The Electrical Resistivity Tomography Technique for Landslide Characterization in Blangkejeren Aceh

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Abstract. Investigation of geophysical methods describes elements and geological geometry based on the physical properties of the subsurface. In the past decade, the application of resistivity methods has experienced a rapid increase in describing geological structures and settings. The Electrical Resistivity Tomography technique used to describe the geometry of a complex landslide in Blangkejeren, Aceh province, Indonesia. This area is highly influenced by the landscape with slopes, high-rainfall, and tectonic activity of the Sumatran fault which can lead to soil movement. The type of landslides in this area is largely controlled by ge-structural characteristics: rotational and translational slides, as well as the phenomenon of the gravitational slope of high steepness. As a preliminary study, the acquisition of resistivity data was conducted at two locations with a length of each measuring path 330 meters and electrodes spacing 6 meters. The Supersting R8/IP instrument unit with Wenner-Schlumberger array is used to obtain data that has a sensitivity to vertical and lateral changes. The resistivity distribution along the path is obtained from both profiles that are perpendicular to the landslide field. ERT modeling results at both locations showed subsurface structures based on resistivity values such as: slate, clay, and sandy clay. The contrast resistivity between each layer makes it easier to describe the characteristics of the landslide slip plane geometry which is affected by the slope angle. The resistivity method has physical properties that are very sensitive to porosity and groundwater which is the main parameter in a landslide. Finally, it should be noted that the use of the ERT technique as an effective and efficient method in conducting landslide studies as a disaster mitigation effort.

1. Introduction
The phenomenon of landslides is one of the most common natural disasters in Indonesia. Since the last two years, there have been reported at least 355 landslide events in 2018 and 473 events in 2017. The impact of material losses caused by landslides is very large; including thousands of homes that have been damaged and also fatalities [1]. One location that has a high potential of landslides in Aceh Province is in the central region, such as Gayo Lues Regency with steep topography due to tectonic processes that occur on the main route of Sumatran Fault. The results of Satellite imagery (Figure. 1) show that in general, this area has high rainfall based on very tight vegetation, in addition to that location there is also a fault structure (red line) which becomes an additional trigger for landslides. So
that it increases the potential threat of landslides. The threat not only has an impact on damage to public housing but also threatens public infrastructure, such as the collapse of the main road which could paralyze the access of the connecting Gayo Lues Regency with Southwest Aceh Regency, this could have an impact on the economic activities of the community. The National Disaster Mitigation Agency (BNPB) of Indonesia notes that every year during the rainy season several landslides have occurred along the central part of Aceh Province. Figure 2 also shows the material events resulting from a landslide collapse and the potential threat to public infrastructure. So, without mitigation efforts, such disasters will continue to occur in the future and more damage will befall human life. To reduce the risk of hazards, more studies are needed that focus on mitigating landslide hazards.

Figure 1. Map of ERT site located in Blangkejeren on the main road of Gayo Lues – Southwest Aceh, Aceh Province, Indonesia. The site has very tight vegetation conditions and influenced by the active fault structure of Sumatran Fault.
Landslides are complex geological disasters with very contrasting physical properties on the subsurface [2]. The complex characteristics of landslide require the need to investigate as much detail as possible. There are various aspects of science that can be used to study areas prone to landslides. Like Satellite imagery, For mapping on a broad scale and the characteristics of slope surface [3]. However, this study is not able to provide detailed information regarding the characteristics of landslides such as the thickness of the sediment layer and the shape of the slip plane that is subsurface. Non-invasive geophysical investigations have been widely used to study subsurface layers from landslides [4], this method measures physical parameters above the surface in response to subsurface material. In another case, many geophysical methods have been developed for lithological mapping [5], archaeology, and environmental sciences [6–8], mineral deposit, and geological prospecting [9–11]. It can be indicated that the geophysical method has usefully implemented in many aspects of the Earth sciences.

The electrical resistivity is the most commonly used geophysical method in landslide mapping [12]. This method has been used successfully in mapping landslide potential in the Basilicata Region, Southern Italy [13]. Meanwhile, this method is not only used for landslide investigations but has been widely applied in other studies such as the sedimentation of Ancient River [14], groundwater contamination [15,16], and shallow faults of the subsurface [9]. Referring to [17] the use of electrical resistivity tomography technique can obtain accurate and precise results related to geometric characteristics landslides in the form of; sediment material thickness and the existence of slip fields as a trigger for landslides. In this study, the electrical resistivity tomography technique was conducted to characterize the geometry of the slip area in a potential landslide area in Blangkejeren, Aceh province, Indonesia.

2. Theory and Methodology

The Electrical Resistivity Tomography (ERT) is a very effective method that using for landslide studies, It is has been proven in several previous studies [4,18,19]. The ERT technique is able to obtain detailed information related to landslide geometry [20]. Meanwhile, the method is able to describe the boundaries between sedimentary material [14]. Resistivity measurements are conducted by injecting current into the ground and measuring the potential difference response using electrodes. The resistivity value is calculated by considering the intensity of the injected current (I), the potential difference (V), and the geometric coefficient (K) related to the arrays of the electrode [17].

$$\rho_a = K \frac{V}{I}$$

Data acquisition was performed using a Supersting R8/IP resistivity meter to obtain resistivity parameter responses from the subsurface. The Wenner-Schlumberger array is used to obtain models that are sensitive towards vertical and lateral [21]. Data measurements were conducted at two locations with the same geological settings. The distance of the ERT profile is 330 meters with a 6 meter spacing between the electrodes. Both profiles are measured directly on the side of the road that experienced a landslide. Profile 1 (Figure 1.a) is measured close to the location of debris flow to obtain the overall geometry of the landslide, both the landslide field and from the previous landslide activity. While profile 2 (Figure 1.b) is measured on the side of the road that has identified a landslide potential on the north side of the profile, this is to get the geometry of the landslide slip plane at the site. In addition, both sites are strongly influenced by steep topography. Distribution of apparent resistivity values obtained at inversion to get the actual resistivity model and landslide geometry [22]. Data inversion to obtain subsurface 2D models was conducted using the AGI EarthImager-2D software.
3. Result and Discussion

Based on the cross-section of the Electrical Resistivity Tomography (ERT) technique, generally profile 1 and 2 consist of three types of layers. The Modeling results in profile 1 (Figure 3) show the geometry of landslides which consists of three types of subsurface layers based on resistivity values. The first layer, near the surface with a depth of 0-20 meters has very resistive properties with a resistivity value of 2500-10,000 Ohm.m interpreted as slate and sludge from debris flow. The second layer with a depth of 20 - 65 meters there is a layer of clay with resistivity 42 - 200 Ohm.m. While the third layer at a depth of 20 - 65 meters and a length of 35 - 145 meters in the profile model there is a gravel layer with a resistivity value of 1500 - 2500 Ohm.m. Meanwhile, the length of the profile 175 - 290 meters has a very conductive subsurface response caused by the presence of water channels; it also plays an important role in increasing the potential for landslides. ERT modeling also provides a detailed description of the characteristics of landslides at the site, which are highly affected by the slope and debris flow with high fluid content based on the resistivity response.

The Electrical Resistivity Tomography modeling data for profile 2 (Figure 4), showing the same subsurface geometry conditions as profile 1 consisting of three different layers. The first layer, near the surface with a depth of 0-10 meters has a very resistive condition with a resistivity value >710 Ohm.m, interpreted as a slate stone deposition. The second layer with a depth of 10 - 35 meters below the surface there is conductive conditions with resistivity values of 12-100 Ohm.m interpreted as sedimentary of clay. While the third layer with a depth of 35-70 meters and a resistivity value of 100-
600 Ohm.m, interpreted as a sedimentary of sandy clay. At a profile length of 200 - 330 meters near the surface, there is debris flow material and is also influenced by the water flow at the site, so the response obtained is very resistive. The characteristics of landslides that are affected by steep topography (>15°) have resulted in the accumulation of ragged material in areas with lower topography.

![Figure 4](image-url) The Electrical Resistivity Tomography model of profile 2. The model is measured in the direction of slope >15°. The black line on the model shows the boundary between each layer that acts as the slip plane and the arrow line as the direction of the landslide.

The interpretation of subsurface models at the study site is based on the resistivity parameter response approach with direct field observations. Both profiles of ERT measurements are conducted in the same geological setting, so the results of both profiles models have the geometric characteristics of adjacent landslides (almost the same). The results of interpretation on profile 1 show the characteristics of unstable soil and the large volume of debris flows deposited material from the landslide body that is perpendicular to the study profile. While on profile 2 shows the characteristics of landslides which are strongly influenced by porosity and fluid. The results of modeling the characteristics of landslides by using the ERT method can provide information related to potential disasters.

4. Conclusion
Based on the results, it can conclude the use of Electrical Resistivity Tomography technique can work very well in describing boundaries between subsurface layers. Due to the ERT technique produces a very contrast resistivity distribution to porosity and groundwater as the main parameter of a landslide. The measurement data shows the high resistivity value in the area that is suspected as debris flow material of landslide. 2D inversion results of resistivity data obtained three subsurface layer structures. The first layer is a razed material with resistivity values >750 Ohm.m. The second layer is clay with a resistivity value of 100 - 200 Ohm.m. While the third layer with a resistivity value of 100 - 2500 Ohm.m is a sandy clay and gravel layer. Thus, using the electrical resistivity tomography technique can provide accurate information related to the geometric characteristics of landslides: such as the boundaries of material deposits and the landslide body properly.

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