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Analysis of Monthly Rainfall Characteristics in Nusa Tenggara Timur and its Spatial and Temporal Shifts

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Abstract: Climate variations that occur spatially and temporally with parameters of average, extreme, and variability rainfall have occurred over the past few years. In Indonesia, there has been global climate change in the form of rainfall with East Nusa Tenggara as a location that has different topographic shapes, sizes, and coastal conditions so that it has unique climate characteristics. Therefore, this region is of important concern considering that its population reaches 4,448,873 people with economic life dependent on the agricultural sector and the occurrence of drought and flood disasters. Thus, this research aims to analyze the spatial and temporal characteristics of monthly rainfall as well as shifts in normal rainfall for the period 1961-2020 using ERA-5 reanalysis data. This research produces the conclusion that the spatial characteristics of rainfall in Nusa Tenggara Timur for the periods 1961-1990 and 1991-2020 show similarities in topography influencing local variations in rainfall intensity. Additionally, inland areas and the northern side of the region experience higher rainfall side than the coastal and southern sides. On the other hand, temporal characteristics reveal a monsoonal rainfall pattern with peak precipitation occurring in January and the lowest rainfall in August. Furthermore, there is a normal shift in rainfall patterns between the two periods, marked by a reduction in the intensity of dark colors in the 1991-2020 period compared to 1961-1990. There is also a positive shift in normal rainfall values for April and December, while the remaining months experience a negative shift.

Keywords: Rainfall Characteristics, Normal Rainfall Shift, Spatial, Temporal

Introduction

In recent years, variations in global climate have affected the spatial and temporal conditions of meteorological parameters, namely rainfall in the form of averages, extremes, and variability [1], [2]. Understanding changes in the intensity, frequency, and duration of extreme events in the future is crucial when formulating mitigation and adaptation strategies that can minimize losses in natural systems and their components [3]. In-depth research into rainfall's spatial and temporal characteristics is necessary, given that it is one of the most crucial aspects of climate change [4].

Global climate change, including rainfall patterns, also occurs in equatorial regions, particularly in Indonesia [5]. Indonesia has unique rainfall characteristics influenced by local conditions such as topography, the size and shape of coastlines, and the coastline configuration [6].

The diversity of characteristics in Indonesia, including the Nusa Tenggara Timur (NTT) province, consisting of island clusters such as Flores, Sumba, Alor, Timor, and several smaller islands, exhibits varying topographical shapes, sizes, and coastal conditions . This region has unique climate characteristics that differ among its areas, with some experiencing a drier climate[7].

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Nusa Tenggara Timur (NTT) is of significant concern as it has a population of around 4,448,873 people [8], and the livelihoods and economic activities of the residents depend on the agricultural sector [9].highly influenced by rainfall characteristics [10]. Moreover, the presence of natural disasters such as drought, with 114 occurrences in 2020 [11] and 191 flood incidents between 2008 and 2020 [12] can disrupt agricultural activities and the economy in this region.

Therefore, this research aims to analyze the spatial and temporal characteristics of monthly rainfall within the time range of 1961-2020 and observe the normal rainfall shifts between the periods of 1961-1990 and 1991-2020.

Materials and Methods

Materials

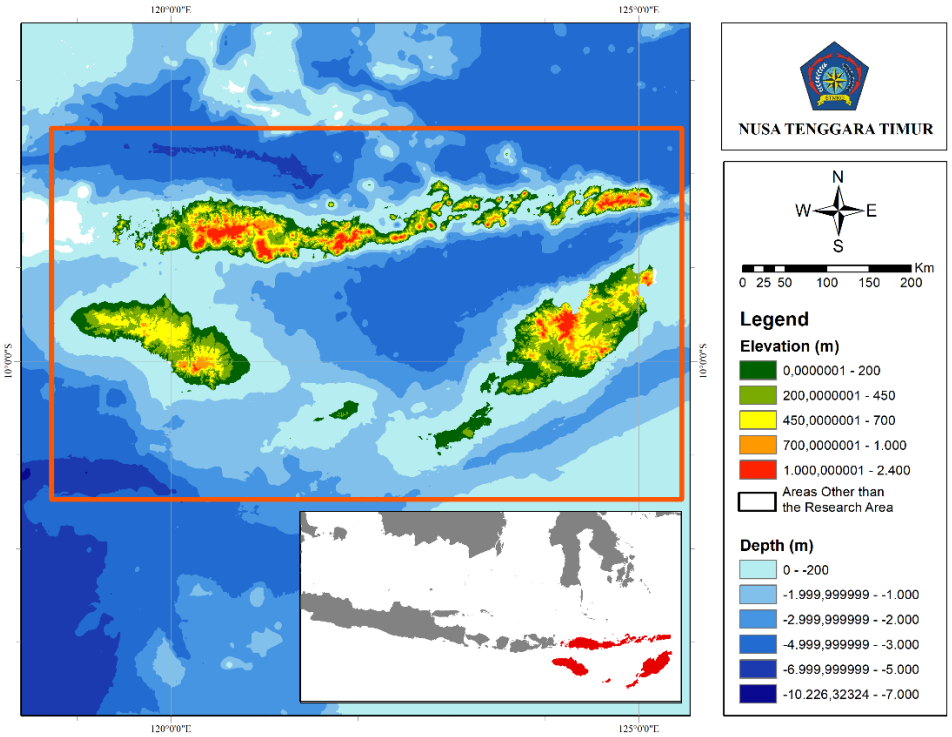

Figure 1. Research Location

The research study focuses on the spatial and temporal analysis of rainfall during the time span of 1961-2020 in the Nusa Tenggara Timur region, utilizing hourly rainfall data from ERA-5 with a spatial resolution of 0.25° x 0.25°. This reanalysis data was obtained from the official website (https://cds.climate.copernicus.eu/) which has been proven to be spatially superior on a global scale [13] as well as the widespread use of historical data to estimate atmospheric conditions for greater accuracy [14]. Therefore, ERA-5 reanalysis data provides better spatial and temporal resolution compared to other secondary data products [15].

Data processing was carried out using the Climate Data Operator (CDO) software, Microsoft Excel for temporal graph visualization, and GrADS software for spatial data visualization. Temporal analysis covers monthly intervals for every 30 years within the periods 1961-1990 and 1991-2020, representing the normal rainfall [16]

Data Analysis Process

Transform the hourly rainfall data into monthly data by summing the rainfall for each hour using the equation

$$Y = \sum_{i=1}^{n} x \qquad (1)$$

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Where Y is the monthly rainfall, n is the number of hours in one month, and x is the hourly rainfall. Then, calculate the monthly rainfall average using the equation [17]

$$Y_{average} = \frac{1}{n}\sum_{i=1}^{n} Y \qquad (2)$$

Where $Y_{average}$ is the monthly rainfall average, n is the number of years used, and Y is the total monthly rainfall.

Furthermore, there is a calculation for the normal rainfall shift between periods using the equation.

$$Normal\ rainfall\ shift = Y_{current} - Y_{past} \qquad (3)$$

Where $Y_{current}$ is the normal monthly rainfall for the period 1991-2020, while Y_{past} is the normal monthly rainfall for the period 1961-1990.

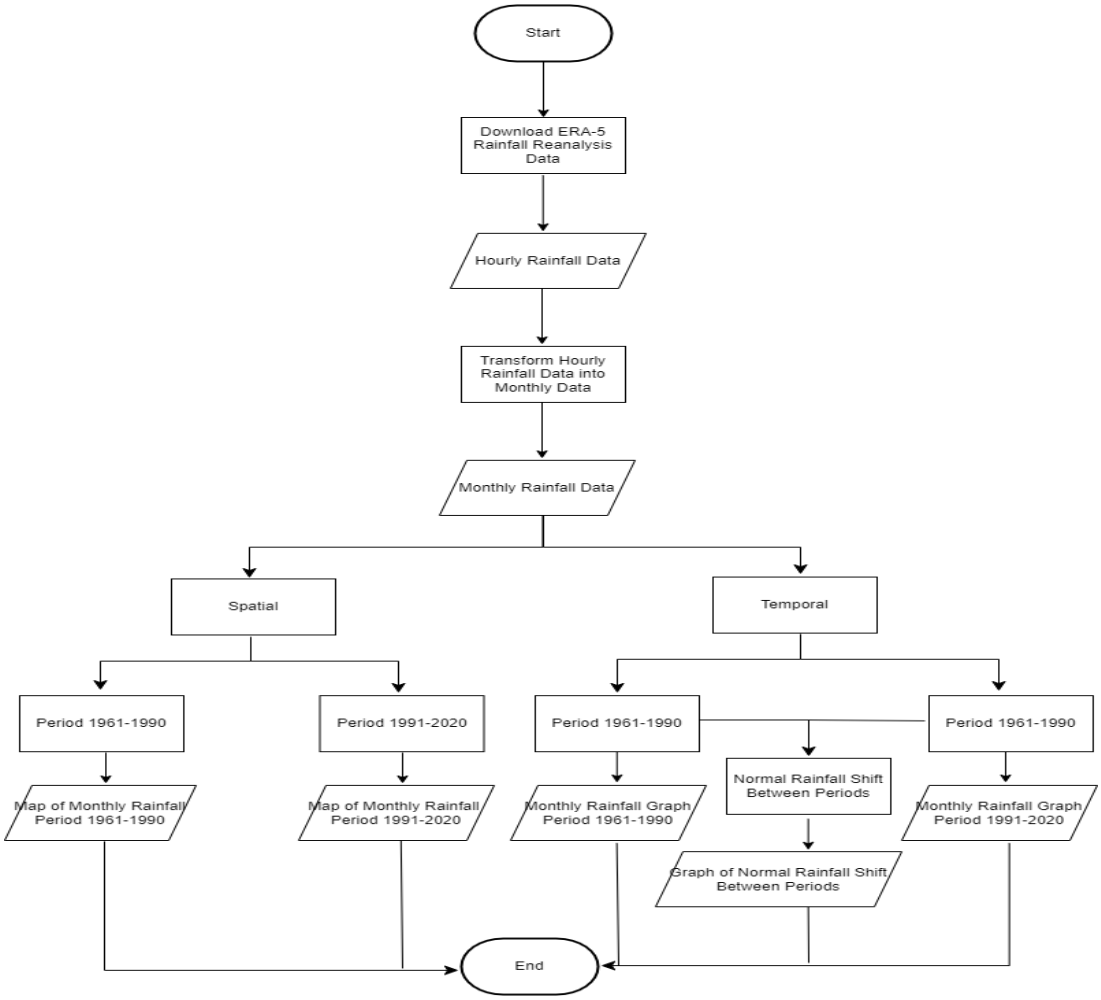

Figure 2. Flowchart

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Results and Discussions

Spatial and Temporal Analysis for the Period 1961-1990

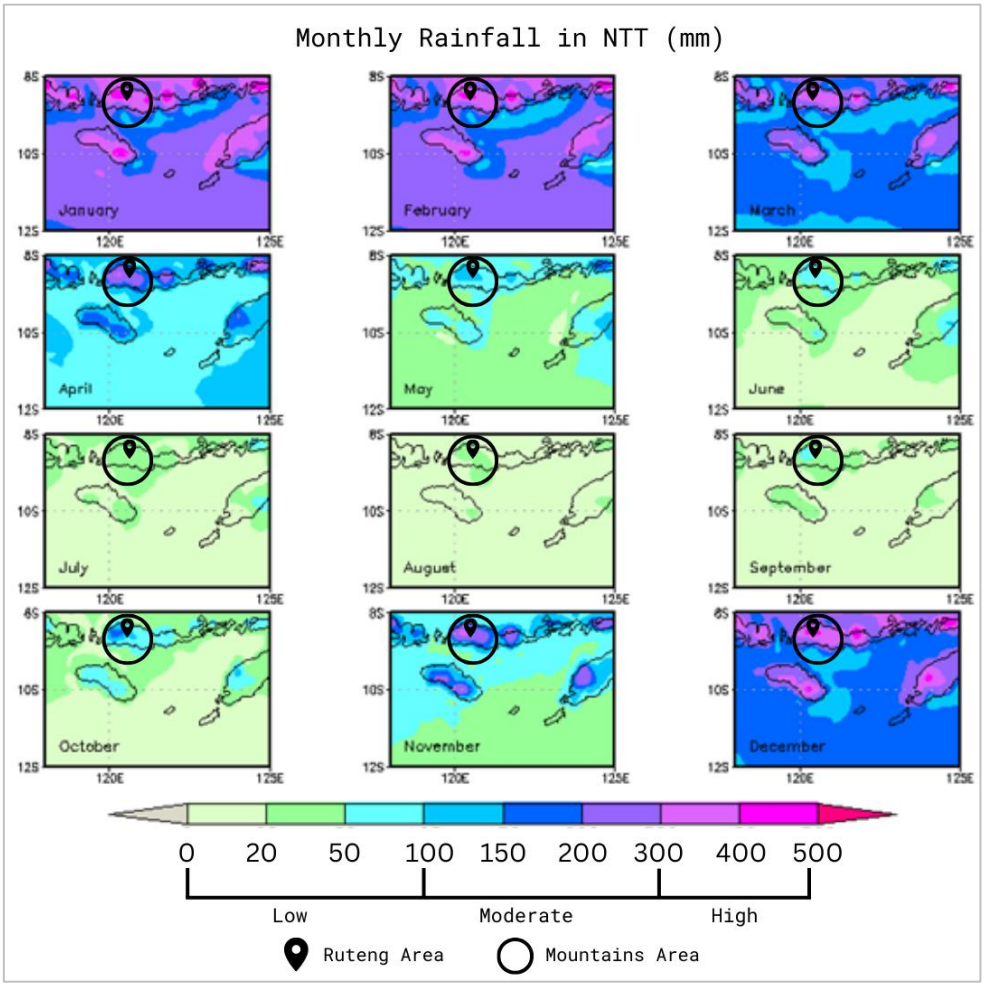

Figure 3. Monthly Spatial Rainfall for the Period 1961-1990 (Source: GrADS Software)

Based on Figure 3, it can be observed that there are variations in rainfall intensity in each region every month. Higher rainfall intensity occurs in high-topography inland areas compared to low-topography areas, indicated by darker colors in the central part of Flores Island, specifically in the Ruteng area. This is consistent with other studies stating that topographic regions like mountains exhibit different rainfall patterns because mountains act as barriers to atmospheric flow, leading to orographic convection that results in localized increases in rainfall [18]. On the other side, coastal areas have lower rainfall compared to inland regions, as indicated by dark blue and light blue colors in the south of Flores Island from December to March. In terms of rainfall distribution, the northern part Nusa Tenggara Timur experiences higher rainfall compared to its southern counterpart.

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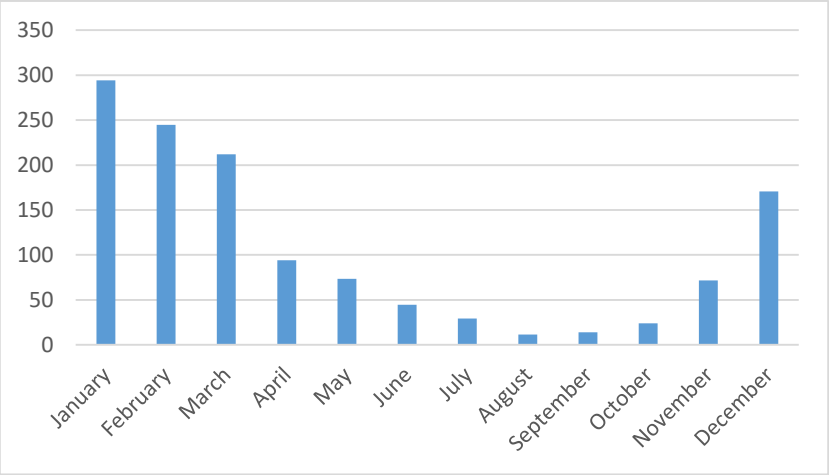

Figure 4. Monthly Rainfall Graph for the Period 1961-1990

In Figure 4, the rainfall pattern formed follows a monsoonal rainfall pattern characterized by a single peak in the rainy season (unimodal) [19]. The peak of rainfall occurs in January with a value of 294.26 mm, while the rainfall trough happens in August with a value of 11.40 mm.

Division into four categories of monthly rainfall according to BMKG, namely low (0-100 mm/month), moderate (100-300 mm/month), high (300-500 mm/month), and very high (> 500 mm/month) [20]. Based on this, the rainfall in Nusa Tenggara Timur for the period 1961-1990 falls into the low to moderate category. Specifically, from April to November, it is in the low category because the value range is 11.40-93.91, while from December to March, it is in the moderate category because the rainfall values that occur range from 170.58-294.26 mm

Spatial and Temporal Analysis for the Period 1991-2020

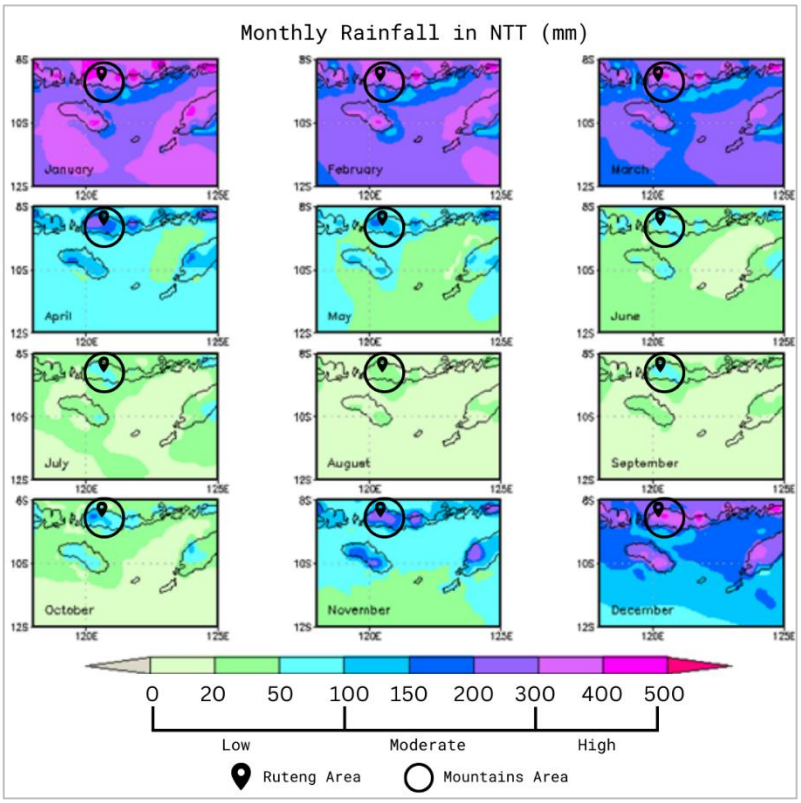

Figure 5. Monthly Spatial Rainfall for the Period 1991-2020 (Author, 2023)

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Based on Figure 5, the overall characteristics of monthly rainfall for the period 1991-2020 are similar to the period 1961-1990 in Figure 3. This similarity includes topographical conditions that result in higher rainfall in higher topography compared to lower topography, higher rainfall intensity inland compared to coastal areas, and a distribution that is more concentrated in the northern part of Nusa Tenggara Timur compared to the southern part. However, there are differences in the intensity and distribution of rainfall, marked by a reduction in the intensity of dark colors replaced by lighter colors, indicating a decrease in rainfall for the period 1991-2020, and the area becomes narrower.

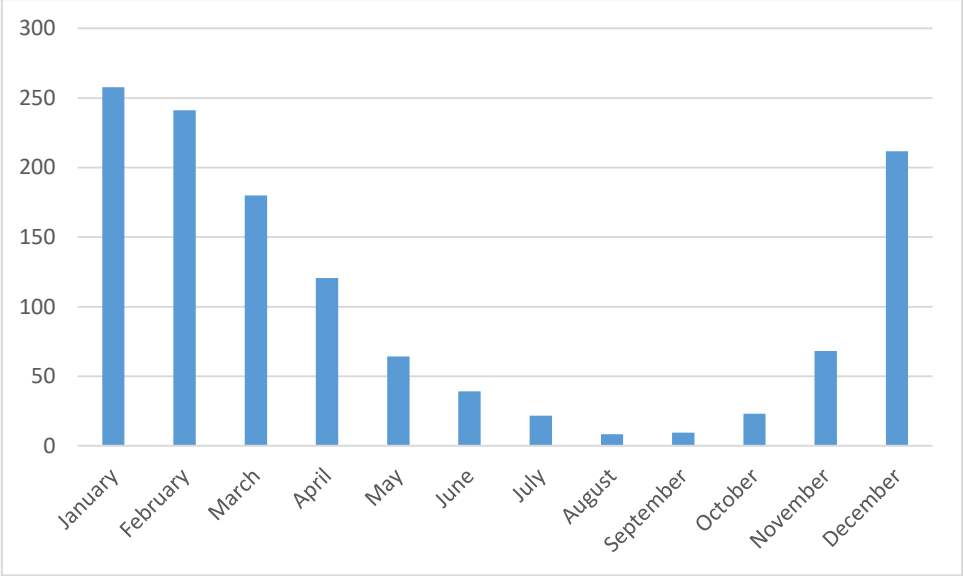

Figure 6. Monthly Rainfall Graph for the Period 1991-2020

Based on Figure 6, the rainfall pattern is the same as the 1961-1990 period, characterized by a unimodal or monsoonal pattern. The peak rainfall time is also the same as the previous period, occurring in January with a value of 257.85 mm, and the trough in August with a value of 8.40 mm. In general, the monthly rainfall for the 1991-2020 period falls into the moderate category from December to April, while from May to November, it is in the low category. There is a noticeable difference in rainfall values between the two periods, which can be seen more clearly in the figure below.

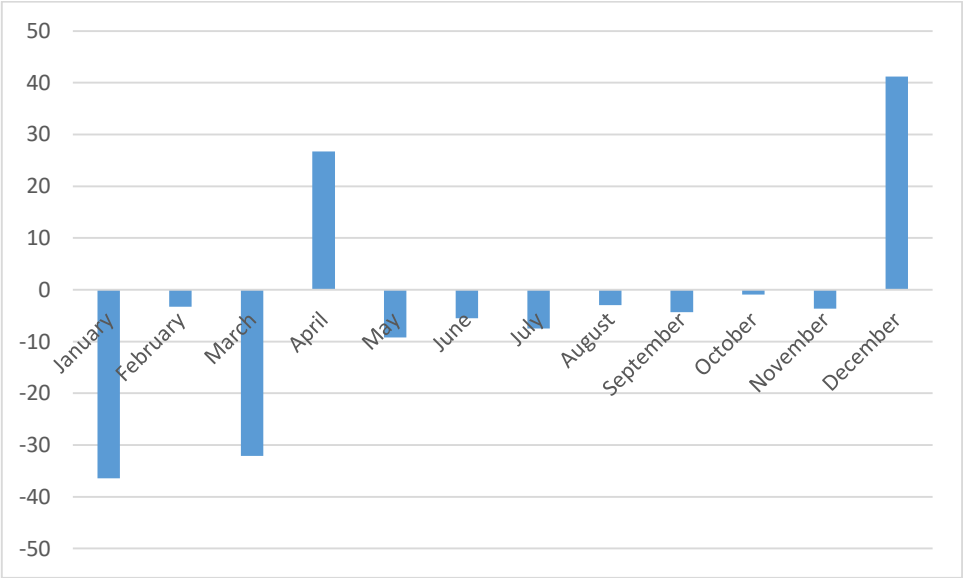

Figure 7. Graph of Normal Rainfall Shift 1991-2020

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Based on Figure 7, it can be observed that there is a positive shift in values for the months of April and December, indicating an increase in the normal rainfall intensity for the period 1991-2020 compared to the period 1961-1990. However, the remaining months have negative values, indicating a decrease in normal rainfall intensity for the period 1991-2020 compared to the period 1961-1990. The highest positive shift occurs in December with a value of 41.19 mm, while the highest negative shift occurs in January with a value of 39.41 mm. The decrease in the normal intensity of rain that occurs, causing a negative shift is caused by global warming which has occurred due to the comsumption of fossil fuels, chemicals, forest fires, the greenhouse effect, and industry emissions [21]. When temperature increases, rainfall decreases or the relationship is inversely proportional [22].

Conclusion

The spatial characteristics of rainfall during the periods 1961-1990 and 1991-2020 indicate similarities in terms of topographical conditions influencing rainfall intensity, where higher topography regions experience higher rainfall. Additionally, rainfall intensity is higher inland compared to coastal areas, and the northern part of Nusa Tenggara Timur has higher rainfall intensity compared to the southern part.

Furthermore, the temporal characteristics of rainfall reveal that both periods exhibit a unimodal monsoonal rainfall pattern with the peak occurring in January, measuring 294.26 mm for the 1961-1990 period and 257.85 mm for the 1991-2020 period. On the other hand, the rainfall trough occurs in August, with a value of 11.40 mm for the 1961-1990 period and 8.40 mm for the 1991-2020 period.

The characteristics between the two periods exhibit differences and undergo spatial and temporal shifts. Spatially, this is evidenced by the reduction in the intensity of dark colors to lighter colors in the 1991-2020 period compared to the 1961-1990 period. On the other hand, temporally, there is an increase in rainfall, indicating the highest positive normal rainfall shift in December with a value of 41.19 mm. However, in January, the highest negative shift occurs with a value of 39.41 mm.

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