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Analysis of Lead Time in The Upstream Citarum River Using Satellite and Stream Gauge Data

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Abstract. Floods in the upstream Citarum, Majalaya, generally occur quickly and experience a rapid rise in the water level, termed flash floods. The short notice and event duration of flash floods often does not allow the affected community to carry out adequate early warning and disaster emergency response. In disaster events, lead time is the interval between the issuance of a forecast and the event itself. Minimizing the risk of flood hazards in the community requires an increase in the lead time. This study analyzed the lead time between rainfall events (from JAXA's GSMaP data) and water level rise in Citarum's Majalaya and Sapan. The water level rise used river authority's gauge records data from 2018 through 2022. The current study shows several differences in the lead time for each event. In 2018, Majalaya to Sapan lead time was 4 hours; in 2019 Majalaya to Sapan lead time was 3 hours; in 2020 Majalaya to Sapan lead time was 3 hours; in 2021, Majalaya to Sapan lead time was 6 hours and in 2022, Majalaya to Sapan lead time was 2 hours. Determining the differences in lead time can be pursued for further refinement.

Keywords: *flood warning system; GSMaP; lead time; upstream citarum river.*

1 Introduction

Flood hazards are Indonesia's most dominating natural disaster trend yearly. Based on Indonesian National Board for Disaster Management (BNPB) data, from 1 January until 18 November 2022, 3.208 natural disasters occurred in Indonesia, and floods dominated 1.344. The province that experienced the most disasters was West Java, with 766 incidents [1]. The morphological conditions of the area in the upstream Citarum River affect the high incidence of flooding in West Java. One of the most flood-prone locations in the Upper Citarum River is the Majalaya Area. The area is at the inflection point between the steep and flatter river slope of the Upper Citarum River. Based on this morphological feature, the area has a high potential for flooding [2].

Floods in Majalaya generally occur in a short time and experience a rapid rise in water level. The 22 February 2018 flood incident inundated 5.35 km2 of the Majalaya area with a peak flow of 155.82 m3/s. The rain caused the flood that lasted for 12 hours [3]. However, there is only 2-3 hours between the start of the rain and the flood. Characteristically, floods in Majalaya usually happen in a relatively short time. The flood water also rises rapidly with a fast stream; thus, it could be categorized as a flash flood [4]. Flash flood events do not provide an adequate opportunity for the community to carry out early warning and disaster emergency response. Based on this, a more reliable flood forecasting method is needed to determine the lead time. Lead time is defined as the time between the issuance of a forecast and the disaster event. Advanced flood warning development is necessary to improve the flood mitigation system [5].

Predicting the lead time needs to be done to minimize the impact or risk in the community. The aim is for the people to have the opportunity to evacuate and reduce losses due to flooding. People who had prepared for household emergencies reported fewer worries and fears, which enabled them to stay calm and take action to increase their chances of survival during the disaster [6]. Kardhana et al., in the research, use SADEWA satellite data to predict floods with a longer lead time [7]. Using satellite data is a consideration to extending the lead time in this research.

According to Pingel et al. [8] to estimate the lead time, each event's annual rain events are analyzed to a conditional probability, which expresses the possibility of a specified lead time, given the need for a warning [8]. This method will produce different lead times with several conditions. The condition will be minimized by determining the midpoint of rain or the rainfall centroid in a watershed. An essential aspect is that catchment response is sensitive to spatial heterogeneity of rainfall, even at small catchment sizes. The timing error introduced by neglecting the spatial rainfall variability ranges between −20 % to 36 % of the corresponding catchment response time [9].

2 Study Area

Citarum River is one of the important rivers in Indonesia, the longest and largest river in West Java [4]. It is the raw source of water for the people of West Java and the flow of Citarum water that turns turbines in three dams, namely Cirata, Saguling, and Jatiluhur to meet electricity needs in Java-Bali. However, Citarum often experiences natural disasters such as floods and landslides, which often occur during the rainy season. The Kompas Research and Development disaster risk index, based on Indonesian National Board for Disaster Management data, found that the most dangerous watershed in Indonesia is the Citarum watershed in West Java, with a score of 0.74. This index has a rating range from 0 to 1. The closer to number 1, the more dangerous the watershed is [10]. The water level monitoring stations, namely Majalaya and Sapan (Figure 1), are in the upper reaches of the Citarum River, which is the flat area in the center part of the basin and the mountainous area surrounding the Bandung basin area, making them vulnerable to flooding [11]. The areas of Majalaya and Sapan watersheds are respectively 205.49 km^2 and 317.83 km^2 (Figure 2).

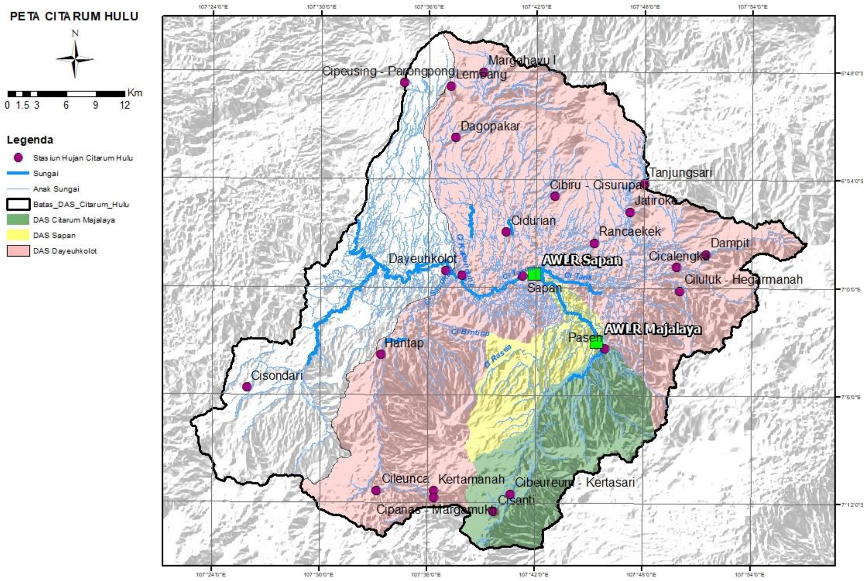

Figure 1. Stream gauge Majalaya and Sapan

The problem with the Citarum watershed is an increasing runoff that causes flooding. Reduced water infiltration into the ground every time it rains produces most runoff water and accumulates into floods and inundation, and this can occur flooding in the Bandung Basin area [12,13].

3 Methodology

The methodology of this research is shown in (Figure 3). There are literature studies, data collection, correction, and lead time analysis. To determine the lead time in this study, using rainfall data from the GSMaP satellite and water level discharge data from the stream gauge Perum Jasa Tirta II.

Figure 2. The areas of Majalaya and Sapan watersheds

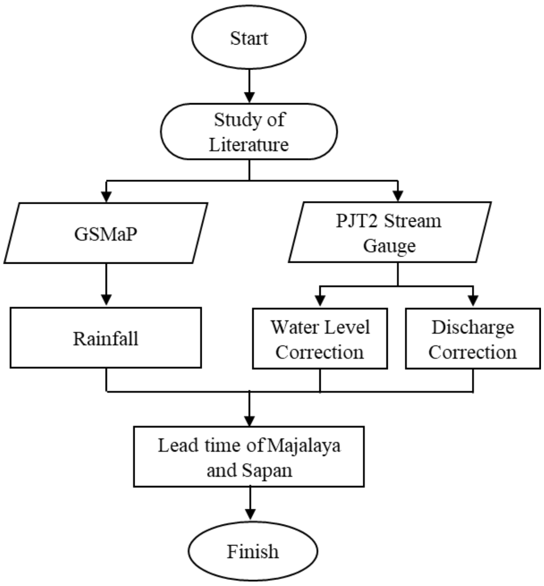

Figure 3. Methodology flowchart

3.1 Data Collection

This study uses rainfall data, water level, and discharge at stream gauge points to predict lead time. The satellite data used is GSMaP. Data on water level and discharge using data from PJT2 (Tirta Jasa Public Corporation 2). Data used in this study are shown in Table 1.

Table 1. Data collection

Category	Data	Spesification	Data Source
Hourly Rainfall	GSMaP	Version 7. since 2014	JAXA
	Observation rainfall	Hourly since 2018 until 2022	BBWSC
Water Level	Majalaya and Sapan gauge	Hourly since 2018 until 2022	PJT2
Discharge	Majalaya and Sapan gauge	Hourly since 2018 until 2022	PJT2

3.1.1 Hourly Rainfall

Downloaded GSMaP data is accessed using FileZilla from 2018 - 2022 in .geo format. Then it is processed using RStudio in .tiff format, which is converted using the Format Conversion Tool software. The results of rainfall that have been processed using RStudio are shown in Figure 4.

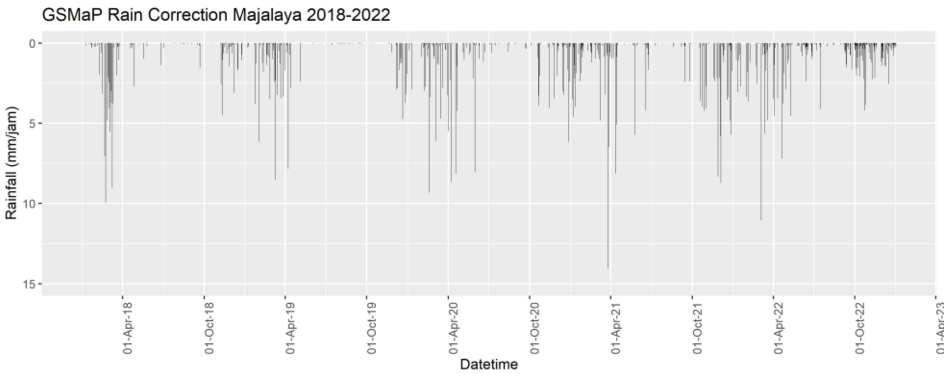

Figure 4. GSMaP Majalaya rainfall from 2018 until 2022

Then, this data is corrected using the quantile mapping method using RStudio to obtain the corrected rain results. GSMaP rainfall data after calibration has the same characteristic as the ground data [14]. The quantile mapping uses rainfall observation in Majalaya and Sapan to adjust for rain in the region. Observational rainfall was processed using the Thiessen method so that rainfall in the Sapan and Majalaya areas was obtained, then quantile mapping was carried out to get the corrected rainfall. The result of the corrected rainfall is smaller than the uncorrected GSMaP rainfall. Data used in this study is corrected rainfall shown in Figure 5.

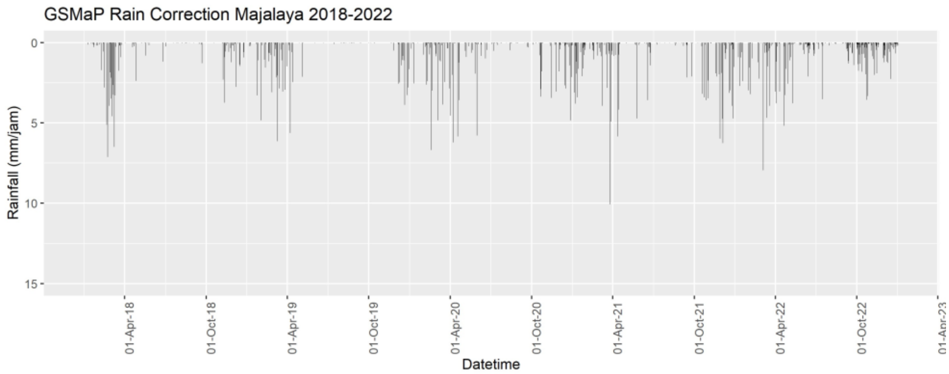

Figure 5. GSMaP Majalaya corrected rainfall from 2018 until 2022

Calibration of measurement data on ground data and satellite data can also experience significant differences, even at peak rainfall events. For this reason, modeling uses the HEC-HMS with rainfall data input as GSMaP data and discharge data calculated from data stream gauges [15].

3.1.2 Water Level and Discharge

Stream gauge data in Sapan and Majalaya were downloaded on the PJT2 website from 2018 to 2022. The downloaded data contains hourly water level data in meters and hourly discharge in cubic meters per second. The data is corrected by deleting data that has experienced a significant spike in less than one hour. Before and after the corrected data are shown in Figures 6 and 7.

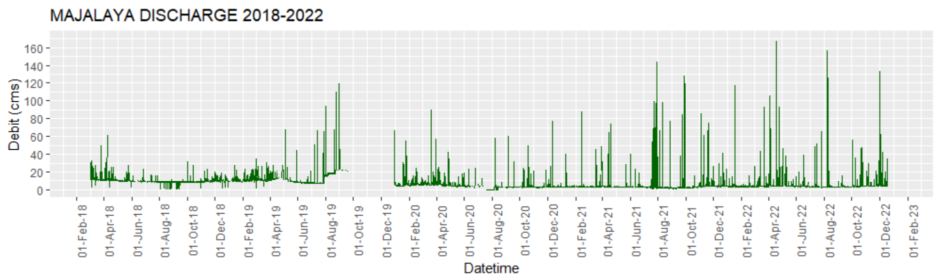

Figure 6. Majalaya discharge from 2018 until 2022

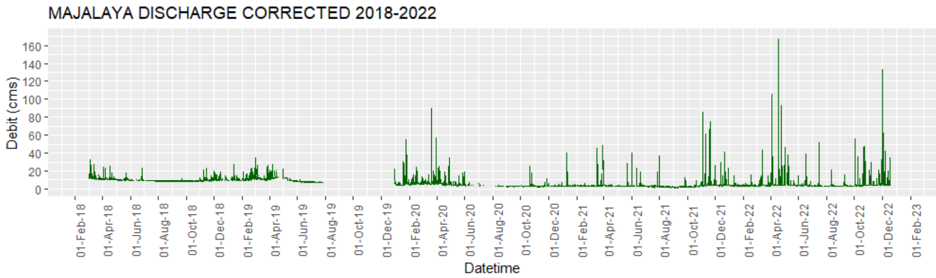

Figure 7. Majalaya discharge corrected from 2018 until 2022

3.2 Data Analysis

The data collected are rainfall, water level, and discharge plotted using RStudio. The highest TMA and discharge data each year from 2018-2022 are representative events taken. There are five events to determine lead time. For each representative event, the time when the peak rain occurs in Majalaya and the time interval required for the water level rise and discharge are determined. Furthermore, the lead time is the time interval required from the rising water level and discharge in Majalaya to Sapan.

4 Results

Table 2. Events of water level rise and discharge

TAHUN	NO	TITIK AWLR	TOTAL CURAH HUJAN (mm)	DURASI (jam)	TMA (m)	DEBIT (cms)	TANGGAL KEJADIAN	LEAD TIME
2018	1	Majalaya	34.17	8	665.22	18.52	2018-11-08 23:00	04:00:00
		Sapan	36.19	8	661.52	88.88	2018-11-09 03:00	
2019	2	Majalaya	12.15	9	665.75	27.93	2019-01-13 20:00	03:00:00
		Sapan	14.63	9	661.69	96.15	2019-01-13 23:00	
2020	3	Majalaya	11.52	4	664.91	14.56	2020-05-18 18:00	03:00:00
		Sapan	12.26	4	661.55	90.14	2020-05-18 21:00	
2021	4	Majalaya	22.37	9	665.66	40.04	2021-06-02 00:00	06:00:00
		Sapan	26.33	9	661.54	89.72	2021-06-02 06:00	
2022	5	Majalaya	31.24	9	666.43	92.54	2022-04-23 22:00	02:00:00
		Sapan	39.99	9	661.89	105.06	2022-04-24 00:00	

Each year event of rainfall, water level and discharge occurs on a different date and year. It can conclude that rainfall causes an increase in water level, and the highest discharge occurs at the beginning and end of the year. In 2018 the high water level and discharge occurred in November; in 2019 occurred in January; in 2020 occurred in May; in 2021 occurred in June; and in 2022 occurred in April. Total rainfall and duration of rainfall events are not comparable. In 2018, total rainfall in Majalaya was 34.17 mm, with a duration of rain events is 8 hours. In

2019 in Majalaya, the total rainfall reached 12.15 mm with a duration of rain events is 9 hours. It will influence by the intensity of rain at the time of the rain incident.

Besides that, the lead time for each event is different. There is no consistent lead time from when it rains to the rising water level and discharge from Majalaya to Sapan. In 2018, Majalaya to Sapan lead time was 4 hours; in 2019 Majalaya to Sapan lead time was 3 hours; in 2020 Majalaya to Sapan lead time was 3 hours; in 2021 Majalaya to Sapan lead time was 6 hours and in 2022, Majalaya to Sapan lead time was 2 hours. This difference causes uncertainty about how much lead time required for and early warning system. Then the method is required to determine the midpoint of occurrence of the rainfall so that it is clear the centroid rainfall occurs and the distance from the rain event to the rise in water level and discharge.

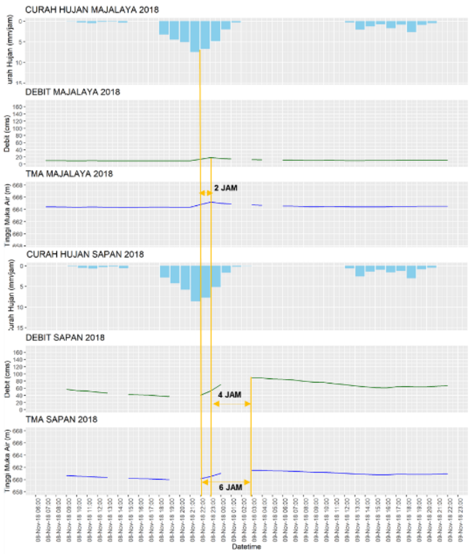

Figure 8. 2018 events

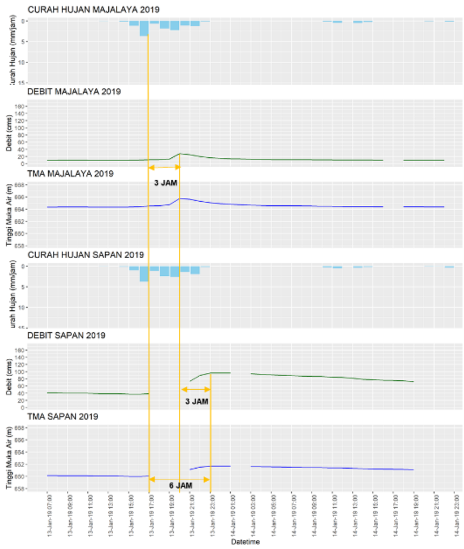

Figure 9. 2019 events

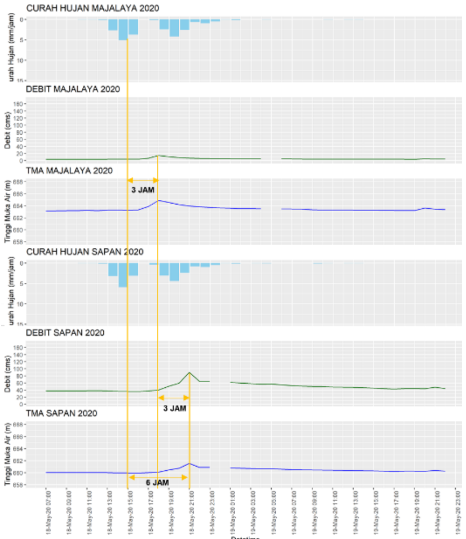

Figure 10. 2020 events

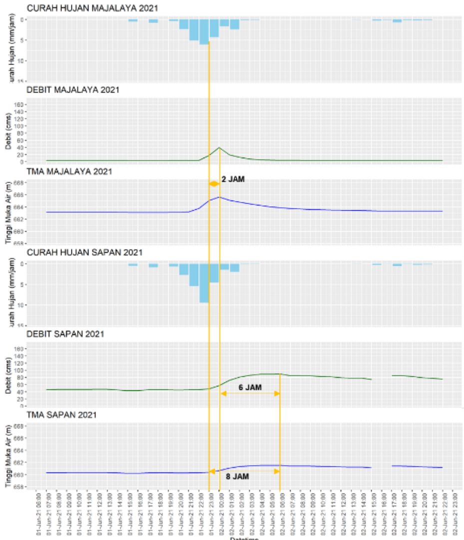

Figure 11. 2021 events

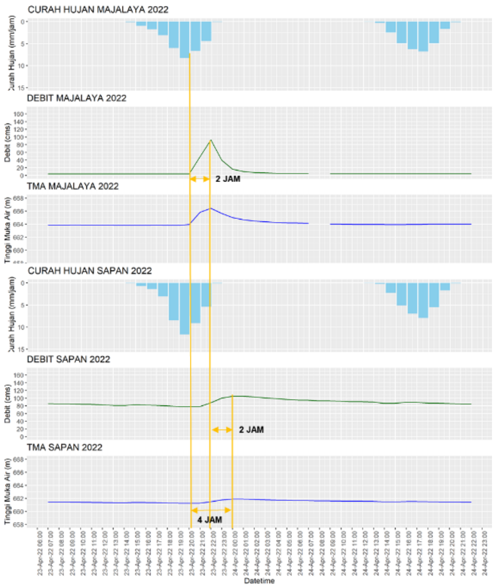

Figure 12. 2022 events

5 Conclusion & Recommendation

5.1 Conclusion

The lead time is extracted from GSMaP rainfall data, water level, and discharge data. However, there was a difference in lead time. In 2018, Majalaya to Sapan lead time was 4 hours; in 2019 Majalaya to Sapan lead time was 3 hours; in 2020 Majalaya to Sapan lead time was 3 hours; in 2021 Majalaya to Sapan lead time was 6 hours and in 2022, Majalaya to Sapan lead time was 2 hours. This difference causes uncertainty about how much lead time must require for an early warning system.

5.2 Recommendation

This research requires further studies to ensure the lead time used for the early warning system. The centroid rainfall method can determine the dominant point of rainfall. Then the lead time from the centroid rainfall to the stream gauge can ensure. This study can become input into an early warning system for affected communities in Majalaya and Sapan and be a lead time reference in anticipating future flood disasters.

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References

[1] Indonesian National Board for Disaster Management (BNPB). Update Bencana di Indonesia 18 November 2022 [Internet]. 2022. Available from: https://twitter.com/BNPB_Indonesia/status/1593608483102167040

[2] Irawan MF, Hidayat Y, Tjahjono B. Penilaian Bahaya Dan Arahan Mitigasi Banjir Di Cekungan Bandung. J Ilmu Tanah dan Lingkung. 2018;20(1):1–6.

[3] Rohmat, Sa'adi Z, Stamataki I, Kuntoro AA, Farid M, Suwarman R. Urban Climate Flood modeling and baseline study in urban and high population environment : A case study of Majalaya , Indonesia. Urban Clim [Internet]. 2022;46(10):101332. Available from: https://doi.org/10.1016/j.uclim.2022.101332

[4] Junnaedhi IDGA, Riawan E, Suwarman R, Hadi TW, Lubis A, Joko Trilaksono N, et al. Majalaya Flood Early Warning System: A Community Based Approach. IOP Conf Ser Earth Environ Sci. 2017;71(1):0–12.

[5] Riyanto BA, Yudianto D. Flood Management Challenges in The Citarum River Basin. Chuncheon Glob Water Forum 2015. 2015;

[6] Diekman ST, Kearney SP, O'Neil ME, MacK KA. Qualitative study of homeowners' emergency preparedness: Experiences, perceptions, and practices. Prehosp Disaster Med. 2007;22(6):494–501.
[7] Kardhana H, Valerian JR, Rohmat FIW, Kusuma MSB. Improving Jakarta's Katulampa Barrage Extreme Water Level Prediction Using Satellite-Based Long Short-Term Memory (LSTM) Neural Networks. Water (Switzerland). 2022;14(9).
[8] Pingel N, Jones C, Ford D. Estimating Forecast Lead Time. Nat Hazards Rev. 2005;6(2):60–6.
[9] Zoccatelli D, Borga M, Viglione A, Chirico GB, Blöschl G. Spatial moments of catchment rainfall: Rainfall spatial organisation, basin morphology, and flood response. Hydrol Earth Syst Sci. 2011;15(12):3767–83.
[10] Wisanggeni SP, Rosalina MP, Krisna A, Budianto Y. Sungai-sungai di Indonesia Semakin Membahayakan. Kompas [Internet]. 2023; Available from: https://www.kompas.id/baca/investigasi/2023/02/22/sungai-sungai-di-indonesia-semakin-membahayakan
[11] Moe IR, Rizaldi A, Farid M, Moerwanto AS, Kuntoro AA. The use of rapid assessment for flood hazard map development in upper citarum river basin. MATEC Web Conf. 2018;229:0–5.
[12] Safarina AB, Chairunnisa, Lestari ND, Aprilianingsih D, Syahrullah FM, Sadidah M. Rainfall Threshold of Citarum River Flood for Early Warning on Urban Area. IOP Conf Ser Earth Environ Sci. 2021;728(1).
[13] Maria R, Naily W, Purwoarminta A, Hendarmawan. Artificial recharge as an effort to increse urban water resilience. IOP Conf Ser Earth Environ Sci. 2019;306(1).
[14] Burnama NS, Rohmat, Farid M, Wijayasari W. Utilization of quantile mapping method using cumulative distribution function (CDF) to calibrated satellite rainfall GSMaP in Majalaya watershed. IOP Conf Ser Earth Environ Sci. 2023;
[15] Burnama NS, Rohmat F, Farid M, Kuntoro AA, Kardhana H, Solehudin. Rainfall-runoff Analysis Using Satellite Data in The Majalaya Watershed. Proc 2nd ITB Grad Sch Conf. 2022;321–31.