Application GIS (Geographic Information System) for multi-hazard mapping in Cisolok Village, Indonesia

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Abstract. Flood, landslide, and Tsunami was a disaster that has highest casualties in Indonesia. Based on BNPB’s data on 2019 flood, landslide, and tsunami cause more than 1000 people died or gone. Cisolok Village is one of many areas in Indonesia that has a potential hazard of that three disasters. Cisolok Village has flat and mountainous landform from zero until more than 25% slope gradient. There are two rivers that stream on Cisolok Village’s west and east side. Moreover, Cisolok Village has a beach with cliff type. That’s physical characteristic of Cisolok Village can cause the settlement become a prone area. This research is aim to do multi hazard mapping and also to know distribution of flood, landslide, and tsunami hazard and prone areas in Cisolok Village. Variable of hazard in this research are slope, distance from river, landform, and altitude. While the prone’s variable is location of settlement in Cisolok Village. Overlay Method was used to create hazard map and prone map. Spatial analysis was implemented to describe the distribution of flood, landslide, and tsunami hazard and prone areas in Cisolok Village. The result show that there ares with high flood, landslide, and tsunami hazard potential in Cisolok Village. High and very high landslide hazard potential area has the largest area (26.6 Ha) than the others. While, Tsunami prone area with high class has the largest areas (8.10 Ha) than the others. Southeast side of Cisolok Village is the prone area with high class in flood, landslide, and tsunami hazard.

1. Introduction
According to United Nations International Strategy of Disaster Reduction (UNISDR), in 2016 Indonesia was place in second ranked, viewed from the number of casualties due to natural disasters tsunami and landslide [1]. The effect of La Nina in Indonesia is also increase the disaster occurrences in Indonesia, which are landslide and flood [2]. Based on BNPB (National disaster management agency) data 2019, more than 1,000 people died and disappeared due to floods, landslides and tsunami in Indonesia [3]. West Java is the province with the highest occurrence of landslides and flood in Java island [4].

Cisolok Village was located in Cisolok District Sukabumi Regency West Java Province, Indonesia. Cisolok Village has two rivers as it borderline. There are Cisolok river on the west and Cipawenang riveron the east. That are rivers divide Cisolok Village with Cikahuripan and Karangpapak Village. Cisolok Village consist of area with height from zero until more than 100 masl. Other than that Cisolok Village is also has steep slope up to more than 25%. Height and slope differences cause Cisolok Village has a flat and mountainous landform type. Most of mountainous area is located in north side. There are mountainous area in the south has to coastal area with slope more than 15%. The Cisolok’s physical
characteristics cause the village become one of many area in Indonesia that prone from some disaster as flood, landslide, earthquake, and tsunami [5,6]. In 2018 flash floods accompanied by landslide occur in Cisolok [7].

Some research show that Cisolok Village is potentially affected by flood, landslide and tsunami [8,9]. Where the potential was increasing by years [6]. Mapping from flood, landslide and tsunami hazard and prone area seems important to do in Cisolok Village. This research is aim to create a multihazard and prone area in Cisolok Village. The result of this research is may practically be applied for the regional planning and development of infrastructures in the area.

2. Methodology
2.1 Data Processing for Hazard Potential Maps

2.1.1 Flood Hazard Potential Map. Flooding can occur due to overflowing river water, therefore the area adjacent to a river flow tends to be more frequently affected by flooding. Besides, flat landform makes it easier for water to enter and inundate an area. Based on previous research slope, altitude, rainfall, and distance from river affects the flood potential [10]. In this research variable of flood hazard potential is distance from river and landform. Landform was made from slope and altitude, while the rainfall is homogen. This following table is the classification of flood hazard levels in this study.

| Hazard Levels | Distance from river (m) | Landform    |
|---------------|-------------------------|-------------|
| High          | < 25                    | Flat/hilly  |
| Moderate      | 25 – 50                 | Flat/hilly  |
| Low           | 50 – 100                | Flat/hilly  |

2.1.2 Landslide Hazard Potential Map. Based on previous research, slope has a big affect for landslide potential [11,12,13]. Based on that, in this research slope is main the variable of landslide hazard potential. This following table is the classification of landslide hazard levels in this study.

| Hazard Levels | Slope (%) |
|---------------|-----------|
| Very High     | > 25      |
| High          | 15 – 25   |
| Moderate      | 8 – 15    |
| Low           | 5 – 8     |
| Very Low      | 0 – 5     |

2.1.3 Tsunami Hazard Potential Map. Tsunami hazard potential levels is measured based on the altitude of areas near the coastline. This following table is the classification of tsunami hazard levels in this study.

| Hazard Levels | Altitude (masl) |
|---------------|-----------------|
| Very High     | < 1             |
| High          | 1 – 3           |
| Moderate      | 3 – 5           |
| Low           | 5 – 10          |
| Very Low      | > 10            |
2.2 Data Processing for Multi-Hazard Potential Map
Multi-Hazard is a combination of the potential danger of floods, landslides and tsunamis that can cause loss and casualties. The multi-hazard potential map was then created by overlaying the flood hazard potential map, landslide hazard potential map and tsunami hazard potential map.

2.3 Data Processing and Data Alaysis for Prone area Map
Prone area of each disaster are made by overlaying between potential hazard areas and settlement areas. Spatial analysis with overlay method is carried out to obtain the distribution of floods hazard potential, landslides hazard potential, tsunami hazard potential, multihazards potential and prone areas.

3. Result and Discussion
3.1 Hazard Potential Areas
Based on figure 1. Cisolok village has an area with a high level of danger for flood hazards, and very high for landslides and tsunamis. The area with high flood hazard level has an area of 16.99 Ha. The area tends to be in the western and eastern parts of the village (figure 1a). That is because in the western part of the village there is Ci (river) Solok flow while in the eastern part there is Ci Pawenang. The western and eastern parts of the village adjacent to the river have a flat landform. Landforms near the river flow further north are undulating with heights less than 50 meters above sea level. Administratively, the areas with high flood hazard levels are mostly in the villages of Cisolok, Cigoler and Cikukulu.

Figure 1. Hazard Potential Areas in Cisolok Village, a) Flood Potential
The high and very high landslide hazard levels area have a total area of 16.60 Ha. Based on Figure 1b. The area tends to be in the Northwest and southeastern parts of Cisolok Village. That is because the area has a terrain that tends to be hilly with an elevation of > 25%. Administratively, high flood hazard areas are mostly located in the villages of Cikukulu, Karanghawu and Cipawenang.

The high and very high tsunami hazard levels area have a total area of 11.77 Ha. Based on Figure 1c. The area tends to be in the southern part of Cisolok Village. The southern part has a terrain that tends to be flat - choppy with a height of less than 10 meters above sea level and a slope of less than 5%. Administratively, high tsunami hazard areas are in the villages of Nambo and Karanghawu.
The low altitude and flat shape of terrain causes the southeast and southwest (the right and left ends of the south) Cisolok Village has high flood and tsunami hazard areas. Administratively the area is located in the westernmost part of Nambo village and the easternmost part of Karanghawu village. While the other southern part of Cisolok Village has a beach area with a cliff. The area has a bumpy - hilly land shape which causes the area to have a high risk of landslides and tsunamis. Administratively the area is in the westernmost part of Karanghawu village.

3.2 Prone Area
Prone areas are settlement or population that are threatened by a disaster. Based on Figure 2, there are settlements of Cisolok Village which are included in areas prone to flooding, landslides and high tsunamis. Based on Figure 2c. High tsunami prone areas tend to be in the southern part of the village. An area of 8.10 Ha, the residential area of Cisolok Village is an area with a high tsunami hazard level and is very high. Meanwhile, based on Figure 2b. high landslide prone areas tend to spread throughout all parts of Cisolok Village. Covering an area of 0.54 Ha, the settlement area of Cisolok Village is an area with high and very high landslide prone levels.

Figure 2. a) Flood Prone Areas in Cisolok Village
Based on Figure 2a. High flood prone areas tend to be in the western and southeastern parts of the village. Covering an area of 1.25 Ha, the residential area of Cisolok Village is an area with high flood-prone levels. In addition to areas with high flood-prone classes, the Tanggara village is the most vulnerable to the three disasters. All three disasters have a high class and are very high in that section. Administratively, Karanghawu village is the most vulnerable area. Corrugated and hilly land forms
cause settlements in the area have high levels of landslide prone. In addition to the river flow in the east and directly adjacent to the sea in the south, making the region has a high level of flood and tsunami prone.

3.3 Multi-Hazard Area
Based on Figure 3. The southern part has a high potential for each disaster. But there is not a location that has a high hazard of all three disasters at once. There are areas with high levels of flood hazard and high landslides but have low tsunami hazards. The area tends to be in the northwestern part of the village. There are areas with very high tsunami hazard levels and moderate landslides but do not have the danger of flooding. The area tends to be in the central part of the southern village of Cisolok. There are areas with high tsunami hazard levels and moderate floods but have low landslide hazards. The area tends to be in the southwest and southeast of the village or to the right and left of the south of Cisolok Village.

![Figure 3. Multihazard Potential Areas in Cisolok Village](image)

4. Conclusion
Cisolok village has a high hazard area in each disaster. Landslide hazard area with high class has an area of 26.6 Ha. That area is the highest hazard area with the highest class compared to other disasters. While the tsunami prone area with high class has an area of 8.10 Ha. That area is the most vulnerable area with the highest class compared to other disasters. The southeastern side of the village is an area that tends to have high levels of flood, landslides and tsunami. Flood and tsunami hazards have both increased to areas with low altitude and flat landform. The area is located in the southeast and southwest of the village. While the landslides and tsunami hazard potential has increased in the southern part of the village. The area has a wavy - hilly landform that is directly adjacent to the sea.
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