Characteristics of flood causes in Majalengka Regency 2014 – 2018

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Abstract. Flood is one of the most common hydrometeorological disasters that occur in West Java, especially Majalengka Regency that has high potency of flood hazards. Furthermore, the floods did not only cause the loss in material, but also non-material things such as the loss of life. The aim of this research is to identify the characteristics of rainfall in flood events in Majalengka District from 2014 to 2018. The variables used in this study included daily rainfall period 2014 - 2018. Rainfall was calculated by the mononobe method to produce daily intensity and was calculated by API5 to calculate soil moisture. The results showed that the incidence of flood in Majalengka Regency was caused by very moist soil moisture, while variations in rainfall and rainfall intensity during the incident did not affect flood.

1. Introduction
Floods are the most common hydrometeorological disasters in Indonesia [1]. Flooding is an event of overflowing water from the river cliff boundary in a relatively short period of time or an event of water flooding on the surface of the land until it exceeds a certain time limit resulting in losses [2]. The main factors causing flooding are meteorological factors such as high rainfall [3].

West Java Province from 2002 - 2015 was recorded as experiencing floods with 614 events followed by landslides with 585 incidents and third place occupied by drought with 312 incidents [4]. Majalengka Regency which is included in the West Java region, according to BNPB has a high risk of flooding [4]. During 2014 to 2018, flooding in Majalengka Regency spread in various heights, namely at an altitude of 0 - 25 m, 25 - 100 m, 100 - 500 m, and > 500 m [5]. Subdistricts affected by flooding at altitudes of 0-25 m or low class include Ligung, Jatituhuh, and Dawuan. Whereas, the subdistrict flooded at an altitude of 25-100 m or a rather low class one example is Panyingkiran Subdistrict [6].

The flood at an altitude of 100-500 m with a medium class occurred in Majalengka Subdistrict [6] and at an altitude of > 500 m as the high class is in Cikijing Subdistrict [6]. In addition, flooding at these altitudes resulted in the loss of casualties and material losses such as submerged rice fields, public facilities, and homes. Therefore, the study entitled Characteristics of Flooding Factors in Majalengka Regency in 2014 - 2018 has the objective of identifying rainfall characteristics in the flood events in Majalengka District which categorize as the low, moderate, and high altitude classification.
2. Methods
Rainfall in this study will be processed with several different methods, such as Thissen Polygon to produce regional rainfall, mononobe to produce daily intensity, and Antecedent Precipitation Index (API) to estimate soil moisture during floods.

2.1 Thissen Polygon
The Thissen Polygon technique is done by connecting one rain gauge with the other by using a straight line [7]. The measurement results are that each rain gauge is first weighted by using parts of the total catchment area represented by rain gauges of each location, then summed. Rainfall in certain areas can be obtained with the same as follows;

\[
\bar{C\bar{H}} = \frac{R_1 a_1}{A} + \frac{R_2 a_2}{A} + \cdots + \frac{R_n a_n}{A} 
\]

Explanation:

\( \bar{C\bar{H}} \) : Average rainfall (mm)

\( R_1, R_2, \ldots, R_n \) : Rainfall in each rain gauge (mm)

\( a_1, a_2, \ldots, a_n \) : Area of each polygon (ha)

\( A \) : Total area of water catchment (ha)

The rainfall results of this region will be classified into 5 classes, namely small, medium, heavy, very thick, and extreme which are written in Table 1.

| No | Classification       |
|----|----------------------|
| 1  | < 20 mm              | Small            |
| 2  | 20 – 50 mm           | Medium           |
| 3  | 50 – 100 mm          | Heavy            |
| 4  | 100 – 200 mm         | Very Thick       |
| 5  | > 200 mm             | Extreme          |

2.2 Mononobe
Rainfall intensity is the height or depth of rain water per unit time [7]. The function of rainfall intensity is to express the amount of rainfall in the short term which gives an illustration of the heavy rainfall per hour [9]. The intensity of daily rainfall can be calculated using the Mononobe formula [10], as follows:

\[
I = \frac{R_{24}}{24} \times \left(\frac{24}{t}\right)^{2/3}
\]

Explanation:

\( I \) : Rainfall intensity (mm/hour)

\( R_{24} \) : Maximum rainfall in 24 hours (mm)

\( t \) : duration of rainfall (hour)

The results of the intensity of daily rainfall will be classified into 4 classes, namely small, medium, heavy, and very thick, which are written in Table 2.
Table 2. Classification of Daily Rainfall Intensity [11]

| No | Classification |
|----|----------------|
| 1  | < 20 mm        |
| 2  | 20 – 50 mm     |
| 3  | 50 – 100 mm    |
| 4  | 100 – 200 mm   |

2.3 Antecedent Precipitation Index (API)
Rain that falls to the earth’s surface will be absorbed by the soil, but saturated soil conditions will cause run off, eventually causing flooding [12]. The API 5 [13] as follows:

\[
API_5 = \sum_{t=5} \frac{p}{t}
\]  

Explanation:

- API5: Value of soil moisture 5 days before the event (mm/day)
- p: Amount of rain in 5 days before observation (mm)
- t: Number of days before the event (5 days)

The API5 calculation results will be classified into 4 classes, which are dry, somewhat moist, moist, and very humid which are written in Table 3.

Table 3. Soil Moisture Classification [13]

| No | Classification |
|----|----------------|
| 1  | < 5 mm/day     |
| 2  | 5 – 10 mm/day  |
| 3  | 10 – 15 mm/day |
| 4  | > 15 mm/day    |

3 Results and Discussion
There were 103 flood events in Majalengka Regency during 2014 to 2018. Based on the graph in Figure 1, 2014 was the flood with the lowest incidence of 6 flood incidents. Flood events most often occur in 2015 with 52 flood incidents, then the number of flood incidents in the following years decreased to 17, 13 and 15 incidents.
The number of flood incidents that occur in Majalengka Regency is not directly proportional to the rainfall in the region. During 2014 to 2018 the highest annual rainfall was in 2016 with a total of 4,067 mm, but only caused 17 flood incidents. If seen in Table 4, the rainfall in 2015 was only 2,757 mm but caused 52 flood incidents. Thus, annual rainfall does not affect the incidence of flooding in Majalengka Regency.

| Table 4. Annual Rainfall of Majalengka Regency in 2014 - 2018 |
|-------------|-------------|-------------|
| No | Year | Rainfall (mm) |
| 1 | 2014 | 3316 |
| 2 | 2015 | 2757 |
| 3 | 2016 | 4067 |
| 4 | 2017 | 2735 |
| 5 | 2018 | 2640 |

If the annual flood event is more detailed, then from 2014 to 2018 flood events most often occur in March with the number 48 and the average rainfall of 553 mm. It has been described in Table 5 and Figure 2, that the average rainfall is the highest compared to the average monthly rainfall. However, if examined in more detail as illustrated in Table 5, March is not the month with the highest rainfall in each year but January in 2014 & 2017 and February in 2015, 2016 & 2018. 2014 monthly rainfall with flood events in 2014 in Figure 3 (A) shows that the two data are not directly proportional, as is the case in other years.

| Table 5. Monthly Rainfall and Flood Events of Majalengka Regency in 2014 – 2018 |
|-------------|-------------|-------------|
| Jan | Feb | Mar | Apr | Mei | Jun | Jul | Agt | Bji | Okt | Nov | Des |
| 2014 | 599 | 1 | 470 | 2 | 511 | 118 | 35 | 109 | 133 | 33 | 2 | 47 | 219 | 589 |
| 2015 | 526 | 2 | 593 | 7 | 536 | 306 | 1 | 118 | 35 | 109 | 133 | 33 | 2 | 47 | 219 |
| 2016 | 502 | 2 | 615 | 5 | 598 | 282 | 194 | 165 | 159 | 94 | 333 | 1 | 403 | 318 |
| 2017 | 684 | 10 | 200 | 3 | 538 | 376 | 109 | 65 | 13 | 64 | 21 | 9 | 403 | 164 |
| 2018 | 233 | 738 | 9 | 581 | 3 | 300 | 83 | 32 | 0 | 0 | 7 | 10 | 230 | 426 | 3 |

Jml: Total Rainfall
JB : Number of flood incidents
Rata: Average Rainfall

Explanation:
Rainfall in units of mm

Figure 2. Map of monthly rainfall comparison with number of flood accidents: (2014) A, F, K, P, U; (2015) B, G, L, Q, V; (2016) C, H, M, R, W(2017) D, I, N, S, X; (2018) E, J, O, T, Y
Based on annual and monthly rainfall, rainfall characteristics that cause flooding have not yet been found, therefore rainfall will be redetermined using daily rainfall during flood (H-0), rainfall intensity on flood day, and estimated soil moisture during 5 days (API5) described in Table 6. The rainfall in Table 6 is calculated by Thiessen polygon which is then weighted based on rainfall stations at each watershed (Table 7). Then, the weighting results are averaged based on the height of the flood location. The intensity at the time of the event is the result of a calculation from the mononobe method which then results are averaged based on height. Likewise, with soil moisture which is the result of API5 calculation which is then averaged based on height.

Based on Table 6 the rainfall area during the flood at altitudes 0 - 25 m and> 500 m is medium. Whereas, at altitudes of 25-100 m and 100-500 m are heavy. Then the intensity of the rain during the flood at a height of 0-25 m and > 500 m are small, while the intensity at the altitude of 25-100 m and 100-500 m is medium. Different from regional rainfall and intensity, soil moisture in each height region is very humid.

### Table 6. Daily Rainfall Characteristics

| No | altitude | watersheds* | rainfall stations** | Rainfall Watershed Area (mm) | Intensity H-0 (mm/hour) | soil moisture (mm/day) |
|----|----------|-------------|--------------------|-----------------------------|------------------------|------------------------|
| 1  | 0 - 25   |             |                    | 33.57 43.39 29.99 33.75 26.89 | 11.64 33.52             |
| 2  | 25 - 100 |             |                    | 71.25 43.06 45.08 34.71 18.92 | 24.70 42.60             |
| 3  | 100 - 500|             |                    | 76.04 32.95 33.95 35.61 15.92 | 26.36 38.89             |
| 4  | > 500    |             |                    | 22.27 23.53 27.78 18.96 16.50 | 7.72 21.81              |

*There are several watersheds at each height, namely:
  a. 0 – 25 m : Ci Balida, Ci Bayawak, Ci Buaya, dan Ci Keruh
  b. 25 – 100 m : Ci Balida, Ci Buaya, Ci Ders, dan Ci Keruh
  c. 100 – 500 m : Ci Balida, Ci Deres, Ci Jurey, Ci Keruh, dan Ci Lutung
  d. > 500 m : Ci Deres, Ci Keruh, dan Ci Lutung

**Rainfall stations and weightings are listed in Table 7.
Table 7. Rainfall stations and weights that affect the watershed

| Rainfall Stations | Name of Watersheds                  | Area of watershed (Ha) |
|-------------------|-------------------------------------|------------------------|
|                   | Ci Balida                           | 8,112.58               |
|                   | Ci Bayawak                          | 4,221.37               |
|                   | Ci Buaya                            | 6,472.11               |
|                   | Ci Deres                            | 8,376.09               |
|                   | Ci Jurey                            | 4,045.55               |
|                   | Ci Kemih                            | 34,403.40              |
|                   | Ci Lutung                           | 41,016.20              |
| Banjaran          | 0.04                                | 0.19                   |
| Cikajang          | 0.11                                | 0.03                   |
| Cireunang         |                                     | 0.08                   |
| Karangsambung     |                                     | 0.10                   |
| Lame              | 0.33                                | 0.00                   |
| Leuweunggede      |                                     | 0.13                   |
| Majap/Ciawi       | 0.30                                | 0.13                   |
| Majalengka        | 0.18                                | 0.04                   |
| Pajajaran         |                                     | 0.06                   |
| Pakumbahan         |                                     | 0.08                   |
| Panyangkaran      | 0.12                                | 0.30                   |
| Pasanggrahan      |                                     | 0.08                   |
| Payung            |                                     | 0.09                   |
| Rawa              | 0.55                                | 0.12                   |
| Sadawangi         | 0.10                                | 0.04                   |
| Sukahaji          |                                     | 0.03                   |
| Sunia             | 0.05                                | 0.01                   |
| Talaga            |                                     | 0.17                   |
| Werasari          |                                     | 0.08                   |
| Total Weights     | 1.00                                | 1.00                   |

4 Conclusion
Flood in Majalengka Regency from 2014 – 2018 were not affected by rainfall on the day of the event, but was influenced by accumulated and rainfall which was deposited in the soil so that the soil was very humid and could not absorb the water which caused flooding.

5 References
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