IDENTIFICATION OF MASS MOVEMENT VULNERABILITY ZONES USING STORIE METHOD IN BARUNAI AND SURROUNDING AREA, LEBAK DISTRICT, BANTEN PROVINCE

Gita Agnes Meilani Hutauruk[1], Euis Tintin Yuningsih[2] Aton Patonah[3], Kurnia Arfiansyah[4]
[1]Faculty of Geological Engineering Padjadjaran University, Indonesia
Corresponding author: gita20007@mail.unpad.ac.id

ABSTRACT

Natural processes cause mass movements when slope materials, such as soil, rock, and mixed materials, shift from their original position in a vertical, horizontal, or inclined orientation. A number of factors, including the relatively steep slope, the status of the rock or soil forming the slope, heavy rainfall, uncontrolled human activities that exploit the environment, and the state of the geological structure, contribute to the occurrence of ground movements. The research is located in Cihara District, Lebak Regency, Banten Province, precisely in the Barunai area. Due to its proximity to fault lines and subduction zones, the study area is prone to mass movements, especially during wet season. The purpose of this study is to determine the areas that are most susceptible to mass movements. By determining the parameters that are thought to affect mass movements, the Storie method is one of the techniques used to determine the areas that are vulnerable to mass movements. Land use considerations, soil type, rainfall, slope, lithology, and geological structure are among the criteria. The study site's ground motion susceptibility is divided into two categories based on the analysis's findings: high, which can reach 34,1%, and moderate, which can reach 65,9%, across the entire study area.

Keyword: Mass Movement Vulnerability, Storie Analysis, Score, Barunai

INTRODUCTION

According to Varnes (1978), Mass movement is the term used to describe the shifting of slope materials in a vertical, horizontal, or inclined direction from their initial location. Examples of these materials include rock, soil, and mixed materials. Indonesia is a country that often faces hydrometeorological disasters, including landslides, which result from climate and weather changes. Based on monitoring by the National Disaster Management Agency, from the beginning of 2024 until June 12th, there have been 75 recorded landslide incidents in Indonesia (BNPB, 2024). Mass movement is an unpredictable natural calamity that can happen at any time. Losses may involve property loss, harm to infrastructure and facilities, and even endangerment of human life.

The Barunai region is situated in the Banten Province's Lebak Regency's Cihara District. Geographically, the research area includes 25 km² and is situated between 106 ° 6 ' 57,202 '' and 106 ° 9 ' 40,799 '' E and 6 ° 48 ' 38,357 '' and 6 ° 51 ' 19,01 '' S. Administratively, this area is a part of Mekarsari Village and Barunai Village. Barunai Village's proximity to a fault zone, subduction zone, and steep slopes may cause mass displacement, particularly during the wet season. Barunai Village and the surrounding areas' mass movement vulnerability zones need to be properly mapped as part of a disaster mitigation plan.

This study aims to identify the areas that are prone to mass movement disaster. Originally developed for agricultural land use assessment, the semi-quantitative Storie approach (Storie, 1978). Nonetheless, this technique was created to evaluate the vulnerability of mass movements (Sitorus, 1995; Arifin et al., 2006). Numerous evaluation characteristics, including as land use, slope, soil type, rainfall, lithology, and the geological structure of the research area, were used to analyze the mass movement susceptibility zones.

Regional geological map of Leuwidamar Sheet showing the research area. (Fig. 1). In particular, the research area includes the Eocene Conglomerate of the Bayah Formation (Teb), the Oligocene Sandstone of the Cijengkol Formation (Toj), the Oligocene Limestone (Tojl), the Oligocene Cikotok Formation (Temv), the Late Oligocene Metamorphic and Cihara Granodiorite (Tomg), the Early Miocene Cimapag Formation (Tmc), and the Dacite (Tmda) (Santosa, S., and Sujatmiko, 1992)

RESEARCH METHOD

There are multiple steps involved in identifying mass movement vulnerability zones: reviewing the literature, gathering data, conducting fieldwork, overlaying and scoring the map, and creating the mass movement vulnerability map (Fig. 2).

E-ISSN : 2579 – 3136

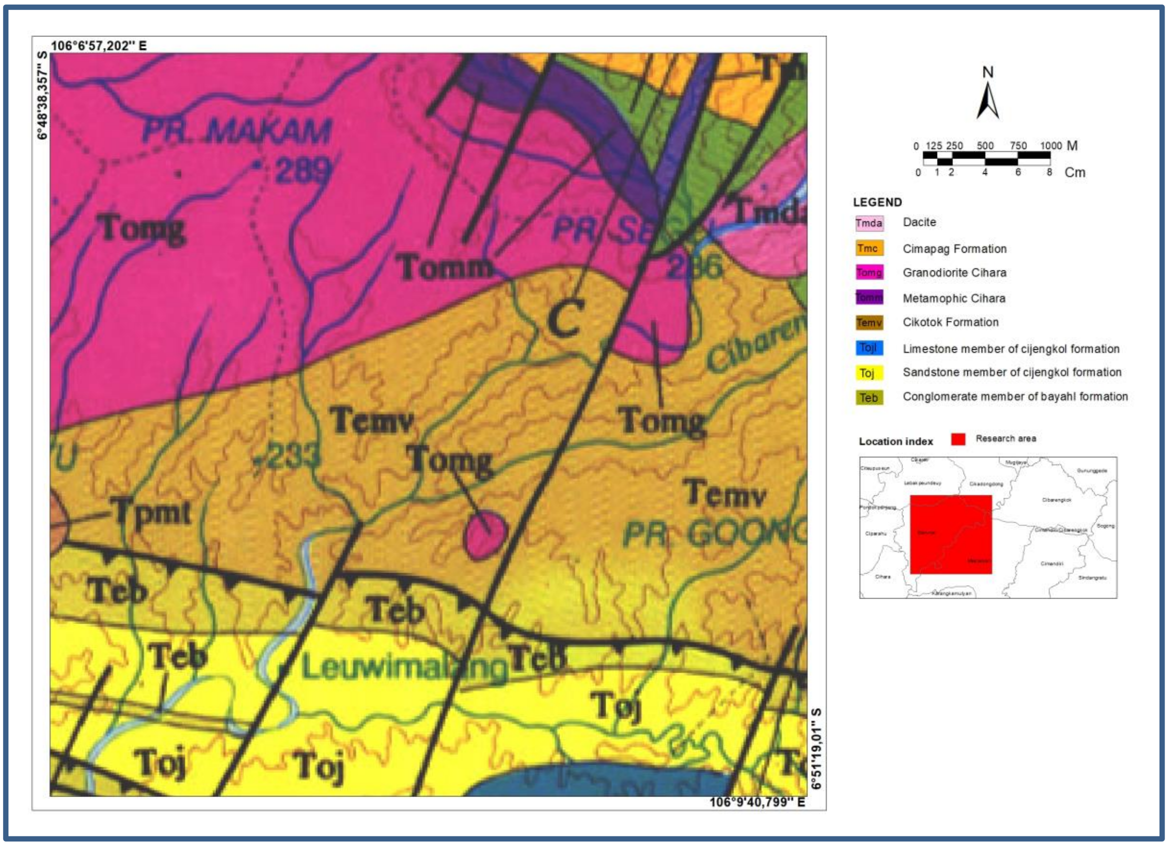

Figure 1. Leuwidamar Sheet Regional Geology Map (Sujatmiko and S. Santosa, 1992)

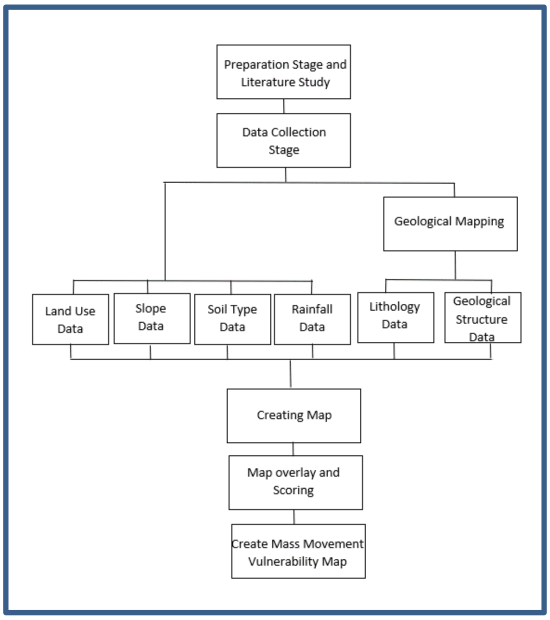

Figure 2. Research Flow Diagram

The Storie Method

Although it was developed for mass movement vulnerability assessment, the Storie index was first applied to agricultural land use assessments (Sitorus, 1995 ; Arifin et al., 2006). When utilizing the Storie index to assess the vulnerability of mass movements, the following revised parameters are applied:

$$L = A \times \frac{B}{10} \times \frac{C}{10} \times \frac{D}{10} \quad \text{.........(1)}$$

Description:

L: Mass Movement Vulnerability

A: Land use

B: Slope

C: Soil type

D: Rainfall

Additional factors, such as lithology and geological structure data, were incorporated into this study to further impact mass movements in the research area. As a result, the following Storie Index formula was applied:

$$L = A \times \frac{B}{10} \times \frac{C}{10} \times \frac{D}{10} \times \frac{E}{10} \times \frac{F}{10} \quad \text{.........(2)}$$

Description:

L: Mass Movement Vulnerability

A: Land use

B: Slope

C: Soil type

E-ISSN : 2579 – 3136

D: Rainfall

E: Lithology

F: Geological Structure

RESULT AND DISCUSSION

The map representing the vulnerability of mass movement in Barunai and its environs is created by superimposing evaluation elements. Calculations are carried out afterwards using the modified storie approach.

Land Use

The land use data used in this study was procured by the Geospatial Information Agency from RBI map of Lebak Regency, Banten Province. According to the land use in research area, classification and score were done based on the rate of erosion (Karnawati, 2003).

Table 1. Land Use Classification

Land Type	Sensitivity Level	Score
Jungle	Not sensitive	1
Shrubs	Less sensitive	2
Plantation	Rather sensitive	3
Settlement	Sensitive	4
Fields	Very sensitive	5

Reference: Karnawati, 2003

Forests, plantations, fields, rice fields, and settlement areas are the land uses in the research area. A total of 4 points are assigned to land used for 4 % residential and 9 % rice fields, 3 points are assigned to 2% plantation land, fields with a 32% area and shrubs 2% area, and 2 points are assigned to forests with a 51% area (Fig. 3).

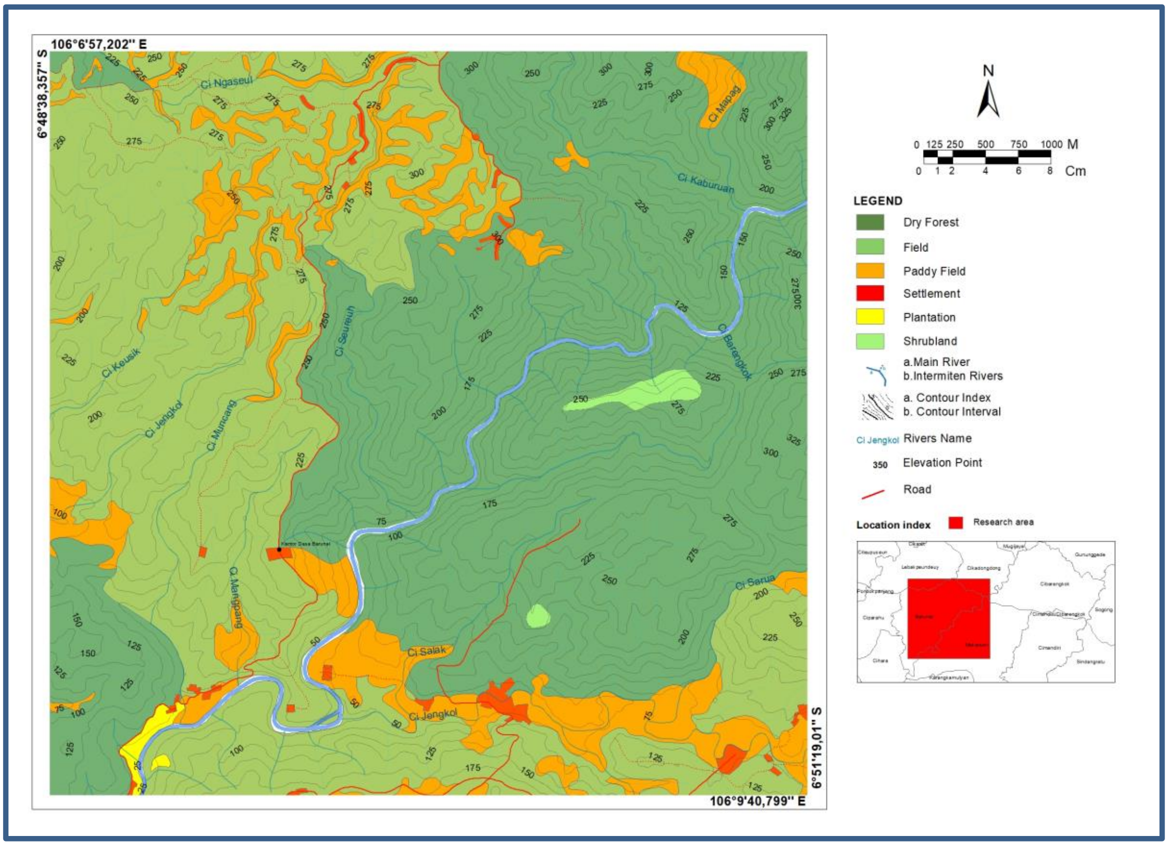

Figure 3. Land Use Map

Slope

The Rupa Bumi Indonesia contour data provided the slope data, which was then utilized to determine the slope using Arcgis 10.8's "slope" feature and group slopes. The proportion of slope is used to classify and determine slope scoring (Van Zuidam, 1983).

E-ISSN : 2579 – 3136

Table 2. Slope classification

Slope (%)	Class	Morphological Unit	Score
0 – 8	Flat	Plain	1
9 -15	Sloping	Smooth relief hills	2
16 - 25	Rather steep	Medium Relief Hills	3
26 – 45	Steep	Rough relief hills	4
>45	Very Steep	Very rough relief hills	5

Reference: Van Zuidam, 1983

Three zones are distinguished by the slope of the research area: very steep, steep, and slightly steep. A high slope of around 37.1% receives a score of 4, an area with a very steep slope of approximately 30.9% receives a score of 5, and a location with a pretty steep slope of approximately 32% receives a score of 3 (Fig. 4).

Soil Type

The Food and Agriculture Organization (FAO) and the United Nations Educational, Scientific, and Cultural Organization (UNESCO) provided the soil types data used in this study. Soil sensitivity to erosion is used to classify and determine the kind of soil (Sobirin, 2013).

Table 3. Soil Type Classification

Soil Type	Sensitivity	Score
Alluvial, Glei	Not sensitive	1
Latosol	Less sensitive	2
Brownforest, Mediteran	Rather sensitive	3
Andosol, Grumosol, Podsol	Sensitive	4
Regosol , Litosol, Organosol	Very sensitive	5

Reference: Sobirin, 2013

According to the FAO/UNESCO soil system, there is just one type of soil in the study region, which is known as orthic acrisols (podsol). A high percentage of clay is a defining feature of this kind of soil. This kind of soil has a score of 4, covering the whole study region (Fig. 5).

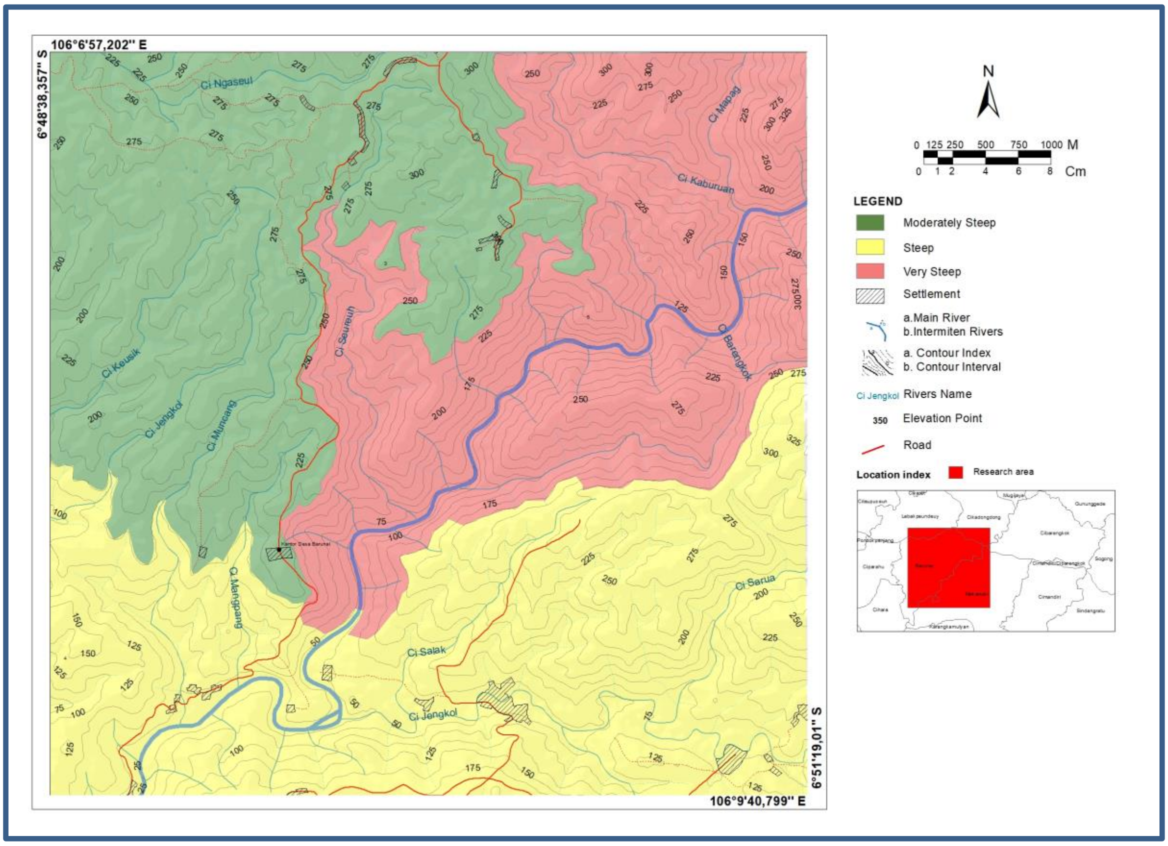

Figure 4. Slope Map

E-ISSN : 2579 – 3136

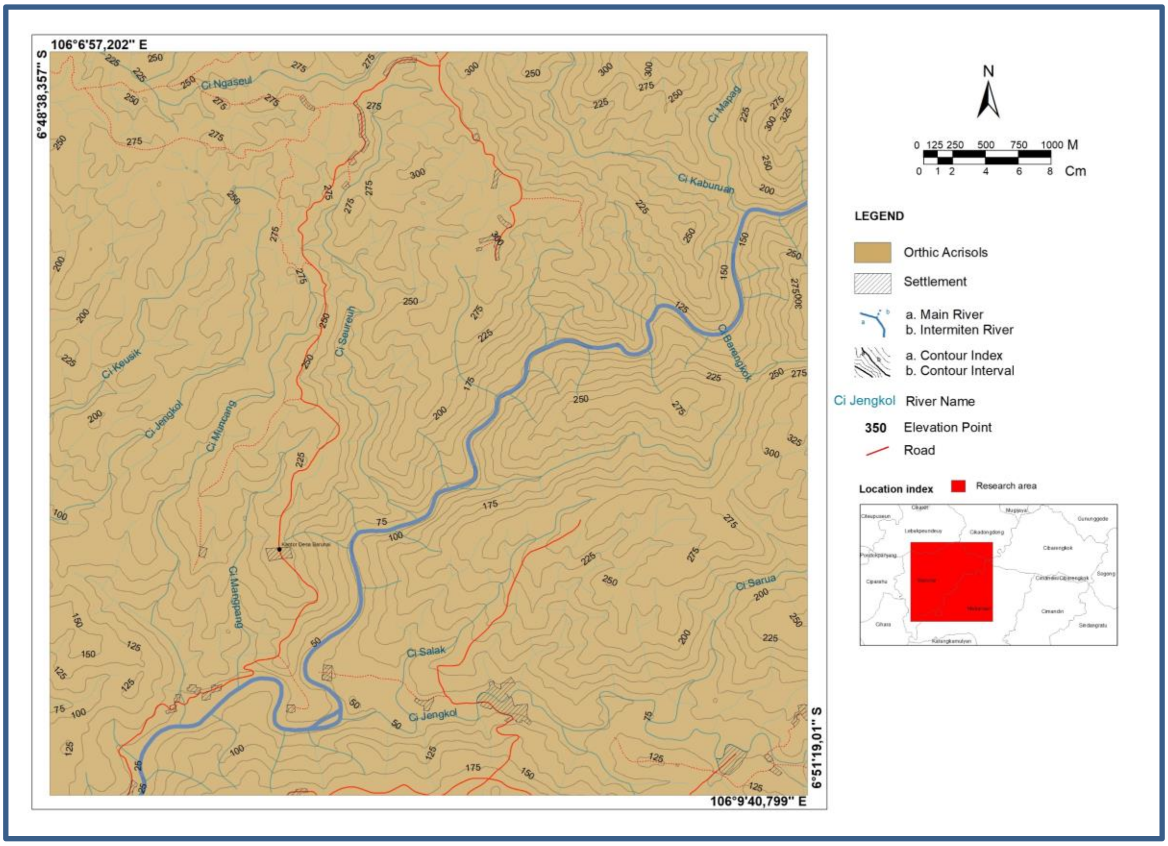

Figure 5. Soil Type Map

Rainfall

The Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS) satellite data for the five years between 2019 and 2024 is the source of the rainfall data for the Barunai surrounding areas. Based on intensity rainfall classification and scoring are determined (Pusat Literatur Tanah, 2004).

Table 4. Rainfall Classification

Intensity (mm/year)	Intensity Level	Score
<2000	Dry	1
2000-2500	Moderate	2
2500 – 3000	Wet	3
>3000	Very Wet	4

Reference: Pusat Literatur Tanah, 2004

There is just one zone that receives more than 3500 mm of precipitation annually. Having a score of 4, this rainfall zoning applies to the whole research area (Fig. 6).

Lithology

Based on the physical attributes and mineral composition of the rock, field mapping of the Barunai environs is the source of the data. The Rupa Bumi Indonesia 2016 was used by Halawa et al., 2023, to score the lithology.

Table 5. Lithology Classification

Lithology	Score
Alluvial Deposits	1
Igneous/Metamorphic Rocks	2
Sedimentary Rocks	3
Volcanic Rock	4

Reference: RBI 2016 in Halawa et al., 2023

Lithology of the study region based on the findings of the geological mapping of the region. Mudstone units, sandstone units, volcanic breccia units, tuff units, granodiorite units, and porphyry dacite units are the different categories of lithology results. About 7% of the study area is covered by the mudstone unit, which has a score of 3, and approximately 17% is covered by the sandstone unit, which has a score of 3, it's consists of sandstone, sandstone interbedded with mudstone, and limestone. With a score of 4, the volcanic breccia unit with volcanic breccia rock makes up about 3% of the research area. Around 24% of the research area is made up of tuff units with tuff, which have a score of 4. Granodiorite units with granodiorite rock have a score of 2 and cover

E-ISSN : 2579 – 3136

41% of the research area. Porphyry Dacite units with porphyry Dacite rock has a score of 2, accounting for 8% of the research area (Fig. 7).

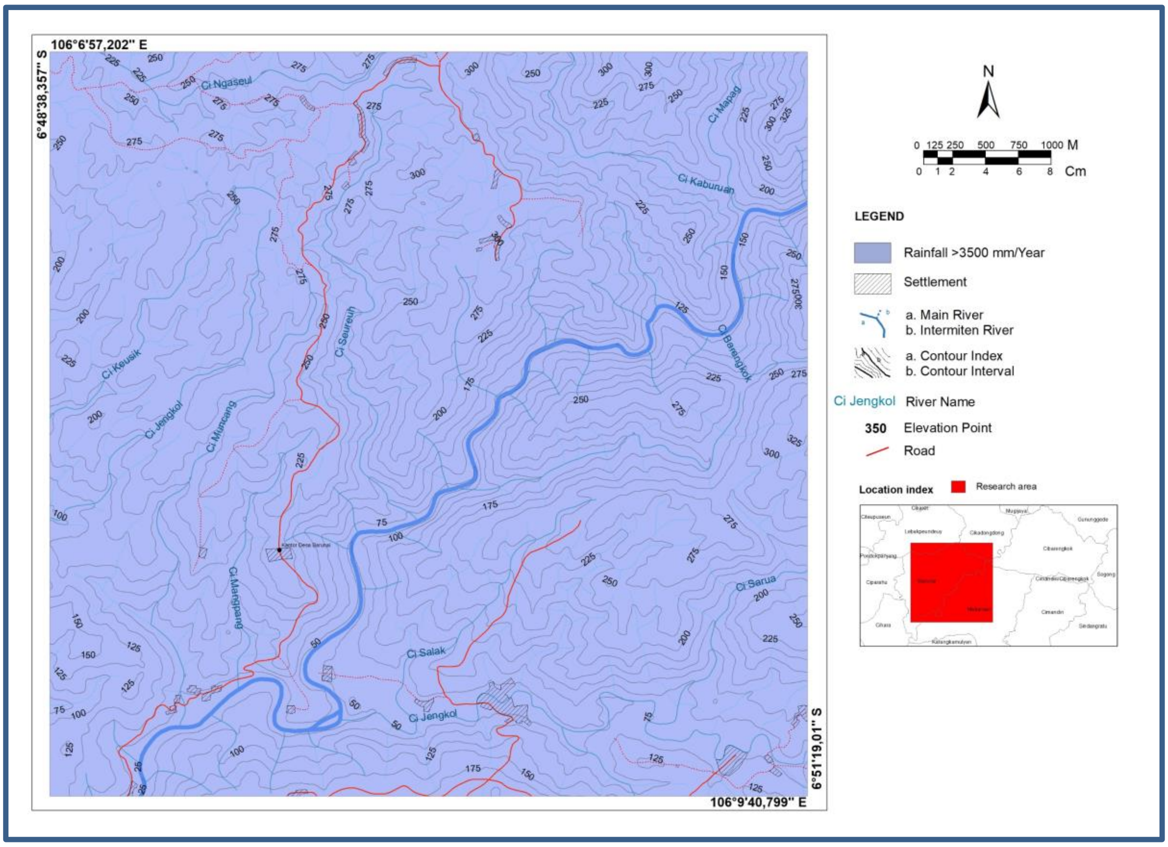

Figure 6. Rainfall Map

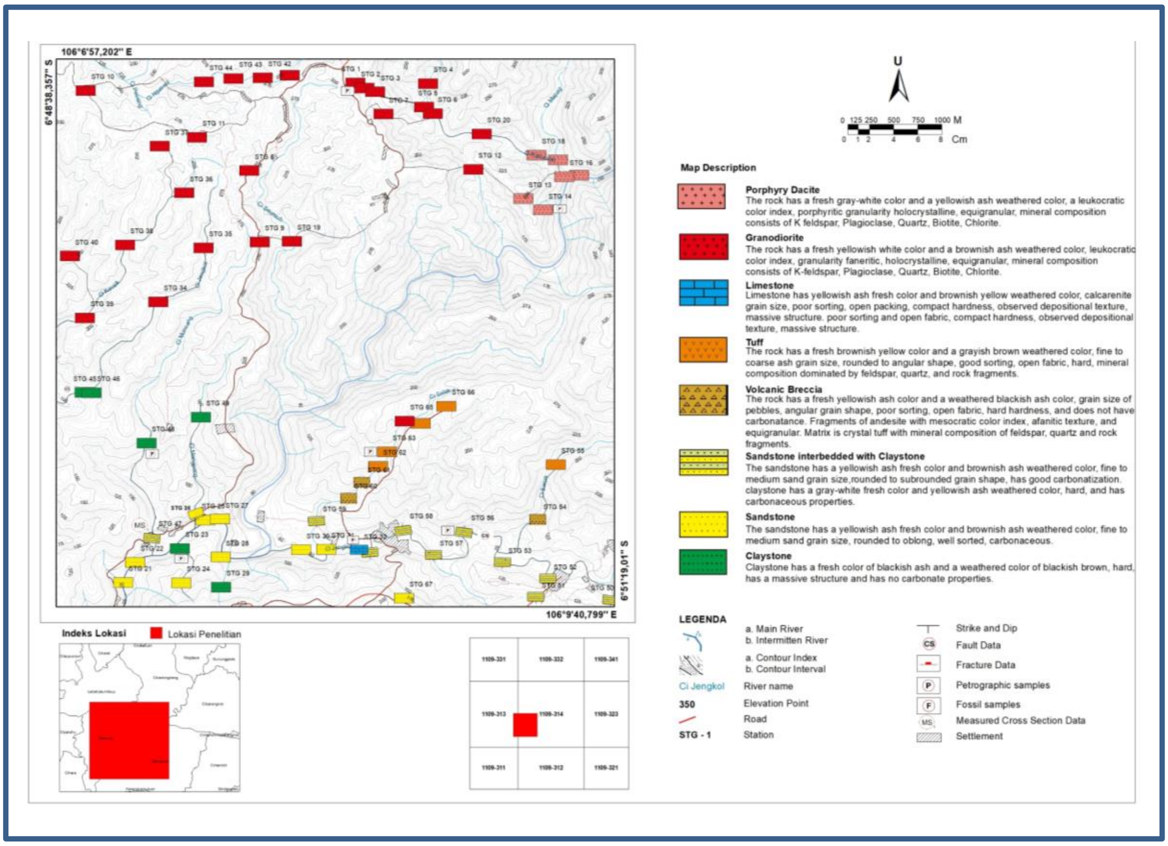

Figure 7. Framework Map

E-ISSN : 2579 – 3136

Geological Structure

Data used are field-mapped geological structure data from the Barunai adjacent areas, based on alignment pattern correlations and fault observations. Classification and score based on Halawa et al., 2023.

Table 6. Geological Structure Classification

Distance from Geological Structures (m)	Score
> 400	1
300 - 400	2
200 - 300	3
100 - 200	4
0 - 100	5

Reference: RBI 2016 in Halawa et al., 2023

Based on the relationship between the strike patterns in the research region and fault data, the geological structure of the area was determined. The research region has anticlines, synclines, thrust faults, and strike-slip faults. The study area is split into five zones: areas that are closest to geological structures (0–100 m) receive a score of 5, areas that are between 100 and 200 m receive score of 4, 200–300 m receive a score of 3, areas that are between 300 and 400 m and distant from geological structures receive a score of 2, and areas that are farther than 400 m from geological structures receive a score of 1 (Fig. 8).

The geological map of the research region, Barunai, and its surroundings that can be made utilizing the information from geological mapping is shown in Figure 9.

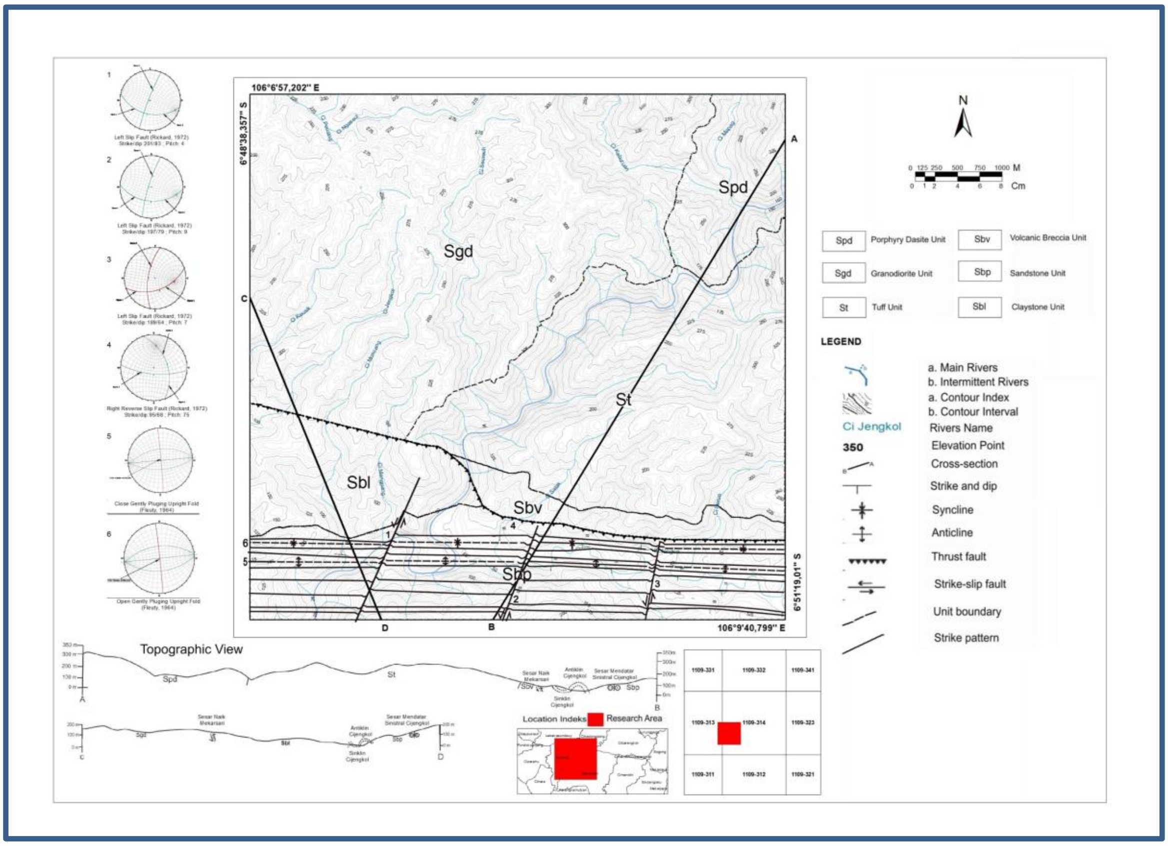

Figure 8. Strike Pattern Map

Vulnerability Level of Mass Movement

By applying the Storie Method to score the preceding factors, a score is generated that can be utilized to assess the vulnerability of mass movement in the following (Table 7):

The research region's mass movement vulnerability level is classified into the following groups (Table 8) based on the results of the storie methods calculations:

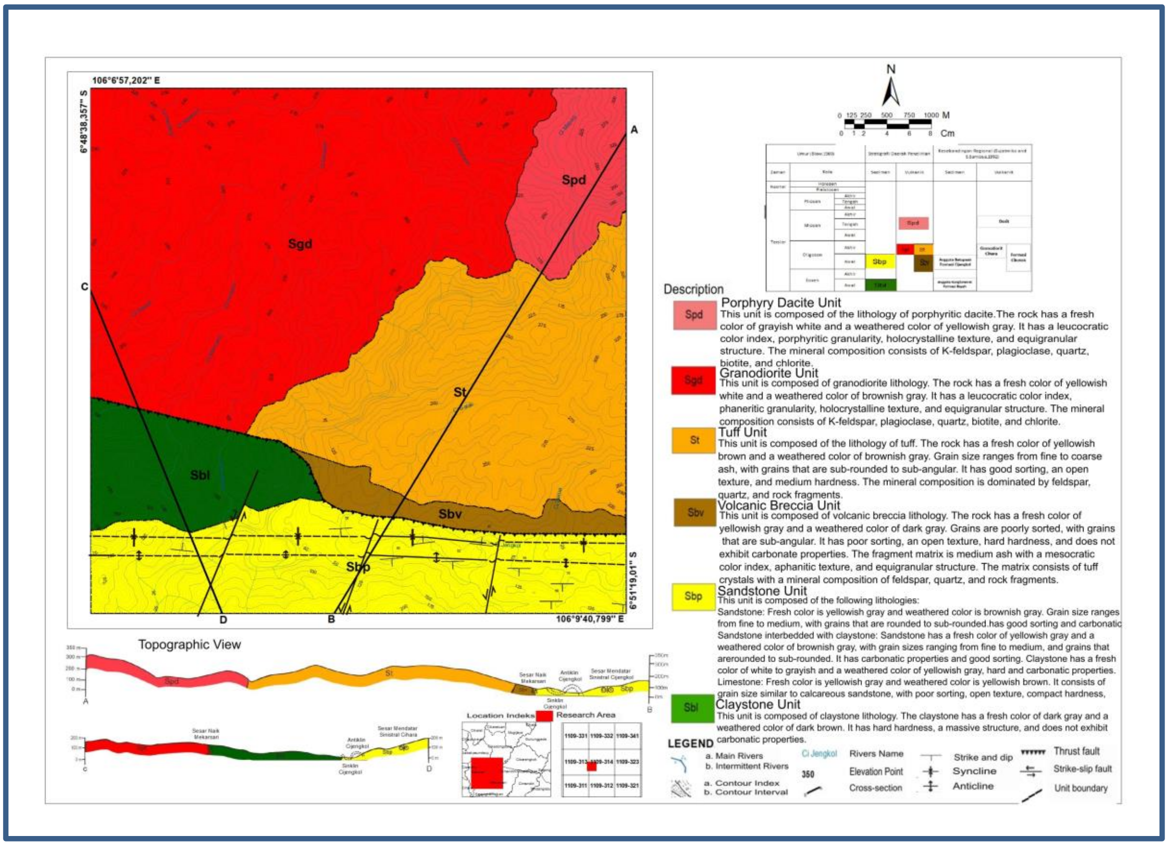

Figure 9. Geological Map

Table 7. Classification of Mass Movement Vulnerability in Research Area Using the Storie Method

Land type	Slope	Soil Type	Rain fall	Litho logy	Geological Structure	Score Analysis	Score Classification	Vulnerability Level
1	1	1	1	1	1	0,00001	<0,00001	Very Low
2	2	2	2	2	2	0,00032	0,00001 – 0,00032	Low
3	3	3	3	3	3	0,00729	0,00032 – 0,00729	Moderate
4	4	4	4	4	4	0,04096	0,00729 – 0,04096	High
5	5	5	5	5	5	0,15625	>0,0496	Very High

Table 8. The research area's vulnerability to mass movements using the Storie Method

Land type	Slope	Soil Type	Rain fall	Litho logy	Geological Structure	Score Analysis	Vulnerability Level
4	4	4	4	3	4	0,03072	High
3	4	4	4	3	4	0,02304	High
2	4	4	4	4	3	0,01536	High
2	5	4	4	4	1	0,0064	Moderate
2	5	4	4	2	1	0,0032	Moderate
3	3	4	4	2	1	0,00288	Moderate

High and moderate are the two levels of mass movement vulnerability that can be identified within the research area based on score calculations made using the storie method. Around 34,1% of the study region is located in the south, where there are high mass movement susceptibility areas, and 65,9% of the study area is located in the north, where

E-ISSN : 2579 – 3136

there are moderate mass movement vulnerability areas. Slopes that are steep, inhabited, composed of volcanic and sedimentary rock, and situated between 0 and 200 meters from geological formations are all considered high mass movement susceptibility zones. Zones with igneous rock that are fields or forests and are more than 400 meters away from geological structures are considered vulnerable to moderate mass movement. Planning for disaster mitigation is necessary, especially in places where there is a high level of mass movement susceptibility, as the southern portion of the research area is highly vulnerable to mass migration (Fig. 10).

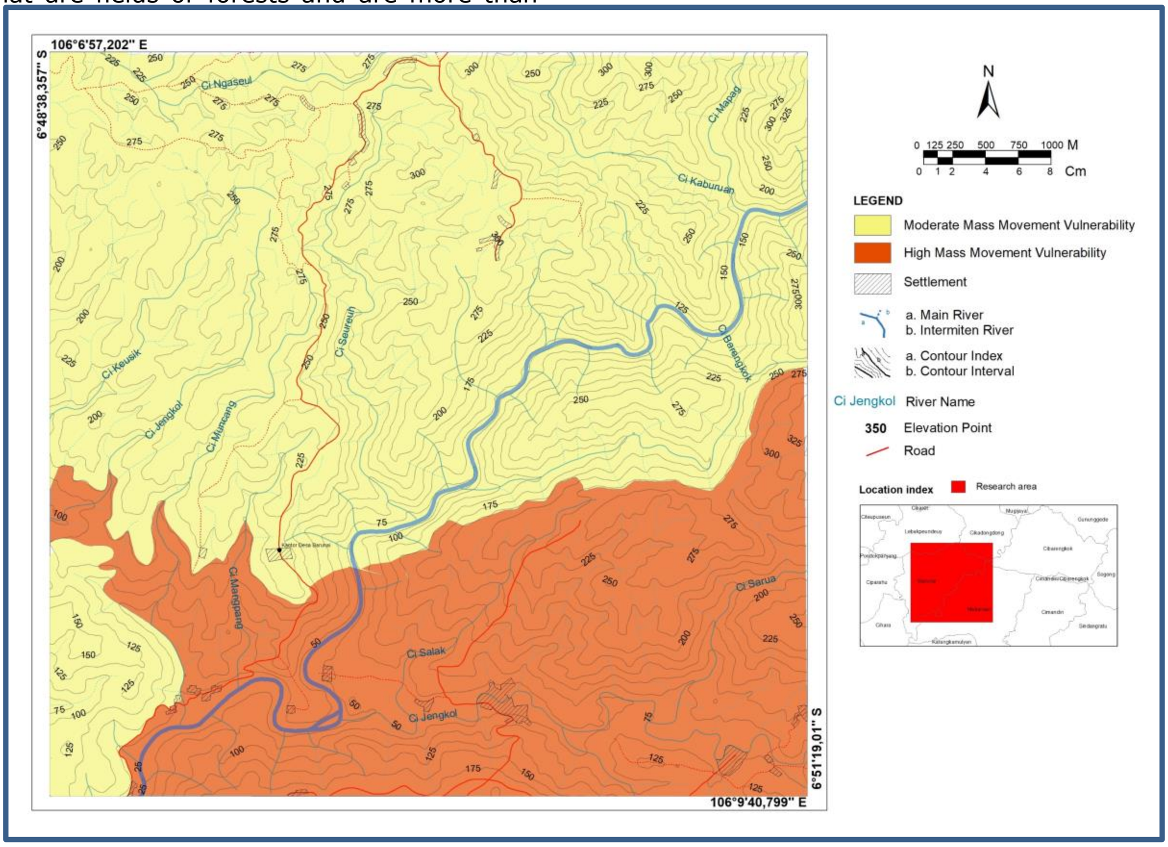

Figure 10. Mass Movement Vulnerability Map

CONCLUSION

High and moderate are the two zones of mass movement vulnerability in the Barunai area and its surroundings. The research region is divided into areas that are very susceptible to mass movement in the south and areas that are moderately susceptible in the north. High mass movement susceptibility is assigned to zones with steep slopes, igneous rock lithology, 0 - 200 m from geological structures, and use as rice fields and towns. On the other hand, igneous rock lithology forests and fields that more than 400 m farther away from geological structures are thought to have a modest vulnerability to mass movement. Of the regions, 65,9% have a moderate level of mass movement vulnerability, while 34,1% have a high level. It is therefore necessary to plan for mitigation mass movement disasters in the research area, particularly in the southern section.

ACKNOWLEDGEMENT

In order to finish this research, the author is grateful to God Almighty for his love and blessings. The author also expresses gratitude to the Padjadjaran University faculty of geological engineering for giving permission to conduct this research, the residents of Barunai village, the author's family for providing moral and material support, and all other people who helped with the research but whose names the author is unable to mention specifically.

REFERENCES

Arifin, S., Carolia, I., Winarso, G. (2006). Implementasi Penginderan Jauh dan SIG untuk Inventarisasi Daerah Rawan Bencana Longsor (Propinsi Lampung). *Jurnal Penginderan Jauh dan Pengolahan Citra Digital*, 3 (1), 7-86.

Badan Informasi Geospasial Republik Indonesia. (n.d.). *Data rupabumi per wilayah digital Lebak, Banten*. Badan Informasi Geospasial Republik

Indonesia. https://tanahair.indonesia.go.id/unduh-rbi/#/

Badan Nasional Penanggulangan Bencana. (2024). Bencana besar tahun 2024. https://gis.bnpb.go.id/arcgis/apps/sites/#/public/pages/bencana-besar-tahun-2024

Climate Hazards Center. (2019–2024). Rainfall estimates from rain gauge and satellite observations. https://data.chc.ucsb.edu/products/CHIRPS-2.0/indonesia_monthly/

Fleuty, M.J. (1964). The Description of Folds. *Proceedings of the Geological Association*, 75(4), 1964.

Food & Agriculture Organization. (2007). *Digital soil map of the world*. https://data.apps.fao.org/map/catalog/srv/eng/catalog.search#/metadata/446ed430-8383-11db-b9b2-000d939bc5d8

Halawa, G. C. M., Botjing, M. U., & Asrafil. (2023). Penentuan Zonasi Tingkat Kerawanan Gerakan Tanah Di Kecamatan Marawola Kabupaten Sigi Sulawesi Tengah. *Bomba: Jurnal Pembangunan Daerah* 1(1),25–34.

Karnawati, D. (2003). *Bencana Alam Gerakan Massa Tanah di Indonesia dan Upaya Penanggulangannya.* Jurusan Teknik Geologi, Universitas Gajah Mada, Yogyakarta.

O'Green, A. T., and S.B. Southard. (2005). A Revised Storie Index Modeled in NASIS. *Soil Survey Horizons* 46 (3), 98-109.

Prastowo, R., Trianda, O., Novitasari, S. (2018). Identifikasi kerentanan gerakan tanah berdasarkan data geologi Daerah Kalirejo, Kecamatan Kokap, Kabupaten Kulonprogo, Yogyakarta. *KURVATEK* 3, 31–40.

Puslit Tanah. (2004). *Klasifikasi Intersitas Curah Hujan*. Puslit Tanah, Bogor

Rickard, M.J. (1972). Fault Classification – Discussion. *Geological Society of America Bulletin*, v. 83, pp. 2545–2546.

Sitorus, S. (1995). *Evaluasi Sumber Daya Lahan*. Tarsito, Bandung

Sobirin, S. (2013). Pengolahan Sumber Daya Air Berbasis Masyarakat. Presentasi disampaikan pada Seminar Reboan Pusat Penelitian Geoteknologi LIPI, Tanggal 8 Mei 2012, Bandung.

Storie, R. (1978). Storie Index Soil Rating. *University of California Division of Agricultural Sciences Special Publication* 3203, Oakland.

Sujatmiko & Santosa, S. (1992). *Geologi Lembar Leuwidamar, skala 1:100.000.* Pusat Penelitian dan Pengembangan Geologi. Bandung

Varnes, D.J. (1978). Slope Movement Types and Processes. Special Report 176; *Landslides; Analysis and Control* (Special Report 176, pp. 11-33). Transport Research Board, National Research Council.

Darmawan, W., Suprayogi, A., & Firdaus, H. S. (2018). Analisis penentuan zona kerentanan gerakan tanah dengan metode Storie (studi kasus Wonogiri). *Jurnal Geodesi Undip,* 7(4), 47-54. https://doi.org/10.14710/jgundip.2018.22407

Zuidam, V. (1983). *Guide to Geomorphology Aerial Photographic Interpretation and Mapping*. Netherlands: International Institue for Aerial Survey and Earth Science (ITC)

E-ISSN : 2579 – 3136