Investigation the Vulnerability Potential of Landslide in Jayagiri Area Using the Geoelectric Method

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Abstract. Landslides are the third-largest natural disaster and have resulted in many victims, both property and casualties. One area where landslides occurred with casualties and heavily damaged houses was in Jayagiri, Lembang, West Java, Indonesia. One essential parameter in researching landslide-prone areas is the sliding area, where rocks or soil above the plane can move, resulting in landslides. Research on landslides continues to be developed from various fields of science. This study uses the Geoelectric method to determine and analyze the sliding area carried out in the Jayagiri area, Lembang. A reasonably significant resistivity value characterizes this field compared to the surrounding rocks. The measurement result on three lines shows that the study area is divided into two parts: the dominance of high resistivity and low resistivity. 2D inversion modeling shows that the slip plane has a resistivity value of 500 ohms.m at a depth between 9 m at the top of the slope and 13 meters at the bottom of the slope. The existence of a relatively shallow sliding field indicates a depth of water infiltration with a resistivity value of 10 Ohm.m, which is shallow enough so that it can be assumed that this area has the potential for landslides.

1. Introduction

Landslides ranked third in Indonesia throughout 2020. This disaster caused a lot of losses, both property and loss of life. Landslides can occur, one of which is caused by climatic conditions. One of the areas where many landslides occur is West Java Province. The climate in West Java has changed compared to the previous year. Air humidity increased from 74 percent in 2019 to 77 percent in 2020, triggering an increase in precipitation with a high level of intensity. In 2020, precipitation ranged from 2000-4000 mm/year, higher than the previous year. The highest precipitation occurs in November and December 2020. One area where landslides occurred in West Java with casualties and heavily damaged houses was in Jayagiri Village, Lembang District, West Bandung Regency, which occurred in December 2020.

In addition to climatic conditions, other parameters that can trigger natural disasters (landslides) are disturbances in soil stability, slip planes, and gravity. The triggering factors for landslides can be in the form of hydrological and geological influences [2],[3],[4]. Landslide identification is generally done through a macroscopic geological approach supported by hydrological data [5],[6],[7]. The physical and mechanical properties of rocks have a significant influence on landslides [8]. The type and composition of slope-forming soil affect soil parameters that contribute to soil shear strength and slope stability [8]. In this study, another approach was used, identifying rock structures that make up the landslide zone based on the physical properties of the rock. This study aims to obtain the distribution of resistivity value variations, the structure of the slip plane layer, the depth of the water catchment area, and the estimation
of areas that are most prone to landslides. One method that can be used is geoelectric. The Geoelectric method measures the electrical properties of rocks below the surface. Electrical properties of rocks below the earth's surface have been widely used for various purposes, including for the analysis of volcanic structures [9,10,11]. The Wenner configuration can be used to map the subsurface in two dimensions. This method is non-destructive to the environment, relatively inexpensive, and can detect the subsurface layer structure of the soil and a slip plane. The slip plane in the landslide area is characterized by very contrasting variations in resistivity values between the two soil/rock layers [12,13].

2. Method
The research was conducted in Lebak Cihideung, Jayagiri Village, Lembang sub-district, Bandung, West Java, as shown in Figure 1. The research area has a slightly steep to steep slope and is included in the zone of moderate to high ground movement potential. In addition, the research area is an area with high-intensity precipitation. Land movement in this area can occur if precipitation exceeds the average, especially in bordering river valleys, cliffs, road cliffs, and slopes [14].

Figure 1. Research Site Map
Based on the geological structure, the Lembang sub-district comprises three rock formations: Quaternary volcanic rocks, Neogene volcanic rocks, and Plio-Pleistocene volcanic rocks [15]. Quaternary volcanic rock formations are the most influential on soil movement based on the three rock formations. In contrast, Plio-Pleistocene Volcanic Rocks and Neogene Volcanic Rocks have less influence on soil movement. Quaternary volcanic rock formations are young volcanic deposits consisting of sand tuff, pumice tuff, lapilli, solid andesite fragments, and breccias. These rocks are the result of the eruption of Mount Tangkuban Parahu.

Based on the soil texture, Lembang District consists of clay soil, clay, and sand [14]. The texture of clay comes from the weathering of rocks and other chemical elements. This soil is the result of clay deposits that are above it. The location of the clay soil texture is close to the Lembang Fault. Coarse textured sand soil sourced from the eruption of Mount Tangkuban Parahu. This type of soil is close to the Tangkuban Parahu volcanic area, which is in the northwest area of the Lembang District. In contrast, the clay texture consists of volcanic ash from Mount Tangkuban Parahu, deposited so that its location is in the northern part of the Lembang District. The topographical condition of the Lembang Sub-district has the characteristics of getting to the south the lower elevation. The location of the clay texture is to the south of the sandy soil.

This research was conducted on three parallel profiles with measurements in a relatively north-south direction. The length of each profile is 80 meters with a space between the electrodes of 5 meters using the Wenner configuration as shown in figure 3. In the Wenner configuration, the distance between the current electrode and the potential electrode is constant [17]. The Wenner configuration has an excellent vertical resolution, high sensitivity to lateral changes but weak current penetration with depth, The geometric correction factor K for this configuration is 2πa. The following equation can obtain the apparent resistivity value.

\[ \rho_a = 2\pi a \left( \frac{\Delta V}{I} \right) \]

where \( \rho_a \) is the apparent resistivity (ohm.m), \( I \) is the current (Amperes), \( a \) is the electrode distance (m), and \( V \) is the potential difference (volts).

![Figure 2. Wenner configuration geoelectrical measurement scheme](image)

The measurement data obtained are variations in apparent resistivity values, electric current strength, potential difference, electrode spacing, and recording time.

3. Results

3.1 Line_01

The 2D inversion modeling was carried out using the Res2DInv software. Figure 3 below shows the cross-section of the 2D inversion in the form of resistivity distribution on Line_01. The altitude (elevation) of line_01 ranges from 1248 m to 1250 m above sea level. The percentage of 2D inversion error is 2.4% for 15 iterations.

![Figure 3. Cross-section of the 2D model of the resistivity distribution for Line_01](image)
Line_01 is located at 06°, 48' 30.6732" South latitude and 107°, 36' 52.0920" East longitude until 06°, 48' 28.8046" South latitude and 107°, 36' 53.6933" East longitude. The distribution of resistivity values of the Line_01 ranges from 7.43 m-553.61 m and is dominated by areas of high resistivity. The maximum depth that can be detected is 13.4 m below the surface.

3.2 Line_02
Line_02 is located at 06°, 48' 30.3403" South latitude and 107°, 36' 53.0117" East longitude until 06°, 48' 29.6935" South latitude and 107°, 36' 54.6957" East longitude. The results of measuring the Line_02 profile are shown in figure 4. The elevation ranges from 1229 m to 1232 m above sea level. Variations in resistivity values ranged from 5.97 m-530.07 m. The maximum depth detected is 13.4 m, with an error percentage of 3.2% for 15 iterations.

3.3 Line_03
Line_03 is located at 06°, 48' 31.2918" South latitude and 107°, 36' 53.0168" East longitude until 06°, 48' 29.7969" South latitude and 107°, 36' 55.4921" East longitude. The elevation ranges from 1226 m to 1232 m above sea level, and the variation of resistivity value of the Line_03 ranges from 8.61 m-932.31 m. The maximum depth that can be detected is 13.4 m. The percentage of error obtained is 2.3% for 15 iterations.

4. Discussion
The 2D resistivity cross-sectional profile of the study area is shown in figure 6. The cross-sectional model shows a pattern that corresponds from one profile to another—the variation of resistivity values from tens of ohmmeters to the order of hundreds of ohmmeters. The high resistivity structure indicates an impermeable layer, while low resistivity indicates infiltration that fills the rock pores. The water that fills the pores of the rock will continually add to the mass of the slope that could result in a relatively high level of vulnerability to landslides, especially if the degree of slope is large.

The 2D resistivity cross-section of Line_01 in figure 6a shows the high resistivity dominant part is at a measurement distance of 10 m - 60 m with a depth of 2 m - 10 m below the surface. In contrast, the dominance of low resistivity is at a measurement distance of 25 m - 80 m below the surface. The high resistivity layer can be assumed as an area/zone where water infiltration occurs. Meanwhile, layers with low resistivity values are zones with high water saturation that contribute to slope mass. A water-saturated zone that adds to the mass of the slope is a trigger for soil movement [18].
On the Line_01 profile, towards the relative south, the seepage zone is getting thicker up to a measurement distance of 50 meters. The permeable layer above the non-permeable layer at a distance of 25 m to 55 m which forms a basin, is an area of water seepage which increases slope mass. The water catchment area on the Line_01 profile ranges between the surface to ± 9 m, with the center of the measurement point 35 m – 50 m being the deepest area. At the same time, the shallowest layer is at the measurement point of ±18 m to ±25 m.

Figure 6b shows the profile of Line_02. In this profile, the high resistivity dominant part is at a measurement distance of 20 m – 45 m, and the low resistivity dominant part is at a measurement distance of 45 m – 80 m. Layers with high resistivity values (order hundreds) show a relatively complex structure to absorb water to be indicated as an avalanche field. The depth of the infiltration area ranges from the surface to ±13 m, with the deepest layer being at the measurement point of 50 – 65 m, while the shallowest layer is at the measurement point of 20 m – 45 m with a depth of only about 4 m.

In the Line_03 profile in Figure 6c, the dominant part of the high resistivity is at a measurement distance of 20 m – 50 m. While the dominance of low resistivity at a measurement distance of 50 m - 80 m. The cross-sectional model of the Line_03 profile shows a more precise structure between the seepage zone in the shallow layer and the water seepage zone in the deeper layer. In this profile, the depth of the infiltration area ranges from 0 to ±13 m, with the deepest area being at the measurement point of 45 – 60 m, while the shallowest seepage area is at the measurement point of 25 m – 45 m, which is around 3.5 m.

The potential for landslides in the research area can be minimized by taking mitigation measures, including carrying out a terracing system and reforestation with plants with deep root systems and proper spacing. In addition, mitigation can be done by reducing the slopes’ steepness, carrying out soil compaction, and closing fractures on the slopes to quickly prevent water from entering the soil.

5. Conclusion

Based on the resistivity distribution, the research area is divided into two parts: the high resistivity domination section and the low resistivity domination section. The distribution of resistivity values in the study area ranges from 5.97 m-932.31 m. The resistivity values in the Line_01 vary between 7.43 m-553.61 m, the Line_02 between 5.97 m-530.07 m, and the Line_03 between 8.61 m-932.31 m. The water catchment area on Line_01 reaches a depth of ± 9 m, with the center of the measurement being the deepest area. On Line_02 and Line_03, the depth of the infiltration area reaches ±13 m at each
measurement point between 50 – 65 m and 45 – 60 m. The 2D inversion model shows the slip plane has a resistivity value of about 500 ohms.m is at a depth between 9 m at the top of the slope and 13 meters at the bottom of the slope. Based on these results, the measurement position of 0 to 50 m has a reasonably shallow slip plane that shows the depth of water absorption with a resistivity value of 10 Ohm.m, which is relatively shallow. Thus, it can be assumed that this area has a high potential for landslides compared to other positions. Meanwhile, the measurement area at a position of ±50 m - 80 m with the characteristics of a reasonably thick water catchment area takes longer to reach its saturation point.

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