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Mapping of Landslide Prone Areas in Ternate City, Indonesia Using Geographic Information System

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Abstract

Landslides seriously threaten safety and sustainable development in Ternate City, Indonesia, due to tectonic activity, steep topography, high rainfall, and urbanization pressure. This study aims to map landslide-prone areas using Geographic Information System and the weighted overlay method by integrating seven parameters: elevation, slope, soil type, geology, land use, rainfall, and distance from active faults. The analysis results show that slopes >40% and areas near active faults have the highest risk. Based on the total area of 10,162 ha, 51% (5,197 ha) is classified as a high-risk zone, 31% (3,123 ha) as medium risk, and 18% (1,842 ha) as low risk. These findings emphasize the need for risk-zoning-based mitigation priorities, such as strengthening spatial planning policies, building disaster-resistant infrastructure, and educating communities. This research not only provides a scientific basis for development planning and disaster risk reduction in Ternate but also provides a methodological framework that can be adapted in other landslide-prone areas, especially in volcanic island regions with similar geographical conditions.

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Abstrak

Longsor menjadi ancaman serius bagi keselamatan dan pembangunan berkelanjutan di Kota Ternate, Indonesia, akibat aktivitas tektonik, topografi curam, curah hujan tinggi, serta tekanan urbanisasi. Penelitian ini bertujuan memetakan daerah rawan longsor menggunakan Sistem Informasi Geografis dan metode Weighted Overlay dengan mengintegrasikan tujuh parameter: elevasi, kemiringan lereng, jenis tanah, geologi, penggunaan lahan, curah hujan, dan jarak dari sesar aktif. Hasil analisis menunjukkan lereng >40% dan area dekat sesar aktif memiliki risiko tertinggi. Dari total luas 10.162 ha, 51% (5.197 ha) tergolong zona risiko tinggi, 31% (3.123 ha) risiko sedang, dan 18% (1.842 ha) risiko rendah. Temuan ini menegaskan perlunya prioritas mitigasi berbasis zonasi risiko, seperti penguatan kebijakan tata ruang, pembangunan infrastruktur tahan bencana, dan edukasi masyarakat. Penelitian ini tidak hanya menjadi dasar ilmiah bagi perencanaan pembangunan dan pengurangan risiko bencana di Ternate, tetapi juga menyediakan kerangka metodologis yang dapat diadaptasi di daerah rawan longsor lainnya, terutama di wilayah kepulauan vulkanik dengan kondisi geografis serupa.

INTRODUCTION

Ternate City, located in the Maluku Islands, Indonesia, has unique geological characteristics, including volcanic activity and steep topography. The presence of Mount Gamalama, an active volcano, greatly influences the geological and hydrological conditions of the region, making it vulnerable to various natural disasters, especially landslides (Zamroni et al., 2020). Landslides pose a serious threat to the safety and livelihoods of local communities, so a comprehensive understanding of the areas at risk is necessary (Mufidawati et al., 2021; Hussain et al., 2025). Climate change leading to increased frequency and intensity of rainfall also exacerbates the risk of landslides in Ternate (Lessy et al., 2024). Heavy rainfall can cause soil saturation, leading to slope instability, especially in areas with loose volcanic material. According to the Meteorology, Climatology and Geophysics Agency (BMKG), the region has experienced significant changes in rainfall patterns associated with global climate phenomena (BMKG, 2024). Understanding these changes is critical to predicting the potential for landslides and implementing effective mitigation strategies (Somae et al., 2022; Demirel et al., 2025).

Landslides and flash floods occurred in Ternate City, North Maluku Province, Indonesia, on August 25, 2024. The disaster was caused by prolonged heavy rainfall, which led to the flow of debris from the summit of Mount Gamalama (CNN Indonesia, 2024). The geological conditions of Ternate Island, consisting of uncompacted volcanic material, as well as deforestation in upstream areas, exacerbated the situation by reducing the soil's ability to absorb water (Sihasale et al., 2023; Rakuasa et al., 2024). This disaster caused 19 deaths, while 8 injured people are being treated intensively in several hospitals in Ternate. There were 25 houses and places of worship destroyed, and one bridge connecting the highway between villages on Ternate Island was broken (Santoso, 2024). Approximately 60 families or hundreds of people were evacuated to several safe places in Rua Village, Ternate City (Santoso, 2024). In response, the Ternate City Government issued a 14-day Disaster Emergency Response status, mobilized a Joint SAR Team with 400 personnel to search for missing victims, and planned post-disaster rehabilitation and reconstruction, including possible relocation of residents from high-risk areas. Therefore, it is important to map landslide-prone areas in Ternate to identify the most at-risk areas and plan appropriate mitigation measures.

The use of Geographic Information System (GIS) in mapping landslide prone areas has proven effective in providing accurate and comprehensive information (Souisa et al., 2016). The GIS has revolutionized the way researchers and policymakers analyze spatial data related to natural hazards (Khalil et al., 2020; Rakuasa et al., 2025a). GIS allows the integration of multiple data layers, including topography, land use, soil type, and rainfall patterns, to identify areas most vulnerable to landslides (Hehanussa et al., 2024; Rakuasa, 2025). This technology facilitates the visualization of complex relationships between various environmental factors, thereby supporting better decision-making in disaster management (Wang et al., 2017; Lokesh et al., 2025). The application of GIS in mapping landslide-prone areas has been recognized in various studies, highlighting the importance of this technology in improving community resilience (Latue et al., 2023). Mapping landslide-prone areas is not only useful for academic purposes but also has practical implications in spatial planning and disaster risk management (Bai et al., 2021). Authorities can take preventive measures by knowing the locations at risk, such as land use reorganization, construction of safer infrastructure, and raising public awareness about landslide risks (Rahim et al., 2018).

In addition, this mapping can also assist in the development of more effective disaster mitigation policies. In the context of Ternate, where population growth and infrastructure development are on the rise, a better understanding of landslide risk is essential to protect communities and existing assets. This research also contributes to the limited existing literature on disaster risk mapping in the North Maluku archipelago. By integrating geospatial data and statistical analysis, it is expected that the results of this study can provide new insights into the patterns and factors that influence the occurrence of landslides in Ternate. Furthermore, this research is expected to be a reference for further research related to disaster mitigation and natural resource management in landslide-prone areas. Thus, the results of this research are not only beneficial for Ternate but can also be applied in other areas that have similar characteristics. To achieve these objectives, this research will involve primary and secondary data collection, as well as analysis using GIS software.

Based on the above background, this study aims to provide a clear picture of landslide prone areas in Ternate and provide recommendations that can be used to reduce disaster risk in the future. Through a systematic and data-driven approach, it is expected that this research can make a significant contribution to disaster mitigation efforts in Indonesia. Finally, it is important to note that collaboration between the government, academia, and the community is necessary to effectively implement the results of this research. Only by working together can we reduce the impact of landslides and protect people's lives and property.

METHOD

This research was conducted in Ternate City, Ternate Island, North Maluku Province, Indonesia. Ternate is a volcanic island located in North Maluku Province, Indonesia (Figure 1). With its hilly and mountainous topography, the island faces a high risk of natural disasters, particularly landslides. The diverse geological structure and climatic conditions make Ternate highly vulnerable to this phenomenon, especially during the rainy season. This research uses monthly rainfall data for 2024 obtained from the Meteorology, Climatology, and Geophysics Agency, Indonesia; soil type data at scale 1:50,000 obtained from the Ternate City Regional Development Agency; geological maps and active fault distances at scale 1:50,000 obtained from the Geological Agency, Ministry of Energy and Mineral Resources of Indonesia; Digital Elevation Model (DEM) data obtained from the Indonesian Geospatial Information Agency; and land use data for 2024 obtained from the Ministry of Environment and Forestry of the Republic of Indonesia at scale 1:50,000.

This study uses the weighted overlay method in GIS to map landslide-prone areas by integrating seven parameters: elevation, slope, soil type, geology, land use, rainfall, and distance from active faults, through weighting and overlaying maps. This method was chosen for its ability to flexibly incorporate multiple parameters, be efficient in spatial analysis, and allow for weight adjustment based on the relative influence of each factor (Arshid et al., 2024). Its advantages lie in simplicity and clear visual interpretation, although it has disadvantages such as dependence on the subjectivity of weighting and simplification of complex interactions between parameters.

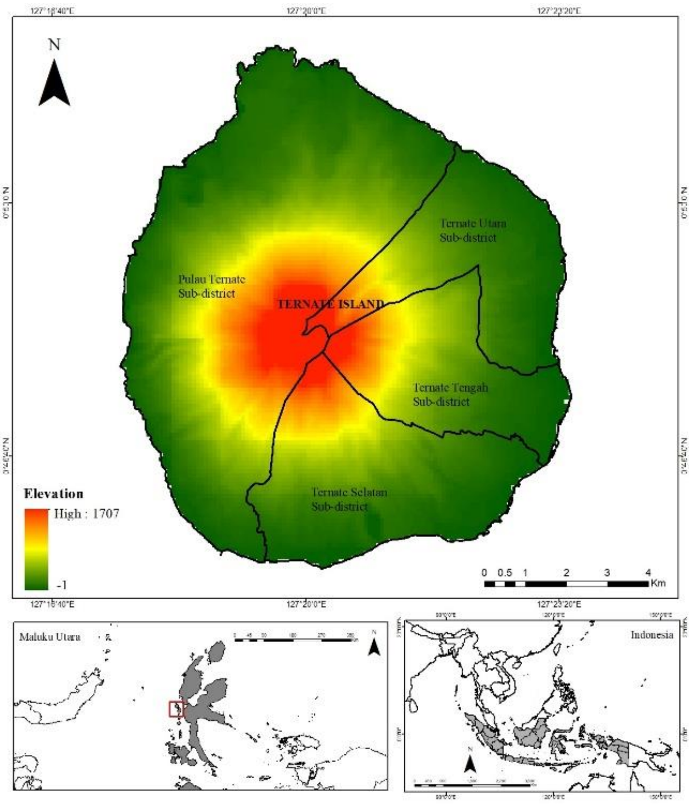

Figure 1. Research Location

Table 1. Landslide Variables

No.	Variables	Classification	Score	Weight
1	Slope	0- 8 %	1	15
		8-15 %	2	
		15-25 %	3	
		25-40 %	4	
		>40 %	5	
2	Elevation	0-20 masl	1	15
		21-50 masl	2	
		51-100 masl	3	
		101-300 masl	4	
		>300 masl	5	
3	Land Use	Built-up Land	4	10
		Open Land	5	
		Agricultural Land	3	
		Forest	2	
		Water Body	1	
4	Distance from active faults	0 -100 m	5	10
		101-250 m	4	
		251-300 m	3	
		301-350 m	2	
		>350 m	1	
5	Geology	Holocene Volcano Rocks (Qhv)	4	15
6	Soil Type	Regosol	4	15
7	Rainfall	2.000 - 2500 mm/year	4	20

Source: Abay et al., 2019; Demirel et al., 2025; Rakuasa et al.,2025a.

Seven physical variables slope, elevation, geology, soil type, land use, annual rainfall, and distance from active faults were integrated based on their influence on landslides that have been tested in previous studies, as well as the geomorphic characteristics of the region (Abay et al., 2019; Saaduddin et al., 2021; Kanwar et al., 2025). Each variable was assigned a score and weight through expert judgment and literature references (Table 1), then combined using the formula 1:

$$Lvi = \Sigma \ (Vs \times Vw) \qquad (1)$$

where Lvi is landslide vulnerability index, Vs is variable score , Vw is variable weight

The results were classified into low, medium, and high-risk zones through spatial analysis in ArcGIS 10.8. Landslide susceptibility maps were overlaid with settlement data to identify vulnerable infrastructure. Although the weighted overlay method offers flexibility in parameter integration and visual clarity, reliance on subjective weighting and simplification of factor interactions are drawbacks. This research provides practical recommendations for disaster-resilient urban planning as well as a framework that can be adapted in areas with similar geological disaster profiles.

RESULT AND DISCUSSION

Landslide Vulnerability Variable

Slope variable is one of the factors that affect the potential for landslides in Ternate City. From the data obtained, areas with a slope above 40% have an area of 3,013 ha, making it the category with the highest risk for landslides. This is in line with previous research, which states that steep slopes tend to be more prone to landslides, especially when influenced by other factors such as high rainfall and unstable soil conditions (Aditian et al., 2018). Meanwhile, areas with 0-8% slope have the lowest area of 1,042 ha, suggesting that flat areas have a lower risk for landslides. Further discussion shows that the slope category between 25-40% also shows a significant area of 2,256 ha, indicating that although not as extreme as slopes above 40%, these areas still require attention in landslide risk management. The slope categories of 15-25% and 8-15% have an area of 2,077 ha and 1,772 ha respectively, indicating that although the risk of landslides in these categories is lower, there is still potential that needs to be well managed. Better management would involve implementing zoning-based mitigation strategies, such as restricting high-risk development on slopes >40%, enforcing slope stabilization measures in moderate-risk zones (25-40%), and promoting sustainable land-use practices (e.g., terracing, afforestation) in lower-risk areas to reduce cumulative vulnerability (Kalmar et al., 2024). The slope map of Ternate City can be seen in Figure 2a.

The result of the elevation classification of Ternate City shows that areas with elevation above 300 masl have the largest area, which is 3,951 ha, indicating that areas with higher elevation tend to be more prone to landslides. This is in line with previous findings stating that mountainous or hilly areas with high elevation often experience landslides due to high rainfall and unstable soil conditions (Mirdda et al., 2022). In contrast, areas with elevation 0-20 masl have the lowest area of 925 ha, indicating that flat coastal areas have a lower risk of landslides. The elevation category area between 101-300 masl also shows a significant area of 2,667 ha, indicating that although not as high as the category above 300 masl, this area still has landslide potential that needs attention. The elevation categories of 51-100 masl and 21-50 masl have an area of 1,433 ha and 1,186 ha respectively, indicating that although the risk of landslides in these categories is lower, there is still attention that needs to be paid to land management and disaster mitigation. Land management includes risk-based land use management, such as limiting dense development in the medium elevation zone (51-300 masl) and implementing ground cover vegetation and effective drainage systems to maintain slope stability and reduce erosion (Asmare, 2022).

Elevation certainly has an effect on landslides as areas with higher elevation tend to have steeper slopes and higher rainfall, which can reduce soil stability and increase the risk of ground movement (Sugandhi et al., 2023). The elevation map of Ternate City can be seen in Figure 2b.

The rainfall map of Ternate City was made based on the precipitation data of 2023 - 2024 CRU TS v4.06, Climatic Research Unit (University of East Anglia), and it was found that the rainfall in Ternate City is evenly distributed with an annual average rainfall of 2,000 - 2500 mm/year. Rainfall certainly has a significant influence on the occurrence of landslides, especially due to the hilly and steep topography of the area. High rainfall can cause the soil to become saturated with water, reducing soil cohesion and slope stability. When the soil is saturated, the risk of ground movement increases, especially on steep slopes, where water can erode and weaken the soil structure (Rahim et al., 2018). In addition, high rainfall intensity can trigger rapid surface flow, which has the potential to erode soil and trigger landslides. The rainfall map of Ternate City can be seen in Figure 2c.

Land use has a significant impact on the potential for landslides. Based on the total land area of Ternate City, agricultural land dominates with an area of 9,014 ha, followed by protected forest with an area of 4,519 ha. Built-up land, which includes settlements and infrastructure, reaches 2,177 ha, while open land and water bodies are 442 ha and 71 ha respectively. Extensive agricultural land use, especially in areas with steep slopes, can increase the risk of landslides, as intensive agricultural practices often result in soil erosion and reduced slope stability. In addition, conversion of forest land to agricultural or built-up land can reduce vegetation that acts as a soil barrier, thereby increasing susceptibility to landslides (Rakuasa et al., 2025b). The results show that open land and water bodies, although smaller in area, also contribute to the hydrological dynamics in the area. Open land can increase surface flow during rainfall, which has the potential to erode soil and trigger landslides, especially in degraded areas. Meanwhile, existing water bodies can serve as a source of moisture that contributes to the saturation of surrounding soils (Saaduddin et al., 2021). Therefore, it is important to consider sustainable land use management and vegetation conservation to reduce the risk of landslides in Ternate. The land use map of Ternate City in 2024 can be seen in Figure 2d.

In general, the soil type of Ternate City is regosol, which is evenly distributed. Regosol soil type in Ternate City has a significant influence on landslide potential, mainly due to its physical and chemical characteristics. Regosols, which are generally formed from the weathering process of volcanic rocks, have a relatively light texture and good drainage. While these properties can be advantageous in terms of agriculture, under certain conditions, Regosols can become prone to landslides, especially when exposed to high rainfall. When Regosol soils are saturated with water due to heavy rainfall, their ability to hold soil particles is reduced, increasing the risk of soil movement. In addition, Regosols often have a thinner and less stable surface layer compared to other soil types, such as Andosols, which are more common in volcanic areas. When heavy rains occur, the top layer of Regosol can easily detach, especially on steep slopes, potentially triggering landslides. Therefore, proper land management and vegetation conservation are essential to reduce the risk of landslides in areas dominated by Regosol soils, especially in Ternate City, which has a hilly and steep topography. The Soil Type Map of Ternate City can be seen in Figure 2e.

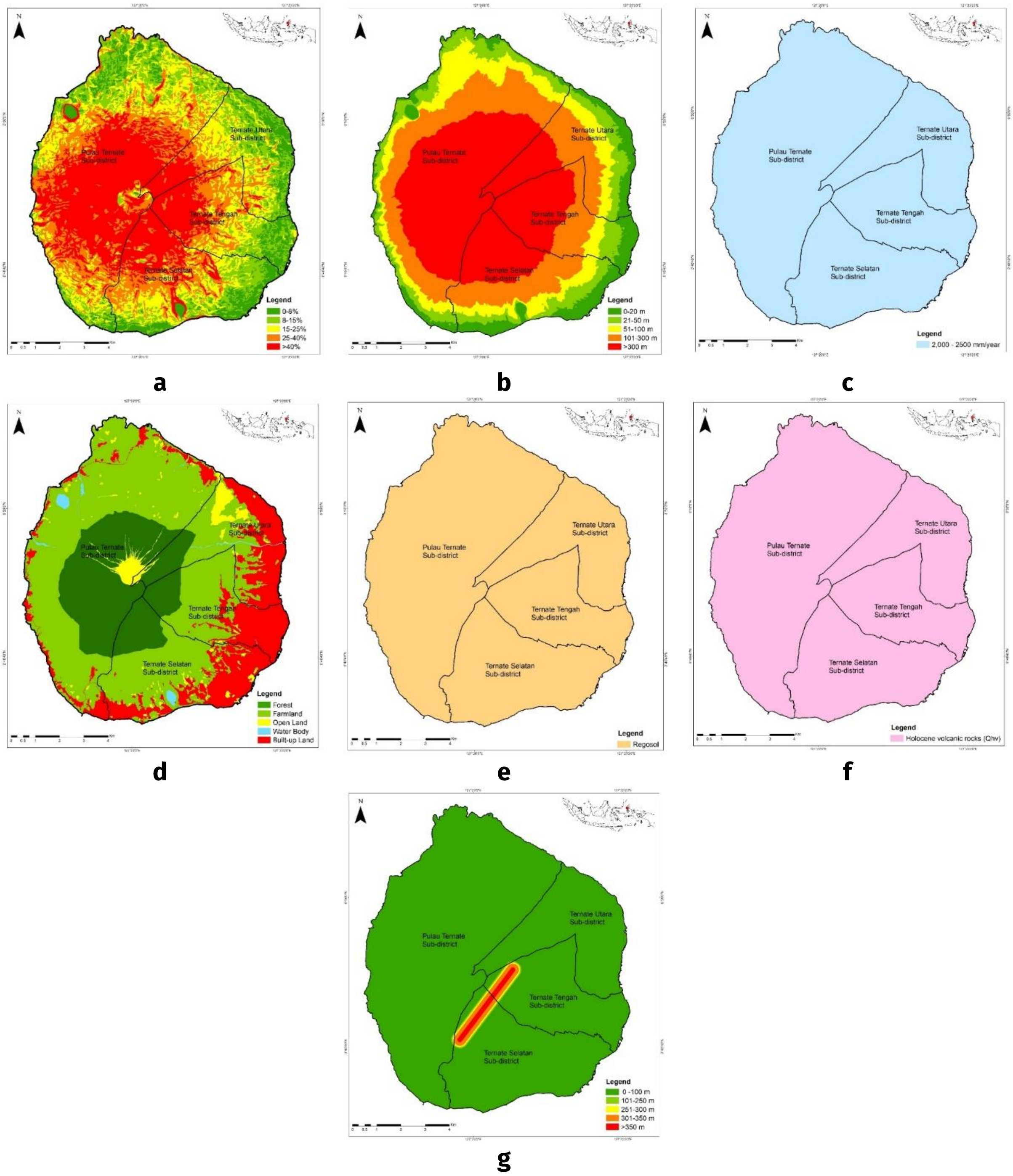

Figure 2. Landslide Variables: a) slope; b) elevation; c) rainfall; d) land use; e) soil type; f) geology; and g) distance from active fault

The geological map of Ternate sheet, North Maluku, scale 1:250,000, by Apandi & Sudana (1980) and the geological map of Ternate sheet from the interpretation of remote sensing imagery scale 1:50,000 by Sidarto (2010), show that the entire Ternate Island is in the Holocene volcanic rocks unit (Qhv). Holocene volcanic rocks (Qhv) in Ternate City have a significant influence on the potential for landslides, mainly due to their physical properties and geologic structure. These rocks, formed from relatively recent volcanic activity, often have different characteristics compared to older rocks. Holocene volcanic rocks tend to have high porosity and permeability, which can affect the movement of water in the soil (Jiang et al., 2025). When rainfall is high, water can quickly seep into these rock layers, causing excessive soil saturation and reducing cohesion between soil particles, increasing the risk of landslides. In addition, the geological structure of Holocene volcanic rocks is often characterized by steep slopes and unstable layers. When erosion or erosion due to water flow occurs, these layers can be dislodged easily, especially in areas that have experienced human activities such as land clearing for agriculture or settlements (Hussain et al., 2025). These activities can worsen the existing geological conditions, thus increasing the vulnerability to landslides. Therefore, it is important to consider geological characteristics and environmental conditions when planning land use and disaster risk mitigation in Ternate City, which has a high potential for landslides due to a combination of geological and climatic factors. The Geological Map of Ternate City can be seen in Figure 2f.

The effect of distance from active faults on landslides in Ternate is significant, as proximity to active faults can increase the risk of landslides. The study area is particularly influenced by the Gamalama Fault, a major active fault system in Ternate that contributes to seismic instability in the region. An active fault is a zone where ground movement can occur due to seismic activity, such as earthquakes. When an area is near an active fault, such as within a radius of 100 m or 250 m, the surrounding soil is more susceptible to vibrations and shifts that can trigger landslides. In the study in Ternate, the area within 100 m of an active fault showed 76 ha identified as landslide-prone, and at a distance of 250 m, the number increased to 125 ha. This suggests that the closer an area is to a fault, the greater the likelihood of landslides due to soil instability caused by seismic activity. In contrast, as the distance from the active fault increases, such as at distances of 300 m, 350 m, and more than 350 m, the number of areas identified as landslide-prone tends to decrease significantly. For example, at a distance of more than 350 m, there are 9,870 ha identified as not landslide prone. This suggests that areas further away from the active fault have better stability and lower landslide risk. Thus, distance from active faults becomes an important factor in landslide susceptibility analysis, and an understanding of this relationship can help in spatial planning and disaster mitigation in Ternate so as to reduce the negative impacts of potential landslides in the area (Saaduddin et al., 2021; Asmare, 2022). A map of the distance from active faults of Ternate City can be seen in Figure 2g.

Landslide Vulnerability Level

Landslide prone areas in Ternate City are then classified into 3 classes: low, medium, and high. Out of a total area of 10,162 ha, the low vulnerability area covers 1,842 ha or 18% of the total area. This area is considered to have a relatively small risk of landslide occurrence, due to factors such as a less steep slope, stable soil type, and lack of extreme rainfall. Nonetheless, it is important to keep monitoring these areas, as environmental changes or human activities may affect the stability of the soil in the future. Furthermore, the medium vulnerability category covers 3,123 ha or 31% of the total area.

This area shows greater landslide potential compared to the low category, but not as strong as the high category. Factors that may contribute to moderate vulnerability include steeper slopes, less stable soil types, and higher rainfall. Areas with moderate vulnerability deserve more attention in terms of land management and disaster mitigation, as they can be at risk of landslides under certain conditions, such as during heavy rains or earthquakes. The high vulnerability category, which covers 5,197 ha or 51% of the total area, indicates that more than half of Ternate is at significant risk of landslides. Factors contributing to this high vulnerability may include steep slopes, easily eroded soil types, and proximity to active faults. These areas require special attention in spatial planning and infrastructure development, as well as implementation of effective mitigation

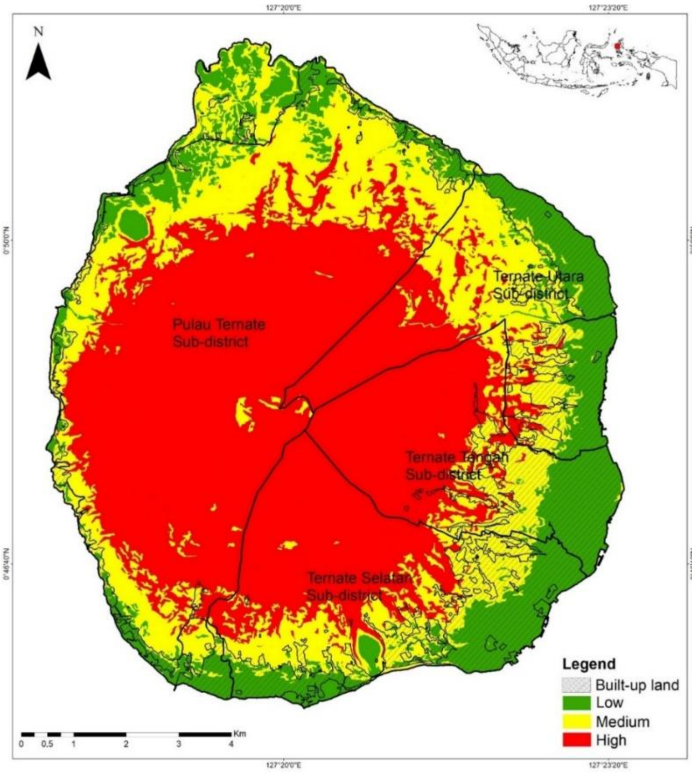

Figure 3. Landslide Vulnerability Map and Affected Built-up Land

measures. The Map of Landslide Vulnerability and Affected Built-up Land of Ternate City can be seen in Figure 3.

Landslide hazard class in North Ternate sub-district, there is an area of 2,926 ha classified in high category, followed by 1,557 ha in medium category, and 635 ha in low category. Meanwhile, Central Ternate sub-district has 842 ha with high vulnerability, 305 ha medium, and 260 ha low. In the South Ternate sub-district, the area with high vulnerability reaches 960 ha, with 603 ha medium and 490 ha low. Finally, North Ternate sub-district shows 469 ha with high vulnerability, 658 ha medium, and 457 ha low. These findings highlight the importance of paying special attention to high vulnerability sub-districts, especially in North Ternate, to develop effective disaster mitigation strategies and protect communities from landslide risk. The extent of landslide-prone areas can be seen in Figure 4.

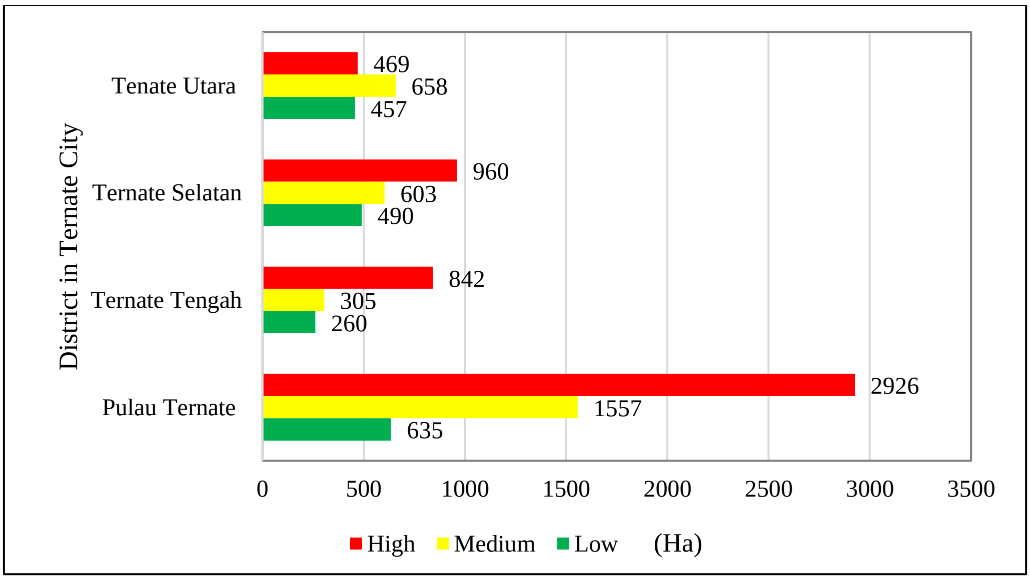

Figure 4. Diagram of Landslide Area per Sub-District in Ternate City

Distribution of Built-up Land in Landslide Prone Areas

Overlaying the landslide prone area data with the total built-up area data shows that 1,271 ha or 64% are in the low vulnerability category. This shows that most of the infrastructure and settlement developments are located in areas that are relatively safe from landslide risk. The existence of built-up land in this area can be considered a good step in reducing potential losses due to disasters, but it is still necessary to be aware of possible changes in environmental conditions that can affect soil stability. The medium vulnerability class covers 696 ha or 35% of the total built-up land. Although there is still a sizable proportion of development in this area, landslide vulnerability remains a concern. Areas of moderate vulnerability may experience the risk of landslides under certain conditions, such as during heavy rainfall or human activities that may alter soil characteristics. Therefore, it is important to implement good land management practices and conduct regular risk evaluations to minimize possible negative impacts. The high vulnerability class covers only 34 ha or 2% of the total developed land, indicating that development in areas with significant landslide risk is minimal. Nonetheless, the presence of infrastructure in these areas remains a major concern, as potential damage from landslides can have a major impact on public safety and economic losses.

Based on the overlay result of landslide prone area data with total built-up area data per sub-district in Ternate Island Sub-district, there are 185 ha of built-up land in low vulnerability area, 108 ha in medium area, and only 2 ha in high area, indicating that development in the risk area is very limited (Figure 4). In contrast, Ternate Tengah sub-district has 260 ha of built-up land in low areas, 305 ha in medium areas, and 842 ha in high areas, indicating a significant concentration of development in the risk zone. South Ternate sub-district recorded 490 ha of built-up land in low areas, 603 ha in medium areas, and 960 ha in high areas, indicating that many settlements are located in areas highly vulnerable to landslides. In the North Ternate sub-district, there are 457 ha of built-up land in low areas, 658 ha in medium areas, and 469 ha in high areas, indicating considerable development in risky areas. These findings emphasize the importance of better spatial management and effective disaster mitigation strategies to protect communities from potential landslide hazards, especially in sub-districts with significant built-up land in vulnerable areas.

The landslide that occurred in Rua Village, Ternate Island District, on August 25, 2024, was a disaster caused by a combination of geological and meteorological factors. Based on available information, this disaster occurred around 3:30 a.m. WIT and was triggered by moderate to high intensity rain that lasted for a long duration (Santoso, 2024). The material deposited in this landslide consisted of a mixture of loose material caused by increased erosional rates and surface water runoff on uncompacted rock and soil material. The affected area was 2.7 ha. The impact of this disaster was significant, with 19 people reported dead as a result of being buried by landslide material, while 8 others were injured. In addition, dozens of housing units were severely damaged as a result of being dragged and buried by landslide materials (CNN Indonesia, 2024). There were 25 houses and places of worship destroyed, and one bridge on the highway between villages on Ternate Island was broken. Approximately 60 families or hundreds of people were evacuated to several safe places in Rua Village, Ternate City (Ichi, 2024).

Based on the results of landslide prone area modeling, it is found that the landslide area in low class is 12 ha, medium class is 97 ha, high class is 377 ha and the residential area that is predicted to be affected by landslide in low class is 9 ha, medium class is 13 ha and high class is 377 ha (Figure 5). Factors causing these landslides include the morphology of the area, which is an alluvial fan plain with steep slopes, as well as soil conditions that cannot absorb water well due to deforestation and degradation of natural vegetation (Santoso, 2024). The interaction between high rainfall, morphology, and the soluble lithologic nature of alluvium creates ideal conditions for debris flows, known as debris flows or flash floods. Therefore, it is important to improve disaster mitigation efforts and community awareness of potential risks. The prediction results of the settlement area in landslide-prone areas per sub-district in Ternate City can be seen in Figure 5.

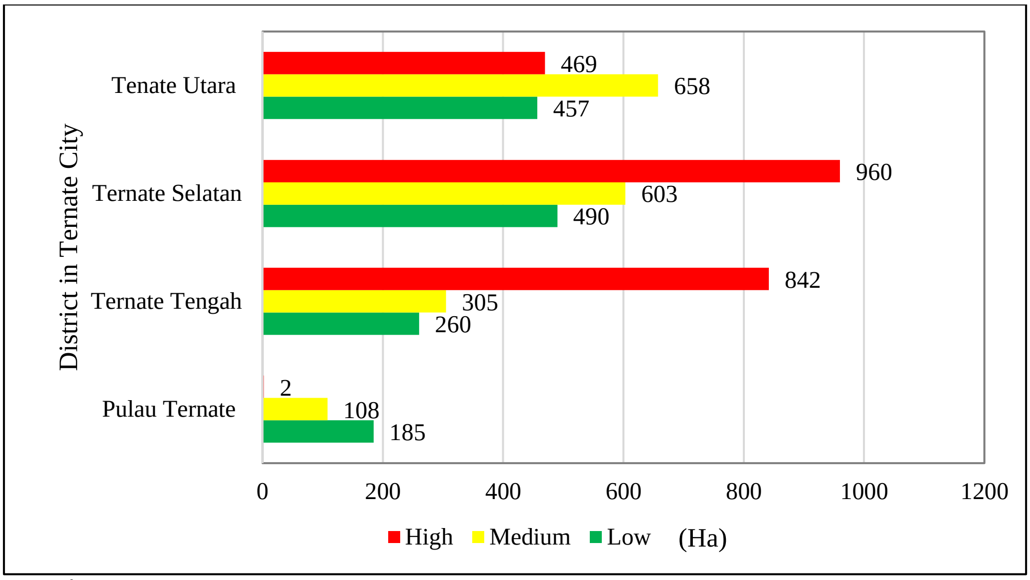

Figure 5. Diagram of Predicted Area of Settlements in Landslide-prone areas per Sub-District in Ternate City

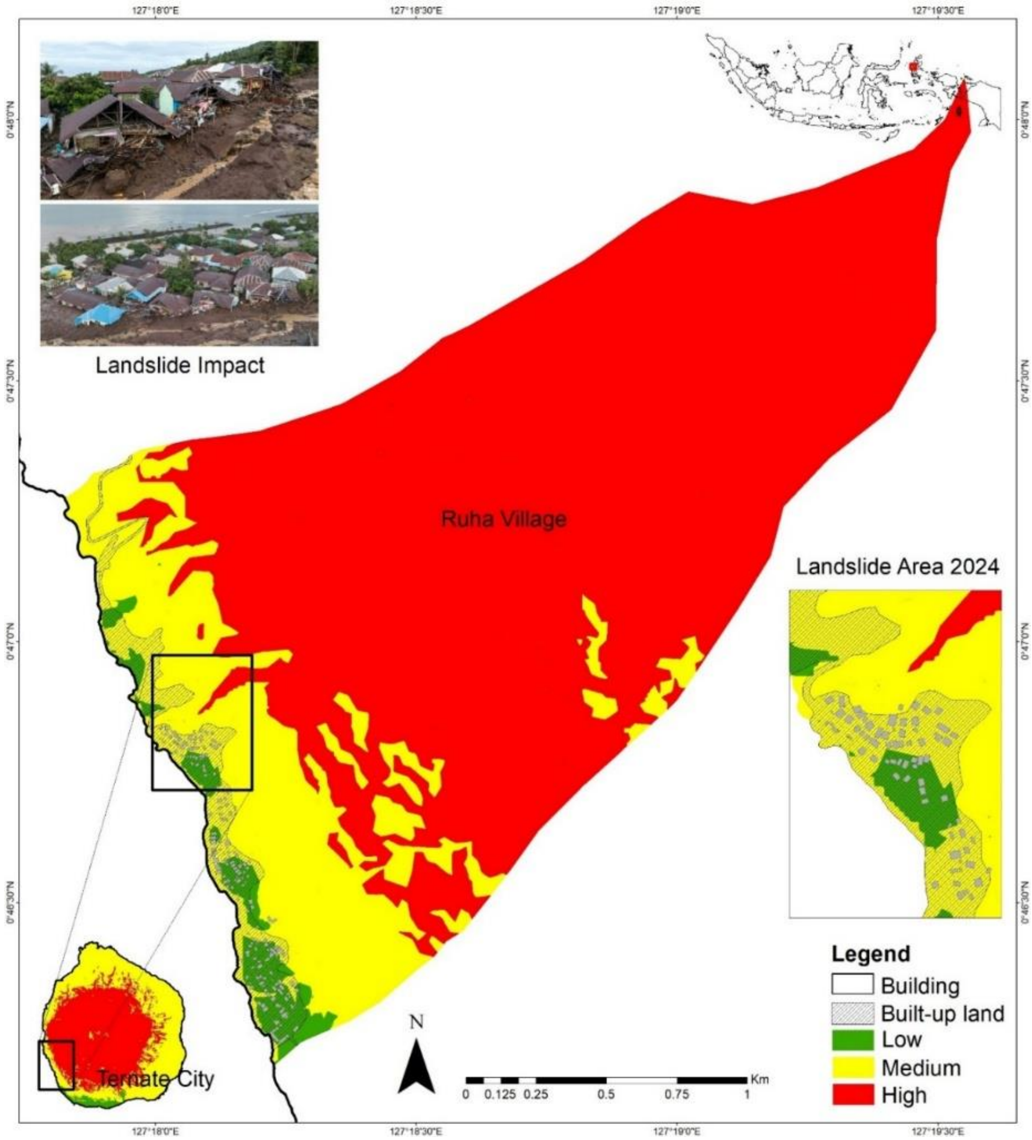

Figure 6. Map of Landslide Area in Ruha Village, Ternate City 2024

Recommendations for Landslide Disaster Mitigation in Ternate City

While this study provides important baseline GIS mapping of landslide-prone areas in Ternate City, we acknowledge several limitations in our methodology that point to opportunities for improved analysis. The current GIS approach, while valuable for initial spatial assessment, could be enhanced by incorporating machine learning algorithms to better analyze complex relationships between variables, statistical validation techniques to quantify uncertainty, and advanced data sources like LIDAR for more precise topographic identification. Our variable selection and mapping methods may have inherent limitations in accurately delineating landslide boundaries, particularly in areas with subtle geomorphological indicators.

Future research should consider integrating multiple analytical techniques, such as combining GIS with statistical models or artificial intelligence approaches, to improve prediction accuracy. These methodological advancements should inform mitigation strategies that include (1) comprehensive risk assessment using improved techniques, (2) sustainable land management focusing on slope stabilization, (3) disaster-resistant infrastructure development with proper drainage systems, and (4) community education programs. We recommend that policymakers view our current GIS-based findings as a first step in ongoing risk assessment that should be regularly updated with more sophisticated analyses as techniques and data availability improve in the region.

CONCLUSION

The results showed that Ternate city has a high vulnerability to landslides, influenced by various natural factors and human activities. The research successfully identified the most at-risk areas through analysis using GIS, which allows the integration of spatial data related to topography, soil type, land use, and rainfall patterns. The mapping results show that areas with steep topography, hilly elevations, and distance from active faults have a significant effect on soil stability, where the closer an area is to a fault, the greater the likelihood of landslides. In addition, this study emphasizes the importance of sustainable land management and safe infrastructure development to reduce landslide risk. Soil conservation practices, such as reforestation and the application of environmentally friendly farming techniques, can improve soil stability and reduce erosion.

The construction of effective drainage channels and retaining walls is also recommended to protect vulnerable areas. Educating and raising public awareness about landslide risk is an important aspect of disaster mitigation. By involving the community in training and socialization programs, it is expected that they can recognize the early signs of landslides and take the necessary steps to protect themselves. Overall, this research contributes significantly to the understanding of the patterns and factors influencing the occurrence of landslides in Ternate, as well as offering practical recommendations for disaster mitigation that can be implemented by the government and communities. With a systematic and data-driven approach, it is expected that mitigation efforts can reduce the negative impacts of landslides and improve community resilience in Ternate City.

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