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Analysis of Rainfall Duration in Dramaga–Bogor in relation to Drainage Infrastructure Planning

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Abstract: Dramaga Subdistrict, Bogor Regency, is the only area in West Java with a Monsoon-1 zone of the Year-Round Rainfall (YRR) type with rainfall exceeding 150 mm/month. The combination of duration and high intensity is an important factor that affects peak discharge/flooding, which in turn determines the dimensions of drainage channels. This study aims to analyze the duration of rainfall in Dramaga - Bogor and other characteristics. The analysis was conducted based on data from the Automatic Agroclimate Weather Station (AAWS) for 2018-2024 at the Bogor Climatology Station. It was found that the duration of heavy and very heavy rainfall in Dramaga was mostly 2 hours. In addition, the highest monthly rainfall in Dramaga occurred in November (419.63 mm/month), while the lowest was in June (107.36 mm/month). Most of the rainfall occurred between 13:00 and 18:00 WIB, with the peak rainfall between 16:00 and 19:00 WIB.

Keywords: rainfall**,** flood discharge**,** drainage, duration

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1. Background

Based on the document “2020 Seasonal Zone Update,” Bogor is the only region in West Java that is included in Monsoon Zone 1, which is classified as Year-Round Rainfall (HST) with two rainfall peaks at the beginning and end of the year and rainfall >150 mm[1]. The Dramaga Class I climatological station recorded an average rainfall of 263-356 mm/month. The high rainfall is influenced by local factors, such as the topography flanked by Mount Salak and Pangrango and the dominance of monsoon winds. Meanwhile, the dominance of afternoon rainfall in Dramaga is related to the dominance of convective clouds that reach an altitude of 4.5 km[12]. These conditions of high rainfall and complex topography increase the risk of flooding if drainage is not designed according to local rainfall characteristics.

Drainage planning requires a deep understanding of diurnal patterns and local rainfall characteristics, such as intensity, frequency, and duration. The combination of duration and high intensity is a crucial aspect because it directly affects peak discharge, thereby influencing the dimensions of drainage facilities [5][8].

Most peak discharge/flood predictions are based on daily rainfall data. The Mononobe equation, which describes the relationship between rainfall intensity and daily rainfall and rainfall duration (t), is often used. However, rainfall duration (t) has been an assumed value because the data is not available.

Research in Petapahan Village estimated maximum intensity using rainfall duration (t) assumptions based on the IDF curve[9]. Research on dominant rainfall duration for the Jakarta and Bogor areas using empirical methods with the Mononobe equation and Alternative Block Method (ABM) has been conducted. The results show that rainfall in Bogor is dominant for 4 hours with maximum intensity in the first 2 hours[7].

For the Dramaga area, previous studies have only discussed monthly rainfall variations, stating that the peak rainfall occurs in February and November (around 410 mm), but have not discussed the duration, frequency, and intensity of rainfall[3].

This study aims to analyze rainfall duration and other local rainfall characteristics in the Dramaga area. The results of this study are expected to provide input for policy makers and technical planners of drainage facilities in Dramaga and its surrounding areas..

2. Method

2.1. Tools And Materials

The equipment used in this study included laptops, Microsoft Word software, and Microsoft Excel. The data used in this study was rainfall data from the Dramaga Automatic Agroclimate Weather Station (AAWS) for 2018–2024, obtained from the Bogor Climatology Station. The data accuracy was 0.2 mm, measured every 10 minutes..

2.2. Prosedur Penelitian

The research was conducted in the following stages:

1. Manually selecting the days on which rainfall occurred each month. Rainy days were defined as days on which rainfall intensity was ≥ 1 mm/hour (referring to BMKG Head Decree No. Kep. 009 of 2010).
2. Calculating the average hourly rainfall and creating a graph to identify monthly diurnal patterns.
3. Rainfall frequency was then analyzed from diurnal patterns based on the time of occurrence (07:00–10:00, ..., 04:00–07:00) to determine the dominant time each month.
4. Rainfall data was then grouped manually based on daily rainfall peaks, which included depth, rainfall class, duration, and time of onset.
5. Analyzing the number of peaks and intensity, then selecting an intensity of ≥10 mm/hour to see the relationship between peaks and heavy rainfall frequency.
6. Performing a classification analysis based on rainfall duration and intensity with duration intervals of <1 hour, 1–2 hours, to 5–6 hours.
7. Determine the dominant rainfall duration based on intensities of 10–20 mm/hour and ≥20 mm/hour

The final results of all these stages produce rainfall duration and other rainfall characteristics for the Dramaga region, including diurnal patterns, maximum rainfall, extreme rainfall types, intensity, and time of occurrence.

3. Result and Discussion

3.1. Monthly Rainfall Diurnal Pattern

The diurnal rainfall pattern is a daily recurrence of rainfall changes within a 24-hour period[11]. The lowest rainfall in the Dramaga area generally occurs between 00:00 and 10:00 WIB, then increases, with the highest rainfall occurring between 13:00 and 18:00 WIB. m). The maximum average rainfall intensity was recorded in November at 89.11 mm/hour at 16:00 WIB, while the lowest intensity occurred in January at 23.73 mm/hour at 15:00 WIB. A summary of the monthly diurnal pattern is shown in **Figure 1.**

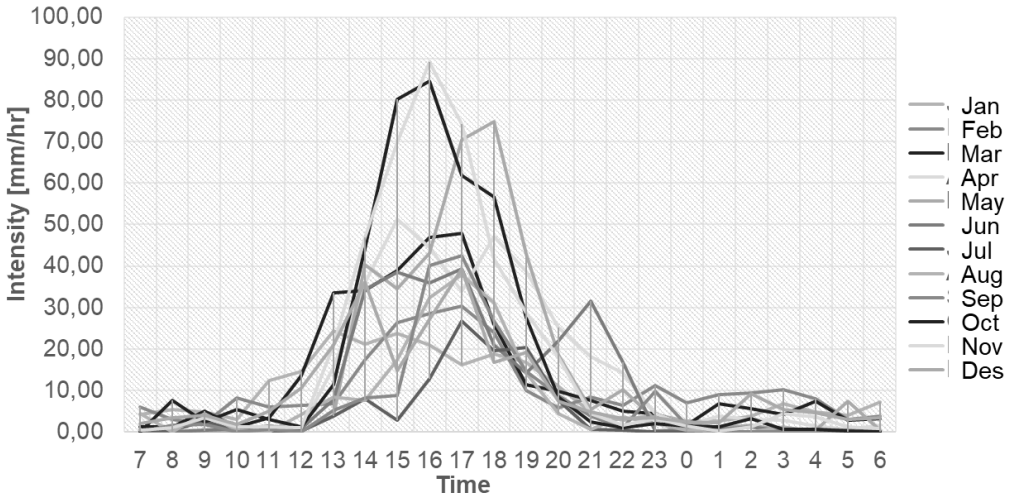
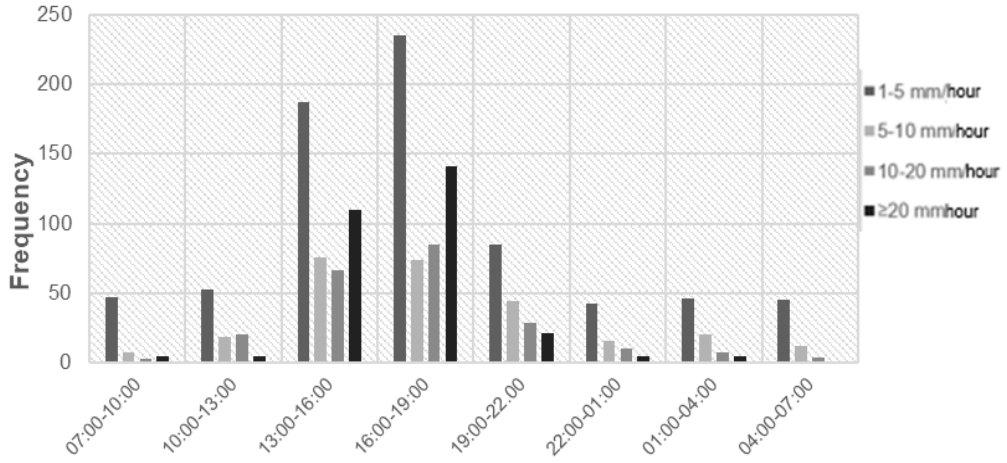


Figure 1 Recapitulation of the diurnal pattern of monthly rainfall from 2018 to 2024

. The analysis also shows that the frequency of peak monthly rainfall predominantly occurs between 16:00 and 19:00 WIB, namely 535 times (35% of the total 1524 rainfall events). Rainfall with an intensity of ≥10 mm/hour was predominantly recorded in October and November, with 13 and 26 events, respectively, as shown in **Figure 2.** This afternoon rainfall pattern is influenced by local mountain winds and the dominance of convective clouds.



Fugure 2 Recapitulation of monthly rainfall frequency 2018-2024

3.2. Monthly Rainfall Characteristics

3.2.1. Monthly Average Rainfall Variation

Bogor is known as the “city of rain” due to its distinctive climatological characteristics. Based on the rainfall type classification released by the BMKG in the document “Seasonal Zones for the Period 1991-2020,” the Bogor region is the only region in West Java that is categorized as a Monsoon-1 zone with Year-Round Rainfall (HST). This type is characterized by high rainfall at the beginning and end of the year, without a distinct dry season.

The monthly rainfall pattern in Dramaga during 2018-2024 follows the Monsoon-1 type, characterized by two rainfall peaks in May (362 mm) and November (420 mm) and the lowest monthly rainfall in July (107 mm). Most monthly rainfall is above 150 mm without any consecutive three-month dry periods (with rainfall below 100 mm). This pattern is influenced by monsoon dynamics, where the Asian monsoon (humid) lasts from November to March and the Australian monsoon (dry) from May to September, forming the typical Monsunal-1 monthly rainfall distribution in Dramaga and its surroundings[3]. The distribution of monthly rainfall in Dramaga for the 2018-2024 period is presented in **Figure 3**.

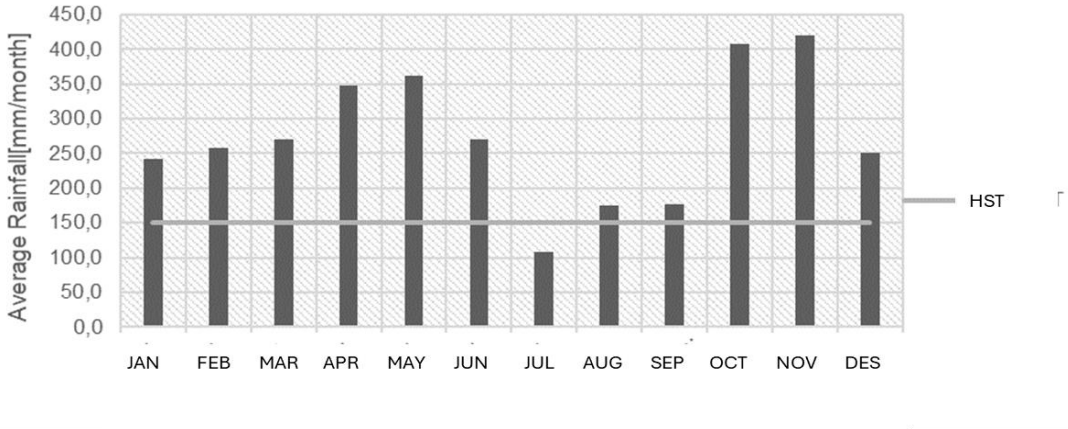


Figure 3 Monthly rainfall distribution in Dramaga District, 2018-2024

3.2.2. Rainfall Frequency by Peak Type

The distribution of monthly rainfall variation at the Dramaga Station does not clearly illustrate the pattern of monthly rainfall variation, so additional information on other rainfall characteristics is needed. The AAWS Dramaga measuring device recorded at least 974 rainy days out of a total of 2556 days during the 2018-2024 period, equivalent to 38%. Rainfall events were identified on a daily basis by categorizing rainfall based on the number of rainfall events per day into three categories, namely single peak, double peak, and multiple peaks (>2). The distribution of monthly rainfall peak types for the 2018-2024 period in the Dramaga District is presented in **Figure 3.**

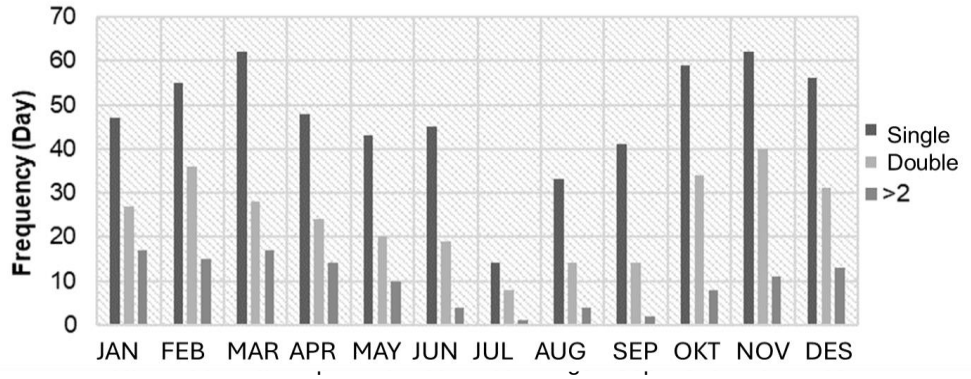


Figure 3 Variations in monthly rainfall peaks in Dramaga, 2018-2024

Based on **Figure 3**, overall, single peak rainfall dominates the Dramaga area with a total of 564 days out of a total of 974 rainy days (approximately 58%). The highest frequency was recorded in November with 62 days, while the lowest occurred in July with 14 days. This is due to the influence of monsoon winds, where the west monsoon that carries water vapor dominates from October to December, thereby potentially contributing to cloud and rainfall formation in Indonesia. Fluctuations in peak rainfall intensity for each month are presented in **Figure 4**.

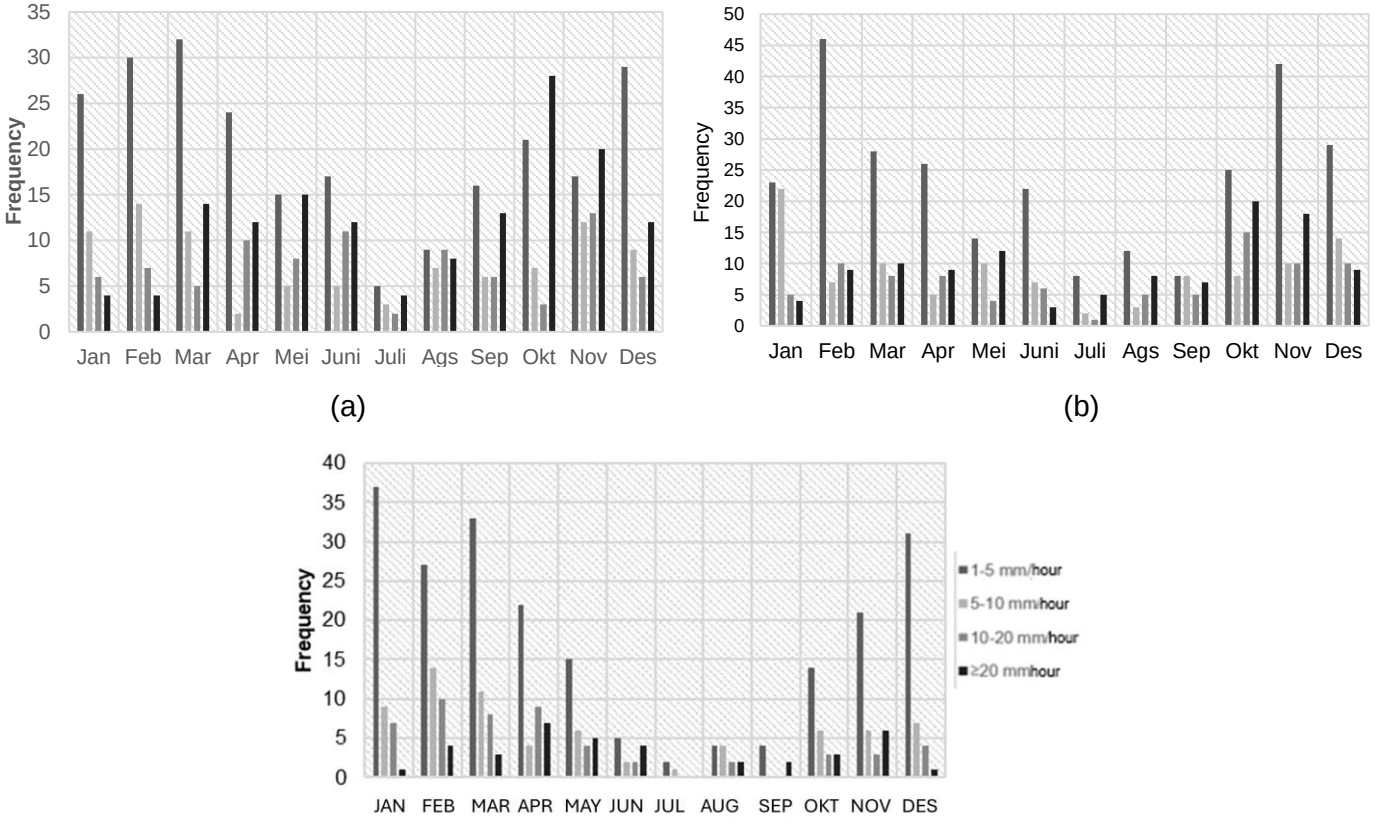


Figure 4 Variations in peak intensity of single rainfall (a), double rainfall (b), and multiple rainfall (c) in Dramaga, 2018–2024

Based on Figure 4, light rain (1-5 mm/hour) dominates almost all months. Rainfall that affects drainage planning is rainfall with an intensity of ≥10 mm/hour [10]. The frequency of rainfall with an intensity of ≥10 mm/hour is low in January–March and July–September. The frequency of rainfall with

an intensity of ≥10 mm/hour increases in October–December (>20 events). According to the BMKG, the increase in rainfall frequency at the end of the year is influenced by changes in wind direction and increased atmospheric humidity. Rainfall patterns influenced by the Asia-Australia monsoon with high rainfall occur in the September-October-November (SON) and December-January-February (DJF) periods due to the sun's shift to the south, while the wet dry season that occurs in June-July-August (JJA) brings dry air from Australia..

The frequency of rainfall with an intensity of ≥10 mm/hour in single-peak rainfall was the highest with 232 rainfall events, while the lowest was in multi-peak rainfall (with 90 rainfall events). The decrease in the frequency of heavy rainfall between these types of rainfall peaks is caused by the release of convective energy divided into several cycles, where the more rainfall events in a day or the more peaks there are, the lower the frequency of rainfall with an intensity of ≥10 mm/hour. The frequency of rainfall with an intensity of ≥10 mm/hour from single-peak, double-peak, and multi-peak rainfall is presented in **Table 2**.

Tabel 2. Frequency of rainfall ≥10 mm/hour in Dramaga 2018-2024

Jenis Puncak	Frequency	Percentage
Single	232	44,35
Double	201	38,43
Multipeak	90	17,20
Total	523	100

3.2.2. Rain Frequency based on Duration

Rainfall duration is an important aspect in calculating peak discharge because the combination of duration and intensity is an input in the Rational equation [6]. Rainfall with an intensity of ≥10 mm/hour has a greater effect on the volume of runoff that occurs when rainfall exceeds the saturation capacity of the soil so that the soil can no longer absorb water [4]. This rainfall frequency analysis based on duration is also useful for identifying critical months in project or drainage planning. Variations in the duration of heavy rainfall (10-20 mm/hour) and very heavy rainfall (≥20 mm/hour) can be seen in **Figure 5**.

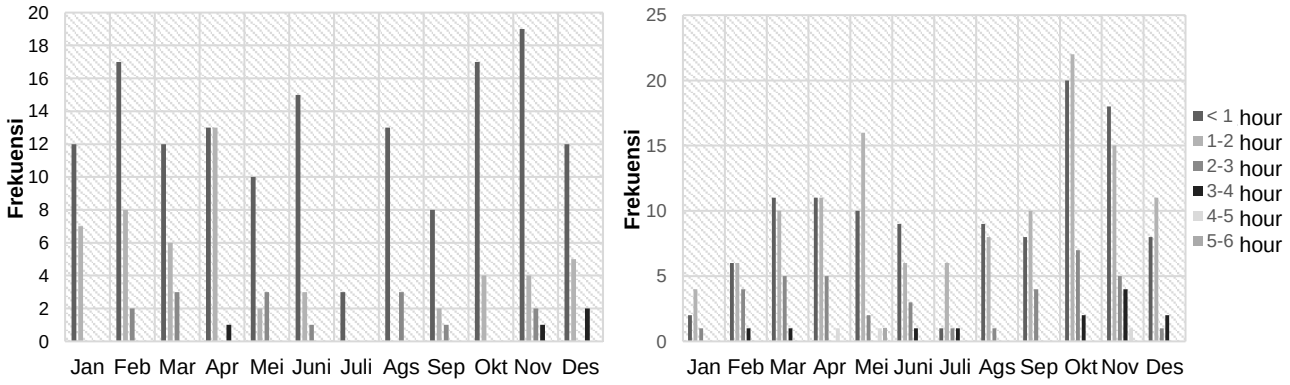


Figure 5 Variations in duration based on (a) intensity of 10-20 mm/hour (b) intensity of ≥20 mm/hour

The duration is divided into six classes, namely <1 hour, 1-2 hours, 2-3 hours, 3-4 hours, 4-5 hours, and 5-6 hours, considering that heavy rain in Indonesia, which has a tropical climate, generally occurs for a short duration (<6 hours)[2]. **Figure 5** shows that heavy rainfall (> 10 mm/hour) most often occurs in February and April, with a total of 27 rainfall events across all duration classes, but the highest frequency of rainfall with an intensity of 10-20 mm/hour occurs in November, with 19 rainfall events lasting less than

1 hour. Overall, heavy rainfall (10-20 mm/hour) predominantly occurred for less than 1 hour, with 151 events. Meanwhile, very heavy rainfall (≥20 mm/hour) was recorded more frequently than heavy rainfall, with 293 events or 19% of the total 1,524 rainfall events. Figure 5 also shows that the dominant duration of very heavy rainfall was 1-2 hours, with 125 events. This type of rainfall occurred most frequently in October, with 22 events. Although it takes longer to reach a large accumulation, this rainfall duration is relatively short due to the influence of the tropical climate[15]. The distribution of rainfall duration based on the overall classification of rainfall intensity in Dramaga for the 2018-2024 period is presented in **Figure 6**.

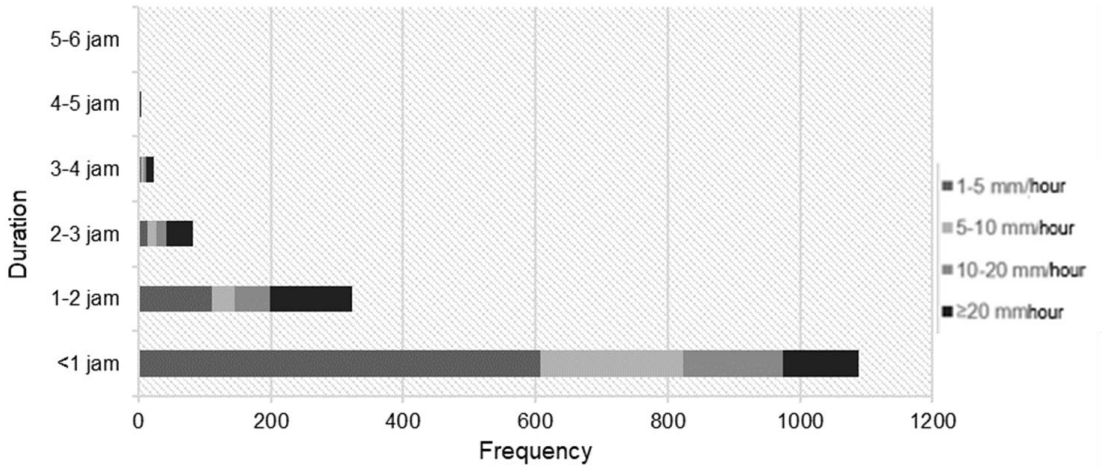


Figure 6 Recapitulation of total rainfall intensity based on duration in Dramaga District, 2018-2024

3.3. Extreme Rainfall Events in Dramaga for the Period 2018-2024

In addition to considering heavy and very heavy rainfall events, drainage planning must also consider the potential for extreme rainfall so that channels can reduce the risk of flooding based on historical data[14]. According to the Meteorology, Climatology and Geophysics Agency (BMKG), extreme rainfall is defined as rainfall with an intensity exceeding 100 mm/day. During the observation period of 2018-2024, there were 17 incidents of extreme rainfall, with the highest frequency occurring in October with 4 incidents. The distribution of extreme rainfall tends to be evenly spread throughout the year, with the highest concentration occurring during the transition months and the beginning of the rainy season. The transition from the southeast monsoon to the northwest monsoon during the transition months contributes to extreme rainfall due to increased air humidity and the intensity of water vapor movement[13]. Extreme rainfall events in Dramaga from 2018 to 2014 are presented in Table 3.

Tabel 3 Extreme rainfall in Dramaga from 2018 to 2024

Date	Intensity (mm/day)	Date	Intensity (mm/day)
19 Jan 2020	100,8	9 Jun 2022	121,4
6 Jan 2021	108,0	15 Jul 2022	107,2
7 Feb 2020	117,0	28 Oct 2018	107,4
29 Feb 2020	121,2	10 Oct 2019	104,4
2 Mar 2024	102,4	20 Oct 2020	108,4
25 Apr 2019	109,4	15 Oct 2024	105,8
1 May 2020	101,4	4 Nov 2023	118,0
16 May 2024	105,6	29 Nov 2023	124,0
24 May 2024	137,8		

4. Conclusion

a). It was found that the duration of heavy and very heavy rain in Dramaga was mostly 2 hours.

b). The highest monthly rainfall in Dramaga occurred in November (419.63 mm/month), while the lowest was in June (107.36 mm/month).

c) Most rainfall occurs between 1:00 PM and 6:00 PM WIB, with peak rainfall between 4:00 PM and 7:00 PM.

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