The relationship of Cilutung River Flood hydrograph pattern with spatial rainfall during rainy season

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Abstract. Rainfall is an input in the hydrological system that delivers the output in the river flow in the form of discharge flow. The Cilutung River is a subsidiary of Cimanuk which has a greater function is to become one of the flood controllers in the area of Muara Cimanuk after Cimanuk in the dammed. This research aims to identify the pattern of flood hydrographs and to know the relationship between the flood hydrograph pattern with rainfall spatial variation in Cilutung river flow with variable rainfall and debit as well as spatial analysis Descriptive and statistical. The flood hydrograph pattern is related to the rainfall in which if the rainfall occurring in the Cilutung river flow is getting higher it will result in a higher flow discharge and form an increasingly high flood hydrograph pattern as well. It is supported by the incidence of 22 samples studied, spatial when the rain falls first in the upper part of Cilutung River basin and accompanied by rainfall and high intensity and a relatively long time will affect the hydrograph pattern The flood that has the highest debit value is getting higher and the higher the discharge volume also or vice versa. This relationship is reinforced by a correlation test result where there is a strong link between the maximum discharge and total discharge with rainfall and rain intensity. This relationship shows the flood hydrograph pattern has a strong correlation with the spatial pattern of rainfall.

1. Introduction

The discharge is the flow rate of water (in the form of water volume) passing through the river per unit of time with its units of cubic meters per second (m³/s) [1]. The Debit of a river is generally determined based on climate factors related to rainfall and its distribution in time dimensions [2]. Rainfall in the hydrological process is an input that delivers the output of the river basin in the form of flow discharge [1]. Therefore, the discharge of a river is a high discharge period during the rainy season and low discharge during the dry season [1]. During the El-Nino period resulted in late rainy season and a long dry season in Indonesia and decreased total rainfall resulting in lower river discharge periods, while La-Nina was the cause of rising rainfall in Indonesia so that the river discharge period is higher [3].

Spatial rainfall can also be interpreted as a monsoon distribution area (upstream, middle or downstream) that has an influence on the flow discharge of a river where if the rainfall in Hulu first comes and is followed by rainfall in Hilir It will affect the flow of river discharge compared to when the rainfall first comes downstream [2]. Besides being influenced by climate factors, the river discharge is also related to the consequences of human intervention on the face of the Earth, which is mainly concerned with changing land use [2,4]. The negative influence of land use change also resulted in declining the ability...
of a river basin to absorb and accommodate rain so as to influence the increase of the river discharge above normal which resulted in the occurrence of Water (Flood) [5,6].

Sungai Cilutung is one of Cimanuk tributary where in Majalengka Regency area of Cilutung River becomes one of the rivers of the two largest rivers [7,8]. The Cilutung River has a greater function of being one of the flood controllers in the estuary of Cimanuk after the Cimanuk is dammed [9,10]. This can be seen in the event of flooding occurred in Indramayu on Monday 16 March 2015 resulting from the symbol of the Cimanuk embankment and the shipment from Hulu DAS Cimanuk which is due to heavy rain in Garut and Majalengka while in Muara Cimanuk (Indramayu) It does not rain throughout the week [9,10]. This incident shows the Cilutung River has control over the flooding in Muara Cimanuk. Reviewing the importance of the function of the Cilutung River to the floods described above, this study was designed to discuss the relationship between the hydrograph pattern of the Cilutung River flow with the spatial pattern of rainfall carried out by mapping input (rainfall) and output (discharge) of the Cilutung River Flow using the analytical method spatial-descriptive.

2. Methods

Cilutung River basin is administratively located in West Java Province includes two districts namely Majalengka and Sumedang with an area of 63.579 Ha where 52.137 Ha is in Majalengka Regency and 11.441 Ha located in Sumedang District. Variables of this research are the discharge and rainfall of the Cilutung River basin during the rainy season that occurs in the period of December 2018 to March 2019.

In this study use different types of research data which are then grouped into primary data and secondary data. Primary data is data obtained directly such as a large survey or data retrieval directly. Secondary data is data that is obtained indirectly such as data obtained from agencies, past research and other information. Primary data includes precipitation data and water height at Cilutung River basin. Here is the post location of the rainfall located at Cilutung River basin (Figure 1).

![Figure 1. Location of The Rainfall Station](image)

For secondary data, the previous processing has been performed. The secondary data used in this study is the boundary data of Cilutung River basin, the daily rainfall of the Cilutung River basin in 2018 to 2019, and the time of the hours of the Cilutung River basin discharge data from 2018 to 2019 (Table 1).

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### Table 1. Data Collection and The Sources

| Data                        | Data Types                     | Sources                                                        |
|-----------------------------|--------------------------------|---------------------------------------------------------------|
| Boundary of Cilutung River Basin | Shapefile (shp)                | Balai Besar Wilayah                                          |
| Daily rainfall flow area Cilutung River year 2018-2019 | Daily rainfall in table Form    | Balai Besar Wilayah                                          |
| Cilutung River Hour-flow time (2018-2019) | Debit hour-era in table Form | Balai Besar Wilyah                                            |
|                             |                                | Sungai Cimanuk-Cisanggarung                                  |
|                             |                                | Majalengka Regency Water Resources Research Center           |

The results of data collection and processing are done using descriptive analysis, hydrology and statistics. Hydrological analysis is done for the processing of debit data using logarithm sourced from the basin of the river area \( Q = C \times B_{eff} \times H^{3/2} \) with \( Q \) is the discharge of river water, \( C \) of 1.64, \( B_{eff} \) of 58.55 and \( H \) is the high water front. Descriptive analysis is used to see the relationship between the hydrograph pattern with a spatial rainfall pattern which will then be strengthened by the statistical analysis using the Person product calculation moment.

#### 3. Result
The daily discharge of Sungai Cilutung in December 2018 to March 2019 has a variation each month (Figure 2). The daily discharge of Cilutung in December 2018 to March 2019 shows the connection between the hydrograph pattern and the rainfall which if the higher the rainfall will be the greater the discharge.

![Figure 2. The daily discharge of Cilutung River flows in December 2018 to March 2019](image-url)
Flood Hydrograph obtained based on the discharge of the hours from December 2018 to March 2019 in the Cilutung River basin. The debits in the Cilutung River basin is obtained based on the calculation of the debit logarithm established by the large hall of the Cimanuk-Cisanggarung River area. The pattern of the flow hydrograph of Cilutung River in December 2018 ranged from 0 to 159 m3/second, in January 2019 ranging from 3 to 204 m3/second, in February 2019 ranging from 14 to 324 m3/second and in March 2019 ranging from 14 to 474 M3/sec (Figure 3).

![Flood Hydrograph Pattern](image_url)

**Figure 3.** Cilutung River Flow Hydrograph pattern in December 2018 to March 2019

The flood hydrograph pattern has maximum discharge, increased time and discharge volume. If the discharge time rises and the discharge time drops from the maximum discharge is almost equal or symmetrical it will form a flow called a flood hydrograph. Flood hydrographs in Cilutung River basin based on maximum discharge value there are 22 sample events spread in 4 months of 5 samples in December 2018, 6 samples in January 2019, 6 samples in February 2019 and 5 samples on March 2019. Based on 3 maximum discharge classification (QMAX) which is < 50 m3/sec, 50 to 100 m3/second and > 100 m3/second produces a sample of the hydrograph pattern that shows the 2 characteristics of having 1 peak discharge and 2 peak discharge (Figure 4).
Of the 22 sample events there are patterns where the maximum discharge value is higher as well as the increased time required to achieve the larger maximum discharge and the decrease time from the maximum discharge will also result in an increasingly large volume of discharge. Also, for example in sample 1st of peak event to 2nd which occurred on December 7, 2018 has maximum discharge of 24 m3/sec by showing the debit volume of only 125 m3/second due to the time needed up only 1 hour and time down From a maximum discharge of only 6 hours, while in the 22nd of the sample incident occurred on 27 March 2019 had a maximum discharge of 474 m3/second with a larger volume of discharge the result was 4442 m3/second due to the bullish time is required for 5 hours and the time dropped from the maximum discharge for 18 hours.

Then from Table 5.1 can also be seen from 22 samples there are samples that have the same maximum discharge in the 3rd sample, the 8th sample and the 9th sample of 82 m3/second. However, the three samples did not have the same discharge volume where the 3rd sample had a discharge volume of 383 m3/second with a characteristic of 1 peak, the 8th sample had a discharge volume of 938 and 905 m3/discharge with a characteristic 2 peaks and The 9th sample has a discharge volume of 700 m3/second with a characteristic 1 peak. The difference in the discharge volume is influenced by the discharge and drop-off time where the 3rd sample only has a 1-hour increase in time and a 5-hour down time, the 8th sample because it has 2 peaks has a 4-hour increase in time and for 2 hours then the time down For 15 hours and 16 hours. While the 9th sample has a time up for 3 hours and a time down for 13 hours.
Spatial variation of rainfall of Cilutung River flow is seen based on 22 samples of rainfall incidence of the region obtained from the results of precipitation processing using Isohyet method (Figure 5). In addition, spatial variation of rainfall is also seen based on the rainfall of the upper, middle and downstream streams of Cilutung River. In Figure 5 obtained precipitation area of Sungai Cilutung Basin. Out of 22 sample events, the highest area rainfall occurs in the sample of the 22nd event where the rainfall is 100 mm and the lowest region rainfall occurs in a sample of the 11th event with a rainfall of 15 mm. Rainfall Region Flow Region The Cilutung River, which is less than 50 mm, occurs 11 samples of events, and then the rainfall between 50 and 100 mm occurs as many as 11 samples of events.

Cilutung River basin is divided into three regions namely Hulu, central and downstream. Rainfall streams the Cilutung river basin has variations that can be seen in Figure 6 below. Out of 22 sample events, the rainfall of the upper part of Cilutung River has a higher rainfall compared to the downstream of Cilutung river flow occurs as many as 12 samples of events, then the downstream of the Cilutung River flow has rainfall is higher than the upstream occurs in as many as 5 samples of the incident and 5 other sample events have higher rainfall in the middle of the Cilutung River basin. Rainfall has the intensity in which the research is done processing rainfall intensity with data sourced from AWS automated in the upstream and downstream areas of the Cilutung River basin. The intensity of the greater rainfall at 22 samples of the dominant occurrence occurs in the upper part of the Cilutung riverbank i.e. in the 2nd sample, the 4th sample, the 6th sample, the 7th sample until the 9th sample, the 11th sample, the 12th sample, the 14th to the 17th sample, the sample 19th and the 20th sample. As for the downstream areas of the Cilutung River flow has a greater intensity only in the 1st sample, the 3rd sample, the 5th sample, the 13th sample, the 18th sample, the 21st sample and the 22nd sample.

Figure 5. Rainfall chart Cilutung River basin area
Figure 6. Rainfall parts upstream, central and downstream Cilutung River flows

Figure 7. Rainfall intensity chart upstream, central and downstream of Cilutung River flow
The relationship of a flood hydrograph pattern with rainfall can be seen based on a variation in the flow discharge which is the main variable in the flood hydrograph pattern with the daily rainfall of the Cilutung River basin. This relationship is found in Table 2 where there is a matrix of connections between the characteristics of hydrographs with rainfall and the intensity of rain.

Table 2. Matrix of relationships between the characteristics of flood hydrography with rainfall and intensity

| Sample Event | Date of Incident | Hydrographic Characteristics | Rainfall (mm) | Intensity (mm/hours) |
|--------------|-----------------|------------------------------|---------------|----------------------|
|              | Qmax (m³/sec)   | Qvol (m³/sec) | m (Hours) | Waktu Total (Hours) | Area | Upstream | Middle | Downstream | Upstream | Downstream |
| 1            | 06-Dec-18       | 20             | 161      | 3             | 12         | 9     | 19 | 12 | 19 | 22 | 0 | 24 |
| 2            | 12-Dec-18       | 159            | 1112     | 2             | 14         | 12    | 96 | 72 | 101 | 100 | 43 | 16 |
| 3            | 15-Dec-18       | 96             | 995      | 2             | 16         | 14    | 78 | 55 | 65  | 78  | 38 | 79 |
| 4            | 21-Dec-18       | 129            | 1113     | 2             | 15         | 13    | 56 | 60 | 56  | 52  | 26 | 0  |
| 5            | 27-Dec-18       | 96             | 1137     | 1             | 31         | 30    | 29 | 18 | 40  | 20  | 14 | 14 |

The relationship of the flood hydrograph pattern with the spatial variation of rainfall can be seen a sample of 11th occurrence and sample 13th occurrence if rainfall occurs only in the downstream of Cilutung River flow with relatively high rainfall will produce a pattern Symmetrical hydrographs, whereas if rainfall in the Hulu section first occurs then amid the incidence of rainfall in the lower downstream and at the end of the incidence of rainfall at the upper and lower part of the same will result in a hydrograph pattern Minimum discharge of 50 m³/sec (Figure 8).
Figure 8. Relationship of flood hydrograph pattern with rainfall spatial variation of the 11th and 13th sample

Table 3. Pearson Correlation Test Results and Classification of Strength Correlation

|                | Upstream | Intensity | Time | Rising | Total | Mobile | Downstream | Upstream | Rising | Total | Mobile | Downstream |
|----------------|----------|-----------|------|--------|-------|--------|------------|----------|--------|-------|--------|------------|
| Debit (m³/s)   | Pearson  | Correlation | Sig. (2-tailed) | Pearson  | Correlation | Sig. (2-tailed) | Pearson  | Correlation | Sig. (2-tailed) | Pearson  | Correlation | Sig. (2-tailed) |
| N              |          |           |      |        |       |        |            |          |        |       |        |            |
| Maximum        |          |           |      |        |       |        |            |          |        |       |        |            |
| N              |          |           |      |        |       |        |            |          |        |       |        |            |
| Correlations   |          |           |      |        |       |        |            |          |        |       |        |            |
| * Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed). | * Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed). | * Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed). | * Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed). |

Based on statistical analysis using Pearson's correlation test, the relationship between the flood hydrograph pattern with a spatial rainfall pattern can be seen in Table 3. If the value is significant (Sig. (2-Failed) < 0.05 Then there is a link between variables that can be seen in the yellow column showing a significant value of < 0.05 which means the maximum discharge has a relationship with total discharge.
rainfall Area, rainfall in the downstream, intensity at the upstream, time rises and total time of the Cilutung River basin. If total discharge, area rainfall, rainfall in the downstream, intensity at the upstream, boarding time and total time of the Cilutung River basin is getting higher then the maximum discharge that occurs will be higher. Furthermore, relationship strength correlation between variables can then be seen based on the Pearson correlation value classified according to Jonathan Sarwono in Table 4.

Table 4. Classification of Strength Correlation

| Pearson Correlation | Correlation strength       |
|---------------------|----------------------------|
| 0                   | No correlation             |
| 0 - 0.25            | Very weak correlation      |
| 0.25 - 0.50         | Insufficient correlation   |
| 0.50 - 0.75         | Strong correlation         |
| 0.75 - 0.99         | Very strong correlation    |
| 1                   | Perfect correlation        |

Maximum discharge with discharge volume has a Pearson correlation value of 0.943, which shows the relationship between maximum discharge and discharge volume is very strong. Then the maximum discharge with downstream rainfall has a Pearson correlation value of 0.513 which shows the relationship between the two strong variables. The maximum discharge with the intensity of the upstream part of the Cilutung River has a Pearson correlation value of 0.706 which negates the relationship between the two variables which are also strong. Meanwhile, the discharge volume with the upstream intensity of the Cilutung River Flow, downtime and total time have a Pearson correlation value of 0.614, 0.570, and 0.625 which shows the relationship between the discharge volume with the upstream intensity of the Cilutung River Flow, downtime and total time have a relationship the strong one.

4. Discussion

Based on the results of the discussion above, the flood hydrograph pattern has a relationship with the spatial pattern of rainfall, where if the spatial pattern of rainfall occurs first in the Upper Watershed of the Cilutung River, a larger flood hydrograph will be formed. This relationship can also be seen based on the results of the correlation test that shows a very strong relationship between maximum discharge and discharge volume, then the strong relationship between maximum discharge with regional rainfall, rainfall in the downstream of the Cilutung River Flow and intensity in the Upper Cilutung River Flow and strong relationship between discharge volume and intensity in the Upper Cilutung River Flow, rise time, fall time and the total time that occurred in the flood hydrograph. it explains that the spatial pattern of rainfall is related to the maximum discharge and discharge volume that represents the flood hydrograph pattern.

5. Conclusion

The flood hydrograph pattern has a strong correlation with the spatial pattern of rainfall. This relationship can be seen from the high correlation between variables. The variable that has a very strong relationship is the maximum discharge variable with the volume of expenditure with a correlation value of 0.943. Then, the variables that have a strong relationship are the maximum discharge with downstream rainfall, the maximum discharge with the intensity of the upstream part, the volume of discharge with the intensity of the upstream part of the Cilutung River Flow, the downtime and the total time with a correlation value between 0.50 to 0.75.
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