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Identification of Potential Landslide Areas in Nusaniwe Sub-district, Ambon City using Slope Morphology Method

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Abstract

This study aims to identify potential landslide areas in Nusaniwe Sub-district using the Slope Morphology Method (SMORPH) based on slope and slope shape analysis. The results show that the complex geological and topographical conditions in the area increase the risk of landslides, with areas of high slope and steep slope shapes tending to be landslide hotspots. Interdisciplinary collaboration, community education, and the development of effective mitigation strategies are key in reducing the risk of landslides in Nusaniwe Sub-district and similar areas.
Keywords: *Landslide; Nusaniwe; Slope Morphology.*

Abstrak

Penelitian ini bertujuan untuk mengidentifikasi daerah-daerah yang berpotensi longsor di Kecamatan Nusaniwe dengan menggunakan metode morfologi lereng (Slope Morphology Method/SMORPH) berdasarkan analisis kemiringan lereng dan bentuk lereng. Hasil penelitian menunjukkan bahwa kondisi geologi dan topografi yang kompleks di daerah tersebut meningkatkan risiko longsor, dengan daerah yang memiliki kemiringan lereng yang tinggi dan bentuk lereng yang curam cenderung menjadi titik rawan longsor. Kolaborasi interdisipliner, edukasi masyarakat, dan pengembangan strategi mitigasi yang efektif merupakan kunci untuk mengurangi risiko longsor di Kecamatan Nusaniwe dan daerah-daerah lain di sekitarnya.
Kata Kunci: Longsor; Nusaniwe; Slope Morphology.

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INTRODUCTION

Landslides are one of the most serious natural disasters and can cause huge losses both in terms of human lives and significant environmental damage (Marzuki & Gayo, 2022). In Indonesia, including in areas such as Maluku, landslides are not only a threat to daily life but also have extensive economic impacts (Rakuasa & Rifai, 2021). Nusaniwe sub-district, located in the eastern part of Ambon City, is known to have complex geographical conditions with the presence of various soil types and diverse topography (Rakuasa & Somae, 2022). This condition makes the area one of the most vulnerable to landslides (Rakuasa et al., 2022). In addition, human activities such as infrastructure development and land use change also contribute to the increased risk of landslides (Somae et al., 2022). With a diverse topography, including slopes and unstable soil types, this area frequently experiences landslide events that can threaten the safety of residents as well as surrounding infrastructure (Latue & Rakuasa, 2023). Therefore, it is important to identify potential landslide areas with appropriate methods to minimize the risk of such disasters.

In 2023, the National Disaster Management Agency (BNPB) noted that 121 houses and one school collapsed due to landslides that hit Nusaniwe Subdistrict, Ambon City, Maluku Province, this occurred after high-intensity rain accompanied by unstable soil structures in the surrounding area (BNPB, 2023). The BNPB Operations Control Center (Pusdalops) noted that this event affected 35 families or 495 people in Latuhalat Village in Nusaniwe District (Harist et al., 2018). From the visual report, it can be seen that the landslide location is on a fairly sloping area. Therefore, the landslide had an impact on residents' houses which suffered damage to the roof with mild to severe categories. This study was conducted in response to the need for more accurate and detailed information on potential landslide areas in Nusaniwe Sub-district. This information is crucial for the planning and implementation of effective landslide mitigation strategies (BNPB, 2021). With the identification of landslide potential areas, the government and community can take proactive measures to reduce the risk and impact of landslides.

One of the methods used in the identification of landslide potential is the Slope Morphology method (Rakuasa & Latue, 2023). This method utilizes slope morphology to identify areas prone to landslides. The Slope Morphology method is based on the understanding of the relationship between slope morphology and the tendency of landslides (Latue et al., 2023). The Slope Morphology Method (SMORPH) is a relatively new approach in landslide analysis. It combines topographic data and slope morphology to detect areas most prone to landslides (Harist et al., 2018). Slope Morphology (SMORPH) method is a spatial analysis method that uses Geographic Information System (GIS) approach to predict potential landslide prone areas based on geomorphological parameters such as slope shape (concave, planar, or convex) and slope slope (Sugandhi et al., 2023). This method is considered effective and efficient in identifying potential landslide-prone areas in areas that have diverse geographical and topographical conditions, such as mountainous and hilly areas. SMORPH uses shape and slope variables based on Digital Elevation Model (DEM) data to better analyze landslide potential compared to other methods such as Storie Index or Stability Index Mapping (SINMAP) (Sugandhi et al., 2023). This method provides a relatively good representation in identifying landslide potential compared to other methods. SMORPH provides a deeper understanding of how physical and geological factors affect landslide potential, which cannot always be detected through traditional methods (Permadi et al., 2019).

Although the Slope Morphology method is effective in identifying potential landslide areas, there are several challenges that need to be addressed. These include the complexity of local geologic and topographic conditions, as well as the limited data available for slope morphology analysis (Triwahyuni et al., 2017). This research aims to increase public awareness about landslide risk and the importance of mitigation. Community education on how to identify potential landslide areas and steps that can be taken to reduce the risk is an integral part of landslide mitigation efforts. In a global context, this study is also relevant as it helps in further understanding of landslide dynamics in tropical and humid climates, which are common conditions in Indonesia. This knowledge can be used to develop more effective mitigation strategies in other regions facing similar challenges. This research highlights the importance of collaboration between different disciplines, including geography, geology and civil engineering, in addressing landslide issues. This multidisciplinary approach is essential to produce a comprehensive and sustainable solution. Overall, the Identification of Landslide Potential Areas in Nusaniwe Sub-district using Slope Morphology Method is a significant contribution to the field of natural disaster research, particularly landslides, in Indonesia. This study shows that with the right approach and advanced technology, we can reduce the risk of landslides and better prepare the community to face such disasters.

METHOD

This research was conducted in Nusaniwe Sub-district, Ambon City, Maluku Province, Indonesia. This study used sub-district administrative boundary data obtained from the Ambon City Government Agency and National DEM data of Ambon City obtained from the Geospatial Information Agency. This research uses Sentinel 2 imagery to analyze built-up land in Nusaniwe Sub-district in 2024. This research uses the slope morphology or SMORPH method. The slope morphology method or SMORPH is a method of identifying landslide-prone areas that focuses on analyzing slope morphology (Permadi et al., 2019). SMORPH uses input parameters such as slope morphology and other factors to identify potential areas prone to landslides (Muin & Rakuasa, 2023).

This research uses Arc GIS 10.8 software to analyze landslide potential in Nusaniwe Sub-district, Ambon City. National DEM data of Ambon City was then processed to produce slope data and slope shape data. The slope shape classification is classified into 3 forms namely concave slope shape with value <-0.1, flat slope shape with value -0.1 - 0.01, and convex slope shape with value >0.01. The slope is classified into 6 classes namely 0-8%, 8-15%, 15-25%, 25-45%, 45-65% and >65%. The data of slope shape and slope slope were ovelayed by referring to the SMORPH Matrix in **Table 1.** The landslide potential area of Nusaniwe Sub-district was then overlaid with built-up land to obtain the built-up area affected by landslide. More details of the work can be seen in **Figure 1.**

Table 1. SMORPH matrix (Ramdhoni et al., 2020)

Slope shape	Slope angle (%)					
	0-8%	8-15%	15-25%	25-45%	45-65%	>65%
Concave	Very Low	Low	Low	Low	Low	Medium
Flat	Very Low	Low	Low	Low	Medium	High
Convex	Very Low	Low	Medium	High	High	High

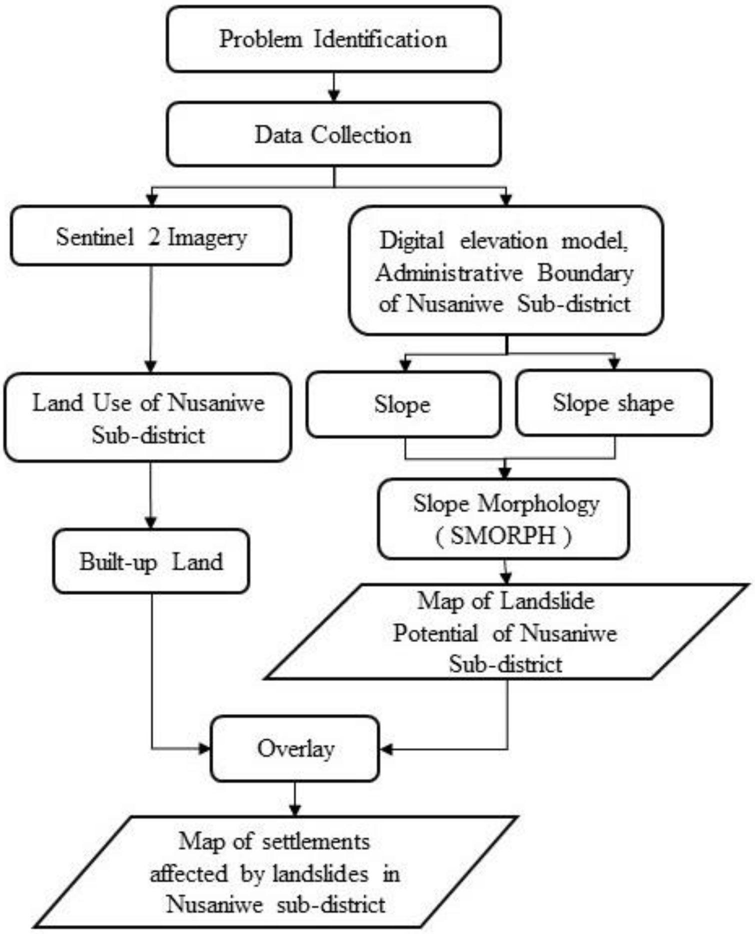

Figure 1. Workflow

RESULTS AND DISCUSSION

Slope

Slope is the angle between a flat plane (e.g., ground or surface) and a vertical line (Ramdhoni et al., 2020). It is measured in degrees and is used to describe how steep a slope is. A greater slope indicates that the slope is steeper, while a lower slope indicates that the slope is more gentle (Wang et al., 2017). The slope in Nusaniwe sub-district is classified into 6 classes consisting of 0-8% covering 12,531.76 ha or 38.49%, 8-15% slope covering 7,446.03 ha or 22.87%, 15-25% slope covering 5. 775.97 ha or 17.74%, slope 25-45% or 4,678.52 ha or 14.37%, slope 45-6% covering 1,427.58 ha or 4.38%, slope >65% covering 701, 76 ha or 2.16%. The relationship between slope and landslide potential is very close. Steep slope becomes one of the main factors of landslide, supported by the earth's gravity. Areas with slope more than 15% are considered prone to landslides (Hoyt and William 2008). Landslides often occur in places with steep slopes, such as mountains or hills, although some areas are covered by vegetation. Other factors affecting landslides besides slope and vegetation are the presence of impermeable layers or sliding planes, as well as differences in soil texture that can affect the speed and intensity of landslides (Katherine Lowe, 2015). Details of the slope map can be seen in **Figure 2a.**

Slope Shape

Slope shape is a physical characteristic of the earth's surface that shows the extent to which an area or region has a slope or steepness (Syarifah et al., 2020; Pratikno et al., 2020; Priambodo et al., 2020; Adri et al., 2020; Yuliarta & Rahmat, 2021; Rahmanisa et al., 2021; Utama et al., 2020; Zakiyah et al., 2022; Rahmat et al., 2020; Kodar et al., 2020; Najib & Rahmat, 2021, Widyaningrum et al., 2020, Muara et al., 2021). This slope shape can consist of convex slope shape, flat slope shape, concave slope shape, depending on the geological process and surrounding environmental conditions [13]. The results of the analysis of the slope shape of Nusaniwe sub-district show that the concave slope shape has an area of 11,224.61 ha or 34.47%, flat slope shape has an area of 5,698.37 ha or 17.50% and convex slope shape of 15,640.53 or 48.03%. Steep or convex slope shapes and high slopes increase the potential for landslides [23]. This is because a high slope can accelerate the flow of water and soil material, which in turn can cause landslides. In addition, the depth of the soil slide plane is also an important factor. Deeper slip planes can store more water and materials, which if given additional loads (such as from heavy rainfall), can cause landslides [24]. More details of the slope shape map can be seen in **Figure 2b.**

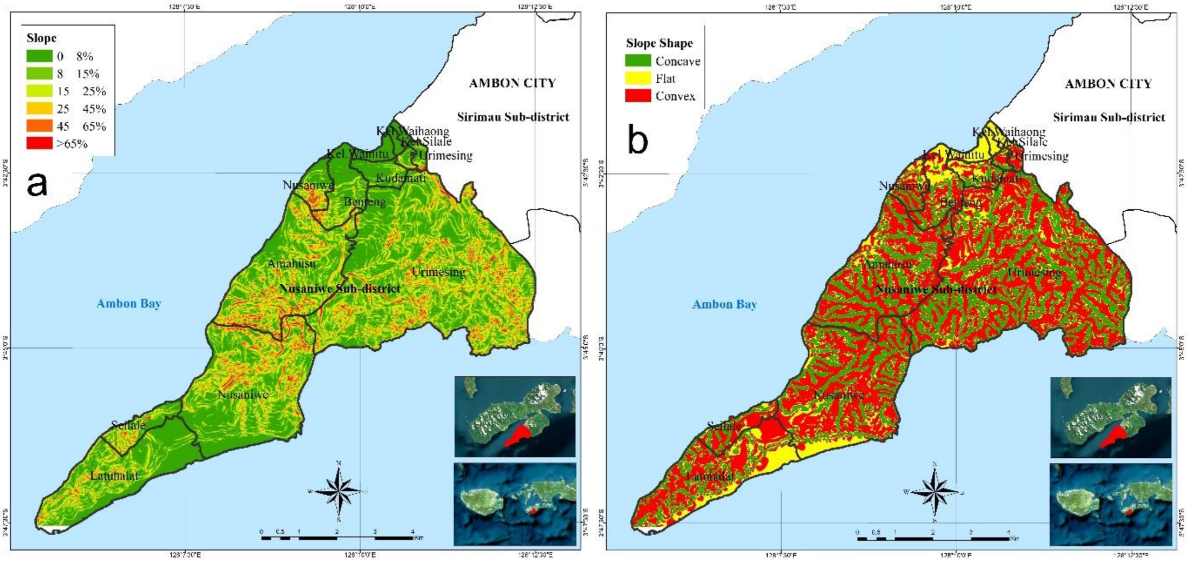

Figure 2. a. Slope Map, b. Slope Shape Map

Landslide Potential Areas

Landslide potential areas are areas that have certain physical and geological characteristics that make them susceptible to landslide events (Rahmat & Alawiyah, 2020; Putri et al., 2020; Gustaman et al., 2020; Ardinata et al., 2022; Marufah et al., 2020; Bastian et al., 2021; Alawiyah et al., 2020; Muara et al., 2021; Rahmat, 2019; Rahmat et al., 2021). Landslides occur when slope-forming material moves down or off the slope, which is a significant displacement of material and can be hazardous to life and property in the vicinity. The landslide potential class in Nusaniwe Sub-district is then classified into 5 classes consisting of very low class with an area of 1,867.12 ha or 39.86%, low landslide potential class has an area of 1,975.79 ha or 42.18%, medium landslide potential class has an area of 431.58 ha or 9.21%, high landslide potential class has an area of 409.51 ha or 8.74% of the total area of Nusaniwe sub-district. The results of the analysis of landslide potential areas in Nusaniwe Sub-district were then overlaid with settlement distribution data to predict the distribution and extent of affected settlements. Landslide-affected settlements refer to residential areas or locations that are located in areas that have a high level of landslide vulnerability (Shaw 1995). This means that the area is located in a zone that has geological and topographical characteristics that make it vulnerable to landslide events. In the very low landslide potential class, settlements predicted to be affected by landslides cover an area of 746.90 ha or 70.93%. Low class is 230.63 ha or 21.90%, medium class is 51.65 ha or 4.90% and high class has a high area of 23.83 ha or 2.26%.

Slope and slope shape have a close relationship with landslide potential in areas such as Nusaniwe Sub-district. High slopes and steep or unstable slope shapes tend to increase the risk of landslides . Strong gravity on slope-forming materials can cause displacement of these materials down or off the slope, which is the main characteristic of landslides. In addition, unstable or excessively steep slope shapes can affect soil stability, making it more prone to landslides, especially after intensive rainfall or climate change. In Nusaniwe sub-district, specific geological and topographical conditions can affect the distribution and frequency of landslides. Areas with high slopes and steep or unstable slope shapes tend to be landslide hotspots. Therefore, a good understanding of the relationship between slope and slope shape with landslide potential is essential for disaster planning and mitigation in this area. The map of landslide potential in Nusaniwe sub-district can be seen in **Figure 3.**

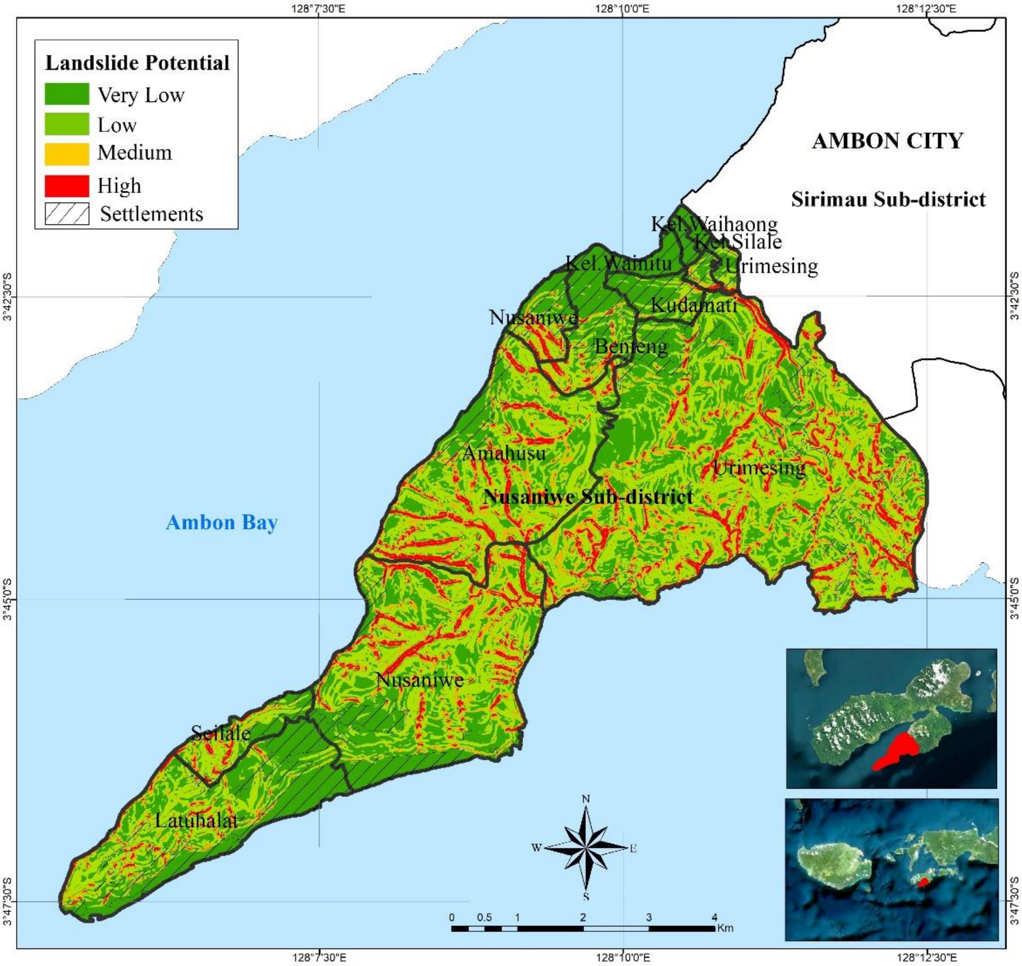

Figure 3. Map of landslide potential of Nusaniwe sub-district

Based on the results of this research, it is necessary to mitigate landslides in Nusaniwe Sub-district which involves a series of actions designed to reduce the risk and impact of landslides. Based on information from the sources provided, some important steps that can be taken include:

1) Risk Assessment and Inventory: The first step is to conduct a risk assessment and inventory of potential landslide areas. This involves identifying areas with high slopes, steep or unstable slope forms, and soil types prone to landslides. Knowledge of the distribution and frequency of landslides in Nusaniwe Sub-district, as mentioned in the source, is essential to determine which areas require mitigation interventions.
2) Infrastructure Development and Environmentally Friendly Development: Avoiding development in areas with landslide potential and promoting environmentally friendly development is essential. This includes avoiding development on steep slopes and ensuring that existing infrastructure is safe and does not exacerbate landslide potential.
3) Water and Erosion Management: Managing water and reducing soil erosion are key in reducing landslide risk. This can involve applying techniques such as terracing, planting ground cover trees, and efficient irrigation systems to reduce excessive water flow and reduce erosion.
4) Community Education and Awareness: Raising public awareness about landslide risks and ways to reduce them is essential. This can involve education campaigns, training, and community dialog to ensure that all community members understand the risks and the actions they can take to reduce the risks.
5) Development of Early Warning Systems: Developing and strengthening early warning systems for early detection of potential landslides is essential. This could involve the use of technology and geospatial data to detect changes that may signal landslide risk and allow sufficient time for intervention.

Through a combination of risk assessment, development of environmentally friendly infrastructure, water and erosion management, community education and awareness, and development of an early warning system, Nusaniwe sub-district can reduce the risk and impact of landslides.

CONCLUSION

Based on the research results of Identification of Potential Landslide Areas in Nusaniwe Sub-district using Slope Morphology Method, it can be concluded that an in-depth understanding of the relationship between slope slope and slope shape with landslide potential is crucial for natural disaster mitigation. This research makes a significant contribution in the effort to reduce landslide risk in the region by identifying vulnerable areas, as well as highlighting the importance of community education, environmentally friendly infrastructure development, and interdisciplinary collaboration in dealing with landslide challenges in tropical and humid climates such as Indonesia.

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