MAPPING OF LANDSLIDE-PRONE AREAS ON ENDE-WOLOWARU ROAD SECTION ENDE REGENCY BASED ON GEOGRAPHIC INFORMATION SYSTEM

Maria Sonya Kae*, Arfita Rahmawati, Bella Theo Tomi Pamungkas
Geography Education Department, Faculty Teacher Training and Education, Nusa Cendana University, Indonesia

*E-mail: mariasonyakae@gmail.com

ARTICLE INFO

Article History
Received : 18/04/23
Revised : 23/05/23
Accepted : 23/01/24

Citation:
Kae, M.S., Rahmawati, A., and Pamungkas, B.T,T., (2024) Mapping Of Landslide-Prone Areas On Ende-Wolowaru Road Section Ende Regency Based On Geographic Information System. GeoEco. Vol. 10, No. 1.

ABSTRACT

Landslides on the Ende - Wolowaru road, Ende Regency often occur every year, especially in the rainy season. Therefore, research was carried out to determine the level of vulnerability to landslides on the Ende - Wolowaru road section, Ende Regency, using an estimation model referring to Puslittanak research in 2004. Mapping of landslide-prone areas was carried out at a radius of 250 meters along the Ende - Wolowaru road section, Ende Regency with area 2,514 ha. The analysis used GIS analysis, such as: scoring and overlay methods based on 2004 Puslittanak Department of Agriculture estimation model. The parameters used are rainfall, rock type, slope, land cover and soil type. The results of the analysis in this study show that the level of vulnerability to landslides at the research location consists of a non-prone class covering an area of 13.38 ha, a vulnerable class covering an area of 1,620.38 ha and a very vulnerable class covering an area of 880.65 ha and (2) the level of validation mapping results that is equal to 88%.

Keywords: *Mapping; Landslide; GIS*

INTRODUCTION

Landslides, also known as ground movements, are natural phenomena that occur due to displacement/movement of rock and soil masses on a slope or ravine that has a certain slope. Based on infographic data from Indonesia's Geoportal Disaster Data, there were 4,467 landslides recorded during 2016 - 2021, with locations spread across Indonesia. Land movement as a hydro-meteorological disaster which ranks third after floods and extreme weather causes damage that is not only direct damage such as damage to public facilities, agricultural land, or human casualties, but also indirect damage that paralyzes development activities and economic activities in the region. disaster and its surroundings (Sukrizal et al., 2019). The landslide is one of the most common natural disasters that occurred along the roads, which caused great economic and human losses (Hang et al., 2021). One area that has a track record of landslides is the Ende - Wolowaru highway in Ende regency.

The Ende - Wolowaru road section itself based on a report from the Center for Volcanology and Geological Hazard Mitigation (Sunimbar & Angin, 2021) states that on March 8, 2015, at 21.00 WITA experienced a landslide or ground movement that occurred at Kilometer 17, Wolotolo Village, Detusoko District, in the form of an avalanche of debris from the cliff slopes on the side of the road which cut off the Ende - Maumere transportation route. It was further explained that the condition of the disaster area based on the Geological Map of Sheet Ende, NTT (P3G) rocks in the disaster area are composed of the Kiro Formation (Tmk) which consists of basaltic – andesitic lava and breccias interspersed with sandy tuff and tuff sand (Sukma, 2015). Besides that, Based on the Forecast Map of Potential Ground Movement Areas in March 2015 in East Nusa Tenggara Province, the ground movement area is located in the medium-high ground movement vulnerability zone, meaning that this zone has the potential for ground movement if rainfall is above normal, especially in areas adjacent to river valleys, gawirs, road cliffs or if slopes are disturbed and old ground movements can be active again.

Apart from the landslide events above, there are several landslides that also hit the Ende - Wolowaru road section which occur almost every year, especially during the rainy season so that they often disrupt the transportation system on that route. Based on these conditions, mitigation efforts are needed to reduce and prevent landslides, namely by knowing the potential and distribution of landslide-prone areas in the Ende - Wolowaru road section by conducting mapping as the first step in disaster mitigation. Identification of landslide susceptibility using a Geographic Information System (GIS) can be made quickly, easily, and accurately (Diara et al., 2022). Through remote sensing data and geographic information systems, landslide hazards will be identified efficiently by using overlays or overlays on landslide triggering parameters to be able to provide spatial information related to landslides. According to (Roccati et al., 2021) landslide susceptibility maps can provide a measure of the potential hazard within an area. However, in several areas, especially mountainous and hilly areas, there are no landslide hazard maps available. In fact, the vulnerability map is necessary to predict landslide susceptible areas on mountainous roads to reduce landslide damage through proper preparation and/or mitigation. Referring to the above description, the researcher is interested in conducting to mapping of landslide prone areas on the Ende - Wolowaru road rection of Ende Regency based on Geographic Information System.

MATERIALS AND METHODS

This research was conducted from September - December 2022 on the Ende - Wolowaru road section which has the status of a national road with the research location being at a radius of 250 meters along the axle of the road which administratively belongs to the East Ende subdistrict, Ende Subdistrict, Detusoko Subdistrict, Lepembusu-Kelisoke Subdistrict, Kelimutu and Wolowaru Subdistrict, with a total research area of 2,514 ha and a road length of 59,249 meters. The equipment used in this study consisted of hardware such as: laptops, cellphones and stationery. While the software used consisted of ArcGIS 10.4, Avenza Maps, Microsoft Excel 2010 and Microsoft Word 2010. The materials used in this study consisted of Sentinel-2B imagery acquired in December 2021, CHIRPS rainfall data for 2021, DEMNAS data of Ende Regency in 2020, digital geological map of Ende sheet Scale 1:250,000, shapefile of Ende Regency soil type map, shapefile of Ende - Wolowaru national road and shapefile of Ende Regency administrative boundary map.

This study began with the collection of secondary data including parameter map data, namely rainfall maps, digital geological maps, slope maps, land cover maps and soil type maps from research locations that were processed using ArcGIS 10.4. Furthermore, mapping the level of landslide vulnerability using scoring and overlapping methods, namely by giving value (scoring) and weight to each parameter that causes landslides referring to the estimation model of the Center for Soil and Agro-climate Research (Puslittanak), Ministry of Agriculture in 2004 (Rahmad et al., 2018) with the following formula:

Cumulative Score = 0.3FCH + 0.2FBD + 0.2FKL + 0.2FPL + 0.1FJ (1)

Information:

FCH = Rainfall Factor

FBD = Rock Type Factor

FKL = Slope Factor

p-ISSN 2460-0768 e-ISSN 2597-6044
https://doi.org/10.20961/ge.v10i1.73223

FPL = Land Cover Factor

FJT = Soil Type Faktor

The weights and scoring in mapping the level of vulnerability to landslides in this study can be seen in **Table 1**

Table 1. Weight and Scoring Vulnerabelity

Weight	Factor	Criteria	Score
30%	Rainfall (mm/year)	Very Low <1000	1
		Low 1,000 – 2,000	2
		Moderate 2,000 – 2,500	3
		High 2500 – 3000	4
		Very High >3,000	5
20%	Slope (%)	>8 (Flat)	1
		8 – 15 (Ramp)	2
		15- 25 (Slightly Steep)	3
		25 – 45 (Steep)	4
		>45 (Very Steep)	5
20%	Rock Type	Alluvial Material	1
		Sediment Material	2
		Volcanic Material	3
20%	Land Cover	Ponds, reservoirs, waters	1
		City/Residential	2
		Forests and plantations	3
		Shrubs	4
		Moor, paddy field	5
20%	Soil Type	Alluvial Gleisol, Planosol, Hydromorph gray, Lateric groundwater	1
		Latosol	2
		Brown Forest Soil, Mediterranean,Cambisol	3
		Andosol, Lateric, Grumosol, Podzolic	4
		Regosol, Litosol, Renzina	5

Source: (Pusat Penelitian dan Pengembangan Tanah dan Agroklimat, 2004; Rahmad et al., 2018)

These five parameters are overlaid by means of overlay union to produce a map of the level of landslide vulnerability. Based on the accumulation of scores and weights calculated according to the formula above, the vulnerability class is classified into three levels, namely not vulnerable, vulnerable and very vulnerable which refers to the 2005 stipulation of the Center for Volcanology and Geological Hazard Mitigation (PVMBG) which can be seen in **Table 2**.

Table 2. Interval and Criteria for Landslide Vulnerability

No	Total Score Interval	Criteria for Landslide Vulnerability
1.	≤2.5	Not Prone
2.	≥2.6 – ≤3.6	Prone
3.	≥3.7	Very Prone

Source: Center for Volcanology and Geological Hazard Mitigation, 2005 in Nusantoro, 2020 with author modifications

After the overlay is done, the distribution of landslide-prone areas in the study location will be seen. Furthermore, the results of the mapping are linked to physical conditions or real conditions in the field by direct checking as a validation test for the accuracy of the results of the spatial analysis with the conditions and events in the field. Mapping validation data was taken by conducting a field survey using a proportional sampling technique, where samples were taken based on landslide vulnerability level, and the proportion of the sample was taken based on the comparison of the area of each vulnerability level. The sample size is determined based on the Anderson formula (Arco Triady Ujung et al., 2019), which is as follows:

$$N = \frac{4pq}{E^2} \quad (2)$$

Information:

N = Number of samples

p = Accuracy expected

q = difference between p and q

E = Error received

Based on the formula above, with a *p* value of 90% and an E value of 10%, a total of 36 samples were obtained. Then the samples were distributed based on the proportion of each level so that the number of samples at the not prone level was obtained1 sample, 24 samples of prone level and 11 samples of very prone level.

RESULTS AND DISCUSSION

Landslide Vulnerability Level

Rainfall

The threat of landslides usually begins in months with high rainfall intensity, because the higher the intensity of rainfall in an area, the greater the possibility of landslides occurring. Furthermore, rainfall is the parameter that causes landslides which has the highest weight percent, namely 30%, which means that rainfall has the biggest role in the occurrence of landslides. The strength, carrying capacity and damage to the soil are determined by high rainfall (Putra & Wardika, 2021).

Based on the processing of 2021 rainfall data from CHIRPS using the inverse distance weighted (IDW) method, the research location is dominated by high rainfall (2,500 - 3,000 mm/year) with the largest area of 1,877.45 ha or 74.67% of the research area covering the entire research area in East Ende and Ende sub-districts and most of the research area in Detusoko, Kelimutu and Wolowaru sub-districts. The next is very high rainfall (>3000 mm/year) with an area of 542.87 ha or 21.59% of the study area which covers part of the study area in Detusoko sub-district, the entire study area in Lepembusu-Kelisoke sub-district and a small part of the study area in Kelimutu sub-district. Then the last is moderate rainfall (2000 - 2500 mm/year) with the smallest area of 93.94 ha or 3.74% of the research area which includes a small part of the research area in Wolowaru sub-district. The map of the results of rainfall data processing in the research location can be seen in **Figure 1.**

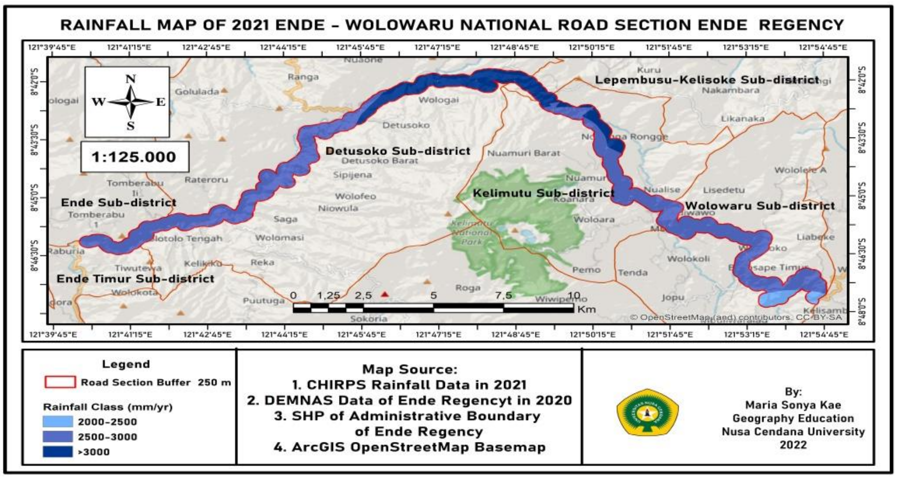

Figure 1. Rainfall of Ende-Wolowaru Road Section

Rock Type

The properties of each rock vary depending on the origin of the formation of the rock where the rock is influenced by texture, structure, joints, mineral content, weather, and sedimentation (Rusdiana et al., 2021). Based on the Geological Map of Sheet Ende, scale 1:250,000, the research location consists of volcanic and sedimentary rock types. Volcanic rocks have the largest area of 2,398.04 ha which is 95.38% of the study area. The sedimentary rocks found at the study site have the smallest area of

116.2 ha or 4.6% of the study area. Thus it can be concluded that the research location is an area dominated by volcanic rocks where this is influenced by the mountains in the research location, namely the young volcanoes of Kelimutu and Kelibara. The map of the results of rock type data processing at the research location can be seen in **Figure 2.**

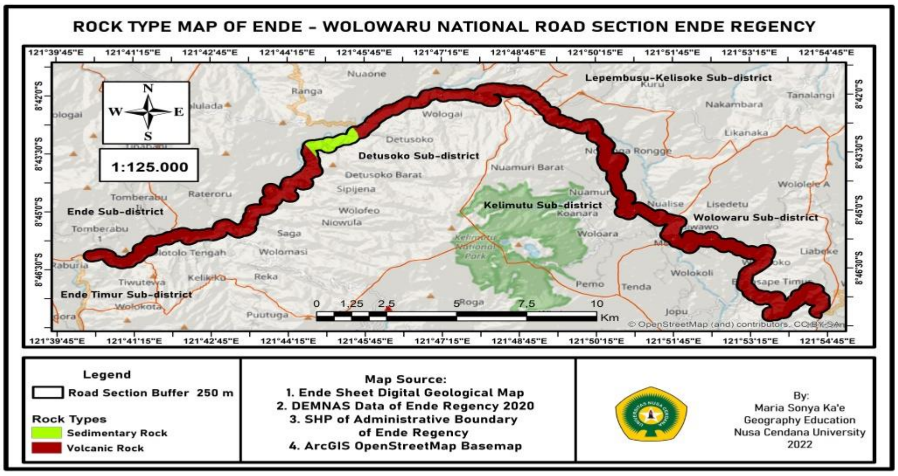

Figure 2. Rock Type of Ende-Wolowaru Road Section

Slope

Based on the results of DEM (Digital Elevation Model) data analysis using the ArcGIS 10.4 application, the study area has a slope that varies, including 276.38 ha or 10.99% of the area of the study area, which is an area with flat topography (slope 0-8%), 425.33 ha or 16.92% of the study area is an area with ramps topography (slope 8-15%), 464.2 ha or 18.46% of the study area is an area with a rather steep topography (slope of 15-25%), amounting to 824.13 ha or 32.78% of the total area of the study is an area with steep topography (slope of 25-45%) and finally covering an area of 524.34 ha or 20.85% of the total area of the study is an area with a very steep topography (slope > 45%). As for the slope map at the research location the results of DEMNAS data processing in **Figure 3.**

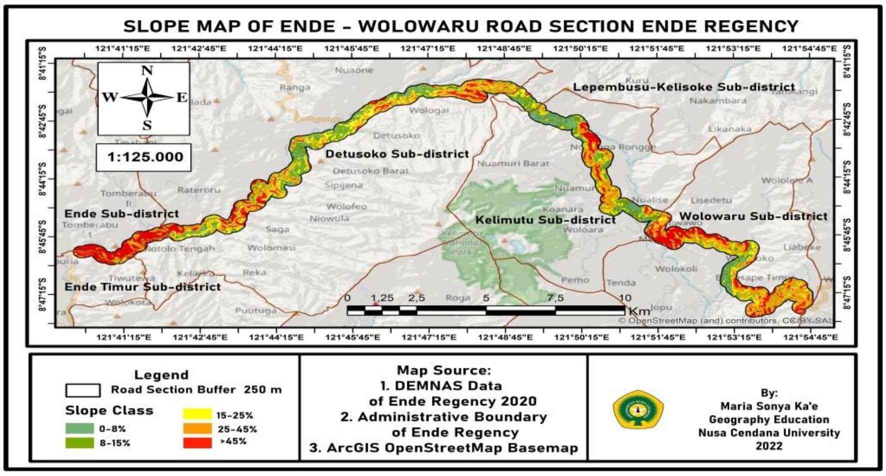

Figure 3. Slope of Ende-Wolowaru Road Section

Land Cover

Land cover is one of the parameters that causes landslides. Based on the results of Sentinel 2-B image processing, the land cover in the research location consists of bodies of water/rivers, settlements/residential, forests and plantations, and paddy fields. The land cover that dominates the research location is forest and gardens with an area of 1,820.50 ha or equivalent to 72.41% of the total area of the study which consists of candlenut, coconut, clove, and bamboo and aur forests, johar, sugar palm and waru. Furthermore, paddy fields covered an area of 572.53 ha or 22.77% of the study area, followed by residential land cover with an area of 88.7 ha or 3.53% of the research area and finally land cover of water bodies/rivers with the smallest area of 32.51 ha or 1.29% of the study area. The land cover map at the research location as a result of Sentinel-2B image processing can be seen in **Figure 4**.

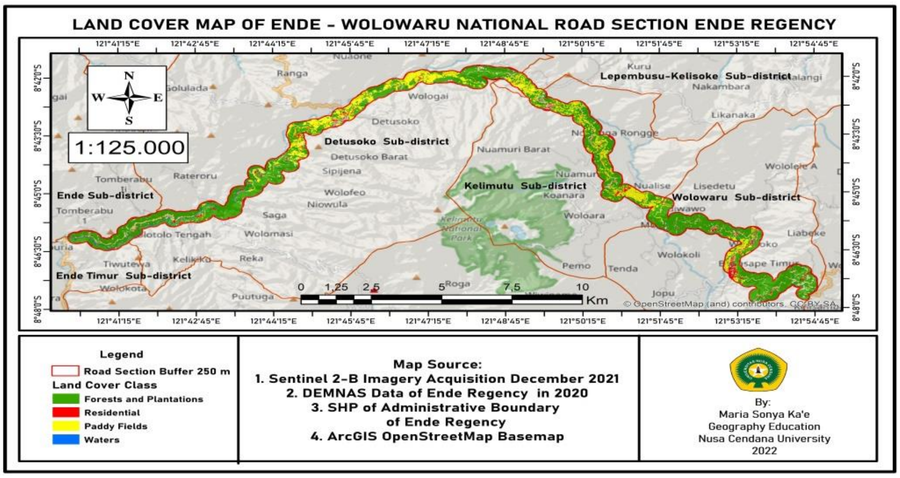

Figure 4. Land Cover of Ende-Wolowaru Road Section

Type of soil

Based on data obtained from the processing of Ende Regency soil type maps from FAO GeoNetwork, the study area consists of cambysol soil types (district cambisol and humic) and alluvial soil types. Cambisol soil has the widest distribution area, namely 2,433.76 ha or 96.79% of the total area of the study. Meanwhile, alluvial soil type has the smallest area of 80.61 ha or 3.21% of the study area. This type of cambisol soil is prone to erosion if it is on steep slopes (Khosiah Khosiah, 2017). The condition of the soil at the study site, especially cambisol soil, experiences weathering on impermeable rocks on steep slopes and there are no perennials so that it often experiences landslides during the rainy season. Map of soil types resulting from data processing can be seen in **Figure 5.**

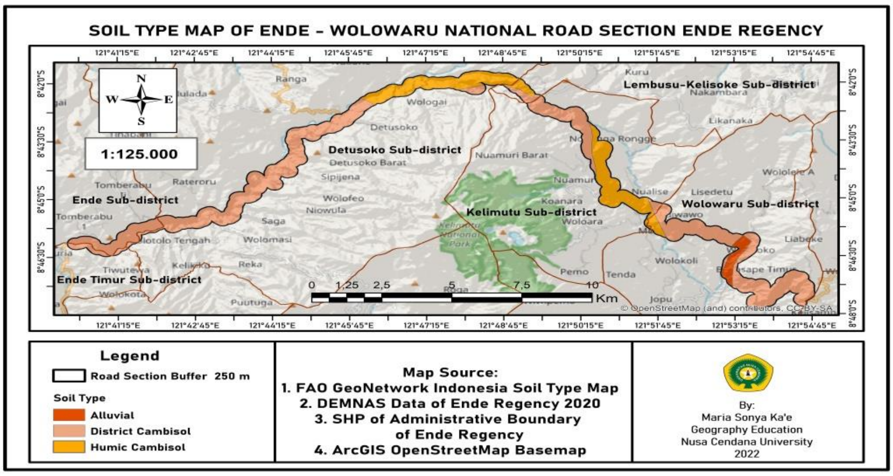

Figure 5. Soil Type of Ende-Wolowaru Road Section

Mapping the level of landslide vulnerability in this study was carried out using scoring and overlay methods, with reference to the estimation model of (Pusat Penelitian dan Pengembangan Tanah dan Agroklimat, 2004).

The landslide vulnerability level map of the analysis results in **Figure 6**.

p-ISSN 2460-0768 e-ISSN 2597-6044
https://doi.org/10.20961/ge.v10i1.73223

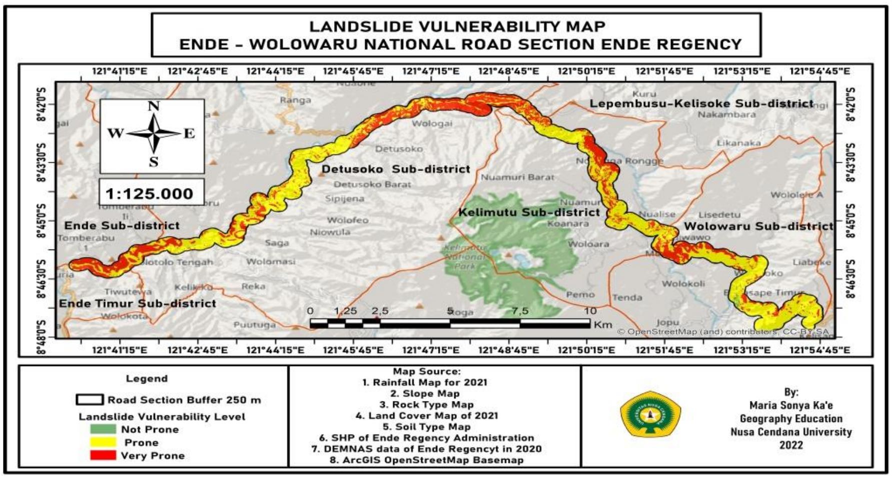

Figure 6. Vulnerability Level Map Landslide of Ende-Wolowaru Road Section

Based on the accumulation of scores and weighting calculated according to Puslittanak 2004 estimation model then the vulnerability class at the research location consists of:

Not Prone Level

Areas that are not prone to landslides are areas that have little or no potential for landslides. This can be triggered because the landslide trigger parameters are very low which are based on the criteria of the Center for Volcanology and Disaster Mitigation Geology (PVMBG) data processing results (cumulative score overlaid results) shows a value of ≤2.5. The level of not prone vulnerability at the study site has the smallest area of 13.38 ha or 0.53% of the total area of the study spread over several points on the road that passes through the East Ende sub-district, Ende sub-district, Detusoko sub-district, and Wolowaru sub-district. Even though the land cover in the form of residential areas, because in a flat area, this location has a small possibility of landslides. The not prone area is shown in **Figure 7**.

Prone Level

From the results of the vulnerability level map analysis, it is known that the study area is dominated by the prone category with an area of 1,620.38 ha or 64.45% of the total area of the study which is spread over roads that pass through East Ende sub-district, Ende sub-district, most of the roads in Detusoko sub-district, Lepambusu-Kelisoke sub-district, Kelimutu sub-district, and most of the roads in Wolowaru sub-district. Based on observations in the field, this location is potentially prone to landslides because located on steep topography, has cambisol soil with a sandy clay texture and has land cover in the form of mixed gardens with fairly dense vegetation in the form of candlenut, sugar palm and clove trees. The prone area is shown in **Figure 8**.

Figure 7. Not Prone Area

Very Prone Level

Very prone class is a class that generally has a high level of vulnerability to landslides. The landslide susceptibility class is very prone to the study site having an area of 880.65 ha or 35.02% of the study area whichspread over most of the roads that pass through the East Ende sub-district, Ende sub-district, most of the roads in the Detusoko sub-district, most of the roads in the Lepembusu-Kelisoke sub-district, Kelimutu sub-district, and Wolowaru sub-district. The results of secondary data analysis show that the level of vulnerability at this location is very vulnerable with a slope of >45%. Based on observations in the field, landslide material was found in the form of soil and rocks. This location has the potential to be very prone to landslides because located on very steep topography, the slopes are composed of thick and brittle weathered rock and are covered with less dense vegetation at the top of the slope. Apart from that, the absence of mitigation efforts in the form of retaining walls or similar causes frequent landslides at this point, especially during the rainy season. The not prone area is shown in **Figure 9**.

Figure 8. Prone Area

Figure 9. Very Prone Area

Mapping Results Validation

The results of processing the parameter map by overlaying show that the distribution of landslide vulnerability level on the Ende - Wolowaru road section has a category of prone level as the widest vulnerability, then very prone, and not prone. Areas that are prone and very prone are areas that must be considered, because landslides are common in these areas.Therefore it is necessary to have a field check to find outsuitability of the mapping results with the conditions in the field. This is intended as a validation test for the accuracy of the results of spatial analysis with conditions and events in the field.

Field validation data in this study were taken using a proportional sampling technique, in which samples were taken based on landslide vulnerability classes, and the proportion of samples was taken based on the comparison of the area of each vulnerability class. In this case the sample used in this study was determined based on Anderson's formula which consisted of 36 points with a sample distribution of 1 sample for the not prone class, 24 points for prone level and 11 points for very prone level. The survey for each level of landslide vulnerability in the field refers to the criteria of landslide vulnerability class according to (Subagio, 2008).

Based on the results of field validation sample observations, there were 32 sample points that matched the results of the landslide vulnerability map analysis, while 4 sample points did not match the results of the landslide vulnerability map analysis. So based on the recapitulation, it was obtained that the suitability level of the processing results with field validation data was 88%. Thus the map of the level of landslide vulnerability is the result of the analysis this is said to be valid because it is in accordance with Sitepu et al., 2017 that the accuracy of an interpretation result can be used for analysis purposes if it has a minimum level of accuracy reaching 80-85% so that the landslide vulnerability map on the Ende - Wolowaru road section using the estimation model from (Pusat Penelitian dan Pengembangan Tanah dan Agroklimat, 2004) can be used for landslide disaster mitigation purposes because it has an accuracy level that meets the standards with an accuracy value of 88.8%.

CONCLUSIONS

Based on the analysis of the research conducted, it can be concluded that: (1) the level of vulnerability to landslides at the study site consists of an area of 13.38 ha not prone, 1620.38 ha vulnerable and 880.65 ha very vulnerable; (2) Based on the results of the validation test from spatial analysis with field data analysis it is declared valid so that the map of landslide-prone areas resulting from analysis using the prediction model from (Pusat Penelitian dan Pengembangan Tanah dan Agroklimat, 2004) can be used for landslide disaster mitigation purposes in the research area because it has a level of accuracy that meets the standards with an accuracy value of 88.8%. In addition, it is suggested to conduct further research on landslide problems in the study area by using the latest basic data (parameters) and the most complete modelling so as to produce a map with the most recent and more relevant geography.

REFERENCES

Arco Triady Ujung, Laila Nugraha, A., & Sugiastu Firdaus, H. (2019).

Kajian Pemetaan Risiko Bencana Banjir Kota Semarang Dengan Menggunakan Sistem Informasi Geografis. *Jurnal Geodesi Undip Oktober*, *8*, 154–164.

Diara, I. W., Suyarto, R., & Saifulloh, M. (2022). Spatial Distribution of Landslide Susceptibility in New Road Construction Mengwitani-Singaraja, Bali-Indonesia: Based on Geospatial Data. *International Journal of GEOMATE*, *23*(96), 95–103. https://doi.org/10.21660/2022.96.3320

Hang, H. T., Hoa, P. D., Tru, V. N., & Phuong, N. V. (2021). Landslide Susceptibility Mapping Along National Highway-6, Hoa Binh Province, Vietnam Using Frequency Ratio Model And Gis. *International Journal of GEOMATE*, *21*(85), 84–90. https://doi.org/10.21660/2021.85.j2222

Khosiah Khosiah, A. A. (2017). Tingkat Kerawanan Tanah Longsor Di Dusun Landungan Desa Guntur Macan Kecamatan Gunungsari Kabupaten Lombok Barat. *Jurnal Ilmiah Mandala Education*, *13*(3), 195–200.

Nusantoro, A. (2020). Analisis Mitigasi Bencana Tanah Longsor Berbasis Kearifan Lokal di Purworejo. *Proceeding of The 11th University Research Colloquium 2020: Bidang Lingkungan Dan Kebencanaan*, 18–26.

Pusat Penelitian dan Pengembangan Tanah dan Agroklimat. (2004). *Laporan Akhir Pengkajian Potensi Bencana Kekeringan, Banjir dan Longsor di Kawasan Satuan Wilayah Sungai Citarum-Ciliwung, Jawa Barat Bagian Barat Berbasis Sistem Informasi Geografi*.

Putra, I. K. A., & Wardika, I. G. (2021). Analisis Kerentanan Lahan Terhadap Potensi Bencana Tanah Longsor pada Wilayah Kaldera Batur Purba. *Media Komunikasi Geografi*, *22*(2), 208. https://doi.org/10.23887/mkg.v22i2.36925

Rahmad, R., Suib, S., & Nurman, A. (2018). Aplikasi SIG Untuk Pemetaan Tingkat Ancaman Longsor Di Kecamatan Sibolangit, Kabupaten Deli Serdang, Sumatera Utara. *Majalah Geografi Indonesia*, *32*(1), 1. https://doi.org/10.22146/mgi.31882

Roccati, A., Paliaga, G., Luino, F., Faccini, F., & Turconi, L. (2021). Gis-based landslide susceptibility mapping for land use planning and risk assessment. *Land*, *10*(2), 1–28. https://doi.org/10.3390/land10020162

Rusdiana, D. D., Nuryandini, R., Heni Imelia, J., & Syifa Hafidah, N. (2021). Pemanfaatan Informasi Spasial Berbasis SIG untuk Pemetaan Tingkat Kerawanan Longsor di Kabupaten Karangasem, Bali. *Jurnal Geosains Dan Remote Sensing*, *2*(2), 49–55. https://doi.org/10.23960/jgrs.2021.v2i2.51

Sitepu, F., Selintung, M., & Harianto, T. (2017). Pengaruh Intensitas Curah Hujan dan Kemiringan Lereng Terhadap Erosi Yang Berpotensi Longsor. *Jurnal Penelitian Enjiniring*, *21*(1), 23–27. https://doi.org/10.25042/jpe.052017.03

Subagio, H. (2008). *Model Spasial Penilaian Rawan Longsor Studi Kasus di Trenggalek. Badan Koordinasi Survei dan Pemetaan*

Nasional.

Sukma, R. (2015). *Studi geologi daerah tanjung ngalebu, kabupaten ende kecamatan maurole, flores provinsi nusa tenggara timur*. UPN Veteran, Yogyakarta.

Sukrizal, S., Fatimah, E., & Nizamuddin, N. (2019). Analysis of Landslide Hazards Area Using Geographic Information System in Gayo Lues District. *International Journal of Multicultural and Multireligious Understanding*, *6*(3), 193. https://doi.org/10.18415/ijmmu.v6i3.807

Sunimbar, & Angin, I. S. (2021). Analisis Geomorfologi Kejadian Longsor Di Kecamatan Wolotolo Kabupaten Ende. *Jurnal Geografi*, *17*(2), 14–22.