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Using GPM and BMKG Satellite Rain Data for Compiling Intensity-Duration-Frequency (IDF) Curves in the Residential Area of Medan Marelan District

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Abstract: Medan Marelan District is a densely populated residential area with an area of 4.20 km2. This area often experiences flooding, particularly during the rainy season. Flooding is caused by water resource infrastructure buildings that do not function optimally, so runoff is not distributed properly. This study aims to compile an IDF curve using *Global Precipitation Measurement* (GPM) satellite data and the Meteorology, Climatology, and Geophysics Agency (BMKG). The IDF curve informs the pattern and characteristics of regional rainfall so that it can be the basis for the planning and evaluation of water resource infrastructure buildings in residential areas. The compilation of the IDF curve started with the validation of the maximum daily rainfall data for 10 years (2014–2023) using the double mass curve method to ensure the consistency and accuracy of the rainfall data from the GPM satellites and BMKG. After data validation, a frequency analysis was performed to determine the probability distribution that matches the characteristics of the rainfall data. The statistical parameters analyzed included the average daily maximum rainfall, standard deviation, skewness, and kurtosis. Furthermore, the Goodness-of-Fit test using the Smirnov-Kolmogorov method was conducted to evaluate the suitability of the probability distribution (Normal, Log-Normal, Gumbel, or Log Pearson III) with the observed rainfall data. The best probability distribution was used to determine the return period rainfall intensity. The analysis results showed that the Log Pearson III distribution was the best distribution for rainfall in the Medan Marelan District. The IDF curve shows the pattern of rainfall intensity and duration for 24 h, with the peak of rainfall intensity and duration occurring in the 6th hour.

Keywords: BMKG, GPM Satellite, IDF Curve Medan Marelan

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1. Introduction

The limited and uneven availability of surface rainfall data is one of the main obstacles in hydrological analysis that directly impacts water resource infrastructure planning [1]. GPM satellite rainfall data have been widely used in hydrological analysis to overcome these obstacles [2]. Wide spatial coverage and high temporal resolution make GPM data capable of supporting water resource management infrastructure planning, such as flood control systems and rainwater harvesting [3-5]. This validation is important to determine an accurate intensity-duration-frequency (IDF) curve as a basis for water resource infrastructure design [6-8].

The GPM and BMKG satellite rainfall data can provide records of rainfall events and intensity over a fairly long period of time [9]. In addition, GPM data also provide information on certain rainfall durations (half an hour and one hour) so that analysis of rainfall intensity and duration patterns can be carried out in detail [3, 10-11]. The combination of both data sources provides accuracy and produces an IDF curve that matches the real conditions in the field.

Tanah Enam Ratus Village is one of the densely populated residential areas in Medan Marelan District, which often experiences flooding during the rainy season (**Figure 1**) [12-13]. This area requires information on rainfall patterns and characteristics as a reference for determining the return period of rainfall for the evaluation and planning of water resource management infrastructure so that the infrastructure built can function optimally and flooding can be overcome optimally.

Figure 1. Flooding in the Medan Marelan Residential Area

2. Methods

The analysis started with the collection of daily rainfall data sourced from the nearest BMKG station located around the area being reviewed, namely the Belawan Maritime BMKG Station with coordinates of 3.78824 ° N and 98.71492 ° E. Meanwhile, the coordinates for GPM satellite rainfall observations were taken from the coordinate range of 3.6365 ^{0}–3.7903 ^{0} N and 98.4375 ^{0}–98.811 ^{0} E. The data collected were daily rainfall data for 10 years (2014–2023) in accordance with SNI requirements [14]. From these two datasets, the maximum daily rainfall value per year was obtained with a duration of 24 h (GPM Satellite Data interval 0.50 h) [9].

Data validation testing was conducted using the double mass curve method to ensure the quality, consistency, and accuracy of data obtained from the GPM and BMKG Satellites. This method compares two sets of observed data and analyzes them cumulatively. Observation data are declared valid and consistent if they have the same cumulative pattern and provide a correlation value close to one ($R \approx 1.00$). The results of the double-mass curve analysis are presented in the form of graphs [14-16]. After data validation, a frequency analysis was performed to determine the probability distribution that best fit the characteristics of the rainfall data. The statistical parameters analyzed included the maximum daily rainfall value, average maximum rainfall, standard deviation (a measure of data distribution), skewness (the skewness of the data distribution to its average value), and kurtosis (the sharpness or peak shape of the distribution). Furthermore, the results of this parameter analysis were tested through a goodness-of-fit test using the Smirnov-Kolmogorov method to check the suitability of the observation data distribution pattern with the probability distribution (Normal, Log-Normal, Gumbel, or Log Pearson III).

The most appropriate probability distribution was then used to determine the value of the return period rainfall intensity. To determine the distribution of the intensity and duration values of the return period rainfall, the distribution of the results of the GPM satellite rainfall observations with a time interval of half an hour (30 minutes) was used. An intensity-duration-frequency (IDF) curve was prepared to describe the relationship between the intensity, duration, and frequency of rainfall. The analytical method is illustrated in **Figure 2**.

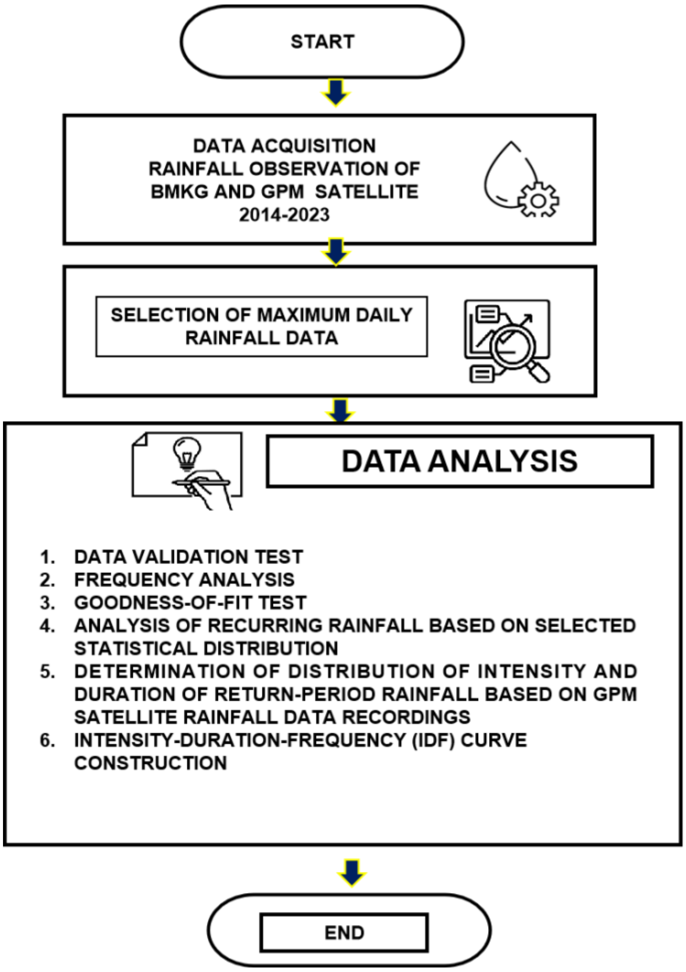

Figure 2. Analysis Method

3. Results and Discussion

The results of the analysis discussed in this study are: (1) Maximum Daily Rainfall; (2) Data Validation Test; (3) Frequency Analysis; (4) Intensity and Duration of Rainfall Recurrence Period; and (5) intensity – duration – frequency (IDF) curve.

3.1 Maximum Daily Rainfall

The maximum daily rainfall recorded at the Belawan Maritime BMKG station and the GPM satellite explains that during the period 2014 to 2023, it has a range of values of 91.50 - 100.00 mm with the highest rainfall value occurring in 2021 at 100.00 mm. In contrast, BMKG data shows a greater variation in values, with the highest rainfall value reaching 159.00 mm in 2020 and the lowest 70.70 mm in 2022. In some years, the data shows a significant difference between the two data as seen in 2020 and 2022 (**Table 1**). This could be due to differences in measurement methods, data resolution, or accuracy scales used by each observation source (BMKG and GPM satellites) [17-18]. This difference indicates that the BMKG data tend to have a higher maximum rainfall value than the data from the GPM. However, during 2020-2021 [19], a significant difference was found in the maximum daily rainfall duration value between data from the Belawan Maritime BMKG Station and GPM, in which daily rainfall values were above 150 mm. In 2006, the Belawan Maritime BMKG Station recorded a daily rainfall of 396 mm [13]. Based on the results of this maximum daily rainfall analysis, it can be concluded that the use of long-term data and continuous rainfall monitoring is important for assessing and observing rainfall patterns and variability in this area [20].

Table 1. Maximum Daily Rainfall

Year	Maximum Daily Rainfall (mm)	
	GPM Rainfall Data	BMKG Rainfall Data
2014	92.03	100.00
2015	95.94	80.50
2016	96.50	109.10
2017	91.50	110.00
2018	99.38	93.00
2019	97.16	88.60
2020	98.48	159.00
2021	100.00	119.50
2022	99.85	70.70
2023	99.29	91.20

3.2 Data Validation Test

The GPM satellite rainfall data were validated by the BMKG rainfall data using the double-mass curve method. The validation test resulted in a correlation value of 0.999, with the data forming a linear line with the equation y = 0.957x + 7.056 (**Figure 3**). Thus, the rainfall data from both (GPM and BMKG Satellites) have a high level of accuracy in representing rainfall patterns and characteristics in residential areas in Medan Marelan District so that both rainfall data can be used in compiling the IDF curve [21].

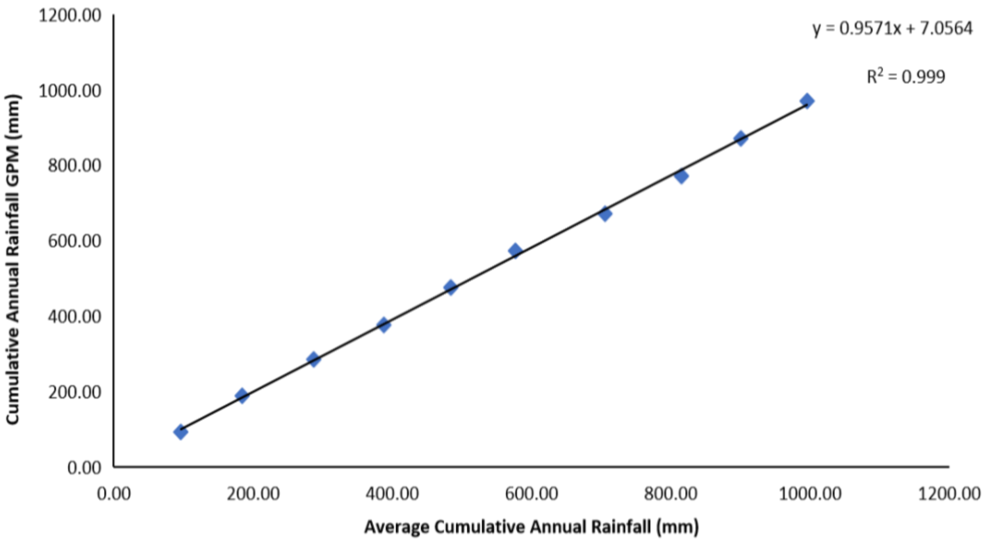

Figure 3. Data Validation Test Results

3.3 Frequency Analysis

The results of the frequency analysis show that the probability distribution that best fits the characteristics of the rainfall data is the log person III distribution. These results were determined through a goodness-of-fit test using the Smirnov Kolmogorov method (**Table 2**). This suitability is proven by the Δmax value of the log person III distribution of 0.160, which is smaller than the Δmax value in other distributions (normal, log-normal, and Gumbel). In addition, the delta max value is also smaller than the critical delta ($\Delta_{max} < \Delta_{criticism}$); therefore, the cumulative distribution of observation data (GPM and BMKG) is in accordance with the statistical distribution (Log Person III) [15-16]. Thus, to determine the return period rainfall value, the log person III distribution equation was used.

Table 2. Smirnov -Kolmogorov Test Results

I (mm/hr)	m	m/(N+1)	1. Normal		2. Normal Log		3. Gumbel		4. Pearson III Log	
			P(x>=X)	Delta P	P(x>=X)	Delta P	P(x>=X)	Delta P	P(x>=X)	Delta P
99.999	1	0.091	0.224	0.133	0.230	0.139	0.191	0.100	0.244	0.153
99,846	2	0.182	0.231	0.049	0.236	0.054	0.196	0.014	0.254	0.073
99,384	3	0.273	0.251	0.022	0.255	0.018	0.211	0.061	0.286	0.013
99.286	4	0.364	0.256	0.108	0.259	0.105	0.215	0.149	0.292	0.071
98,480	5	0.455	0.294	0.160	0.294	0.160	0.245	0.210	0.347	0.107
97.155	6	0.545	0.362	0.183	0.357	0.188	0.301	0.245	0.435	0.111
96,503	7	0.636	0.398	0.238	0.390	0.246	0.332	0.305	0.476	0.160
91,500	8	0.727	0.676	0.051	0.659	0.068	0.635	0.092	0.731	0.003
84.110	9	0.818	0.935	0.117	0.933	0.115	0.980	0.162	0.918	0.100
80,682	10	0.909	0.977	0.068	0.979	0.070	0.999	0.090	0.956	0.047
Eligibility calculation			ΔMax	0.238	ΔMax	0.246	ΔMax	0.305	ΔMax	0.160
Critical Delta =		0.410		accept-ed		accept-ed		accept-ed		accept-ed

The rainfall return period was calculated using the log person III distribution equation [15-16]. Rainfall intensity values are presented for return periods of 1, 2, 5, 10, 25, 50, and 100 years (**Table 3**). The values ranged between 73.161 and 104.506. This indicates an increase in the intensity of each return period. The largest percentage increase in intensity values occurred in rainfall return periods of 1 and 2 years with a difference of 22.949 mm/h or 31.370%, compared to the values of other return periods, which were around 0.37 - 4.74%.

Table 3. Rain Intensity of Return Periods Based on Log Person III Distribution

No	Time to Repeat T (year)	Rain Intensity (mm/hour) Pearson Log III Distribution X_T
1	1	73.161
2	2	96.11
3	5	100.661
4	10	102.295
5	25	103.548
6	50	104.123
7	100	104.506

3.4 Intensity and Duration of Return Period Rainfall

The intensity and duration of the return period rainfall were determined based on the results of observations of the average maximum daily rainfall intensity and duration patterns of the GPM satellite with a half-hour interval and a rainfall duration of 24 h [22]. GPM data observations begin at 07.00 WIB following the daily rainfall measurement method carried out by BMKG [9]. The results of these observations are shown in **Figure 4**.

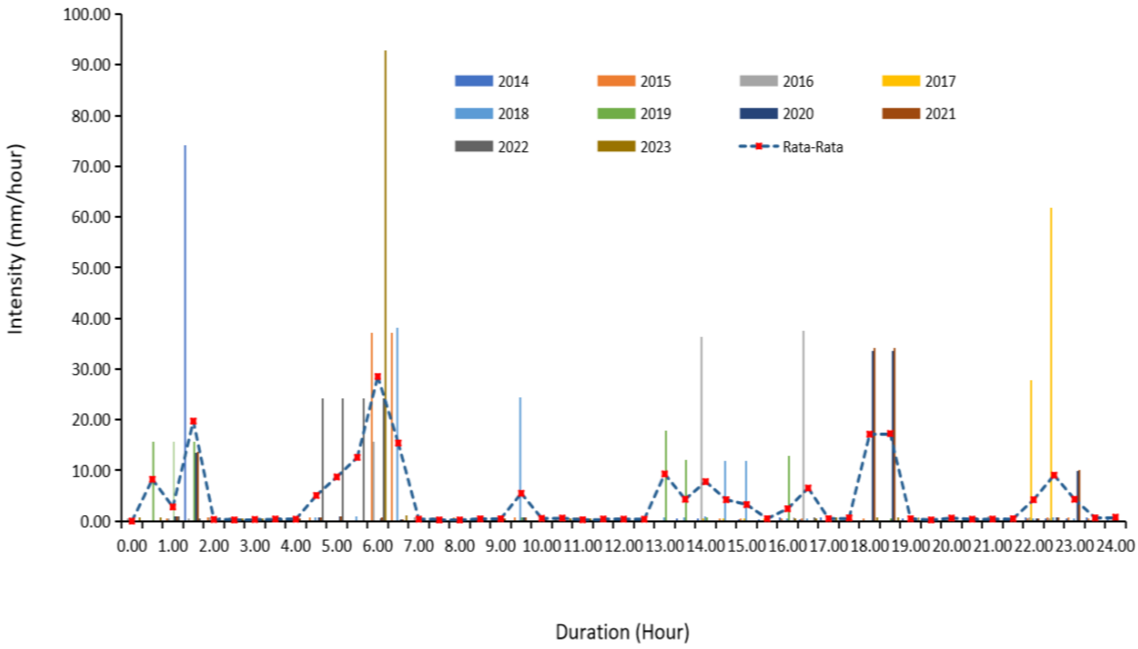

Figure 4. GPM Maximum Daily Rainfall Intensity and Duration Pattern (2014-2023)

The results of the analysis of the intensity and duration of rain during the 24-hour return period show that the rainfall pattern in Medan Marelan District consists of several high-intensity rainfall peaks, ranging from heavy to very heavy rain categories [23], and occurs over a short duration (1.00 - 2.00 h). There is still light-to-moderate rainfall between these rainfall peaks [23]. The highest intensity rainfall peak occurs in the 6th hour, as shown in **Figure 5**.

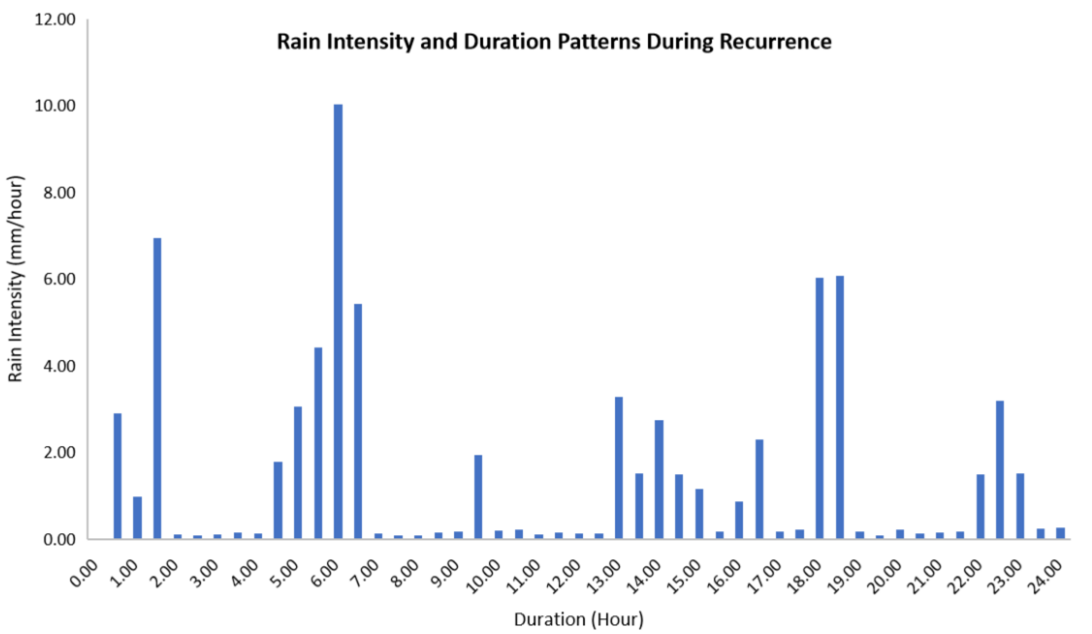

Figure 5. Results of Analysis of Intensity and Duration of the Return Period Rainfall

3.5 *Intensity-Duration-Frequency (IDF) Curve*

The intensity–duration–frequency (IDF) curve describes the relationship between rainfall intensity, rainfall duration, and frequency of occurrence for return periods of 1, 2, 5, 10, 25, 50, and 100 years. Based on the results of the analysis, the highest rainfall intensity value is 14.33 mm/hour, with a cumulative rainfall of 104.506 mm/h (**Figure 6**). The IDF curve is an important requirement that must be met in compiling an analysis or evaluating water resource management infrastructure buildings [14].

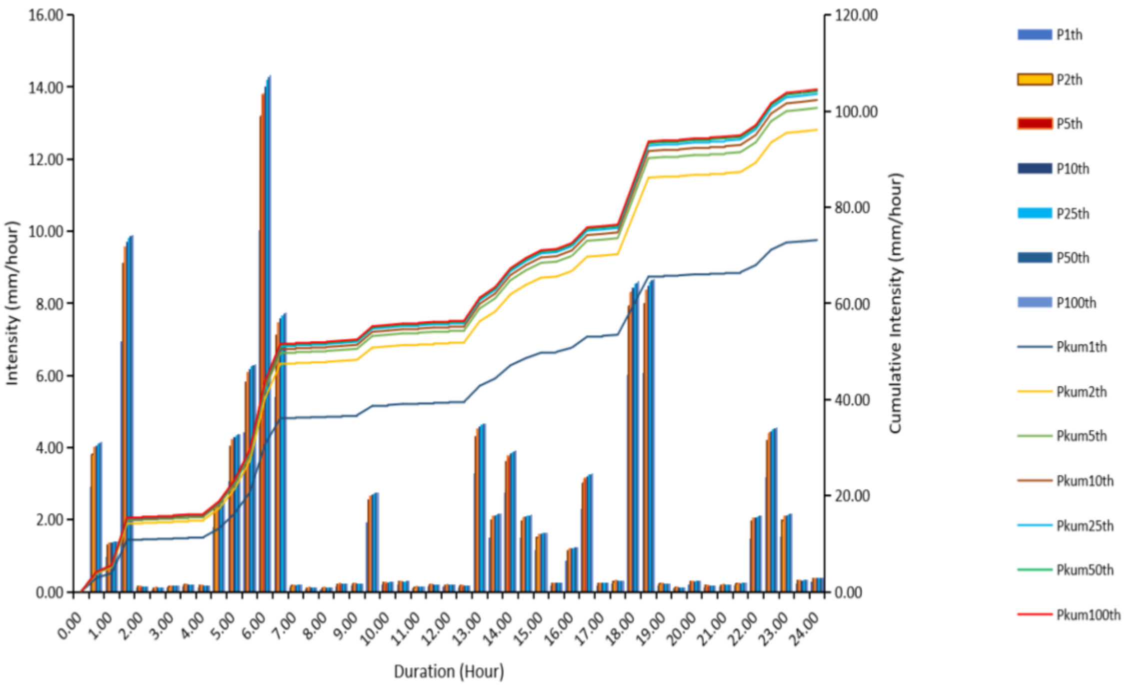

Figure 6. Intensity-Duration-Frequency Curve

4. Conclusion

4.1 GPM and BMKG Satellite rainfall data can be used to construct the IDF curve in the Residential Area in Medan Marelan District. The validation results of both datasets showed a correlation of 0.999 with a linear equation of y = 0.957x + 7.056.

4.2 Frequency analysis shows that the distribution of the GPM and BMKG satellite rainfall observation data is in accordance with the log person III probability distribution, with a maximum delta value of 0.160.

4.3 The intensity and duration of rain during 24 h in the Marelan Residential Area show a pattern of peak rain with high intensity and occurs in a short duration (1.00 - 2.00 h). However, between the peaks, there was still light to moderate rain.

4.4 The IDF curve produced in this study can be used to compile an analysis or evaluate water resource management infrastructure buildings in the residential area of Medan Marelan District.

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