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Analysis of Landslide Disaster Potential in Meulaboh Area, West Aceh Regency, Aceh Using Resistivity and Geospatial Methods

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Abstract

Meulaboh, in West Aceh Regency, is one of the areas with potential for landslides. The goal of this research is to identify soil conditions that could lead to landslides based on resistivity data, as well as to analyze the distribution of landslide potential using geospatial data. This research provides benefits to various stakeholders, including the government. It contributes to improved disaster mitigation planning, reduced risk of losses, and the selection of appropriate materials to construct more disaster-resilient infrastructure. The research methods used are 2D resistivity and geospatial methods with weighted overlay analysis. Based on the processing results of 2D resistivity data from profiles 1 and 2, the study area is characterized by silt, sand, and sandstone. The resistivity values of the material in profile 1, identified for silt, range between 1 and 119 Ω.m at depths of 2-59 meters. For sand, the resistivity values range between 120-225 Ω.m at 2-61 meters depths. Sandstone has resistivity values that range between 226-500 Ω.m at depths of 3-62 meters. The resistivity values of the material in profile 2, identified for silt, range between 1-119 Ω.m at depths of 1.5-60 meters. For sand, the resistivity values range between 120-225 Ω.m at 9-59 meters depths. Sandstone has resistivity values that range between 226-500 Ω.m at depths of 15-39.4 meters. The presence of silt (1-119 Ω.m) increases the potential for landslides due to its cohesive nature. Based on the weighted overlay analysis processing results, the study area has a moderate potential for landslides. The study area has characteristics such as a gentle to steep slope (8-45%), a high rainfall rate (2500-3000 mm/yr), a lithology consisting of rocks from the Tutut Formation, including silt, sand, and a small amount of conglomerate, and land that is used for plantations and rice fields.

Introduction

Indonesia is a country that has a significant potential for natural disasters, including landslides. Landslides are one of the disasters that have frequently occurred in recent years.

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This is because a large part of Indonesia consists of hilly and mountainous areas, making it highly prone to landslides. Landslides are natural events that involve the movement of large volumes of soil or rock masses over a short period. Landslides can occur due to the influence of several factors, including slope gradient, rainfall intensity, land use, rock type, the presence of slip surfaces, and other related aspects. Regions characterized by steep slopes, high rainfall intensity, dense populations, sparse vegetation, rock types with high water absorption capacity but limited ability to release trapped water, and the presence of slip surfaces are often identified as areas with a high susceptibility to landslides [1].

Meulaboh is one of the areas that experienced a landslide disaster on May 7, 2023, which disrupted access to the West Aceh-Pidie provincial road. Meulaboh also has a history of landslides, such as the one in 2019, which caused flooding and landslides in several sub-districts. This occurs due to Meulaboh's morphology, which features low hilly terrain in some areas and experiences high rainfall intensity. Landslides in Meulaboh often occur along road sections, obstructing road access. Due to the high frequency of landslides in Meulaboh, research on landslide potential is essential to help reduce losses and casualties in the future. This study could facilitate the implementation of landslide mitigation measures and advise road users to exercise caution when traveling through areas prone to landslides. This can be achieved by mapping landslide-prone spots using geospatial methods. This research can also contribute to the consideration of constructing robust structures, such as roads and retaining walls, by studying the subsurface structure of landslide-prone spots using resistivity methods [2].

This study offers significant benefits to various stakeholders, including the government. The first benefit is improved disaster mitigation planning [1]. The findings of this study provide essential data and information regarding landslide vulnerability, which are critical for disaster mitigation planning, such as the construction of landslide barriers, effective drainage systems, and warning signs. Secondly, the research contributes to reducing the risk of losses. By understanding landslide potential, governments can take appropriate preventive measures to minimize material losses. Lastly, this study serves as a reference for selecting suitable materials for constructing more disaster-resilient infrastructure. It provides a foundation for designing and building landslide-resistant roads, including choosing appropriate materials, applying proper construction techniques, and adjusting road designs to local geological conditions [2].

Previous researchers have analyzed landslides using various methods, including geophysical techniques. These techniques include resistivity, seismic, and geospatial methods. The resistivity method utilizes the electrical properties of rocks to study subsurface layers, achieved by transmitting an electric current from the surface. The seismic method, on the other hand, uses wave propagation velocities to investigate subsurface conditions. Lastly, the geospatial method is a data analysis technique that incorporates location-based references [4].

Each of these methods has its advantages. However, in this study, the resistivity and geospatial methods were chosen. They are more effective in analyzing landslide potential because they provide comprehensive information compared to a single method. Additionally, it allows for easier and more environmentally friendly data collection, produces more interpretable data processing results than other combined methods, and offers adequate solutions to the landslide issues occurring in Meulaboh. [5].

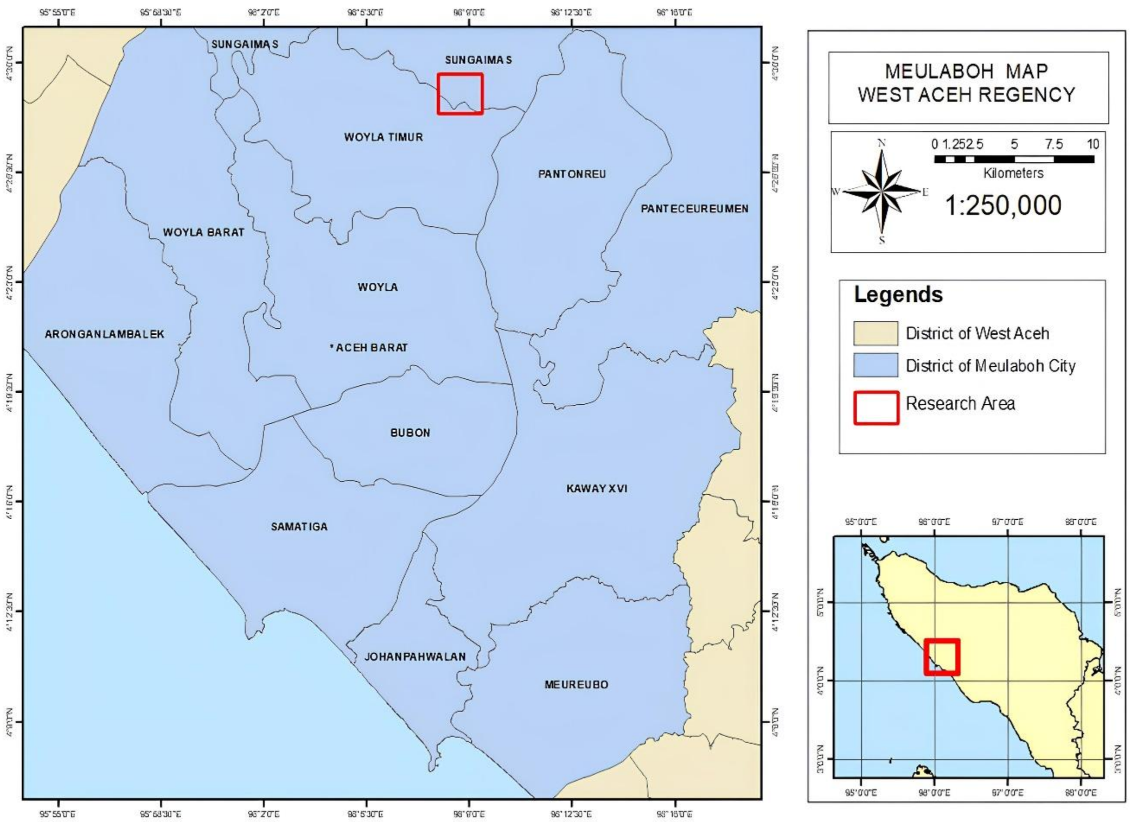

Figure 1. Map of Meulaboh [3].

This study employs the 2D resistivity and geospatial weighted overlay analysis methods. This research aims to assess the subsurface conditions for disaster mitigation considerations based on resistivity data and map the distribution of landslide potential and mitigation measures using geospatial data. The role of the resistivity method in this research is to determine the subsurface lithology to identify rock layers that have the potential to become sliding planes. This information can be utilized for disaster mitigation purposes. Meanwhile, the geospatial method plays a crucial role in mapping the distribution of landslide-prone areas by analyzing the contributing factors of landslides [6].

Theory and Calculation

Landslide

Landslides are events in which soil or rock moves downhill along a slope under the influence of Earth's gravity. Landslides are natural phenomena that occur in many places across the globe. This disaster can occur due to human activities that lead to environmental damage and significant material losses. Landslides are triggered by several factors, including heavy rainfall, slope steepness, soil type, and land cover type [7]. Landslides can occur due to the influence of several factors, including slope gradient, rainfall intensity, land use, rock type, the presence of slip surfaces, and other related aspects. Steep slopes, high rainfall intensity, dense populations, sparse vegetation, rock types with high water absorption capacity but limited ability to release trapped water, and the presence of slip surfaces are identified as a high susceptibility to landslides [1].

Rock Resistivity

The resistivity of a rock is its ability to resist the flow of electric current through it. Rock resistivity is a parameter used in the geoelectrical resistivity method to obtain subsurface layer information [5]. The general equation for resistivity is shown in (1).

$$\rho = R\frac{A}{L} \tag{1}$$

The resistivity of rock is affected by several factors, including rock type, porosity, water content, mineral content, and temperature. Different rock types exhibit different resistivity values; for instance, igneous rocks generally have higher resistivity than sedimentary rocks. Rock porosity, water content, mineral content, and temperature also affect the resistivity value. The higher the rock's porosity, the more space to be filled by water and minerals, leading to higher conductivity and lower resistivity. As rock temperature increases, its conductivity increases, resulting in lower resistivity [8].

Table 1. Rock and Mineral Resistivity [9]

Material	Resistivity (Ω.m)
Sand	$1 - 10^3$
Sandstone	$2x10^2 - 8x10^4$
Silt	$10 – 2x10^2$
Clay	$1 - 10^2$
Groundwater	$5x10^{-1} - 3x10^2$
Alluvium	$10 - 8x10^2$
Gravel	$10^2 – 6x10^2$
Dry Gravel	$6x10^2 – 10^4$
Andesite	$1,7x10^2 – 4,5x10^5$
Basalt	$2x10^2 – 10^5$
Limestone	$5x10^2 – 10^4$
Breccia	$201 – 10^3$
Tuff	2000 (wet) - 10^5(dry)
Quartz	$5x10^2 – 8x10^5$

Methods

Resistivity Method

The resistivity method is a geophysical technique that utilizes electrical properties to obtain information about subsurface layers, including the structure of rock layers, their depth, and the electrical properties of the rocks. Rocks can exhibit electrical properties when an electric current is passed through them. The electric current is derived from natural sources, causing an imbalance that can be studied through the rocks' conductivity, dielectric constant, and electric potential [6].

The resistivity method uses the resistivity contrast produced by rocks to obtain information about subsurface layers. The resistivity values obtained are expressed as apparent resistivity [5]. The equation for apparent resistivity is shown in (2).

$$\rho_a = K\frac{V}{I} \tag{2}$$

Apparent resistivity is the resistivity value measured, representing a combination of the resistivities of various rock layers beneath the surface. This apparent resistivity differs from the actual resistivity of each rock layer [10].

Wenner-Schlumberger Configuration

The resistivity method is employed to identify rock layers that cause landslide susceptibility using various configurations, one of which is the Wenner-Schlumberger configuration. The electrode setup in the Wenner-Schlumberger configuration resembles that of the Wenner-Alpha. However, the spacing between the current and potential electrodes is "n" times larger than the distance between the two potential electrodes. The distances are equivalent in this configuration: C1P1 = P2C2 = na, while C1P2 = P1C2 = na + a. The geometric factor for the Wenner-Schlumberger method is k = πn (n+1) a, as shown in Figure 2 [29, 30].

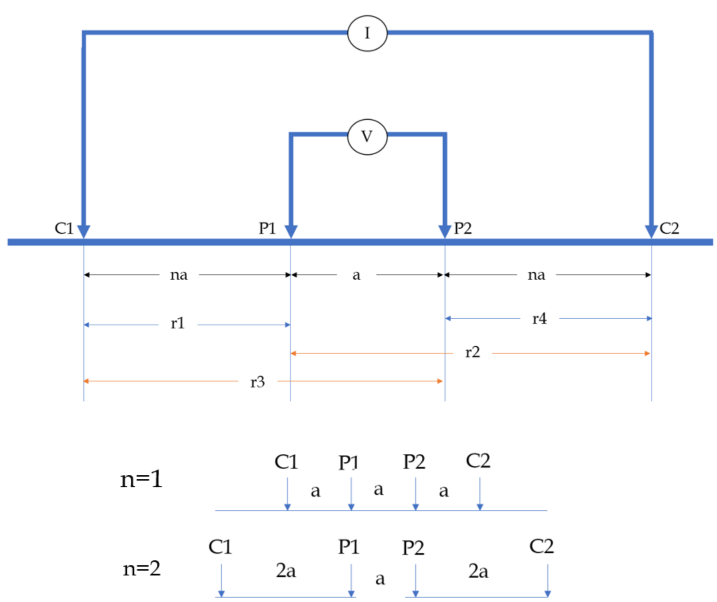

Figure 2. Wenner-Schlumberger configuration [30]

The Wenner-Schlumberger resistivity configuration method is highly suitable for determining subsurface soil structure and layers, as it can monitor subsurface conditions horizontally and vertically. The Wenner-Schlumberger configuration is based on the need to analyze subsurface resistivity changes in the horizontal (lateral) direction, which is commonly known as lateral mapping [6].

Geometric Factor

The geometric factor is one of the crucial components of the resistivity method. This is because the geometric factor can affect measurement results, such as influencing the depth of the measurement, the resolution of rock layer contrast, and allowing for the actual resistivity of the rock to be obtained from the apparent resistivity measurement [5]. The geometric factor is generally symbolized by 'K' with a general equation shown in (3).

$$K = 2\pi\left(\frac{1}{na} - \frac{1}{na+a} - \frac{1}{na+a} + \frac{1}{na}\right)^{-1} \tag{3}$$

The geometric factor depends on the electrode configuration, resulting in different geometric factors for each configuration [30]. The equation used for the Wenner-Schlumberger configuration is shown in (4).

$$K = \pi n(n+1)a \tag{4}$$

Weighted Overlay

The Weighted Overlay method is a spatial analysis technique that uses overlay techniques on maps representing factors influencing vulnerability assessment. The tool used in this analysis is a Geographic Information System (GIS). The function of the Weighted Overlay method is to solve multi-variable problems such as suitability modeling or optimal location selection. The Weighted Overlay method is one of the features available in ArcGIS software, which combines various input data from AHP experts in grid maps with weighted factors [12].
The Weighted Overlay method uses raster data, consisting of pixels, to score and weigh each pixel with its respective value. It overlays multiple raster data layers using a standard measurement scale, and weight values are adjusted according to the needs. In its application, the Weighted Overlay method requires all raster data to be in integer form [4].
Raster data in floating-point format must first be converted into integer format before being used in the Weighted Overlay method. The classes of values in the input raster data are then assigned new values based on the evaluation scale used. Each raster layer that has been input is then weighted or represented according to the required percentage, with the total percentage of the weight's influence adding up to 100%. Changes in the influence percentage or evaluation scale can alter the results of the Weighted Overlay analysis [12].

The research was conducted at Sungaimas Subdistrict, Meulaboh, West Aceh Regency. This research was conducted in three stages: preliminary, data collection, and data processing. The research process is outlined in a flowchart, as shown in Figure 5.
The preliminary stage involves preparation before conducting the research. During this stage, a literature review, such as collecting references from books and papers with specific topics, is performed to identify the factors that cause landslides, compare the analysis methods previously used by researchers, select the most suitable method, and find research gaps in prior studies.

The literature review on landslide potential analysis is done by collecting references from scientific journals [1,4,6,7]. The topics of the scientific journals used include landslide potential analysis using geophysical methods and geospatial analysis in the form of the Weighted Overlay method, as well as journals on the geology of the research site, Meulaboh, to study its geological conditions. This literature review identifies research gaps in the analysis of landslide potential utilizing two different methods: the resistivity method and geospatial analysis.

Resistivity data collection was carried out by gathering raw data previously acquired in the field by the lecturers. This resistivity data serves as secondary data to support geospatial analysis data, which is the primary data for this study. The resistivity data provides information on the subsurface conditions of landslide-prone areas. This data includes potential (V) and electric current (I) values.

Data collection for geospatial analysis involves gathering shapefile data of parameters affecting landslides. This includes shapefile data on rainfall, slope gradient, soil type, and land cover in Meulaboh, West Aceh Regency, Nanggroe Aceh Darussalam Province. This data is used to create a landslide susceptibility map. The geospatial analysis data is obtained from the Indonesian Geospatial website.

The resistivity data processing stage includes determining the geometric factor (K) and apparent resistivity (ρ_a). The data obtained from the field must be processed using Microsoft Excel to calculate the values of the geometric factor and apparent resistivity. Data processing in Microsoft Excel involves inputting the field data, analyzing the displayed numbers, and ensuring all data columns are filled. The processed data is transferred to Notepad along with other information such as electrode spacing, configuration type, number of data points, cross-section code, measurement code, topography code, number of electrodes, and elevation. Once the data is formatted as a .txt file, it is input into the Res2Dinv software for inversion to produce a subsurface cross-section image. The data is re-edited if the RMS value is too high.

Table 2. Weighted overlay parameter score [13].

No	Parameter	Class	Score	Weight
1	Raindrops	PGA > 3000	5	
		PGA 2500-3000	4	
		PGA 2000-2500	3	20%
		PGA 1500-2000	2	
		PGA < 1500	1	
2	Type of Rock	Sand, silt, mudstone, fine tuff, marl, clay, mud, organic clay, peat.	3	
		Sandstone, coarse tuff, siltstone, arkose, greywacke, volcanic breccia, agglomerate, sedimentary breccia, conglomerate, shale, tephra.	2	30%
		Andesite, granite, diorite, metamorphic rock, limestone, basalt, quartzite, phyllite.	1	
3	Land Cover	Residence, transmigration, mine, open land.	5	
		Airport, Harbor.	4	
		Plantation, rice field, dry farm, mixed dry farm.	3	20%
		Shrubland, swamp shrubland.	2	
		Dryland forest, planted forest, and savanna.	1	
4	Slope Gradient	> 45 %	5	
		25-45	4	
		15-25	3	30%
		8-15	2	
		<8	1	

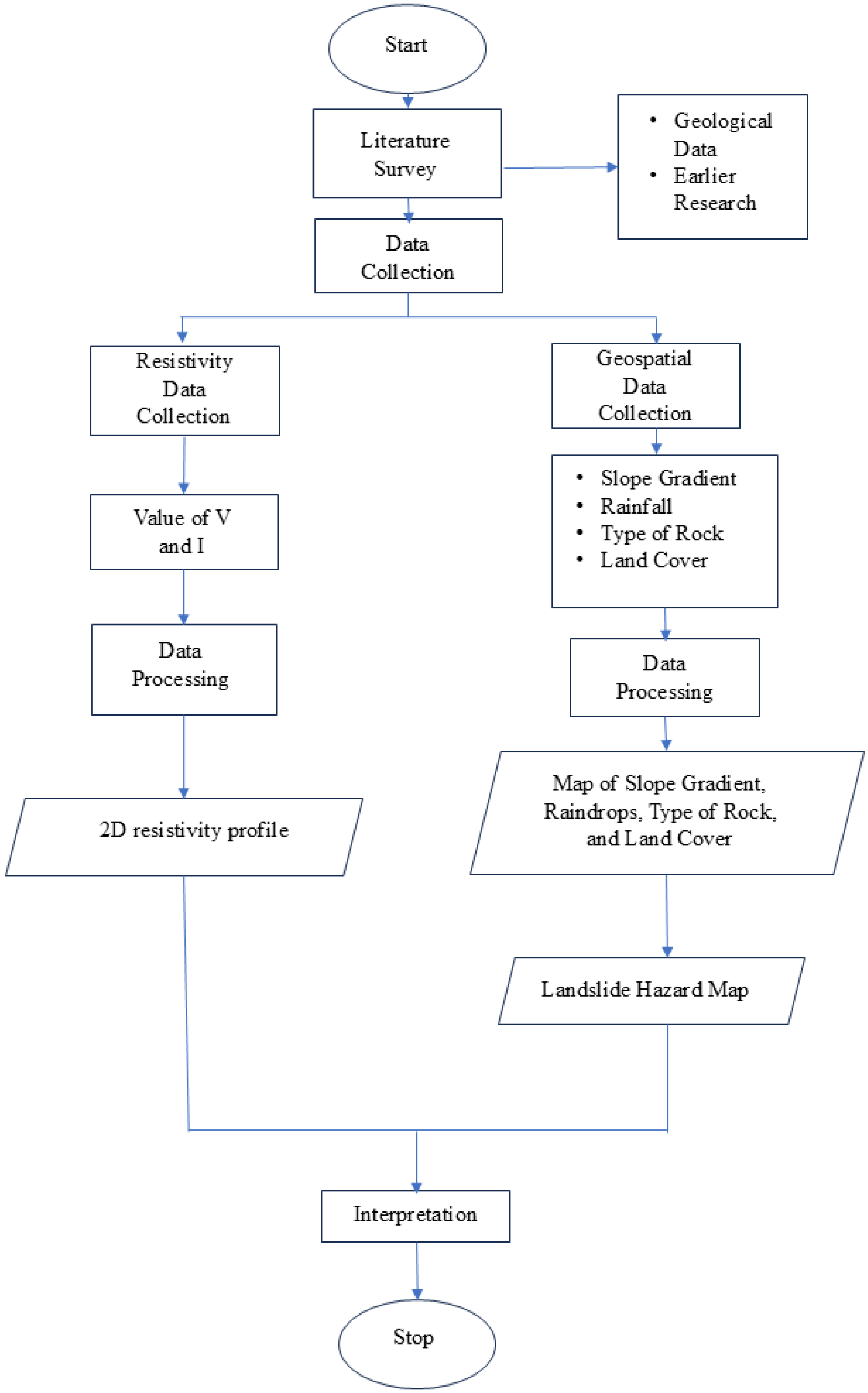

Figure 3. Flowchart.

Result and Discussion

In the two-dimensional modeling using Res2dinv software, resistivity values of subsurface materials are obtained, each indicated by a color on the legend. These resistivity values are used to identify subsurface materials by matching them with the study area's resistivity table and geological conditions.

The shapefile data of landslide parameters and the district are processed using ArcGIS software to create a landslide susceptibility map. This map provides an overview of the distribution of landslide potential and its susceptibility levels.

1. Geoelectrical Method

The cross-sections in Figures 6 and 7 represent the resistivity cross-sections along profiles line 1 and 2 obtained from the resistivity data processing in the Sungaimas Subdistrict, Meulaboh, West Aceh Regency.

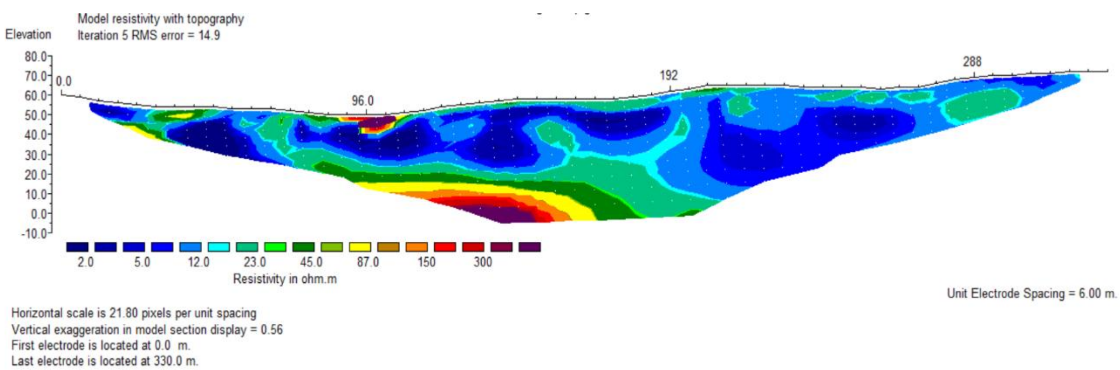

Figure 4. The results of the 2D resistivity modeling for Line 1.

Table 3. Resistivity range and interpretation of lithology of Line 1 in Meulaboh City, West Aceh.

No	Resistivity range (Ω.m)	Depth (m)	Type	Interpretation of lithology
1	1-199	2-59	Low	Silts
2	120-225	2-61	Medium	Sands
3	226-500	3-62	High	Sandstones

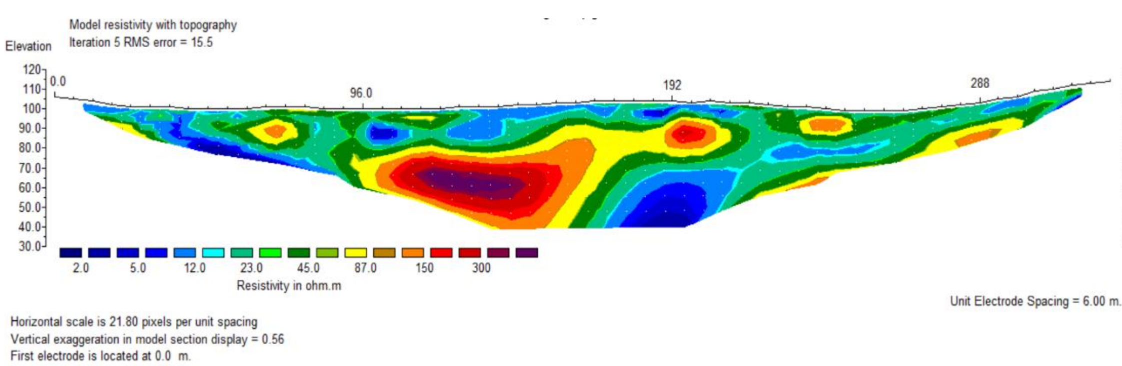

Figure 5. The results of the 2D resistivity modeling for Line 2.

Table 4. Resistivity range and interpretation of lithology of Line 2 in Meulaboh City, West Aceh.

No	Resistivity range (Ω.m)	Depth (m)	Type	Interpretation of lithology
1	1-119	1.5-60	Low	Silts
2	120-225	9-59	Medium	Sands
3	226-500	15-39.4	High	Sandstones

Based on the analysis of the two 2D resistivity cross-sections above, it is evident that the study area has a widespread distribution of silt. The extensive distribution of silt increases the potential for landslides. That is because silt is almost similar to clay, which has a cohesive structure; when this layer becomes saturated with water, its cohesive bonds weaken, making it prone to landslides.

2. **Geospatial methods**

   A. **Slope Gradient Map**

   Slope steepness is one of the factors contributing to landslides. In general, landslides often occur in areas with steep slopes. Therefore, slope steepness is always considered one of the main factors, as the higher the slope steepness, the greater the susceptibility to landslides in that area. The slope map is one of the parameters for landslide occurrences, with an influence of up to 30% [13]. The slope levels in the study area are categorized into five classes based on the Republic of Indonesia Law No. 26 of 2007 concerning spatial planning: flat (0-8%), gentle (8-15%), sloping (15-25%), steep (25-45%), and very steep (>45%). The study location is predominantly characterized by land with a gentle slope to steep (8-45%), as illustrated by the green to orange colors on both profiles.

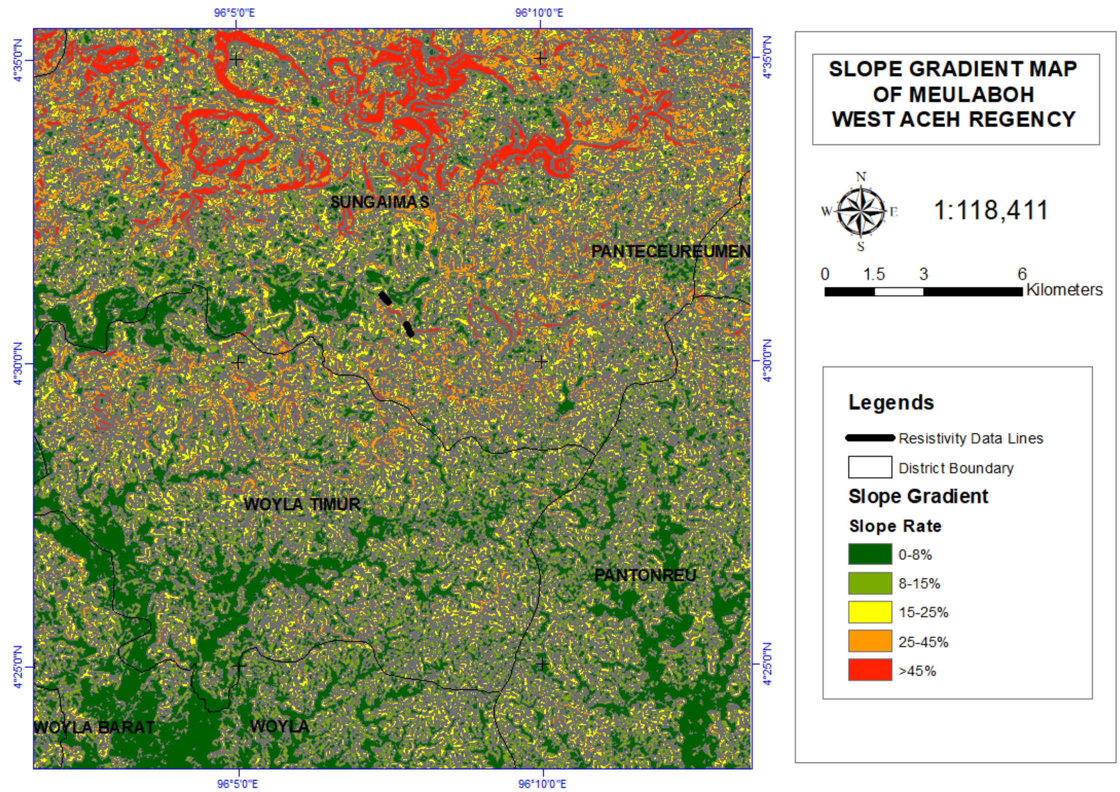

Figure 6. Slope gradient map.

B. Rainfall Map

Rainfall is one of the climatic elements that plays a significant role in landslides. Rain can trigger landslides if its intensity is sufficiently high and lasts for an extended period. The rainfall map is one of the parameters for landslide disasters, with a 20% influence on the vulnerability weighting system [13]. Rainfall data indicates that the rainfall intensity in Sungaimas District, Meulaboh, is 2500-3000 mm/year, which falls under high rainfall. The regional or large-scale nature of the rainfall intensity results in Sungaimas District, Meulaboh, having a single rainfall intensity value that develops in the research area.

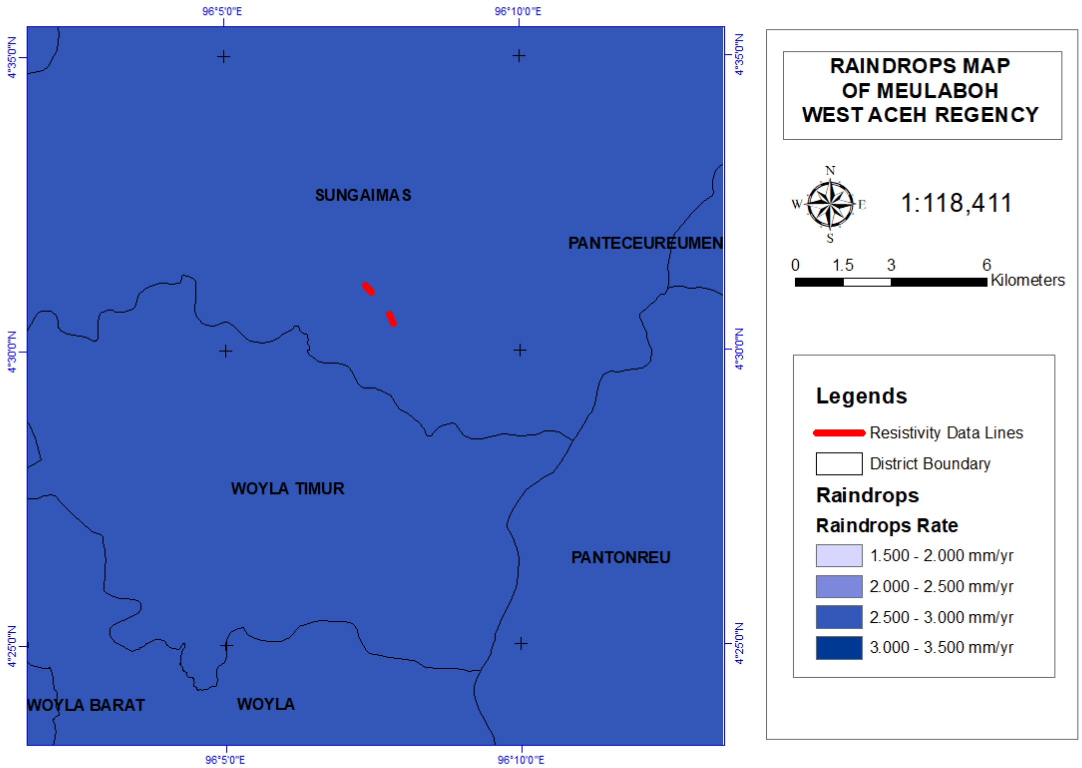

Figure 7. Rainfall map.

C. Rock Type Map

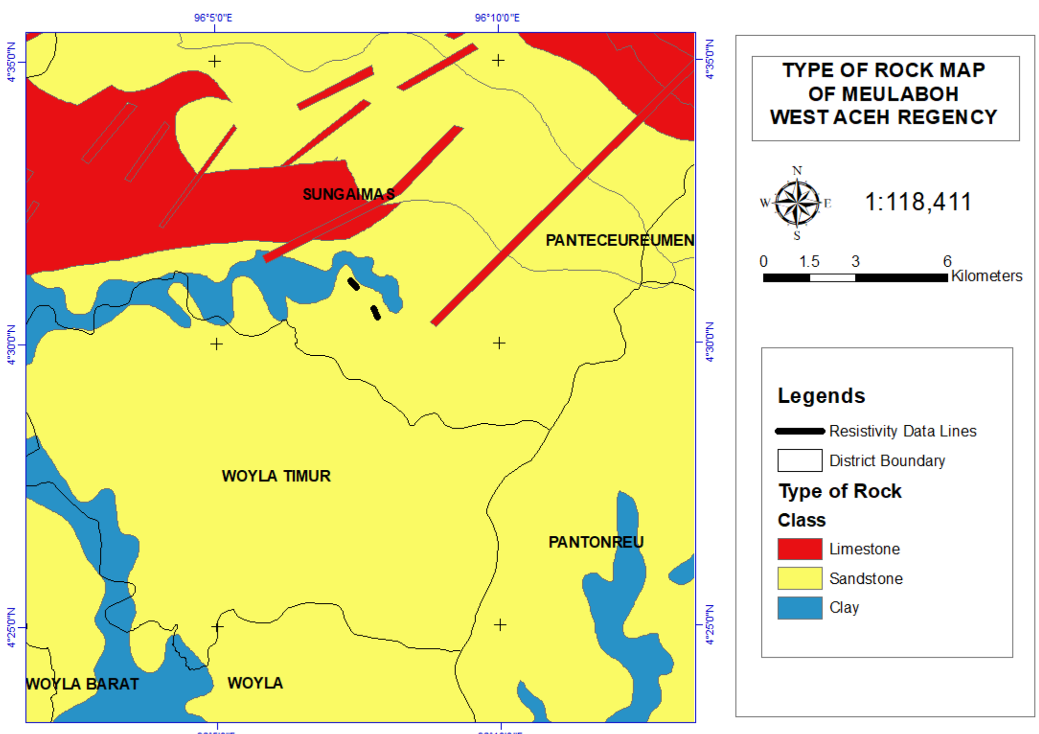

Figure 8. Type of rock map.

Rock type is one of the factors contributing to landslides. This can be studied by examining the distribution of rocks and their characteristics, such as permeability levels, the ability to transmit water infiltration, cohesive and adhesive properties of the stones, and other related factors. The rock type map has a 30% influence on landslide susceptibility [13]. Lithology or rock type data from the Aceh Geological Spatial Data indicates that the Sungaimas District, Meulaboh, has a lithology consisting of rocks from the Tutut Formation, including silt, sand, and a small amount of conglomerate.

D. Land Cover Map

Land cover refers to the characteristics of land use in a particular area. Land cover can contribute to landslides by considering the residence distribution and the vegetation levels present. Land use on the surface significantly impacts the continuity of the hydrological cycle, influencing up to 20% [13]. In the study location, land use is predominantly in plantations and rice fields. Resistivity profiles 1 and 2 are located near agricultural fields.

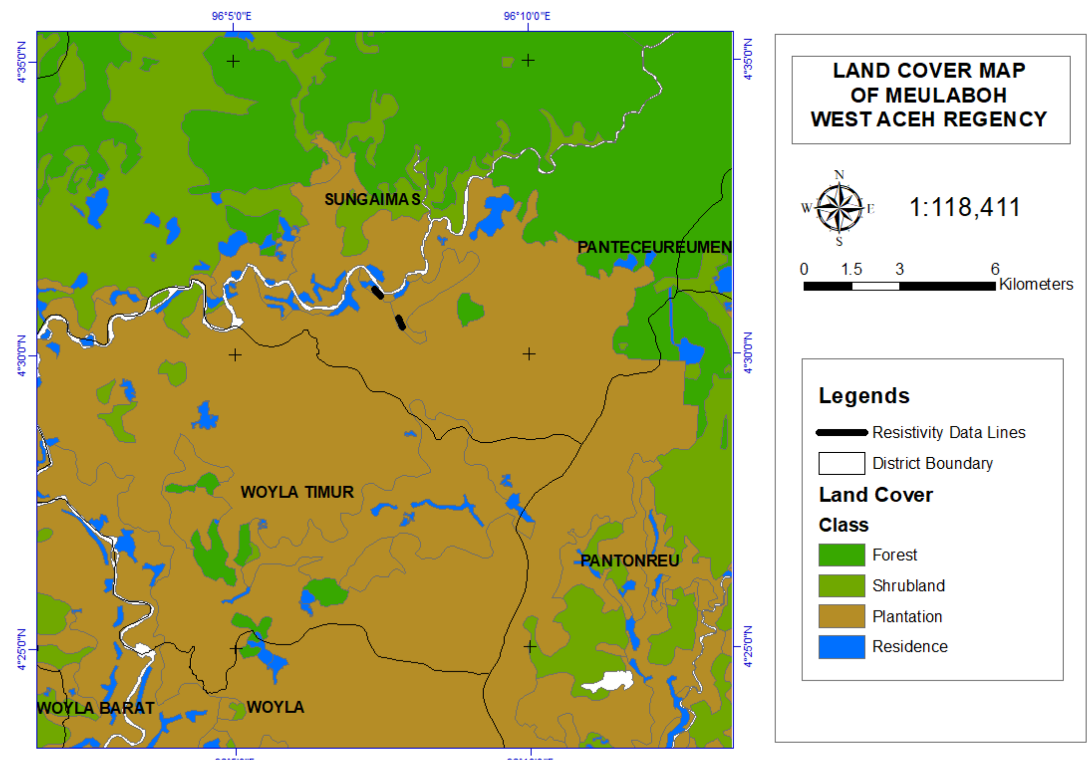

Figure 9. Land cover map.

E. Landslide Hazard Map

Geospatial data analysis identified several conditions that impact landslide potential based on causal parameters. The analysis of land cover data revealed that the study area mainly consists of plantations, rice fields, and settlements in specific locations. This classification indicates that the area has a moderate to high potential level for land use. The lithological analysis revealed that the study area is characterized by silt, sand, and minor conglomerates, as part of the Tutut Formation. This composition contributes to a moderate to high potential level due to these rock types' water-saturated and cohesive nature. Slope gradient analysis indicated that the study area has moderate to high potential levels, with slope gradients ranging from gentle to steep (8%-45%). Finally, rainfall analysis showed that the study area experiences a moderate potential level, with an annual rainfall of 2500-3000 mm/year.

Table 5. Classification of landslide hazard [13]

No	Hazard Rating	Total Score
1	Very low	< 1.1
2	Low	1.2 – 2.6
3	Moderate	2.7 – 3.6
4	High	3.7 – 4.1
5	Very high	≥ 4.1

The data were analyzed using the weighted overlay method, which considered the influence of various parameters. The slope gradient was assigned a weight of 30%, rainfall 20%, rock type 30%, and land cover 20%. The analysis revealed that the study area has a moderate landslide potential. This moderate potential is primarily observed in most areas of the Sungaimas and the East Woyla sub-districts of Meulaboh City.

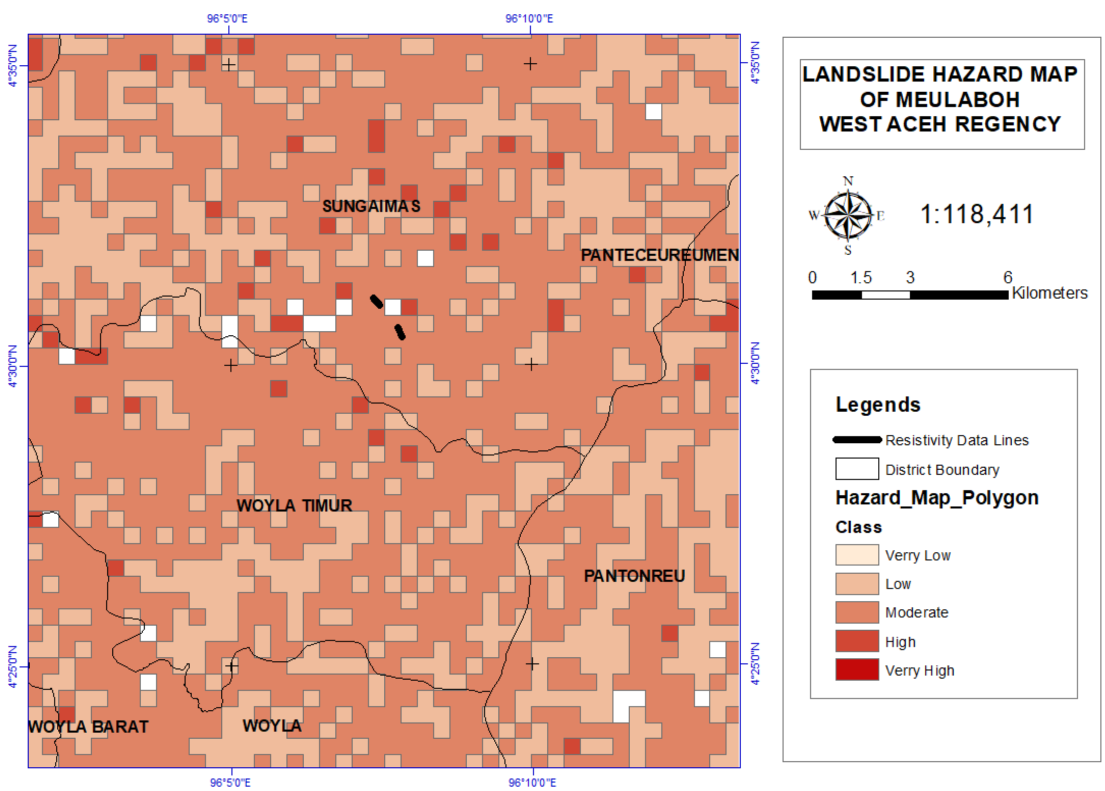

Figure 10. Landslide hazard map.

Conclusion

The study area is believed to consist of silt, sand, and sandstone. Based on the analysis of the two 2D resistivity sections, the study area has a widespread distribution of silt. The extensive distribution of silt increases the potential for landslides. That is because silt has a cohesive structure, and when this layer becomes saturated with water, the cohesive bonds weaken, making the layer prone to landslides. Based on the result of weighted overlay analysis, the study area has a moderate potential for landslides. The study area has a characteristic like a gentle to steep slope (8-45%), a high rainfall rate (2500-3000 mm/yr), a lithology consisting of rocks from the Tutut Formation, including silt, sand, and a small amount of conglomerate, and a land that used for plantations and rice fields. The moderate potential level primarily exists in most Sungaimas and East Woyla sub-districts, Meulaboh City. This research provides benefits to the government. It contributes to improved disaster mitigation planning, reduced risk of losses, and the selection of appropriate materials to construct more disaster-resilient infrastructure.

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References

[1] S. G. Fatmawati, and Afdal, "Investigasi Bidang Gelincir Tanah Longsor Menggunakan Metode Geolistrik Tahanan Jenis 2 Dimensi Konfigurasi Wenner (Studi Kasus: Padayo Bukit Atas Indarung Kecamatan Lubuk Kilangan Kota Padang)," *Jurnal Fisika Unand*, vol. 11 no. 4, 487–493, 2022.

[2] Musliyadi, "Hujan Berkepanjangan Sebabkan Bencana Banjir Di Kota Meulaboh, Aceh Barat," *Serambi Konstruktis,* vol. 1 no. 4, pp. 51-54, 2019.

[3] Y. D. F. Hawari, R. Andriansyah, and F. Agustin, "Pemodelan Endapan dan Estimasi Sumber Daya Batubara PT XYZ di Daerah Meulaboh Kabupaten Aceh Barat," *Institut Teknologi Sains Bandung*, 2020.

[4] B. N. L. Azis, K. A. Wikranta, N. S. Anifah, W. Q. Syamsiyah, and D. Wahyuzar, "Integrasi Metode Resistivitas, Seismik Refraksi, Geologi Berbasis Geospasial untuk Identifikasi Potensi Longsor di Srimartani, Yogyakarta," *Indonesian Journal of Earth Sciences*, vol. 1 no. 2, pp. 109–122, 2021.

[5] R. Perdhana, Nurhasanah, and R. Adriat, "Identification of Landslide-Prone Areas in Sanggau Regency, West Kalimantan using GIS and Resistivity Method," *Jurnal Fisika Flux: Jurnal Ilmiah Fisika FMIPA Universitas Lambung Mangkurat*, vol. 20, no. 1, pp. 1-11, 2023.

[6] Irmayanti, M. L. Said, and A. Wahyuni, "Aplikasi Sistem Informasi Geografi (SIG) dan Metode Geolistrik Dalam Pembuatan Peta Rawan Longsor di Kecamatan Alla Kabupaten Enkerang," *Jurnal Fisika dan Terapannya*, vol. 7 no. 2, pp. 166–174, 2020.

[7] M. S. S. Ahmad, Sahara, and A. Wahyuni, "Identifikasi Potensi Longsor Dengan Metode Geolistrik di Desa Onang Utara Kecamatan Tubo Sendana Kabupaten Majene," *Teknosains: Media Informasi Sains dan Teknologi*, vol. 16 no. 2, pp. 179-190, 2022.

[8] S. Kamur, S. Awal, and A. Iskandar, "Identifikasi Bidang Gelincir Zona Rawan Longsor Menggunakan Metode Geolistrik di Ruas Jalan Toraja-Masama. *Majalah Geografi Indonesia*,"vol. 34 no. 2, pp. 101-107, 2020.

[9] W. M. Telford, L. P. Geralt, and R. E Sherrif, "Applied Geophysics Second Edition," Cambridge University Press, 1990.

[10] A. Chaniago, and Afdal, "Identifikasi Bidang Gelincir Pemicu Longsor dengan Metode Geolistrik Resistivitas 2 Dimensi Daerah Wisata Bukit Chinangkiek, Kabupaten Solok, Sumatera Barat," *Jurnal Fisika Unand*, vol. 11 no. 2, pp. 160–165, 2022.

[11] A. Mohamad, "Development of a geophysical and geochemical methodology for the characterization of hydrocarbon contamination of soil and groundwater," Ph.D. dissertation, Dept. Science, Roen Univ., France, 2017.

[12] N. F. Yasien, F. Yustika, I. Permatasari, and M. Sari, "Aplikasi Geospasial Untuk Analisis Potensi Bahaya Longsor Menggunakan Metode Weighted Overlay (Studi Kasus Kabupaten Kudus, Jawa Tengah)," *Jurnal Geosains Dan Remote Sensing*, vol. 2 no. 1, pp. 33–40, 2021.

[13] I. Pratiwi, M. A. Itto, M. A. R. Harahap, F. Steven, "Pemetaan Rawan Longsor Daerah Palu Dengan Metode Weighted Overlay,"*Jurnal Geosains dan Remote Sensing (JRGS),* vol. 2 no. 2, pp. 74-81, 2021.

[14] R. R. Pambudi, M. Nurul, W. P. Prihadita, and R. Mulyasari, "Analisis Kelongsoran Dengan Metode Geolistrik Konfigurasi Wenner-Schlumberger Dan Wenner-Alpha Di Jalan Raya Suban Bandar Lampung," *Jurnal Geocelebes,* vol. 6 no. 2, pp. 108-116, 2022.

[15] P. B. Utama, "Mapping of Landslide Areas Using Geographic Information System In Kebonharjo Proge Regency," *Journal of Information and Telecommunication Engineering,* vol. 5, no. 2, pp. 395-404, 2022.

[16] L. Y. Irawan, A. Yulyanto, A. T. S. Zaini, A. Ma'ruf, E. N. Sa'idah, and F. M. Setiawan, "Identifikasi Bahaya Longsor Lahan Di Sebagian Wilayah Poncokusumo Dan Wajak Kabupaten Malang," *Geodika,* vol. 4 no. 2, pp. 160-171, 2020.

[17] R. Atfar, S. Azzahra, S. Sari, Annur, N. Fitriani, and A. Nurfalaq, "Pemanfaatan Citra Satelit dan Data Geolistrik untuk Zonasi Daerah Rawan Longsor di Kecamatan Walenrang Barat Kabupaten Luwu," *Jurnal Fisika dan Terapannya,* vol. 11 no. 1, pp. 78-90, 2024.

[18] R. Rubarkah, Muhardi, and R. Perdhana, "Pemetaan Daerah Rawan Longsor di Kabupaten Sanggau Provinsi Kalimantan Barat," *Geo-Image Journal,* vol. 13 no. 2, pp. 73-81, 2023.

[19] J. A. Susetyo, S. Bachri, Sumarni, and T. Mutia, "Pemetaan Kerawanan Tanah Longsor Dengan Metode Weighted Overlay Di Kabupaten Jember," *Geography: Journal of Educational Studies, Research and Development,* vol. 12 no. 2, pp. 695-705, 2024.

[20] D. I. Wambrauw, R. Mirino, and K. E. Pamuji, "Analisis Bidang Gelincir Tanah Longsor Menggunakan Metode Geolistrik Tahanan Jenis di Kampung Sowi Distrik Manokwari Selatan Kabupaten Manokwari," *Prosiding Seminar Nasional MIPA UNIPA IV,* 2019.

[21] R. Amukti, C. Damayanti, A. K. Yamko, and J. D. Lekalette, "Aplikasi Metode Geolistrik Konfigurasi Dipole-Dipole untuk Identifikasi Daerah Rawan Longsor (Studi Kasus di Desa Poka, Ambon)," *Teknik,* vol. 42 no. 1, pp. 79-86, 2021.

[22] D. Chandrasasi, R. Asmaranto, and N. M. C. Partarini, "Penerapan Metode Geolistrik Konfigurasi Wenner-Schlumberger Untuk Analisis Rembesan Pada Maindam Waduk Greneng, Kabupaten Blora," *Jurnal Teknik Pengairan,* vol. 9 no. 2, pp. 114-124, 2018.

[23] M. Adrian, M. L. Said, and Fitriyanti, "Identifikasi Zona Rawan Longsor Menggunakan Metode Geolistrik Resistivitas Di Desa Pao Kecamatan Tombolo Pao Kabupaten Gowa," *Jurnal Fisika dan Terapannya,* vol. 9 no. 2, pp. 148-159, 2022.

[24] F. M. Putra, M. Rusdi, and H. Basri, "Penentuan Tingkat Kerawanan Longsor Menggunakan Sistem Informasi Geografis Berdasarkan Parameter Curah Hujan," *Jurnal Ilmiah Mahasiswa Pertanian Unsyiah,* vol. 4 no. 1, pp. 708-713, 2019.

[25] I. Prabowo, Jamaluddin, and F. A. Pratikno, "Integrasi Data Geomorfologi dan Data Geospasial Untuk Pemetaan Kawasan Rawan Pergerakan Tanah Wilayah Kecamatan Balikpapan Utara," *Jurnal Ilmiah Geologi Pangea,* vol. 10 no. 1, pp. 46-54, 2023.

[26] J. Pangaribuan, L. M. Sabri, and F. J. Amarrohman, "Analisis Daerah Rawan Bencana Tanah Longsor di Kabupaten Magelang Menggunakan Sistem Informasi Geografis Dengan Metode Standar Nasional Indonesia Dan Analythical Hierarcy Process," *Jurnal Geodesi Undip,* vol. 8 no. 1, pp. 288-297, 2019.

[27] R. C. Wibowo, I. Maulia, N. Haerudin, and M. Sarkowi, "Sliding Plane Identification for Landslide Hazard Mitigation with Electrical Resistivity Tomography Method," Indonesian Physical Review, vol. 6, no. 1, pp 1-10, 2023.

[28] M. H. Loke, "2-D and 3-D Electrical Imaging Surveys," www.geotomosoft.com, 2023.

[29] R. C. Wibowo, I. Maulia, N. Haerudin, and M. Sarkowi, "Sliding Plane Identification for Landslide Hazard Mitigation with Electrical Resistivity Tomography Method", Indonesian Physical Review, vol. 6, no. 1, p 1 10, 2023.

[30] W. M. Telford, L. P. Geldart, and R. E. Sheriff, Applied Geophysics: Second Edition. Cambridge University Press, 1990.