Estimation of flash flood loss level in Banjaririgasi Village, Lebakgedong Sub-district, Lebak Regency, Banten

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Abstract. The flash flood that occurred at Lebak Regency on January 1st, 2020, has caused around 30 villages in 6 sub-districts area were affected. The most affected area among 30 villages was Banjaririgasi Village. The research of estimating flood damage in Banjaririgasi Village was based on damage data, also based on the location of the village itself that located at the upper Ciberang Hulu river basin which has sloping topography. The goal of this research was to determine the physical characteristics of flash flood inundated area based on two-parameter: slope steepness and elevation difference from the river, and to estimate the amount of economic loss caused by flash floods. The estimation was obtained by overlaying the inundation map and land use map, then calculate the area of affected land use, and compared to the economic exposure value of each type of land use. Results showed that the inundated area of the flash flood in Banjaririgasi Village has physical characteristics: it has low slope steepness categorized as flat to gently slope (0–15 % sloping), and low elevation difference (5–10 m) from the river. Total economic loss caused by flash flood in Banjaririgasi Village estimated at around IDR 71,539,847,517.00, with the highest damage was IDR 59,415,832,341.00 from the damaged/destroyed government facility, and the lowest damage was IDR 59,457,216.00 from damaged forestry. The highest land use inundated area was paddy field with 25 ha inundated area, and the lowest was forestry with 0.41 ha.

Keywords: Flash flood, inundated area, land use, loss level, economic exposure value

1. Introduction
Flood has become a problem around the world during this decade. The increase in flood frequency was highly influenced by high rainfall, climate changes, and high population growth that leads to the massive development of settlement areas [1]. The impact caused by floods is increasing every year so that flooding is a disaster that threatens human life, around 84 % of deaths by the natural disaster were caused by flooding, and those numbers continue to increase [2]. The increase in victims due to flood disasters caused by population growth and development causes environmental and climate degradation [3]. Not just human casualties, the flash floods also affecting settlements, agricultural land, livestock, road networks, economic and business buildings, education facilities, and water resources [4].

One of the most destructive flood type was a flash flood. Flash floods are the most destructive floods that caused large numbers of victims [5]. Flash floods occurred by a sudden and unpredictable when a large amount of water with a high speed, a high volume of water flows from higher land to the lower
A large amount of water flowed also contained materials that are carried away such as dirt, wood, and rocks, causing heavy damages to everything that stands in its way [6]. In Indonesia, a recent flash flood phenomenon has occurred at Lebak Regency, Banten Province. The flash flood in Lebak Regency was caused by extreme rainfall up to 301.6 mm per hour at 05.00 local times, and occurred in 6 different sub-districts areas: Cipanas, Maja, Curugbitung, Sajira, Lebakgedong, and Cimarga, also caused 30 villages, 1,580 households are damaged, 26 bridges, 11 school buildings, 24 religious buildings, water, and electric network and supply are destroyed, and also caused 2 deaths and 837 casualties affected [7]. Meanwhile, one of the most damaged villages from that flash flood occurred was Banjaririgasi village that located at Lebakgedong sub-district [7]. The amount of flash flood damage estimated by local authorities around 108 residents was damaged; 65 of them are relocated, most of the residents were located at the riverside; river dam, river cliffs, and 2 bridges were destroyed [7]. Those huge number of damages caused by most rural settlements are located in the floodplain area, which flowed away or badly destroyed when the flash flood occurred.

The research topic of flash flood economic loss became important in further study and research in flash flood risk and mapping the risk area [8]. Previous research topics about estimating the economic losses due to floods and/or flash floods using the economic exposure value of land use type are mostly conducted in a larger study area [9-13]. As a novelty, in this study we conducted the research topic about estimating the economic losses caused by flash floods in a smaller area, like village administrative area.

Based on the data and explanation above, this study was conducted in Banjaririgasi Village with two goals: determining physical characteristics of the inundated area of a flash flood, and estimating the amount of economic loss level in the inundated area using economic exposure value per each land use type. Both of these goals are explained spatially.

2. Materials and method

2.1. Study area
Banjaririgasi Village located at Lebakgedong sub-district area, Lebak Regency, Banten Province, and also located at Ciberang river basin upstream with a total of 9,227 km² area (figure 1). The Ciberang river basin was a part of the major Ciujung river basin, located near Mount Halimun National Park, also located around two cities/regencies and six sub-districts by administrative data with a total area of 32,094.44 ha.

The topography of the study area is mostly sloped hills located almost all around the village, with a floodplain in the middle part of the village area. The elevation ranges from the lowest 168 meters above sea level up to the highest 571 meters above sea level. Mostly, areas in Banjaririgasi Village have 200–275 meters elevation above sea level located at the floodplain area (middle area of the village), when areas with elevation > 400 meters above sea level are located at the outer area of the village administrative boundary. Slope steepness in the study area ranges from 0 % (flat) to > 40 % (extremely steep), and mostly it has 2–15 % slope steepness (gently slope) located at the floodplain area when 15–40 % steepness located at the outer area of the village.

The land use in the study area is classified into several types: agriculture, paddy field, residential area, forestry, and government facility (eg. national road and bridge, national school). Agricultural in the study area is dominating around 72 % from total village area, covered almost all-around village area. Settlement area and government facility are most less land use type, covered around 3 % of the total village area.

2.2. Method
In this study, we approach from a flash flood that occurred on January 1st, 2020, at Lebak Regency as a case study. The flash flood itself caused heavy damages and economic losses as an effect. To estimate economic losses due to flash floods, first, we determine the inundated area of the flash flood. From the first components, we have two variables and parameters each: physical characteristics of the inundated
area and economic losses. The physical characteristics of the inundated area have two parameters, slope steepness and elevation difference from the river. Meanwhile, the economic losses are determined by the economic exposure value of each land use type (figure 2). As a final result the estimated economic losses level is determined by overlaying the land use map and the economic exposure value of each land use type.

Figure 1. Study area

Figure 2. Study framework
2.2.1. **Data.** The data required in this study mostly GIS data obtained from the Agency of Geospatial Information (BIG), Google Earth Satellite, and SRTM (30 × 30 m resolution), and DEMNAS (8 × 8 m resolution) as elevation data. The data from Google Earth Satellite obtained by digitizing points/polylines/polygons (table 1). To obtain the economic exposure value of each land use type, we used classifications of these values from [11].

2.2.2. **Processing method.** To estimate economic losses due to flash floods, we process the GIS data collected in ArcMap 10.6. The list of processes we have done using ArcMap 10.6 are explained below:

**Phase 1: Processing physical data of inundated area.**
To obtaining information about the physical characteristics of the inundated area, we used the elevation data as input. The elevation data obtained from SRTM 30 × 30 m was used for determining Ciberang river basin elevation and slope creating, while DEMNAS 8 × 8 m elevation data was used for determining elevation and slope creating (for bigger scale) both in study area and the inundated area. The classifications of slope steepness percentage are explained in table 2 [12]. Meanwhile, to determine the changes of the floodplain area, we are digitizing satellite imagery from Google Earth from August 2019 and mid-2020 and compare both of them to identifying the floodplain area.

The elevation data used in study area also processed and classified into several elevation level based on contour line with 5 m interval.

**Phase 2: Estimating economic losses in inundated area.**
To estimating the number of economic losses due to flash floods, we are overlaying the inundated area to the land use map obtained from BIG and Google Earth imagery. The overlaid map was then calculated for each land use type area and compared to each matched economic exposure value respectively (see table 3) [9, 11].

| Table 1. Data required of study |
|---------------------------------|
| Type          | Source                              | Year                  |
|----------------|-------------------------------------|-----------------------|
| Elevation      | SRTM 30 x 30 m                      | 2020 (Both data)      |
|                | DEMNAS 8 x 8 m                      |                       |
| Inundated area | Google Earth Satellite              | 2019 and 2020 for comparing the change of floodplain area |
| Land use       | BIG and Google Earth Satellite      | 2020                  |
| Road and river network | BIG                              | 2020                  |
| Village and city/regency boundary | BIG                              | 2020                  |

| Table 2. Classifications of slope steepness (degree and percentage). |
|---------------------------------|
| Slope classification | Percentage (%) | Degree (°) |
|----------------------|----------------|-----------|
| Flat                 | 0–2            | 0–2       |
| Gently slope         | 2–15           | 2–8       |
| Sloping              | 15–25          | 8–15      |
| Steep                | 25–40          | 15–25     |
| Extremely Steep      | > 40           | > 25      |
### Table 3. Economic exposure value of land use type.

| Land use type                                      | Economic exposure value (× 1000 US $/ ha) |
|----------------------------------------------------|------------------------------------------|
| Agriculture                                        | 2.35                                     |
| Paddy field                                        | 1.6                                      |
| Forestry                                           | 10.4                                     |
| Settlements and other activities                   | 246.2                                    |
| Government facility (eg. national schools, national roads and facilities) | 301                                       |

![Figure 3](Google Earth)

**Figure 3.** The comparison of the inundated area before and after the flash flood occurred; (a) before the flash flood occurred, obtained from August 2019 Google Satellite Imagery; and (b) the inundated area after the flash flood, obtained from mid-2020, obtained from mid-2020 Google Satellite Imagery.

3. Results and discussion

3.1. *Inundated area of flash flood*

Figure 3 showed the inundated area of flash flood in the study area. The shape of the inundated area is almost around the Ciberang river with a distance up to more than 100 m in the northern part, while there
are several parts with a distance less than 1 m. It can be stated that the flash flood has caused a lot of damage and economic losses, as showed in figure 3, numbers of the settlements and other land use are depleted, either washed away or severely damaged. From 2019 imagery (figure 3a) shows that there were several settlements, two river bridges, and other croplands. Meanwhile, from 2020 imagery (figure 3b) shows the aftermath of the flash flood that damages and/or washed away the land use above.

3.2. Physical characteristics of inundated area

3.2.1. Slope steepness. The inundated area of the flash flood in the study area mostly has 2–15% (gently slope) slope steepness. From that conditions were highly affecting the inundated area, due to lower slope causes more vulnerable to flood/flash flood. There are mostly northern to the middle part of the inundated area has low slope steepness, while the southern area has more steeps slope. It looks like the southern part of the inundated area has a lower vulnerability to flash floods, due to higher slope steepness. However, these areas also vulnerable to landslides/land erosion caused by flash floods, therefore these areas are not completely safe from flash floods and other natural disasters as effects such as landslides/land erosion (figure 4).

3.2.2. Elevation difference. The elevation difference of inundated area around 5–20 m. Mostly, the areas with high interval distances per contour unit are inundated, except for the southern of the inundated area, which has a 15–20 m elevation difference, but with a lower interval distance per contour unit. It showed that these areas have a steep slope, and during the flash flood these areas are caught by erosion from the water flow of flash flood (figure 5).

3.3. Land use
In Banjaririgasi Village, the land use is mostly covered by forestry located around all the village area, while the other land use type like settlements and agricultural/paddy field are located in the middle part of the village. During the flash flood on January 1st, 2020, the most damaged both area and economic losses were government facilities, and the less damaged both area and economic losses was forestry. The details of the inundated area of land use type and its economic losses are both explained in figure 6 and table 4.

Figure 4. Slope steepness
Figure 5. Elevation difference

Figure 6. (a) Land use, and (b) estimation of economic losses
Table 4. Estimated number of economic losses

| Land use type      | Economic exposure value (x 1000 US$/ha) | Inundated area (ha) | Estimated economic losses (US$) | Estimated economic losses (IDR) |
|-------------------|----------------------------------------|---------------------|--------------------------------|--------------------------------|
| Agriculture       | 2.35                                   | 4.38                | 10,239                         | 143,525,592                    |
| Paddy field       | 1.6                                    | 25                  | 40,000                         | 557,760,000                    |
| Forestry          | 10.4                                   | 0.41                | 814,922                        | 59,457,216                     |
| Settlements       | 246.2                                  | 3.31                | 814,922                        | 11,363,272,368                 |
| Government facility | 301                                    | 14.16               | 4,261,032                      | 59,415,832,341                 |
| **Total**         |                                        |                     | **71,539,847,517**             |                                |

[Source: Data processing]

3.4. Comparison to previous studies
The estimated amounts of economic losses above when compared to [9] and [10], both explains the spatial distribution of estimated economic losses. However, the difference from this study is the lack of damage modelling and depth-damage curve in this study. Further data collecting and processing are required in order to obtaining the damage modelling and depth-damage curve. Meanwhile, compared to [14], this study only defines the economic losses based on the damages of the land use. According to [14], the estimated losses and damage are divided into two separated definitions. The economic losses are caused by estimated loss of sales and services, loss in income, and clean-up cost. The physical damages and losses are caused by estimated loss from building structure, vehicles, and building contents.

4. Conclusion
The flash flood that occurred in Banjaririgasi Village has caused many casualties, losses, and damages. The inundated area of the flash flood in Banjaririgasi Village is around the Ciberang river, ranging from 0 m up to > 100 m from the riverside. Physical characteristics of the inundated area have mostly low slope steepness (gently sloped/2–15 %), and elevation difference from Ciberang river mostly has < 10 m difference.

The economic losses due to flash floods in Banjaririgasi Village estimated around total IDR 71,539,847,517.00, with most economic loss contributors from damaged government facility around IDR 59,415,832,341, while fewer contributors of total economic loss from damaged forestry around IDR 59,457,216. The most damaged land use type area was paddy field, with a total inundated area of 25 ha, and the less damaged land use type area was forestry with a total inundated area of 0.41 ha.

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