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Topography Effects on Rainfall Characteristics in Bandung City and Cilacap Regency for the 2016-2020 Period

Fadhli Aslama Afghani[1], Imawan Mashuri[2*], Ramadoni Khirtin[3], Muhammad Adi Cahyo[4]
*e-mail: imawanmashuri19@gmail.com

[1,2]*Department of Climatology, Sekolah Tinggi Meteorologi Klimatologi dan Geofisika, Tangerang Selatan Indonesia*
[3,4]*Department of Instrumentation, Sekolah Tinggi Meteorologi Klimatologi dan Geofisika, Tangerang Selatan Indonesia*

ABSTRACT

Topography and rainfall correlate with each other. Therefore, this study aims to determine the effect of topography on rainfall characteristicss in the Cilacap and Bandung areas. The research method used is a descriptive statistical analysis of average monthly, seasonal, and annual rainfall. In addition, time series and regression tests were carried out using the SPSS application. The data used is the daily rainfall data period of 2016–2020. The results of the descriptive analysis show that the variability of monthly rainfall in Bandung is higher than in Cilacap, with a value range that is 113.6–643.82 mm/month for Bandung and 92.1-355.56 mm/month for Cilacap. Global climate dynamics for instance apparent sun motion, Monsoon, ITCZ, ENSO, and IOD, as well as local weather systems like valley winds, also affect seasonal and annual rainfall variability in Bandung and Cilacap. The rainfall time series test produces values that are not stationary concerning the variance but stationary concerning the average. A simple linear regression test shows the effect of a topography of 55.2% on rainfall. The purpose of simple linear regression is to understand and model the relationship between two variables: the independent variable (topography) and the dependent variable (rainfall characteristics).

Keywords: rainfall, regression, time series, topography.

INTRODUCTION

Indonesia is located in the equatorial region, so it is vulnerable to climate change (Syahbuddin, H., Manabu, D., Yamanaka, & Runtunuwu, 2004). Climate can be defined as the average condition of air humidity, rainfall, wind direction, air temperature, air pressure, and other climate parameters over a relatively long duration (Bayong Tjasyono H. K., 2004). Rainfall is one of the main elements of climate in the form of the accumulation of water that falls at the bottom of the earth's surface within a certain time range measured in millimeters as a unit of elevation (Triatmodjo, 2008). Rainfall patterns are divided into three types i.e., equatorial, monsoonal, and local (Aldrian & Susanto, 2003). However, most of the rain in the Indonesian region is associated with monsoonal rainfall patterns (Webster, 1987).

One of Indonesia's regions vulnerable to climate change is Java Island, which has an area of 126,700 square meters and an astronomical position at 730'10" S and 11115'47" E. The Geographical location of Java Island on the west side is bordered by Sumatra Island on the west side, Bali Island on the east side, Kalimantan Island on the north side, and Australia on the south side. In addition, Java Island is surrounded by the Java Sea on the north side, the Indian Ocean on the south side, the Sunda Strait on the west side, and the Bali Strait on the east side. Java Island has diverse regional topographical characteristicss, ranging from mountains to coasts.

Bandung is the capital city of West Java Province with hilly topographical conditions. As a non-coastal region, the weather conditions in Bandung City are still relatively cold with rain falling for quite a long time due to the type of convective clouds that cover the area in the form of cumulonimbus clouds (Hidayati, Ramalis, & Mujtahiddin, 2015).

On the other hand, Cilacap Regency is an area on the south coast of Java Island and is directly adjacent to the Indian Ocean. This area has natural resources such as fish ponds (Triyanti, Wijaya, Koeshendrajana, & Priyatna, 2010). In addition, this area often experiences relatively high-intensity rainfall. Rainfall condition occurs due to several factors, such as Indonesian waters, which are classified as warm causing convergence and triggering the formation of convective clouds (Azka, Dzikiro, Simanjuntak, & Winarso, 2018).

The intensity of rainfall varies significantly depending on the topography. (Prasetyo, Irwandi, & Pusparini, 2018). Topography and rainfall exhibit a correlation. This phenomenon can occur due to the significant role played by Indonesia's topography in the creation of weather and climate. The interaction of solar heating and the pronounced surface roughness leads to the generation of turbulent flows. When it occurs at low levels, it can lead to the formation of convective clouds on a relatively smaller scale (Prasetyo, S., Kurniawan, W., & Rumahorbo, 2021).

The objective of this research is to assess the extent of topography's influence on rainfall patterns in Java, particularly in the regions of Bandung and Cilacap, and to make a comparative analysis of the conditions in these two distinct areas. Bandung City represents an area with high topography while Cilacap Regency represents an area with low topography. The situation of the two places is inversely proportional.

MATERIAL AND METHOD

The research article focuses on the characteristics of rainfall on Java Island, grouped based on the variety of topography, namely Bandung City with a mountain slope topography and Cilacap Regency with a coastal topography type.

This research took rainfall data for five years, from January 2016 to December 2020. The data is derived from daily observations recorded at the meteorological stations in both Bandung and Cilacap. The five-year rainfall data can represent climate conditions for each region.

The method used in this study is a descriptive statistical analysis by calculating the average, maximum value, and minimum value for monthly, seasonal, and annual rainfall variability. Calculation of the average rainfall using the average of the following equation

$$P = \frac{P_1 + P_2 + \ldots + P_n}{n} \quad (1)$$

where P is an average value, P_1 P_2 P_n is data values, and n is the amount of data.

In addition, inferential statistical analysis was carried out in the form of time series tests and simple linear regression using the SPSS application with the independent variable in the form of topography and the dependent variable in the form of rainfall. Mathematically, the calculation of time series, i.e.

$$F(Z_{t1}, \ldots, Z_{tm}) = F(Z_{t1+k}, , \ldots, Z_{tm+k}) \quad (2)$$

where Z_t is the observed value at time t, while Z_{t1+k} is the observed value at time t+k which is k steps ahead of time t. Furthermore, a simple linear regression was selected due to its utilization of a single independent variable and a corresponding dependent variable. The equation of a simple linear regression is

$$Y = a + bX \tag{3}$$

where Y is the dependent variable, α is the constant, b is the regression coefficient and X is the independent variable.

Table 1. Research Location Information

No	Research Location	Astronomical Location	Station Name	WMO Code	Elevation (Meter)
1	Bandung City	6°30 - 6°55’LS 107°36 - 107°73’BT	Husein Sastranegara Meteorology Station	96781	812
2	Cilacap Regency	7°30 - 7°45’LS 108°4 - 108°30’BT	Tunggul Wulung Meteorology Station	96805	0,18

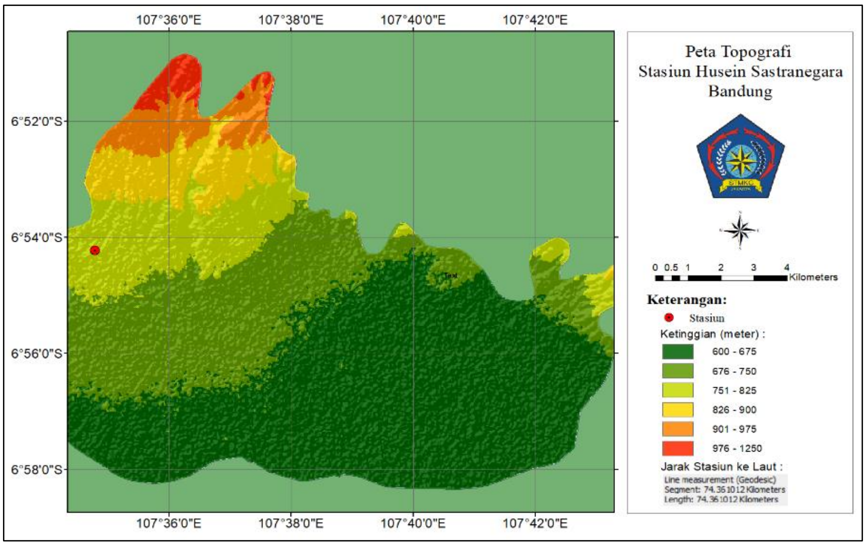

Figure 1. Topographic Map of Bandung City (Author, 2023)

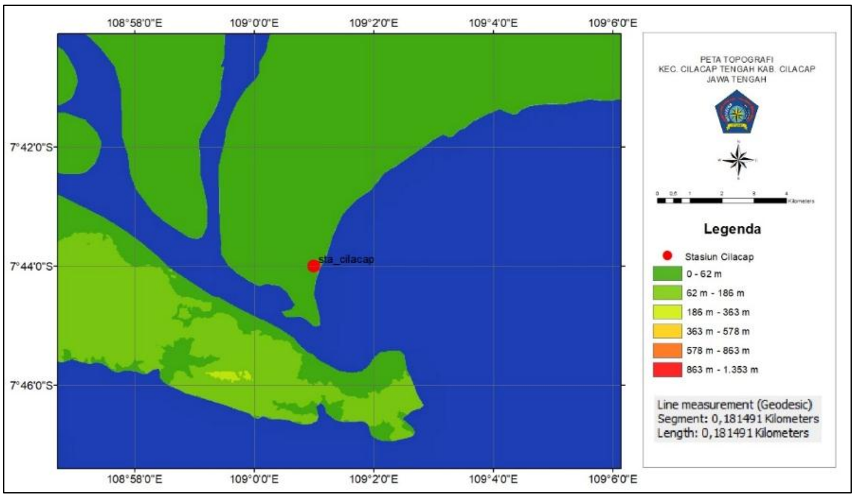

Figure 2. Topographic Map of Cilacap Regency (Author, 2023)

RESULT AND DISCUSSION

Monthly Rainfall Variability

The categorization of monthly rainfall by BMKG into four groups includes low rainfall (0–100 mm/month), moderate rainfall (100–300 mm/month), high rainfall (300–500 mm/month), and very high rainfall (> 500 mm/month). (Supriyati, Tjahjono, & Effendy, 2018).

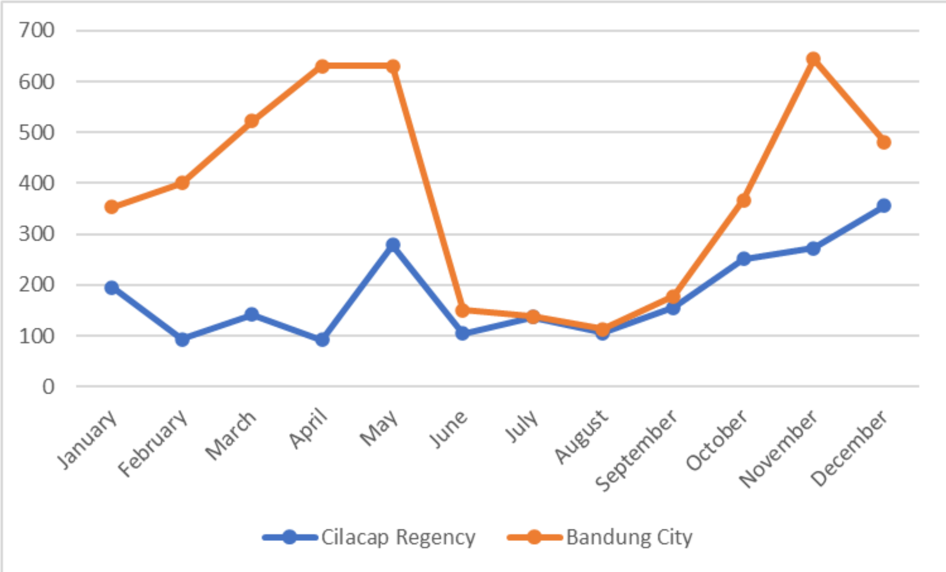

Figure 3. Monthly Rainfall Period of 2016–2020

Figure 3 shows that the five-year average of monthly rainfall from 2016 to 2020 exhibits considerable variation. Rainfall in the Bandung area is classified as moderately high, with monthly rainfall varying from 113.6 to 643.82 millimeters. In contrast, the monthly rainfall in the Cilacap area falls within the low-high category with a range of 92.1-355.56 mm/month values.

The highest rainfall or peak of the rainy season in the Bandung area occurs in November with a value of 643.82 mm and the lowest rainfall or peak of the dry season occurs in August with a value of 113.6 mm. On the other hand, Cilacap Regency experienced the highest rainfall or peak rainy season of 355.56 mm in December, while the lowest rainfall or peak of the dry season was 92.1 mm in April.

The reason for the monthly rainfall exhibiting more fluctuations in Bandung than in Cilacap is attributed to both global and local climate dynamics. Global dynamics, in the shape of La Niña leading to increased rainfall from January to May, and El Niño causing reduced rainfall starting from June to September, exert a significant impact (Nabilah, Prasetyo, & Sukmono, 2017). In addition, local dynamics such as topography that tends to be hilly and valley can form vertical wind characteristicss, namely mountain and valley breezes (Ahrens, 2007). These winds induce upward movement of air, leading to the formation of clouds that eventually result in orographic rainfall.

Seasonal Rainfall Variability

Rainfall in Java Island is generally in the form of a monsoonal characteristics characterized by a peak rainy season unimodal (Hermawan, 2010). In addition, another feature of this characteristics is that there is a clear contradiction between the dry and rainy seasons (Tjasyono, 1999).

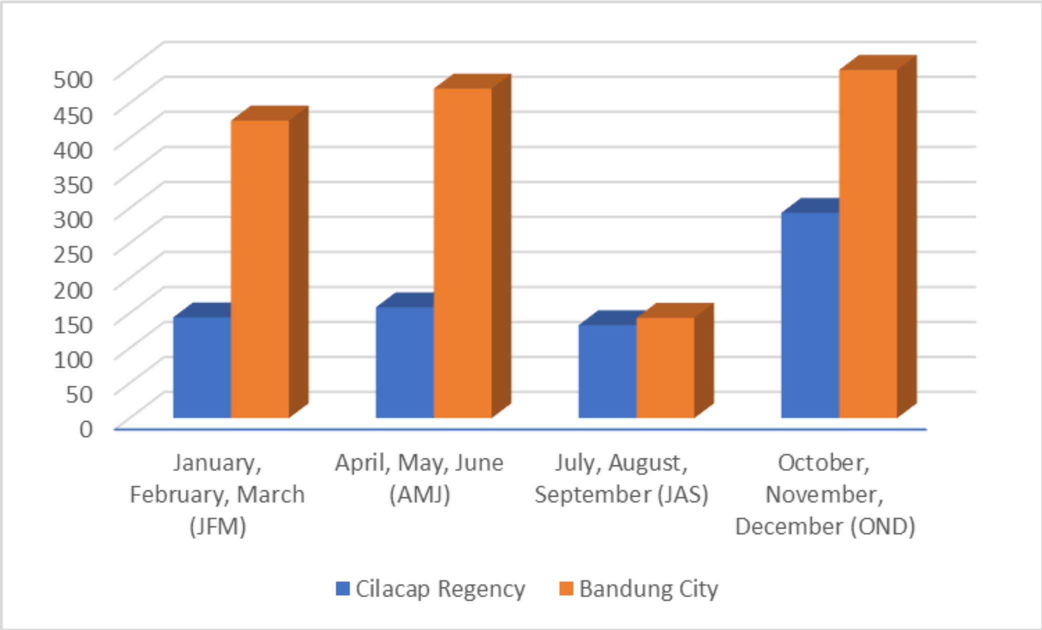

Figure 4. Seasonal Rainfall Period of 2016–2020

The range of seasonal rainfall in Bandung City increases during the JFM period, from 352.825 to 522 mm. There was generally an increase followed by a significant decrease compared to the previous period with the AMJ period being between 150.88 and 630.575 mm. The JAS period experienced degradation compared to the AMJ period with rainfall ranging from 113.6 to 178.5 mm. The peak period of the highest seasonal rainfall occurred in OND with a range of 366.6 to 643.82 mm.

Instead, seasonal rainfall in Cilacap Regency tends to decrease during the JFM period with a range of 93.425 to 195.9 mm. During the AMJ period, there were fluctuations in May with a rainfall range of 92.1 to 278.26 mm. In the JAS period, the rainfall is higher than the AMJ period with values ranging from 117.92 to 171.92 mm. Then the peak of the highest seasonal rainfall occurs in OND with a range of 251.27–355.56 mm.

The fluctuations in rainfall values observed in Bandung City and Cilacap Regency are attributed to the apparent movement of the sun. In March and October, when the sun passes through the equator, or during equinox conditions, there is an increase in rainfall during the JFM period in Bandung City and OND in both locations.

In addition, the presence of monsoons affects the intensity of rainfall in Indonesia, with the east monsoon occurring from December to March, which results in a decrease in rainfall intensity. During the JFM period in Cilacap Regency, there was a decrease in rainfall. Meanwhile, there is a decrease in rainfall in Bandung City, which was significant in December during the OND period (Wahid & Phi, 2018).

The existence of the ITCZ moving south will cause rainfall in the Indonesian region from January to June. These phenomena affect the fluctuation of rainfall in May during the AMJ period in Cilacap Regency. Meanwhile, the rainfall in Bandung City has no fluctuation in May (Satiadi & Fathrio, 2011; Tukidi, 2010). The presence of El Nino affects the intensity of rainfall in Indonesia (Tjasyono K, B. H., & Harijono, 2008). When El Nino occurs from May to July, it makes rainfall significantly decreases in Cilacap Regency and Bandung City. During the occurrence of El Niño from May to July, there is a substantial reduction in rainfall in both Cilacap Regency and Bandung City. (Safitri, 2015).

Annual Rainfall Variability

The annual precipitation in Java Island exhibits a notable contrast between the regions of Bandung City, characterized by mountain slopes topography, and Cilacap Regency, featuring coastal topography, as illustrated in Figure 5.

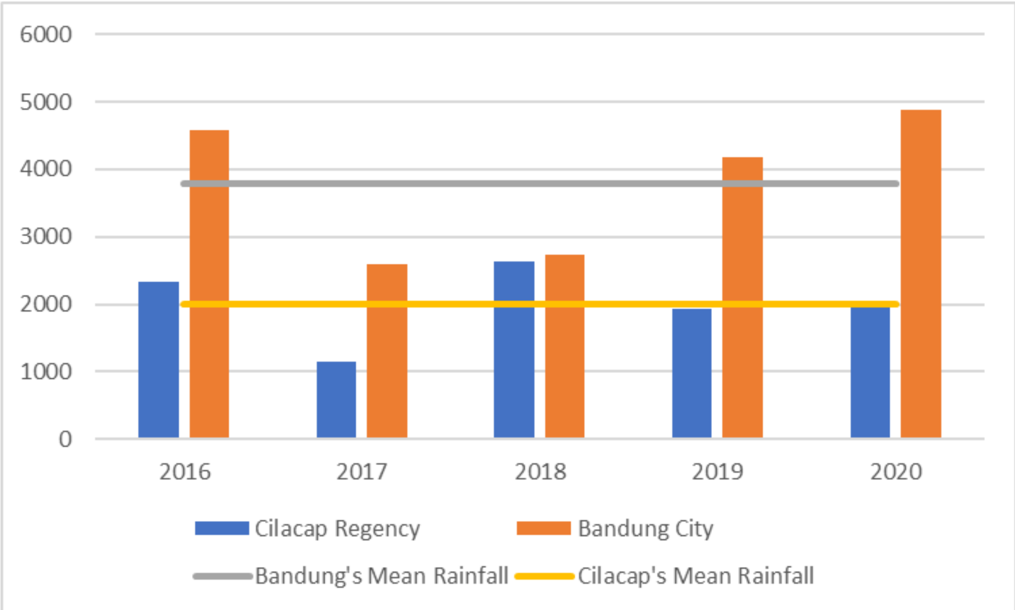

Figure 5**.** Annual Rainfall Period of 2016–2020

Figure 5 shows that annual rainfall accumulation in both Bandung City and Cilacap Regency has fluctuated for five years. The accumulated annual rainfall in the Bandung displays diverse values within the range of 2593 to 4877.8 mm/year, and the average annual rainfall is 3792.7 mm/year. The annual rainfall in Bandung City is a wet category (Primayuda, 2006). The influence of local weather elements, such as the presence of valley breezes and the formation of topographic clouds contribute to the occurrence of exceptionally high rainfall in the Bandung area.

Otherwise, the accumulated annual rainfall in Cilacap Regency exhibits diverse values within the range of 1145 to 2641.6 mm/year with the average annual rainfall is 2006.16 mm/year. Thus, the annual rainfall in Cilacap Regency falls within the moderate category. (Primayuda, 2006). It is due to the movement of the east monsoon, which carries a little water vapor from Australia to Asia. In addition, climate variability in the form of a positive Indian Ocean Dipole (IOD) will have an impact on cooling sea surface temperatures and reduced rainfall intensity in Cilacap Regency (Rahayu, Sasmito, & Bashit, 2018).

The annual rainfall conditions that experience anomalies in both Bandung City and Cilacap Regency show similarities. Both experienced positive anomalies or increases from the average in 2016, 2019, and 2020. Meanwhile, negative anomalies or reductions from the average were observed in the years 2017 and 2018. The occurrence of this negative anomaly is attributed to the impact of global climate variability, specifically the El Niño Southern Oscillation, commonly referred to as ENSO. In 2017 and 2018, the ENSO value exceeded 0.5, signifying the presence of El Niño (Nurafifah, Zainuri, & Wirasatriya, 2022). The El Niño phenomenon, characterized by elevated sea surface temperatures in the eastern Pacific Ocean, results in a reduction of rainfall in Indonesia.

Time Series Test

A time series chart can display the stationarity of rainfall data against its variance.

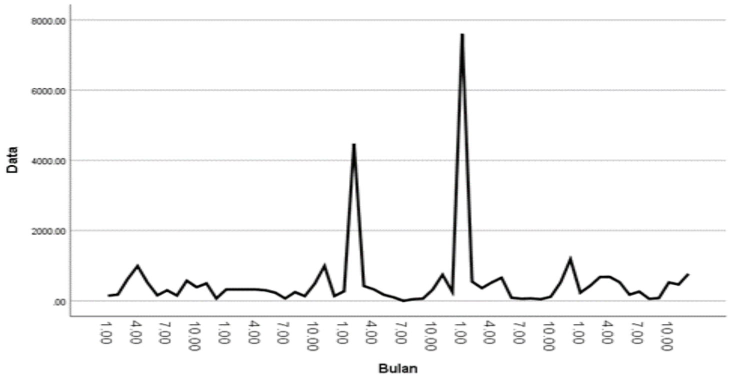

Figure 6. Rainfall Time Series Graph of Bandung City

Figure 6 illustrates a noticeable variation in the average rainfall data for Bandung City. It can be interpreted that the value of rainfall data in the time series for the time monthly during 2016–2020 is not stationary concerning the variance.

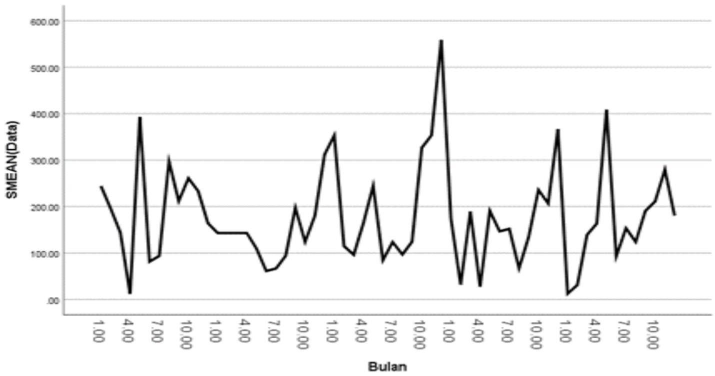

Figure 7. Rainfall Time Series Graph of Cilacap Regency

Conversely, Figure 7 displays the fluctuation in the average value, indicating that in Cilacap Regency, the rainfall data values over the time series for each month during 2016–2020 exhibit non-stationarity in terms of variance.

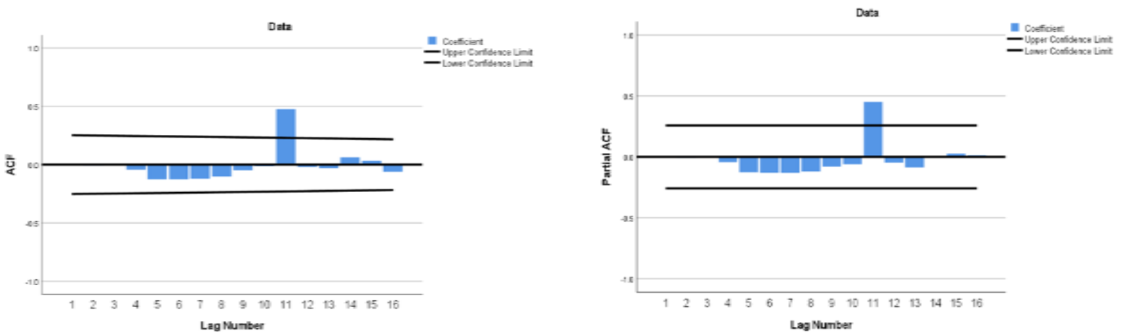

Figure 8. a) Autocorrelation Function (ACF) b) Partial Autocorrelation Function (PACF) of Bandung City

Based ACF graph in Figure 8 a), there is a lag that exceeds the average line value by 1 point on the 11th lag number. In the PACF graph in Figure 8 b), there is also a lag that exceeds the average line value by 1 point on the 11th lag number. The intensity of rainfall in Bandung City is stationary concerning the average value.

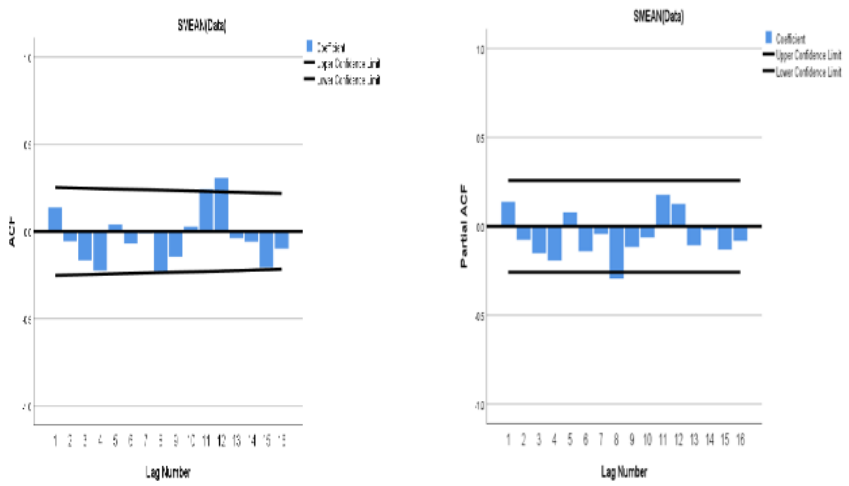

Figure 9. a) Autocorrelation Function (ACF) b) Partial Autocorrelation Function (PACF) of Cilacap Regency

On the other hand, based ACF graph in Figure 9(a), there is a lag that exceeds the average value line by 3 points at the 8th, 11th, and 12th lags. The PACF graph in Figure 8(b), has a lag that exceeds the average value line by 1 at the 8th lag. The rainfall intensity is stationary concerning the average value in Cilacap Regency.

In contrast, Figure 7 depicts the variability in the average values, suggesting that, in Cilacap Regency, the rainfall data values over the monthly time series from 2016 to 2020 lack stationarity with respect to variance.

Simple Linear Regression Test

The model summary results and regression coefficients are based on Table 3 and Table 4.

Table 3. Model Summary

Model Summary				
Model	R	R Square	Adjusted R Squared	Std. Error of Estimate
1	0.552[a]	0.305	0.273	146.6529

The R-value shows the correlation value between topography (elevation) and rainfall is 0.552 or 55.2%. Moreover, a coefficient of determination of 0.305 is obtained, which means that the value of variance is 30.5%.

Table 4. Regression Coefficient

Coefficients[a]						
	Unstandardized Coefficient					
Model		B	Std. Error	Standardized Coefficient Beta	t	Sig
1	(Constant)	181.978	42.344		4.298	0
	Elevation	0.229	0.074	0.552	3.106	0.005

Based on Table 4, it is known that the constant value (a) is 181.978 with a height value of 0.229, so the regression equation becomes:

$$Y = a + bX \quad (4)$$

$$Y = 181{,}978 + 0{,}29X \quad (5)$$

The regression coefficient value X (elevation) is 0.229, which states that for every 1% addition of the elevation value, the rainfall value increases by 0.229, or 22.9%, and so for the opposite circumstances. Therefore, the regression coefficient has a positive value, so the direction of the influence of the variable X on Y is positive.

CONCLUSION

Based on the analysis of the effect of topographical variation on rainfall characteristics for the 2016–2020 period, it can be concluded that the monthly rainfall variability in the Bandung area is in the medium-high category ranging from 113.6 to 643.82 mm/ month. Low-high category, with a value range of 92.1 to 355.56 mm/month. Seasonal and annual rainfall variability in Bandung City and Cilacap Regency has fluctuated due to global climate dynamics for instance apparent sun motion, Monsoon, ITCZ, ENSO, and IOD. Additionally, local weather systems such as valley winds also influence the intensity of rainfall. The rainfall time series analysis indicates that both Bandung City and Cilacap Regency exhibit stationarity with respect to the average value but lack stationarity in terms of variance. In addition, a simple linear regression test shows that topography has an effect of 55.2% on rainfall.

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