Landslide Zoning with GIS Analysis Method: Case Study Cipelah And Its Surroundings Area, Rancabali Subdistrict, Bandung Regency, West Java

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Abstract. Mass Movement often occur in Cipelah, especially when the rainy season arrives, it caused either physical damage and/or casualties. All these conditions make the Cipelah belong to areas that are quite a high potential for landslides. With the development of the human activity to prevent and anticipate natural disasters from landslides, a landslide risk map of Cipelah is needed, by a combination of vulnerability maps and hazard maps as important considerations in landslide prevention and mitigation. This study was conducted to map and analyze the potential of ground movement by a quantitative method. Direct observation was done by taking into account internal factors (lithology) and external factors (slope, rainfall, and land-use). The quantitative method was done by analysis based on Geographic Information System (GIS) on the parameters that have been weighted, including lithology, geological structure, slope, rainfall, and land-use. The research area expresses steep slopes dominantly composed of Andesitic Breccia and Tuff Breccia and has an average rainfall of 253 mm/year. This research brings about a map of prone to landslides, that is divided into two zones including the medium and high zone; medium zone with an area of 125.64 m² (12%) and the high zone with an area of 921.36 m² (88%). Types of ground movements that exist in the research area are debris flow and earth flow. The results of the study can be used as baseline information for disaster mitigation, and regional development.

1. Introduction

Landslide is one of the natural disasters that often occur in Indonesia especially in Java, which has a high frequency of landslides and almost increases every year triggered by topographic conditions and high intensity of rainfall. Not except in Bandung District, Cipelah Region, especially in Rancabali District where this research was conducted (Figure 1), is a landslide-prone area that often occurs on steep slopes and causes material losses until humans death. This disaster needs special attention by analyzing and dividing landslide-prone areas with certain geological parameters.

Natural factors of landslides are included earth surface morphology, land-use, lithology, geological structure, rainfall, and seismicity. In addition to natural factors, landslides are also caused by human activity that affects the landscape such as agricultural activities, slope loading, slope cutting, and mining. West Java Province is one of the areas that have a high potential for landslides. This is also caused by the hilly and mountainous topography of the region, as well as high population density which causes pressure on the ecosystem. Landslide-prone areas in West Java Province include in Bandung, Cianjur, Bogor, Sukabumi, Majalengka, Sumedang, Ciamis, Tasikmalaya, Kuningan, and Purwakarta. From the demographic aspect, the area is densely populated.
This study aims to utilize modeling in GIS technology and remote sensing for the analysis of potential landslide hazards and their causal factors, and then be able to provide information to the community of research areas about zones that are vulnerable to ground movement. The important value of this research can provide the final results in the form of quantitative analysis which is data from a combination with the specific weighting of each parameter and analyzing mitigation efforts against landslide-prone areas in the area of Cipelah Village, Rancabali District.

2. Methods
The method used in this research is quantitative method with the analysis procedure of Geographic Information System (GIS) software consisting of factors that influence the distribution of soil movement factors. The results obtained consist of zoning areas that are vulnerable to land movements in the Cipelah and surrounding areas so that it is expected to be of use to the government and the community to overcome and increase the likelihood of danger from such as land movements. In conducting the research, several steps were carried out, namely the acquisition, synthesis, and GIS analysis. The Acquisition step is the initial data approval or materials used as research support. This study uses secondary data (Geological Map of Sindangbarang Sheet and Bandarwaru, Java scale of 1: 100,000 [5], Topographic Map of West Java, Land Use Map of Bandung Regency, West Java Province, and rainfall data).

The analysis of landslides vulnerability is carried out on thematic maps namely Rain Map, Geological Map, Land Slope Map, and Land Cover Map of this area available and ready in the form of digital maps. When it is synthesized with existing data, each type of map is carried out with a score and is given weight then overlapped. The overlay is done using GIS software. In the process of overlaying each parameter has a multiplied score by each parameter, then the results of the multiplication score and the weight are added up.

The method used in this study is regarding the Decree of the Minister of Energy and Mineral Resources of the Republic of Indonesia No.1452 K/10/MEM/2000 concerning Technical Guidelines for Monitoring Land Damage Zones. The division of landslide-prone zoning uses the indirect mapping method, which is by overlapping procedures to determine the factors needed in the map parameters to the distribution of soil motion, then analyzed using GIS to determine the zonation of changes in ground motion.
3. Results and Discussion

3.1. Geographical Condition
Cipelah Village and its surroundings, Rancabali District, Bandung Regency are physiographically located at The steep hills bordering the southern Cianjur regency are characterized as plantation and agriculture areas. The area has a wet tropical climate with rainfall ranges between 2000 - 3000 mm/year (Figure 2).

![Rainfall Map](image)

Figure 2. Rainfall Map (Meteorology Climatology and Geophysics Council (BMKG))

In determining the rainfall score, [1] divides into five classes, the higher rainfall score as listed in Table 1. The rainfall will affect the condition of groundwater and the soil, where soil water content increases then the mass will increase and the lower the level of density and compactness. Based on these classifications the study area has a score of 3 with a class of moderate rainfall parameters.

| Rainfall Parameter Class (mm/year) | Weight 20% | Score |
|-----------------------------------|------------|-------|
| a. Really Wet (>4000)            | 5          |
| b. Wet (3000 – 4000)             | 4          |
| c. Medium (2000 – 3000)          | 3          |
| d. Dry (1000 – 2000)             | 2          |
| e. Very Dry (<1000)              | 1          |

Source: [1]

The population of the village of Cipelah reached 10,209 with an area of 1,047 hectares, most of the livelihoods as farmers. This form of the landscape which in general is a bumpy topography is generally
cultivated as agriculture and plantations, and only a small portion is used for rice fields and settlements. (Figure 3)

Figure 3. Land Cover Map (Digital Earth Map of Indonesia 1:25,000, Sheet 1205 – 541 Rancabali.)

Land covered by forests and plantations is relatively more able to maintain land stability due to a deep root system that can maintain the cohesiveness between soil particles and soil particles with bedrock and can regulate runoff and water catchment when it rains. Settlements have a smaller share because more runoff occurs compared to inundation and catchment because of the nature of the surface that is waterproof both the surface soil conditions and because the ground cover is concrete or the like. Fields and rice fields have vegetation that cannot maintain surface stability because they are inundated, and have a shallow root system so they do not maintain the compactness of soil particles. Scores and weights of land cover parameters can be seen in Table 2.

Table 2. Land Cover Condition

| Land Cover Parameter Class       | Weight 20% | Score |
|---------------------------------|------------|-------|
| a. Moor, Rice Field             | 5          |       |
| b. Shrubs                       | 4          |       |
| c. Forest and Plantation        | 3          |       |
| d. Settlement                   | 2          |       |
| e. Pond, The Water              | 1          |       |

Source: [1]

3.2. Geology
The village of Cipelah and its surroundings is geomorphologically a mountainous slope area ranging from 1% to 45% (Figure 4). Based on the classification of [6], it can be divided into 2 landform units namely Volcanic Valley and Volcanic Hills.
Geologically, the research area is an area with a rock structure that is strongly influenced by the surrounding mountainous conditions. The technical properties of rocks differ depending on their origin. In general, the technical characteristics of rocks are influenced by structure and texture, mineral content, stocky/combined shape of the base plane layer, weather conditions and sedimentation/bonding.

Stratigraphically, the study area is composed of volcanic rocks which are divided into four rock units in order from old to young, namely: Pyroclastic deposits are inseparable (in the form of Andesite Breccias, Tuff Breccias, and Lapilli Tuff), Lava and Lava Mount Kendeng (Flow lava interspersed with lava deposits in the form of andesite breccias and tuff breccias, angular components up to 40 cm in diameter), and Lava of Mount Patuha (Lava and lava andesite pyroxene which is solid and hollow from Mount Patuha with a matrix of sandy tuffs). (Figure 5).

Rock types are classified based on their origin, namely volcanic rocks, sedimentary rocks, karst, and alluvial rocks. Volcanic rocks are irreducible volcanic rocks. This species has high sensitivity to landslides. Scoring and weighting for each type of rock can be seen in Table 3. Based on the classification of [1] the classification of rock formations in the village of Cipelah based on the origin of the formation is divided into one namely volcanic rock with a scoring value of 5.

| Table 3. Rock Type Classification |
|-----------------------------------|
| **Sensitivity to Landslide Parameter Class** | **Weight** 25% | **Score** |
| a. High Sensitivity to Landslide | 5 |
| b. Medium Sensitivity to Landslide | 3 |
| c. Low Sensitivity to Landslide | 1 |

Source: [1]
3.3. Mass Movement and Zonation Prone to Landslide

Rock mass movement occurs when the distribution of forces acting on a slope is disturbed. Basically the forces acting on a slope can be distinguished between forces that cause motion and forces that are holding. If the driving force is greater than the holding force, then the mass movement of the soil/rock will occur.

Mass movements can be classified into various types, based on the speed of movement, the presence or absence of the slip plane, the shape of slip plane, and the type of mass that moves. For example, if the movement is fast, there is a slip plane and the moving mass is rock, then it is called a rockslide. If the moving mass of the land is called a soil slide. Meanwhile, if the movement is slow usually in the form of flow, it can be in the form of debris flow, rock debris, or wet soil and mudflow.

Mass movements that were found in the study area, generally in the form of soil and rock flow. The results of an inventory and analysis carried out by the geological agency for the events of the movement rock mass found in the study area, can be detailed as set out in Table 4.
Figure 6. Mass Movement type of soil flow (3,4) also ground and stone flow (1,2) in Cipelah village.

Table 4. Inventory of landslide events in the study area.

| No | Location               | Morphology                        | Lithology                     | Inundated                   | Land Use                          | Landslide Type |
|----|------------------------|-----------------------------------|-------------------------------|-----------------------------|-----------------------------------|----------------|
| 1  | Giriluyu, Cipelah Village | Very steep slopes above and ramps below | andesite breccias and tuff breccias (Ql) | Very abundant, there are many springs | On the river's edge and settlement | debris flow    |
| 2  | Cisabuk, Cipelah Village | Slope of the slope is rather steep to almost upright | andesite breccias and tuff breccias (Ql) | Very abundant, there are many springs | plantation and settlement | debris flow    |
| 3  | Muara, Cipelah Village | Corrugated hills with low to rough relief | andesite breccias and tuff breccias (QTv) and Mt. Kendeng Lava. (Ql) | Abundant Water | plantation and settlement | earth flow |
| 4  | Babakan Garut, Cipelah Village | Steep hill slopes at the top, very steep in the middle to the bottom | andesite breccias and tuff breccias (Ql) | Very Abundant | Rice Field and settlement | earth flow |

Source: Ministry of Energy and Mineral Resources, Geology Agency

To determine landslide-prone zoning, an evaluation of the parameters used as an indicator of the role of landslide events, namely slope, rock type (lithology), geological structure, land use, and rainfall. Weighting is done by giving a value to each of these factors with a scale of 5-1-5, then the quantitative method is done using the help of the GIS program, and calculations with formulas as follows:

$$ \text{Weight} = (35\% \times \text{Slope}) + (25\% \times \text{Rock Type}) + (20\% \times \text{Land Cover}) + (20\% \times \text{Yearly Rainfall}) $$
Table 5. BBSDLP Parameter Assessment 2009

| No. | Parameter      | Score | Weight (%) |
|-----|----------------|-------|------------|
| 1   | Slope          | <8%   | 8-15%      | 15-25% | >45      | 35      |
| 2   | Rock Type      | Lava and Breccia | Forest and Plantation | Shrub | Rice Field | 20 |
| 3   | Land Cover     | The waters Settlement | 2000-3000 mm/year | 20 |
| 4   | Yearly Rainfall| 2000-3000 mm/year | 20 |

TOTAL 100

After evaluating, zoning is carried out in the study area into 2 (two) zoning landslide hazard, consisting of Medium Zone and High Zone, with the following description:

Table 6. Weighting Analysis Results for Determination of Zoning Prone to Mass Movement

| Zonation | Score | Wide Area | Slope | Land Use | Material | Information |
|----------|-------|-----------|-------|----------|----------|-------------|
| Medium   | 2     | 125.64 m² | Slope the slope is rather steep with morpholagy the valley and the hills | plantation and bush and still was found settlement | Andesite Breccia, Breksi Tuff, and Lapilli Tuff | If construction of facilities public and settlements carried out, it is advisable to plant trees with strong and deep-rooted perennials that function to hold the slope and also to arrange surface drains and household wastewater with waterproof construction. |
| High     | 3 until 4 | 921.36 m² | slope rather steep to very steep | plantation bush, rice field and still was found settlement | Andesite Breccia, Breksi Tuff, and Lapilli Tuff | There are several points flow type landslides and stone with scale big enough. This area does not recommended development |
The results of the map stacking method that contain all the parameters used in the analysis, the landslide-prone zoning map of the research area is arranged (Figure 7).

![Landslide Zoning Map (GIS Analysis)](image)

**Figure 7.** Landslide Zoning Map (GIS Analysis)

### 4. Conclusions

Geomorphologically, the study area is a mountainous area with a slope varies between 1% to >45%. Based on the classification of [6] it can be divided into 2 landform units namely Volcanic Valley and Volcanic Hills. Stratigraphically, the study area is composed of volcanic rocks divided into four rock units in order from old to young, namely: Pyroclastic Deposits, Inseparable, Lava and Lava of Kendeng Mountain, and Lava and Lava of Mount Patuha. The study area is divided into two landslide-prone zones, namely the medium zone with an area of 125.64 m² (12%) and also the High Zone with an area of 921.36 m² (88%).

The types of landslides found in the study area are the type of earth flow and debris flow, in areas such as this it is necessary to install disaster-prone signs of land movement to increase awareness and monitoring of soil movements therefore If the construction of public and residential facilities is carried out, it is advisable to plant trees with strong and deep-rooted perennials that hold the slope and also arrange surface drains and household wastewater with waterproof construction.

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