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Mapping of Landslide Prone Areas in Huamual Sub-District, Seram Bangian Barat Regency, Indonesia

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Abstract
This research aims to map landslide-prone areas in Huamual Sub-district, West Seram Regency, Indonesia. Through the collection and analysis of geospatial data, including characteristics of slope, land elevation, geology, rainfall, land cover and distance from active faults, this study successfully identified areas with high potential landslide risk. The results showed that the area in low landslide class has an area of 5,076.67 ha, the area in medium class has an area of 20,979.79 ha and the area in high landslide prone class has an area of 7,430.88 ha. The results of this study provide an important contribution in landslide risk mitigation planning, through identification of zones that need special attention, safer spatial planning, and more effective early warning system. This research provides a strong scientific basis for the government and other stakeholders to take appropriate preventive measures, so as to improve public safety and protect important assets from potential landslide hazards in Huamual Sub-district area.

Keywords: *Landslide, Huamual,Mapping*

Abstrak
Penelitian ini bertujuan untuk melakukan pemetaan daerah rawan longsor di Kecamatan Huamual, Kabupaten Seram Bagian Barat, Indonesia. Melalui pengumpulan dan analisis data geospasial, termasuk karakteristik kemiringan lereng, ketinggian lahan, geologi, curah hujan, tutupan lahan dan jarak dari sesar aktif, penelitian ini berhasil mengidentifikasi daerah-daerah dengan potensi risiko longsor yang tinggi. Hasil penelitia menunjukan bahwa daerah yang berada pad kelas longsor rendah memiliki luas 5.076,67 ha, daerah yang berada pada kelas sedang memiliki luas 20.979,79 ha dan daerah yang berada pada kelas rawan longsor tinggi memiliki luas 7.430,88 ha. Hasil penelitian ini memberikan kontribusi penting dalam perencanaan mitigasi risiko bencana longsor, melalui identifikasi zona-zona yang perlu mendapat perhatian khusus, perencanaan tata ruang yang lebih aman, dan sistem peringatan dini yang lebih efektif. Penelitian ini memberikan dasar ilmiah yang kuat bagi pemerintah dan pemangku kepentingan lainnya untuk mengambil langkah-langkah preventif yang sesuai, sehingga dapat meningkatkan keselamatan masyarakat dan melindungi aset-aset penting dari potensi bahaya longsor di wilayah Kecamatan Huamua

Kata kunci: Huamual, Pemetaan, Tanah Longsor,

Introduction

Indonesia is a country located in the collision zone of tectonic plates and has a diverse topography, which includes lowlands, mountains and hills. One of the impacts of these geographical characteristics is its vulnerability to natural disasters, such as landslides (BNPB, 2021). Landslides are natural disasters that often cause huge losses both in terms of casualties and environmental and economic damage (Bai et al., 2021; Somae et al., 2022). According to Lowe, (2015), Landslides are natural events that occur when large amounts of soil, rocks, boulders, or other materials slip or fall from the slopes of mountains, hills, hills, or cliffs. Landslides can occur for many reasons, including excessive rainfall, earthquakes, human activities such as uncontrolled quarrying, or unstable natural geological conditions (Rakuasa & Rifai, 2021; Rakuasa et al., 2022; Sugandhi et al., 2023).

Landslides can be very destructive, and often result in loss of life, property damage, and disruption to infrastructure and the environment (Jakob, 2022; Muin & Rakuasa, 2023). For this reason, monitoring, mitigation and management of landslides are crucial in an effort to protect communities and the environment. The area of Huamual Sub-district, West Seram Regency, Indonesia, is not exempt from this risk. Therefore, research on mapping landslide-prone areas in this region is important to identify and manage the potential hazard. Huamual sub-district is located on Seram Island, which is part of Maluku Province, Indonesia. The area has a steep topography with sharp slopes and is often exposed to high intensity rainfall. These factors together increase the risk of floods and landslides in this area (Muin & Rakuasa, 2023). In addition, West Seram Regency also has a history of significant landslide occurrences, which caused huge losses in terms of both human life and infrastructure damage.

Over the past few years, global climate change has also increased vulnerability to landslides in many parts of Indonesia (BNPB, 2022). High rainfall variability and changes in rainfall patterns can affect slope stability, worsening the condition of landslide-prone areas (McColl, 2022; Manakane et al., 2023). According to Pakniany et al., (2023), increased human activities, such as land use change and deforestation, have been important factors that exacerbate landslide susceptibility in Huamual District. Uncontrolled expansion of settlements and agriculture can damage the soil layer and increase the pressure on slopes, thus triggering landslides (Latue et al., 2023). Therefore, a better understanding of the factors that cause landslides and the mapping of landslide-prone areas is becoming increasingly important in disaster mitigation efforts (Manakane et al., 2023). Landslide prone area mapping is the first step in identifying areas most vulnerable to potential landslides (Latue et al., 2023). Landslide prone area mapping is also important in the context of ecological sustainability. Uncontrolled land use change can threaten natural ecosystems and biodiversity in the Huamual sub-district area. It is important to take preventive measures, such as wiser land use planning, infrastructure improvements, and early warning to local communities. In addition, mapping landslide-prone areas can also help in emergency response planning and evacuation in the event of a disaster (Harist et al., 2018).

Basically, mapping landslide-prone areas involves analyzing factors such as soil characteristics, topography, slope, rainfall and land use patterns. Geospatial data and satellite mapping technology have played an important role in this kind of research. However, in many areas of Indonesia, including Huamual sub-district, information is quite limited and often not well integrated. In addition, although there have been several attempts at mapping landslide-prone areas in Indonesia, many areas are still not covered by these studies. Huamual sub-district is one example where research on mapping landslide-prone areas is not yet adequately available. Therefore, this research is expected to make a significant contribution to the understanding of landslide risk in this area. The importance of mapping landslide prone areas in Huamual Sub-district is also closely related to the sustainability of the region's development. With a better understanding of landslide risks, authorities can plan safer and more sustainable infrastructure development and land use. This will help protect local residents and reduce losses caused by landslides.

In this context, this study aims to map landslide-prone areas in Huamual Sub-district, West Seram Regency, Indonesia, using geospatial data and modern mapping technology. The results of this study are expected to be a valuable contribution to landslide risk mitigation efforts in this region and may also serve as a guide for other regions in Indonesia facing similar risks.

Research Method

This research was conducted in Huamual District, West Seram Regency. The software used for data processing and analysis in this research is Microsoft Office 365 and ArcGIS 10.8. Variables that affect the occurrence of lom in this study consist of land elevation and slope processed from the National Digital Elevation Model (DEMNAS) of Seram Island - Geospatial Information Agency, land cover processed from Worldview -2 satellite image in 2023 - Maxar Technologies, distance from faults obtained from the results of buffer analysis of active faults and geological data processed from the map of Geological Map System, Indonesia Sheet: Ambon 2612-2613, scale: 1,250,000 - Indonesian Geological Agency and rainfall obtained from the analysis of monthly rainfall data - Meteorology Climatology and Geophysics Agency. Based on the data obtained, the variables influencing the landslide hazard level and its exposure level in residential areas in Huamual Sub-district, West Seram Bangian Regency were processed and referenced from previous studies. The variables were then subjected to spatial analysis using weighting and scoring methods referring to Table 1.

Table 1. Landslide Susceptibility Variable

No	Variables	Class	Score	Weight
1	Slope	0- 8 %	1	20
		8-15 %	2	
		15-25 %	3	
		25-40 %	4	
		>40 %	5	
3	Elevation	0-20 mdpl	1	15
		21-50 mdpl	2	
		51-100 mdpl	3	
		101-300 mdpl	4	
		>300 mdpl	5	
3	Land Cover	Built-up Land	4	

		Open Land	5	10
		Agricultural Land	3	
		Forest	2	
		Water Body	1	
4	Distance from Active Fault	0 -100 m	5	15
		101-250 m	4	
		251-300 m	3	
		301-350 m	2	
		>350 m	1	
5	Geology	Alluvium	5	20
		Batu gamping koral	3	
		Batuan ultramafik	2	
		Kompleks taumusa	4	
		Batuan gunung api Ambon	1	
6	Rainfall	>3000 mm/bln	5	20

Source: (Rakuasa & Rifai, 2021)

The weighting of landslide susceptibility in the study area was calculated using an arithmetic formula modified from previous studies as follows:

Landslide Hazard = 10 × slope + 10 × land cover + 20 × rainfall + 20 × geology + 15 × land elevation + 15 × distance from fault .... (1)

The interval of landslide vulnerability level in the study area was classified using the following formula:

Width of Interval = Range or difference between the highest data value minus the lowest data / Number of class intervals .... ……… (2)

The level of flood vulnerability in Huamual Sub-district is classified into 3 classes consisting of: low, medium and high. The existing landslide prone area map was then overlaid with built-up land/settlement data obtained from land cover data to determine the distribution of built-up land/settlement in the three landslide prone classes.

Results and Discussion

Landslide Vulnerability Variables

Landslide susceptibility variables refer to factors that are used to measure or determine the extent to which an area or population is vulnerable to landslides. In this context, landslide susceptibility variables refer to aspects that can increase the potential damage or negative impacts caused by landslides. One of the variables that affect landslides in Huamual Sub-district is land elevation. Land elevation or elevation in Huamual Sub-district at 0-20 masl has an area of 2,093.36 ha, at 21-50 masl has an area of 1,862.43 ha, at 51-100 masl has an area of 2,635.06 ha, at 101-300 masl has an area of 19,697.55 ha and at >300 masl has an area of 7,198.93 ha.

Land elevation in Huamual Sub-district has a significant impact on the potential for landslides. Areas located at higher elevations often have steeper slopes and soils that are more prone to land movement. This factor, together with rainfall which can be higher in high contour areas, can increase the risk of landslides. In addition, the condition of soil and rock types in the area can also be affected by elevation, affecting their susceptibility to landslides. Therefore, an in-depth understanding of the land elevation factor is key in mitigating and managing landslide risk in Huamual Sub-district as well as in safer spatial planning (Rakuasa & Somae, 2022).

The slope variable of Huamual Sub-district is classified into five classes: slope with 0 - 8% slope covering 3,046.05 ha, slope with 8 - 15% slope covering 1,602.53 ha, slope with 15-25% slope covering 3,484.29 ha, slope with 25-40% slope covering 12,265.40 ha and slope with >40% slope covering 13,089.07 ha. Slope in Huamual sub-district has a significant influence on the risk of landslides. Steep slopes or those with significant slope have a greater potential to experience landslides. This factor is caused by additional pressure on unstable soil or rock layers that can trigger sudden ground movements. Therefore, understanding and monitoring the slope in this area is crucial in landslide risk mitigation efforts, with measures such as slope reinforcement, proper land use, and early warning to reduce the impact of landslides that may occur (Ristya et al., 2019).

The variable distance from the fault is classified into five classes, namely the area within 0-100 m from the fault has an area of 1,741.60 ha, the area within 101-250 m from the active fault has an area of 2,547.29 ha, the area within 251-300 m from the active fault has an area of 836.80 ha, the area within 301-350 m from the active fault has an area of 830.80 ha and the area >350 m has an area of 27,530.85 ha. Distance from active faults has a significant impact on the risk of landslides in Huamual sub-district. Active faults are cracks in the earth's crust where movement of tectonic plates occurs, and areas adjacent to active faults tend to have higher landslide risk (Asmare, 2022). This is due to geological strains that can undermine the stability of slopes and surrounding rocks, increasing the potential for sudden ground movements to occur. Therefore, distance from active faults should be a major consideration in spatial planning and landslide risk mitigation in Huamual Sub-district, with careful geological surveillance and planning that takes into account the potential impacts of possible active fault activity (Lowe, 2015).

Land cover in Huamual Sub-district is classified into five classes consisting of forest covering 11,871.46 ha, agricultural land covering 20,621.72 ha, built-up land covering 556.47 ha, open land covering 312.77 ha and water body covering 124.92 ha. Land cover plays an important role in determining landslide risk in Huamual Sub-district. Land use types such as forests, natural vegetation, or erosion-bearing crops can provide protection against sudden ground movement. Good land cover is able to infiltrate rainwater, bind soil, and reduce water stress in the soil, thereby reducing landslide potential (Li et al., 2019). However, if the land has been subjected to deforestation, poorly managed agriculture, or inappropriate land use, effective land cover may be compromised (Wang et al., 2017). Therefore, the maintenance of healthy and sustainable land cover and nature conservation efforts are essential in reducing the risk of landslides in Huamual District and preserving the environment (Permadi et al., 2019).

Based on the Geological Map of Indonesia, sheet: Ambon 2612-2613, the geology of Huamual Sub-district consists of Ultramafic Rocks (JKu) with an area of 3,061.25 ha, Taunusa Complex rocks (Pzta) with an area of 23,882.26 ha, Coral Limestone rocks (Q1) with an area of 1,396.75 ha, Aluvium rocks (Qa) with an area of 2,786.51 ha and Ambon Volcano Rocks (Tpav) with an area of 2,360.58 ha. Geology plays a central role in influencing the risk of landslides in Huamual sub-district. The nature and type of rocks and soils present in an area directly affect slope stability and the potential for ground movement (Mufidawati et al., 2021). Areas with clay or loamy soils tend to be more prone to landslides compared to areas with solid rock (Paronuzzi et al., 2022). In addition, the presence of fragile rock layers or geological cracks that allow water to rapidly seep into the soil can increase the risk of landslides. Therefore, an in-depth understanding of the geological characteristics in Huamual Sub-district is crucial in identifying high-risk areas and taking mitigation measures to reduce the impact of potential landslides.

Huamual sub-district rainfall map is made based on average rainfall data and isohit map from BMKG Kairatu Station, the results show that Huamual sub-district rainfall is evenly distributed. The average rainfall in Lokki Village in 2023 is 3,018 mm/month, causing this area to fall into the category of very prone to flooding. Rainfall is the main factor influencing the occurrence of landslides in Huamual Sub-district. High rainfall can cause the soil to become water-saturated, reduce its carrying capacity, and trigger ground mass movement (Harist et al., 2018). Prolonged or heavy rain can damage soil and rock structures and increase the risk of landslides (Susetyo et al., 2022). In addition, rain can also rapidly fill waterways and rivers, creating water pressure that can force ground movement (Harist et al., 2018). Therefore, weather monitoring and weather-related early warnings are important in identifying conditions that could potentially cause landslides due to heavy rainfall, as well as in risk mitigation planning to protect residents and infrastructure in Huamual District (Pánek et al., 2019).

Landslide Vulnerability Level

Landslide susceptibility level is defined as a measure of the extent to which a certain area or location is prone to landslides. It reflects the level of risk or potential loss that can result from landslides in the area. The assessment of landslide susceptibility level involves various factors, including geological characteristics, topography, land use, rainfall, vegetation, geological rocks and distance from active faults in the area. The higher the landslide vulnerability level, the greater the potential for landslides to occur and the impacts they may cause, so that appropriate mitigation measures and spatial planning can be taken to reduce the risk. Based on the results of the classification of landslide vulnerability areas in Huamual Sub-district, the area in the low vulnerability class has an area of 5,076.67 ha, this is because this area has a hilly topography, Ambon volcanic rocks and dominating land cover which is agricultural and forest areas, as well as a long distance from the fault which makes the area has a low risk.

The medium vulnerability class has an area of 20,979.79 ha. This is because this area is located in the lowlands and the dominating land cover is open land and settlements, the slope and elevation of the land is flat and gentle and the geological structure is ambon volcanic rocks and taumusa complex rocks making this area in the medium vulnerability class. The high vulnerability area is 7,430.88 ha. Most of these areas are located on slopes >40, areas located at altitudes >300 meters above sea level, areas located on developed and open land, areas located >350 m from active faults, areas located on Alluvium rocks and areas with rainfall

>3000 mm/month. The spatial map of landslide vulnerability in Huamual Sub-district can be seen in Figure 1.

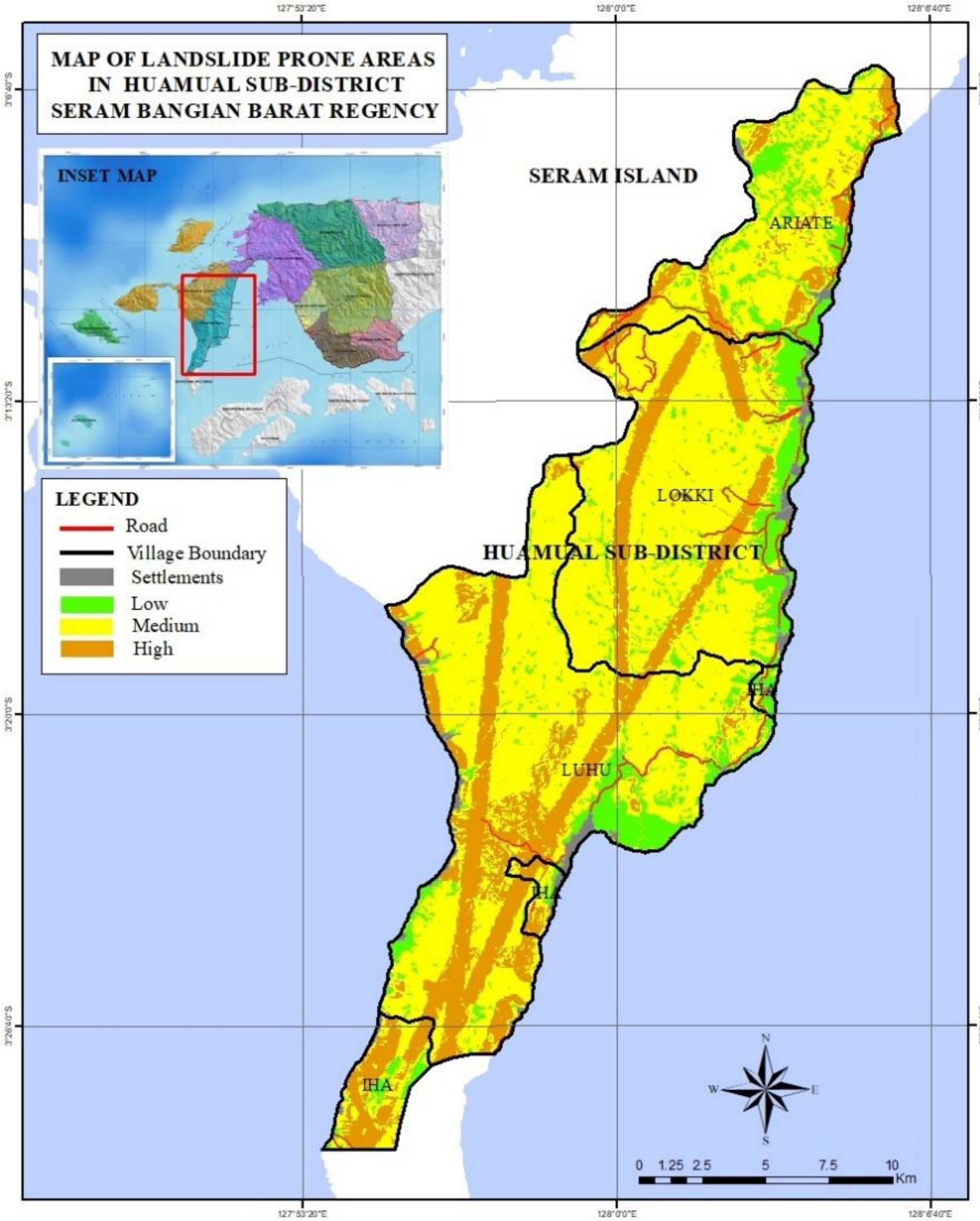

Figure 1. Landslide Vulnerability Map in Hunimual District

Based on data obtained from the National Countermeasure Agency, Hunimual Sub-district is at the intensity of moderate and high landslide hazards, therefore landslide mitigation must be carried out to anticipate the impacts and losses caused both material losses and casualties (BNPB, 2021). The mapping of landslide-prone areas in Huamual Sub-district, West

Seram Regency, Indonesia has significant benefits in risk mitigation efforts and protection of the community and environment. The following are some of the main benefits of the mapping:

1. Identification of Potential Hazards: Landslide prone area mapping can identify areas that have high potential for landslides. This allows the government and related parties to better understand and identify vulnerable areas and potential hazards that may occur, which can help in mitigation planning.
2. Safer Spatial Planning: Information from mapping can be used in safer spatial planning. Areas declared as landslide-prone can be avoided for residential development or critical infrastructure. This will help reduce risks to people and assets
3. Early Warning: Mapping landslide-prone areas can be the basis for an effective early warning system. When extreme weather or other factors that increase the risk of landslides are detected, warnings can be given to residents in vulnerable areas so that they can take steps to protect themselves and their property.
4. Informative Decision Making: Mapping provides informative data for governments, aid organizations and decision makers to plan more effective mitigation measures. This includes development of drainage systems, construction of landslide barriers, and afforestation of vulnerable areas.
5. Public Awareness Raising: Mapping landslide-prone areas can also be used to raise public awareness. By knowing the landslide risks around them, residents can become more vigilant and better prepared to deal with emergency situations.
6. Fund Saving: Although it requires an initial investment, mapping landslide-prone areas can save funds in the long run by preventing major losses due to landslides. Appropriate mitigation measures and preventive actions can reduce losses caused by natural disasters.

With a better understanding of landslide-prone areas in Huamual Sub-district, risk mitigation efforts can be implemented more effectively, and people's lives and property can be better protected from potential landslide hazards.

Conclusion

Based on the research on landslide prone area mapping in Huamual Sub-district, West Seram Regency, Indonesia, it can be concluded that this mapping has a very important value in landslide risk mitigation. The data and information obtained from the mapping allows the identification of areas with landslide potential, as well as assisting in safer spatial planning and effective early warning systems. In addition, the mapping also helps in more informed decision-making for the government and other decision-makers to design appropriate mitigation measures. With a better understanding of landslide risks and appropriate mitigation measures, communities in Huamual Sub-district can be better prepared to deal with potential landslide hazards, and losses that may be caused by this natural disaster can be minimized. Mapping landslide-prone areas is an essential step in safeguarding the safety and well-being of residents and protecting valuable assets.

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