeed been a recurring issue for some time. This is because the region is in the lowlands and is prone to high rainfall, especially in the rainy season. The frequency and intensity of rainfall in this area are increasing over time due to climate change, thus exacerbating the flood problem. Handling flood problems cannot be separated from the availability of flood control infrastructure such as dams, irrigation networks, drainage canals, and others. In designing the flood control water building, maximum rainfall data information with a certain repeat period is needed (Basuki et al., 2009).

This study was conducted to predict rainfall data in Nusawungu District taken from the google earth engine for ten years from 2010 - 2019. This time series has developed several predictive methods. One of the methods used is time series analysis with the Moving Average and Seasonal Exponential Smoothing methods. The Moving Average method is a method that illustrates that the variable is influenced by the residual value of the past time. Thus, the Moving Average method is in principle the same as the regression method, but what acts as an independent variable is the residual variable of the previous period (Tumanggor, 2021).

Based on the description above, the author would like to examine the problem by analyzing the frequency and intensity of rainfall in Nusawungu District using Pearson Log Distribution Type III and seasonal time series analysis using the Moving Average and Seasonal Exponential Smoothing methods, which can provide a better understanding of upcoming rainfall patterns in the region and provide information that can help develop management strategies and more effective flood prevention.

2. Literature Review

A. Previous Research

A study has been conducted to analyze the maximum daily rainfall frequency in the Akuaman River region, West Sumatra (Fauzi & Handayani, 2012). The data used came from 12 rain stations spread across the Antokan, Batang Anai, Kuranji, Batang Air Dingin, Pariaman, Batang Mangau, and Batang Arau River areas. In this study, four types of distribution have been used Normal, Gumbel, Log Pearson Type III, and Iway Kadoya. The results showed that each test method produced a different type of distribution for each river basin. The Type III Pearson Log distribution is considered the most dominant under the Kolmogorov-Smirnov Method, while the normal distribution is considered the most dominant based on the Chi-Square test for the entire river basin. Therefore, in choosing the distribution of the daily maximum rainfall frequency, it is important to evaluate and select suitable distribution methods using various valid test methods and approaches.

Research that once used the moving average method to test the premise that U.S. stocks exhibit characteristics of average returns in the short to medium term (one week to one year), with "average" being the most used moving average (Alajbeg et al., 2017). Analysis shows that there is a relationship between the distance of stock prices to moving averages and subsequent results, portfolios of stocks priced lower to the moving average generally outperform portfolios of stocks priced higher to the moving average. Moving averages are shorter than 20 and 50 days and are particularly strong in short-term holding periods such as one and two weeks. The analysis conducted in this study shows that there is a relationship between the distance between stock prices with their respective Moving Average methods and subsequent returns.

Previous research has developed a hybrid STL-ML (Seasonal-Trend decomposition and Machine Learning) method for more accurate time series rainfall modeling and forecasting. This method aims to overcome the limitations of traditional approaches that rely solely on dynamic models (He et al., 2022). This study used three Machine Learning models, namely GRU, multi-time GRU, and LightGBM, to model and predict trends, seasonality, and residual components of precipitation time series. The analysis showed that all three models successfully modeled and predicted each component well. Each model can adjust for different characteristics of each component, including seasonal trends and patterns in rainfall data. The results of this study suggest that the proposed STL-ML hybrid approach provides more accurate rainfall predictions. By analyzing seasonal trends and using three different machine learning models, the method is effective in identifying and predicting each component. These findings make an important contribution to improving the understanding of rainfall time series and providing a more powerful tool for forecasting future rainfall.

B. Theoretical review

a. Rainfall

Rainfall is the amount of rain that is poured (falls) in an area in a certain period. Differences in rainfall in each region on the surface of the earth cause differences in animal types and variations in the characteristics of vegetation that inhabits the region. Areas that have high rainfall are areas inhabited by several types of animal species with varying numbers (Winarno et al., 2019).

b. Frequency Analysis

The analyst is the frequency of precipitation is the recurrence of precipitation, both the sum of the frequencies, the unity of time, and its repeated periods. Frequency analysis must be done gradually and by the existing work sequence because the results of each calculation depend on and influence each other on the results of previous calculations. The following is the application of frequency analysis steps after data preparation is conducted (Soewarno, 1995).

1. Average

$$\bar{x} = \frac{1}{n}\sum_{1=s}^{n} xi \tag{1}$$

2. Standard Deviation

$$S = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} \tag{2}$$

3. Coefficient of Variation

$$\mathrm{Cv} = \frac{\mathrm{S_R}}{\bar{\mathrm{x}}} \tag{3}$$

4. Asymmetry/skewness coefficient

$$\mathrm{Cs} = \frac{\mathrm{n\ x}\ \sum_{i=1}^{n}(x_i - \bar{\mathrm{x}})^3}{(\mathrm{n}-1)(\mathrm{n}-2)\left(\mathrm{S_R}^3\right)} \tag{4}$$

5. Koefisien kurtosis

$$\mathrm{Ck} = \frac{\mathrm{n}^2\ \mathrm{x}\ \sum_{i=1}^{n}(x_i - \bar{\mathrm{x}})^4}{(\mathrm{n}-1)(\mathrm{n}-2)(\mathrm{n}-3)\left(\mathrm{S_R}^4\right)} \tag{5}$$

Information:

$\bar{x}$	= Average
xi	= N number of measurements of a variate
n	= Amount of data
Cv	= Coefficient of variation
Cs	= Asymmetry/skewness coefficient
Ck	= Coefficient kurtosis
S_R	= Standard Deviation
X_i	= i-th variant value

c. Time Series

Time Series is a sequence of observations taken sequentially over a period. The main feature of time series is that adjacent observations depend on each other. This dependence has significant practical implications. Time series analysis involves this dependency analysis technique and requires the development of stochastic and dynamic models for time series data. The use of such models is especially important in various applications (George et al., 2016).

d. Moving Average

The time series method consists of several methods, one of which is Moving Average forecasting or moving average. The Moving Average method is used if the past data is data that does not have elements of trend or seasonal factors. Moving Average forecasting is widely used to determine the trend of a time series (Makridakis et al., 2008). Moving Average develops a model based on the results of calculating the average of most studies using the equation (4).

$$MA(Ft) = \frac{\sum amount\ of\ data\ before\ n}{n} \tag{6}$$

Information:
n = amount of data
(Ft) = forecasting of upcoming data

e. Seasonal Exponential Smoothing

The Seasonal Exponential Smoothing method is used to forecast rainfall considering existing seasonal fluctuations. This method is also often called the *Holt-Winters* method. It can be calculated using the equation formulas (3.10), (3.11), (3.12), (3.13).

Smoothing Level:

$$L_t = a(X_t - S_{t-s}) + (1-a)(L_{t-1} + b_{t-1}) \tag{7}$$

Smoothing Trend:

$$b_t = \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1} \tag{8}$$

Seasonal Smoothing:

$$S_t = \gamma(X_t - L_t) + (1-\gamma)S_{t-s} \tag{9}$$

Forecasting:

$$F_{t+m} = L_t + m_{bt} + S_{t-s+m} \tag{10}$$

Information:
L_t = Smoothing Level
X_t = Actual data of the period to t
b_t = Smoothing trends
S_t = Seasonal smoothing
α = Data smoothing constants
β = Estimation of trend smoothing constants
γ = Estimated Seasonal smoothing constant
m = The number of upcoming periods to predict
m_{bt} = The number of upcoming periods in the smoothing of the t-th time trend.
S = Seasonal periods

3. Method

In this study, the author uses quantitative research methods, data analysis will be presented in the form of variables related to rainfall using the Distribution method and *the Time Series* method. The quantitative research method is research that uses research data in the form of numbers and analysis to obtain information. The variables studied in this study are rainfall data by taking rainfall climate variables per year for 20 years.

In this research process, a flow and description of the research to be carried out are compiled. The goal is to explain in detail the stages of work to be conducted and become the basis for overcoming the problems to be raised as research objects. The following is a series of studies that will be conducted in Figure 1.

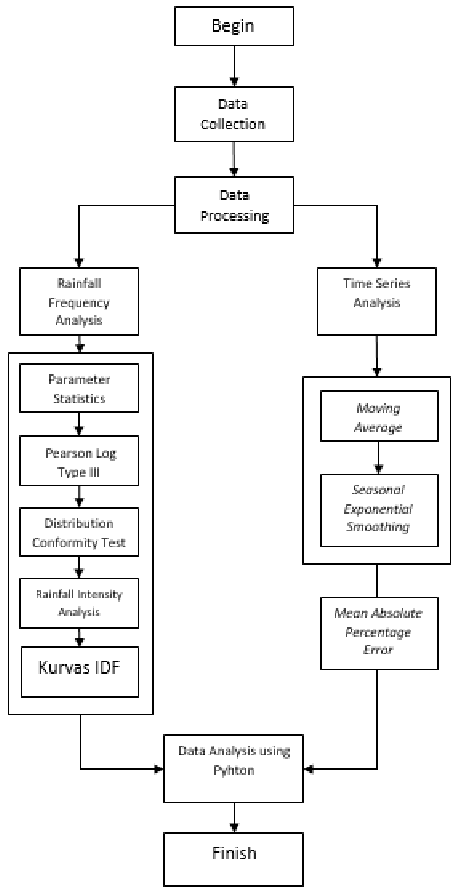

Figure 1. Research Flow

4. Results and Discussion

A. Writing Results

The data used in this study is secondary data of daily rainfall obtained from the Google Earth Engine service in the Nusawungu District area in 2000 – 2019 which amounted to 7304 data in which some variables or factors can understand the potential risk and magnitude of flood events in an area. The data used for forecasting future rainfall was taken from 2010 – 2019 which amounted to 50 data. The research was conducted this time using two data samples, namely daily maximum rainfall and daily rainfall which are used in rainfall frequency analysis and rainfall forecasting.

B. Data Processing

The data processing stage is important in rainfall analysis. At this stage, rainfall data that has been obtained must be processed so that it can be used for research purposes with optimal data quality. This is done to prevent errors such as errors, missing values, and data inconsistencies that can affect the integrity of research results. In the analysis of rainfall frequency, there were 7304 rainfall data obtained over 20 years from 2000 to 2019.

1. Frequency Analysis

The precipitation frequency analysis phase aims at determining rainfall plans for different repeat periods based on the most appropriate distribution. In this study, designs with birthdays of 2, 5, 10, 25, 50, and 100 years were used.

a. Parameter Statistics

Statistical parameter tests have statistical parameter requirements for distribution through the Gumbel, Normal, Normal Log, and Pearson Log Type III methods. The results of the statistical parameter test can be seen in Table 4.3.

Table 1. Statistical Parameters

No	Types of Distribution	Condition	Result	Information
1	Gumbel	Cs=1,14 C=5,4	Cs = 1,72 Ck =212.790	Non-Compliant
2	Normal	Cs ≈ 0 Ck = 3,0	Cs = 1,72 Ck = 212,789	Non-Compliant
3	Log-Normal	Cs= 2 Ck = 4	Cs = 0,007 Ck = 3	Non-Compliant
4	Log Pearson III	In addition to the above values	Cs = 0,621	Meet

b. Pearson Log Type III

Calculating maximum rainfall with the Pearson Log Type III Distribution aims to obtain a planned estimate of rainfall that may occur in repeated periods. The calculation results obtained from the process of adjusting data parameters to the distribution requirements of Pearson Log Type III can be seen in Table 2.

Table 2. Results of Pearson Type III Log Distribution Data

No	Year	Rmax	Xi	Log Xi	Log (Xi-Xt)	Log (Xi-Xt)^2	Log (Xi-Xt)^3
		(mm)	(mm)/day				
1	2000	100	180	2,26	178,162	0,174	0,0728
2	2001	119	119	2,08	117,162	0,057	0,0134
3	2002	43	106	2,03	104,162	0,035	0,0066
..	….	…	…	…	…..	….	…..
18	2017	180	43	1,63	41,162	0,042	-0,0085
19	2018	40	40	1,60	38,162	0,056	-0,0131
20	2019	39	39	1,59	37,162	0,061	-0,0150
Sum		∑	1492	36,75	1455	0,57	0,055

Average (Log Rt) $= \frac{\sum_{i=1}^{n} log(X_i)}{n} = \frac{36,75}{20} = 1,84$

Standard Deviation (Log Sr) $= \frac{\sum_{i=1}^{n}\{log(X_i) - log(\bar{X})\}^2}{n - 1} = \left(\frac{0,567}{20 - 1}\right)^{0,5} = 0,173$

Coefficient Asymmetry (Cs) $= \frac{n^2 \text{ x } \sum_{i=1}^{n}(x_i - \bar{x})^4}{(n-1)(n-2)(n-3)(S_R{}^4)} = \frac{20 \times 0,05481}{(20-1)(20-2)(0,17^3)} = 0,62$

The result of Cs is 0.62 to determine the value of the repeat period requires Cs values of 0.6 and 0.7 from the Pearson Log Type III method reduction frequency table. The results of Cs with repeat periods can be seen in Table 3.

Table 3. Interpolation Cs Log Pearson Type III

PUH	2	5	10	25	50	100
0,6	-0,099	0,8	1,328	1,939	2,359	2,755
0,62	-0,102	0,798	1,329	1,945	2,369	2,769
0,7	-0,116	0,79	1,333	1,967	2,407	2,824

Table 3 describes the result of the reset period with Cs 0.62 further calculated the logarithm of the rain plan with the re-period with the equation formula (11).

$$10\text{^}(Log\ \bar{R} + K_{Tr}\ \times\ S\ Log\ R \quad (11)$$

Table 4. Results of Rainfall Plans

Tr (Year)	Ktr	RTr (mm)
100	2,769	207,22
50	2,369	176,70
25	1,945	149,25
10	1,329	116,81
5	0,798	94,55
2	-0,102	66,07

c. Distribution Conformity Test

The purpose of the distribution conformity test is to ensure that the empirical approach can be represented by theoretical curves. In this study, the distribution suitability test was conducted using the Smirnov-Kolmogorov test. The details are recorded in Table 5.

Table 5. Distribution Conformity Test Results

No	Tahun	Xmax (mm)	Xi (mm)	Log Xi	P	f(t)	P'	ΔP
1	2000	100	180	2,255	0,048	2,415	0,007	0,041
2	2001	119	119	2,076	0,095	1,376	0,050	0,045
3	2002	43	106	2,025	0,143	1,085	0,129	0,014
..	….	…	…	….	….	….	….	….
18	2017	180	43	1,633	0,857	-1,182	0,891	0,034
19	2018	40	40	1,602	0,905	-1,364	0,921	0,016
20	2019	39	39	1,591	0,952	-1,427	0,930	0,022
Dmaks								**0,193**

Table Description:

Column P	=	Empirical money (calculated by Weibull's equation)
Column f(t)	=	Calculation Results (Log Xi- Log Xt) / Log Sr. The value in column f(t) aims to determine theoretical opportunities
Column P'	=	Determined based on the value of f(t) from the Table of theoretical opportunity values
ΔP column	=	The calculation result of (P' - P) the result will be used to determine the Dmax value

Average $= \frac{\sum_{i=1}^{n} log(X_i)}{n} = \frac{36,75}{20} = 1,84$

Standard Deviation $= \frac{\sum_{i=1}^{n}\{log(X_i) - log(\bar{X})\}^2}{n-1} = \left(\frac{0,567}{20-1}\right)^{0,5} = 0,173$

$D_{Kristis}$ = 0,29

D_{Maks} = 0,193

Table 6. D_{Kritis} Trust Degrees Table

N	**a (Degrees of trust)**			
	0,2	**0,1**	**0,05**	**0,01**
5	0,45	0,51	0,56	0,67
10	0,32	0,37	0,41	0,49
15	0,27	0,3	0,34	0,4
20	0,23	0,26	0,29	0,36
25	0,21	0,24	0,27	0,32
30	0,19	0,22	0,24	0,29
35	0,18	0,2	0,23	0,27
40	0,17	0,19	0,21	0,25
45	0,16	0,18	0,2	0,24
50	0,15	0,17	0,19	0,23

Source (Suripin, 2004).

From the calculation of the degree of confidence value (Dmax) in Table 5. shows that, the value of Dmax = 0.193 is taken from the largest value. For the 5% confidence degree taken from Table 6. the critical value of the Smirnov-Kolmogorov test, then obtained D_{Kritis} = 0.29. Since the Dmax value < DKritis (0.193 < 0.29), the distribution conformity test is acceptable.

d. Rainfall Intensity Analysis

The results of the analysis of rain intensity during the period with various durations from daily rain data using an approach with the Mononobe Formula with equation (13). The equation formula determines the value of T for Hours using the equation formula (12).

$$\mathrm{T(Hour)} = \frac{T(Minute)}{60} \tag{12}$$

$$I = \frac{R_{24}}{24} \cdot \left(\frac{24}{t}\right)^{\frac{2}{3}} \tag{13}$$

Information:

I = Average planned rain intensity in T hours (mm/h)
R_{24} = Maximum daily rain height or rain plan (mm)
t = rain duration or concentration time (hours)

2-year return period:

$$I = \frac{R_{24}}{24} \cdot \left(\frac{24}{t}\right)^{\frac{2}{3}} = \frac{66{,}07}{24} \times \frac{24}{T(Jam)} = 120{,}1\ mm$$

10-year return period:

$$I = \frac{R_{24}}{24} \cdot \left(\frac{24}{t}\right)^{\frac{2}{3}} = \frac{94{,}55}{24} \times \frac{24}{T(Jam)} = 171{,}82\ mm$$

15-year return period:

$$I = \frac{R_{24}}{24} \cdot \left(\frac{24}{t}\right)^{\frac{2}{3}} = \frac{116{,}81}{24} \times \frac{24}{T(Jam)} = 212{,}26\ mm$$

25-year return period:

$$I = \frac{R_{24}}{24} \cdot \left(\frac{24}{t}\right)^{\frac{2}{3}} = \frac{149{,}25}{24} \times \frac{24}{T(Jam)} = 271{,}21\ mm$$

50-year return period:

$$I = \frac{R_{24}}{24} \cdot \left(\frac{24}{t}\right)^{\frac{2}{3}} = \frac{176{,}70}{24} \times \frac{24}{T(Jam)} = 321{,}08\ mm$$

100-year return period:

$$I = \frac{R_{24}}{24} \cdot \left(\frac{24}{t}\right)^{\frac{2}{3}} = \frac{207{,}22}{24} \times \frac{24}{T(Jam)} = 376{,}5\ mm$$

Table 7. Results of Rainfall Intensity Analysis

T(Minute)	**T (Hour)**	**Return Period**					
		2	**5**	**10**	**25**	**50**	**100**
5	0,08	120,1	171,82	212,26	271,21	321,08	376,5
10	0,17	75,6	108,24	133,71	170,85	202,27	237,2
20	0,33	47,6	68,19	84,23	107,63	127,42	149,4
…	….	…	….	….	….	….	….
60	1,00	22,9	32,78	40,50	51,74	61,26	71,8
660	11,00	4,6	6,63	8,19	10,46	12,38	14,5
720	12,00	4,4	6,25	7,73	9,87	11,69	13,7

Table 7 describes the rainfall taken as rainfall intensity analysis calculations taken from planned rain calculations in the re-period of the Pearson Log Type III distribution. The variable used for the time of occurrence of rain uses a clock with a total of 12 hours. The higher the birthday period, the higher the rainfall intensity, while the greater the rainfall concentration time, the smaller the rain intensity, the Rainfall Intensity Graph can be seen in Figure 2 graph.

e. Kurva IDF

The duration and results of the analysis of rainfall intensity for each repeat using the Mononobe Formula approach are then depicted at cartesian coordinates. The abscissa axis (x) expresses duration, while the ordinate axis (y) expresses intensity. The results of the data depiction, hereinafter named the IDF Curve. IDF Curve Graph Rainfall Intensity Analysis can be seen in Figure 2.

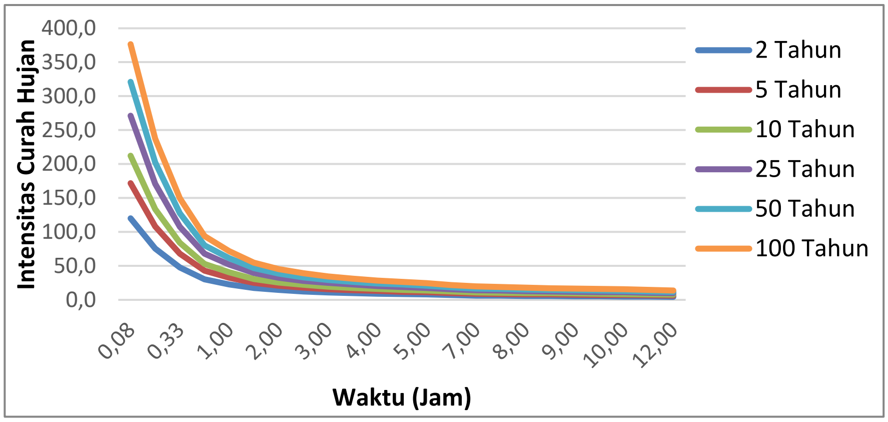

Figure 2. IDF Curve Rainfall Intensity Analysis

2. Seasonal Time Series Analysis

Time series analysis is the process of analyzing data in chronological order to identify patterns, trends, and seasonal patterns that can be used to forecast future data. Data will be predicted using the Moving Average and Seasonal Exponential Smoothing methods using monthly rainfall data. This study uses data that is by the month of rainfall or is seasonal, taken from January 2010 to December 2019 as many as 50 rows of data contained numerical data related to prediction research of variables in a period per month.

a. Moving Average

The use of the Moving Average in this study aims to combine data correlation, but the moving average method in this study uses data separated according to the month of rainfall, the data each year will be broken down into several parts according to the number of months. The data to be used was obtained from the Google Earth Engine service in the Nusawungu District area in 2010 - 2019 as many as 50 rows of data contained numerical data related to many variables that can be used for prediction research of each variable in a period per month. The calculation results of the Moving Average method can be seen in Table 8.

Table 8. Moving Average Periode n=5

Year	Rainfall	Forecast n=5
Jan-10	515	#N/A
Feb-10	321	#N/A
Mar-10	349	#N/A
Nov-10	342	#N/A
Dec-10	504	406,20
Jan-11	410	385,20
….	…	…..
Dec-18	364	354,00
Jan-19	368	331,00
Feb-19	259	306,80
Mar-19	482	362,60
Nov-19	154	325,40
Dec-19	252	303,00
Jan-20		**286,75**

Table 8 shows the results of rainfall forecasting calculations in Nusawungu District with a period of Average (n) = 5. November - February has no forecasting value because this calculation uses 5 previous months' data to predict the next month. The calculation of the forecasting value for January 2020 is obtained from the average value of February 2019 – December 2019.

Table 8 states that rainfall forecasting in Nusawungu District for the next month or period has a value of 286.75 mm/month showing results for monthly rainfall in the medium category for rainfall in that month. visualization of the prediction calculation results can be seen in Figure 3.

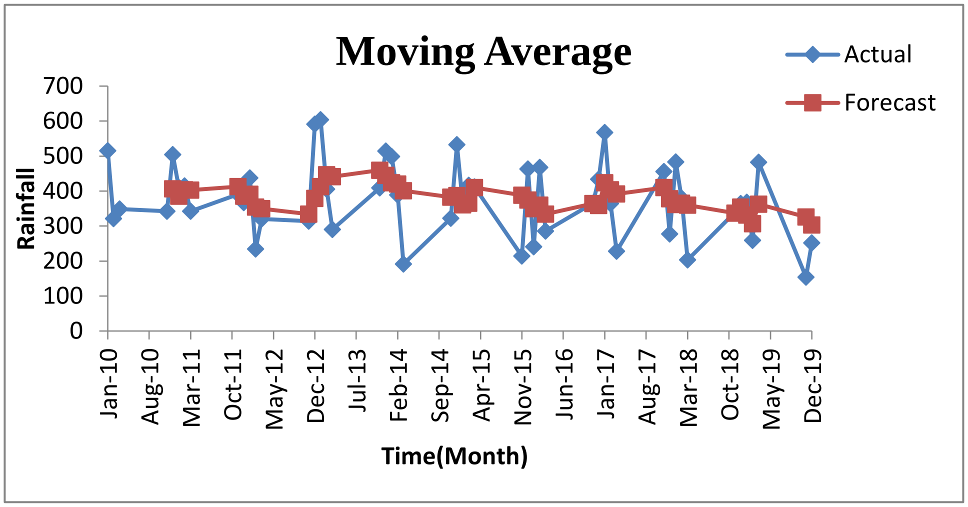

Figure 3. Moving Average Forecast n=5

b. Seasonal Exponential Smoothing

The Seasonal Exponential Smoothing Additive method has been applied to perform forecasting on monthly rainfall data. alpha, beta, and gamma parameters used in the Seasonal Exponential Smoothing Additive method with alpha = 0.5, beta = 0.1, and gamma = 0.5. Using these values, forecasting can be done by considering the degree of adjustment to the most recent historical data *(alpha)*, the speed of adjustment to trend changes (*beta)*, and the influence of seasonality in the data *(gamma)*. The calculation results of the Seasonal Exponential Smoothing method can be seen in Table 9.

Table 9. Seasonal Exponential Smoothing with Season=5

Year	Rainfall	$Y_{L+t} - Y_t$	At	Tt	St-L	St	Forecast
	515	-100	…..	…..	…..	519,24	…..
	504	-94	…..	…..	…..	508,24	…..
2010	349	42	…..	…..	…..	353,24	…..
	342	25	…..	…..	…..	346,24	…..
	321	21	406,2	-4,24	…..	325,24	…..
….	….	…..	….	…..	….	…..	…
	482	…..	-63,31	-2,6	549,62	547,46	491
	368	…..	-84,17	-4,43	470,42	461,29	405
2019	259	…..	-121,14	-7,68	412,69	396,42	324
	252	…..	-117,67	-6,57	358,52	364,1	230
	154	…..	-120,77	-6,22	271,3	273,03	147
Forecasting results for the next month							**420,48**

Table 9 Forecasting results on monthly rainfall estimates for the next 5 months with a value of 420. This method considers trend patterns and seasonality in monthly rainfall data to produce appropriate forecasting. Forecasting results are predictions and need to be validated with actual data to measure the level of forecasting accuracy. A chart of the Seasonal Exponential Smoothing pattern can be seen in figure 4.

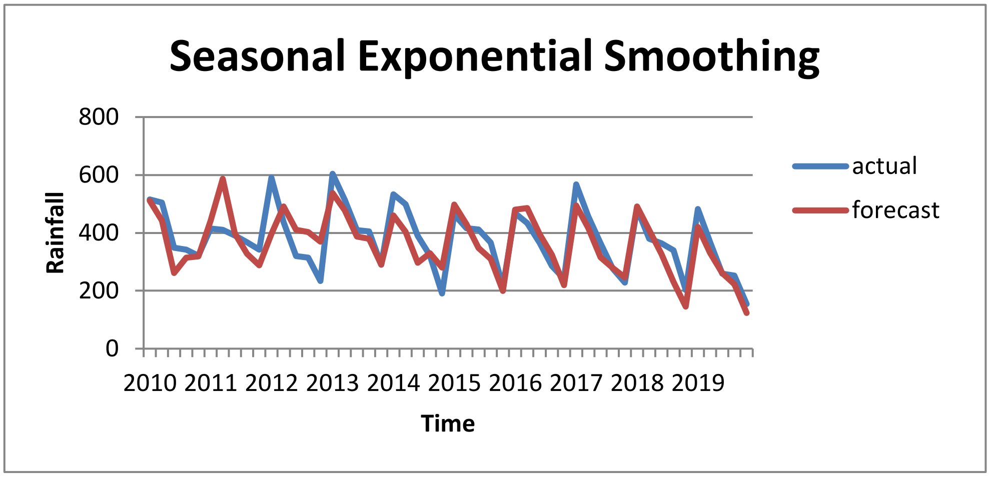

Figure 4. Seasonal Exponential Smoothing Rainfall Graph

c. Mean Absolute Percentage Error

The error test in this study uses Mean Absolute Percentage Error (MAPE). Error test results for rainfall forecasting using the Moving Average method can be seen in Table 10.

Table 10. MAPE Results Moving Average Method

Rainfall	Forecast n=5	Error Value (A-F)	Absolute Value (D)	Absolute Value / Actual Value
515	#N/A	…..	…..	…..
321	#N/A	…..	…..	…..
349	#N/A	…..	…..	…..
342	#N/A	…..	…..	…..
504	406,2	-97,80	97,80	0,1940
410	385,2	-24,80	24,80	0,0605
415	404	-11,00	11,00	0,0265
234	354,2	120,20	120,20	0,5137
…	….	…..	…..	……
320	349,8	29,80	29,80	0,0931
380	364,8	-15,20	15,20	0,0400
203	359,8	156,80	156,80	0,7724
482	362,6	-119,40	119,40	0,2477
154	325,4	171,40	171,40	1,1130
252	303	51,00	51,00	0,2024
		MAPE		**0,25**

The error test using the Mean Absolute Percentage Error (MAPE) error test in the Moving Average method shows a result of 0.25. A MAPE value of 0.25 indicates an error rate of 25% in forecasting monthly rainfall using the Moving Average method. Indicates a significant deviation between the actual value and the forecasting value. The Moving Average method can provide a general idea of the trend of the data, but the results tend to have a higher degree of inaccuracy. This study provides an important understanding of the performance comparison between the Moving Average and Seasonal Exponential Smoothing Additive methods in forecasting monthly rainfall.

Table 11. MAPE Results Seasonal Exponential Smoothing Method

Rainfall	Forecast	Error	Absolute Value	APE
515,00	…..	…..	…..	…..
504,00	…..	…..	…..	…..
349,00	…..	…..	…..	…..
342,00	…..	…..	…..	…..
321,00	…..	…..	…..	…..
415,00	921,20	506,20	506,20	1,22
410,00	627,55	217,55	217,55	0,53
391,00	323,35	-67,65	67,65	0,17
367,00	313,13	-53,87	53,87	0,15
342,00	284,71	-57,29	57,29	0,17
591,00	349,32	-241,68	241,68	0,41
437,00	511,92	74,92	74,92	0,17
320,00	367,61	47,61	47,61	0,15
…….	…..	…..	……	…….
604,00	336,52	-267,48	267,48	0,44
203,00	248,87	45,87	45,87	0,23
482,00	490,61	8,61	8,61	0,02
368,00	404,51	36,51	36,51	0,10
259,00	324,10	65,10	65,10	0,25
252,00	229,70	-22,30	22,30	0,09
154,00	147,06	-6,94	6,94	0,05
		Mape		**0,17**

The error test using Mean Absolute Percentage Error (MAPE) shows a result of 0.17. The MAPE value of 0.17 shows that the monthly rainfall forecasting produced using the Seasonal Exponential Smoothing Additive method has an error rate of 17%. Forecasting shows a fairly good level of accuracy in forecasting monthly rainfall. The lower the MAPE value, the more accurate the resulting forecast.

C. Comparison of rainfall frequency analysis and seasonal time series

The comparison stage of results for comparison between rainfall frequency analysis and seasonal time series analysis is to gain a more comprehensive understanding of rainfall data. By comparing these two approaches, it can combine information about the frequency distribution of precipitation events and seasonal change patterns in rainfall data. The results of the rainfall frequency analysis can be seen in Table 12.

Table 12. Results of Plan Rainfall Frequency Analysis

Rainfall Category	Maximum Rainfall	Reset Period
Very High	207,22 mm	100
Tall	176,70 mm	50

Enough	149,25 mm	25
Keep	116,81 mm	10
Light	94,55 mm	5
Very Light	66,07 mm	2

Rainfall Categories Explained:

1. Very Light: Daily rainfall below 66.07 mm, which is considered exceptionally light.
2. Light: Daily rainfall between 66.07 mm to 94.55 mm, which is considered light.
3. Moderate: Daily rainfall between 94.55 mm to 116.81 mm, which is considered moderate.
4. Moderately High: Daily rainfall is between 116.81 mm to 149.25 mm, which is considered quite high.
5. High: Daily rainfall between 149.25 mm to 176.70 mm, which is considered high.
6. Very High: Daily rainfall is above 176.70 mm, which is considered extremely high.

Table 4.13 Results Analysis of rainfall frequency is used to study rainfall events in a certain period to understand the pattern or distribution of rainfall. The result value in millimeters (mm) indicates the estimated rainfall for a specific period with events in units of years. This data provides information about rainfall estimates over a period with events that may occur on an annual scale.

Table 13. Results of Seasonal Time Series Analysis

Year	Rainfall	Moving Average	Seasonal Exponential Smoothing
Jan-10	515	#N/A	#N/A
Feb-10	321	#N/A	#N/A
Mar-10	349	#N/A	#N/A
Nov-10	342	#N/A	#N/A
Dec-10	504	406,20	#N/A
Jan-11	410	385,20	921
…….	……	……	….
Jan-18	483	361,60	491
Feb-18	380	364,80	405
Mar-18	203	359,80	324
Nov-18	340	336,60	230
Dec-18	364	354,00	147
Forecasting Results		**286,75**	**420**
MAPE		**0,25**	**0,17**

Table 13 Results Seasonal Time Series forecasting analysis is used to predict or forecast future values based on available historical data. Methods used in time series forecasting analysis include the Moving Average method and Seasonal Exponential Smoothing. The forecasting results for the Moving Average method show Intermediate monthly rainfall and the Seasonal Exponential Smoothing method show high levels of monthly rainfall.

In this study, both forecasting methods were used to estimate monthly rainfall based on patterns and trends contained in historical data. These forecasting results are based solely on the data contained in this study, and a more comprehensive analysis will require more complete data as well as a deeper understanding of the forecasting methods used.

Frequency analysis is used to evaluate rainfall patterns and characteristics over the long term. Through frequency analysis, it can identify the planned rain recurrence period, which is the estimated time interval needed for rainfall of a certain intensity to recur. The results of frequency analysis provide information on long-term rainfall trends and assist in water resource planning, irrigation, and other related infrastructure.

Analysis time series is used to forecast rainfall in the short term, such as 1 month ahead. In time series analysis, methods such as Moving Average and Seasonal Exponential Smoothing identify patterns and trends in the monthly rainfall data that has been collected. By modeling these patterns and trends, it can make rainfall forecasts for future periods, such as the next 1 month. These forecasting results provide information on expected rainfall forecasts in the short term and can be used in operational decision-making. The comparison between frequency analysis and time series analysis involves the use of different methods and different purposes. Frequency analysis focuses on long-term rainfall patterns and characteristics, while time series analysis focuses on short-term forecasting of rainfall.

5. Conclusion

Based on frequency analysis using the Log Pearson Type III method, the results of this study show the existence of significant rain re-period plans for various re-period values. The value of the planned rain reset period obtained, 100 years of 207.22 mm, 50 years of 176.70 mm, and 25 years of 149.25 mm, can be used as a reference in infrastructure planning and water resources management in Nusawungu District. In addition, through the suitability test of the distribution of Pearson Log Type III, it can be concluded that the rainfall data used in this study is acceptable and represents the characteristics of rainfall in the Nusawungu sub-district area. Seasonal time series analysis, moving average, and seasonal exponential smoothing methods are used to model and predict seasonal patterns of precipitation. The results showed that both methods had a satisfactory level of accuracy in predicting seasonal rainfall in Nusawungu District. By using the Mean Absolute Percentage Error (MAPE) as an evaluation indicator, a MAPE value of 0.25 for the moving average method and 0.17 for seasonal exponential smoothing was obtained. Low MAPE values indicate a small rate of prediction error, so both methods can be used as effective tools in predicting future seasonal rainfall.

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