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LANDSLIDE RISK IN JAYAPURA REGENCY USING PARAMETER WEIGHTING METHOD FOR DISASTER MITIGATION

Kristia Yuliawan[1*]
[1]Computer Science, STMIK Pesat Nabire
email : *christianpesat@gmail.com

Abstract: This study maps the vulnerability of landslides in Jayapura Regency, Indonesia, using a parameter weighting method within the framework of the Geographic Information System (GIS). The study identified key factors that contribute to landslide risk, including slope, soil type, rainfall, geology, and land use. The analysis revealed significant areas prone to landslides, with substantial portions classified as moderate to high risk. Comparison with the BNPB Inarisk method shows variations in the percentage of risk areas, highlighting the importance of the double assessment technique. The study underscores the need for an integrated, multidisciplinary approach to landslide risk management, emphasizing accurate data collection, land-use planning, and targeted mitigation strategies. These findings provide valuable insights for policymakers and disaster management agencies to minimize the impact of future landslides and promote sustainable development, especially in light of the 2019 landslide disaster in Sentani.
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Keywords: landslide; jayapura regency; parameter weighting method; inarisk BNPB methods; disaster mitigation.

Abstrak: Penelitian ini memetakan kerentanan tanah longsor di Kabupaten Jayapura, Indonesia, menggunakan metode pembobotan parameter dalam kerangka Sistem Informasi Geografis (GIS). Studi ini mengidentifikasi faktor-faktor kunci yang berkontribusi terhadap risiko tanah longsor, termasuk kemiringan, jenis tanah, curah hujan, geologi, dan penggunaan lahan. Analisis mengungkapkan area signifikan yang rentan terhadap tanah longsor, dengan porsi substansial diklasifikasikan sebagai risiko sedang hingga tinggi. Perbandingan dengan metode BNPB Inarisk menunjukkan variasi persentase area risiko, menyoroti pentingnya teknik penilaian ganda. Studi ini menggarisbawahi perlunya pendekatan multidisiplin yang terintegrasi untuk manajemen risiko tanah longsor, menekankan pengumpulan data yang akurat, perencanaan penggunaan lahan, dan strategi mitigasi yang ditargetkan. Temuan ini memberikan wawasan berharga bagi pembuat kebijakan dan lembaga penanggulangan bencana untuk meminimalkan dampak tanah longsor di masa depan dan mempromosikan pembangunan berkelanjutan, terutama mengingat bencana tanah longsor tahun 2019 di Sentani.
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Kata kunci: tanah longsor; kabupaten jayapura; metode pembobotan parameter; metode BNPB Inarisk; mitigasi bencana.

INTRODUCTION

Studying landslide risk is beneficial because it helps us understand the factors that cause landslides and their relationships with each other. Some of the causes of landslides are steep slopes, very thick and loose types of volcanic rocks that form very thick soils, inappropriate land use patterns, poor drainage systems that can increase pressure on slopes, extreme rainfall, and development that does

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not pay attention to the environment[1]. Other consequences of landslides can lead to the death of people and damage to infrastructure, buildings, and agriculture. Landslides can also cause deforestation, soil erosion, and destruction of natural habitats, all of which can have lasting environmental impacts[2]. Research related to landslides can provide benefits in providing information on land use planning and infrastructure development to minimize the risk of landslides[3]. The factors affecting landslide risk can be directed to reduce the potential risk of landslide disasters.

The diverse topography of Jayapura Regency, which includes lowlands, mountains, and coastal areas, is similar to that of many regions in Indonesia. Most of Jayapura Regency is mountainous, including part of the Cyclops Mountains. Its steep slopes and distinct contours increase the likelihood of landslides, particularly during heavy rainfall. One of the most severe landslides and floods occurred in March 2019 in Jayapura Regency, particularly in Sentani. Heavy rain caused landslides and overflowing rivers, resulting in flash floods. Dozens of people died, hundreds were left homeless, and thousands were affected by the disaster. Infrastructure, such as houses, bridges, and roads, suffered severe damage. Head of BNPB Data and Information Center Sutopo Purwo Nugroho stated that the encroachment of 43,030 people in the Cyclops Nature Reserve since 2003, the use of mixed dry land covering an area of 2,415 ha of Water Storage Area (DTA), the cutting of trees for land clearing, housing, and timber needs, as well as the presence of quarry mines were the causes of this landslide and flood[4].

Landslide disaster mitigation planning can be used to minimize threats and vulnerabilities and to optimize capacity. One way to do this is to map landslide-prone areas using the Geographic Information System (GIS) to determine appropriate mitigation strategies based on the condition of the area[5]. Mapping using Geographic Information Systems (GIS) is essential for determining disaster mitigation strategies for various natural disasters, such as landslides, droughts, and floods. GIS enables the integration and analysis of a wide range of spatial data, such as topography, land use, soil type, and rainfall patterns, to identify areas vulnerable to such disasters and assess their vulnerability[6]. Some of the factors taken into account in GIS analysis to determine landslide topography and soil type include rainfall, slope, soil type, land use or cover, geology, and groundwater conditions[7].

One of the landslide mapping techniques in GIS is to provide weighting and assessment to map landslide vulnerability. This technique assigns weights to several parameters and scores to each parameter based on its contribution to landslide vulnerability. Then, these parameters are overlaid to generate a landslide vulnerability map[8]. Slope, soil type, rainfall, land use, and geological factors are some of the parameters used in landslide vulnerability mapping. One of the advantages of the weighting method in mapping landslide vulnerability is that it is so simple and easy to use, that many people can use it[9].

Research conducted by Farouki Dinda Rassarandi and Bungaran Roy Satria Tambunan entitled the application of fuzz logic in the creation of an element at risk map of the flood overflow disaster of the Bengkulu River in Bengkulu City shows that the application of fuzzy logic is effective in making a map of flood risk elements in the Bengkulu River River, Bengkulu City, which allows the identification of areas with different levels of

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vulnerability to flooding [10]. Research conducted by Veybi Djoharam, et al. on Flood Management Models: A Systematic Review and Directions for the Future shows that future flood management needs to integrate multidisciplinary approaches, utilize modern technology, and involve the active participation of communities to achieve sustainable solutions.[11]. Research conducted by Agus Setyo Muntohar, et al. on The Spatial Model using TRIGRS to determine Rainfall-Induced Landslides in Banjarnegara, Central Java, Indonesia shows that the TRIGRS spatial model is effective in predicting the location of landslides due to rainfall in Banjarnegara, Central Java, Indonesia, by comparing the prediction results with field observations of landslides[12].

Research conducted by Aisyah Nur Isneni, et al. entitled Analysis of the Distribution of Landslide-prone Areas Using Remote Sensing and Analytical Hierarchy Process (AHP) in Magelang Regency, Central Java Province showed that the combination of remote sensing and Analytical Hierarchy Process (AHP) was effective in mapping the distribution of landslide-prone areas in Magelang Regency, by identifying the most influential geological and environmental factors[13]. Research conducted by Sri Fauza Pratiwi, et al. on the Study and Evaluation of Landslide Disasters in Tanjungsari District to RT/RW Bogor Regency shows that RT/RW Bogor Regency needs to be evaluated and adjusted to the conditions of landslide disaster vulnerability in Tanjungsari District to minimize disaster risk[14]. Research conducted by M.R Gojali, et al. on the Spatial Modeling Model of Landslide Hazard in the Ciliwung Hulu Watershed, Bogor Regency concluded that factors such as slope slope, rainfall, soil type, and land use have a significant influence on the potential for landslide hazards in the region[15]. Research conducted by Imam A. Sadisun, et al. on Landslide susceptibility zonation of Rongga District and Surrounding Areas using weight of evidence (WoE) method shows the effectiveness of the method in identifying high-risk areas based on geological and environmental factors[16]. Research conducted by Desi Permata Sari1, et al on Landslide susceptibility mapping in Berastagi district with regency on geographic information systems showed the identification of high-risk areas based on factors such as slope, rainfall, land use, and soil type[17].

In landslide vulnerability mapping, weighting methods are used to limit each parameter. The weighting process can be subjective and vary depending on the field of study and research objectives. In this study, the determination of parameters was based on the opinion of experts who assessed each parameter based on their knowledge of the region hit by landslides and the factors contributing to landslides. This study focuses on the risk of landslides because landslides are one of the most frequent natural disasters in Jayapura Regency and there are other reasons why they occur the development of modern technology, such as Geographic Information Systems, allows researchers to study landslides more efficiently and effectively[18].

METHOD

Geology and morphology of the region

In landslide vulnerability mapping, the parameter weighting method involves collecting and analyzing data on various factors that affect landslide disasters. Landslide parameter data were obtained from InaRISK BNPB, including

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geographical, risk, and historical data. InaRISK BNPB is a system developed by Indonesia's National Disaster Management Agency (BNPB) to manage and analyze disaster risk-related information. Jayapura Regency is located between 129°00'16"-141°01'47" East Longitude, 2°23'10" North Latitude, and 9°15'00" South latitude.

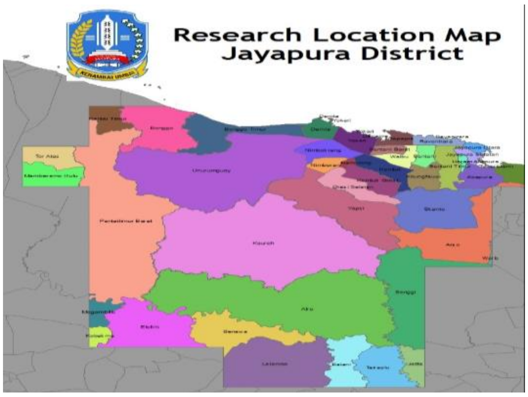

Figure 1. Jayapura Regency Administration Map as a Research Location

Research Design

Rainfall, geological conditions, soil type, and slope slope are some of the natural factors that can cause landslides, other factors come from human intervention such as land cover[19]. The Center for Volcanology and Geological Hazard Mitigation (PVMBG) and similar institutions analyze various geological, topographical, hydrological, and geotechnical factors to compile and determine landslide vulnerability zones. The creation of a map of the vulnerability zone of ground movement must be based on accurate data, as shown in Figure 2.

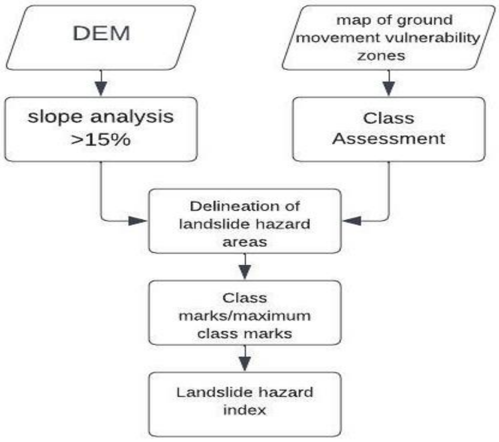

Figure 2. The process flow of making maps based on vulnerability zone maps Land movement (Source: BNPB, 2016)

RESULT AND DISCUSSION

The distribution of landslide risk can be identified and assessed based on several parameters that affect the potential for landslides. The weighting of these parameters can be performed using a risk analysis approach. Some parameters that are generally considered in landslide risk weighting include slope, rainfall, soil type, land use, and geological factors.

Soil Type

High-Volume Change Clay Soil (HVCCS) is a common type of soil in the United States and has the potential to cause landslides, especially expansive landslides. These landslides can cause a variety of infrastructure problems, including landslides on highway embankments[20]. Because of their high porosity and permeability, sandy soils can cause landslides, and water-saturated sandy soils are less stable and prone to landslides than other soil types.

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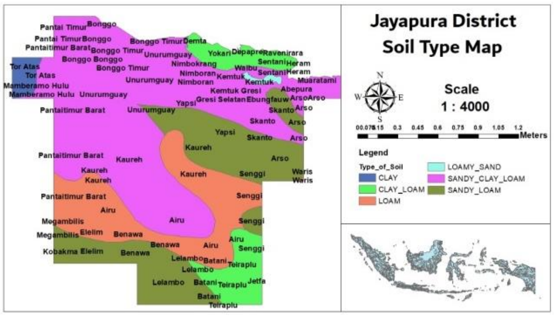

Figure 3. Soil Type Map

The type of soil in Jayapura Regency based on the soil type map issued by FAO (*Food and Agriculture Organization*) shows that Jayapura Regency consists of several types of soil, namely clay, clay, loamy sandy, sandy clay (sandy clay), and sandy loam.

Slope

Landslides can be caused by the angle of inclination or slope. Landslides occur when the angle of inclination exceeds a critical point, causing instability and downward movement of the soil and rocks. Some factors that can cause landslides include the historical slope time of the slope surface, displacement, and slope surface slope angle[21]. The angle of inclination, the amount of water present, and the type of soil are factors that can cause slopes to experience landslides, research shows that slopes with an angle of more than 30 degrees are more susceptible to landslides[22]. To predict and reduce landslide risk, it is important to understand the relationship between slope angle, displacement, and slope angle.

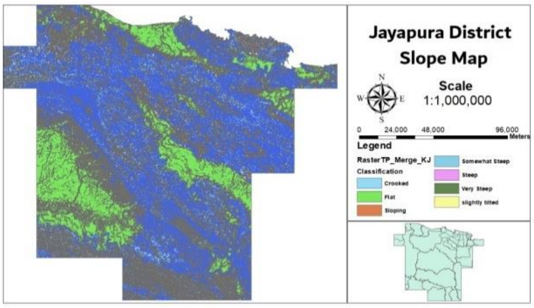

Figure 4. Slope Map

The results show that Jayapura Regency has slopes with slope angles between 15-30 degrees with a crooked classification that has a percentage of 21.70%; thus, this slope angle is very prone to landslides.

Rainfall

Landslides caused by rainfall are the main cause of landslides, particularly in mountainous areas. Landslides caused by rainfall can endanger the lives and property of people living in hilly areas[23]. The soil can expand due to high rainfall, especially in areas with large soils, such as red-layer weathered soil; This expansion is due to the hydration of soil particles and the influence of particle orientation. If there is a lot of rain, the pore pressure of the soil increases, which can cause landslides in areas with weak rock structures or unstable slopes. Although heavy rainfall can cause landslides, it is not the only cause of landslides. Soil composition, slope stability, and deforestation are other factors that can cause landslides, in addition to rainfall.

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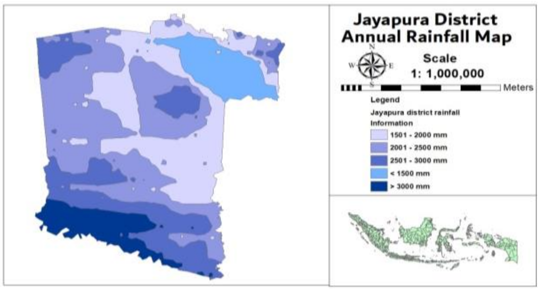

Figure 5. Annual Rainfall Map

The results show that Jayapura Regency has a yearly rainfall of 25.88% with a wet classification with an area of 4853051685, and 9.42% with a very wet classification with an area of 1768024608.

Geological Factor

The geological conditions of the Jayapura Regency consist of 25 types of rocks, but four types of rocks dominate: alluvium rock types (18.9 %) and unknown formation rock types by 17.05%, namely Aurimi Formation rock types (11.59 %) and Makats Formation rock types (10.49 %). Alluvium rock is a loose type of unconsolidated soil or sediment (not cemented into solid rock) that is more susceptible to erosion and movement.

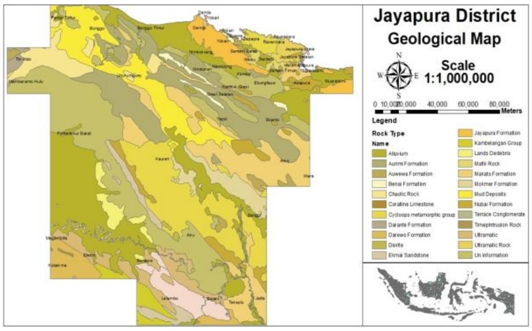

Figure 6. Geologic Map

Land Use

Human actions, such as land conversion and improper land management, have been identified as major contributing factors to landslide occurrence. Uncontrolled forest clearing, for example, can lead to the loss of vegetation cover, an increased risk of landslides, and decreased soil stability and surface runoff. This suggests that improper land transformation can be a major cause of landslides, In addition, unplanned development due to urbanization and increased development activity can lead to improper and rushed land use, which can increase the risk of landslides.

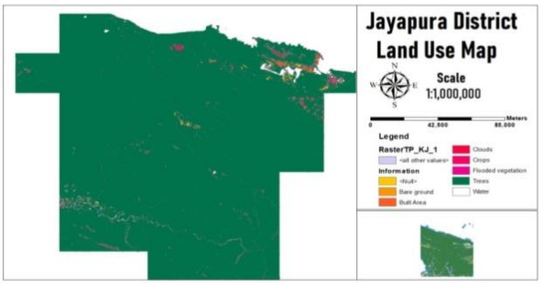

Figure 7. Land Use Map

The results of processing land use data show that in Jayapura Regency, forest land is dominant at 97.30%. Forests play an important role in preventing landslides and maintaining soil stability because massive deforestation can reduce soil resistance to erosion and landslides.

The calculation of landslide risk is based on a combination of rainfall parameters, soil type, slope, geological factors, and land cover, involving an integrative analysis of these factors. After scoring each parameter to produce a forecast of the landslide risk area in Jayapura Regency, the results are as follows:

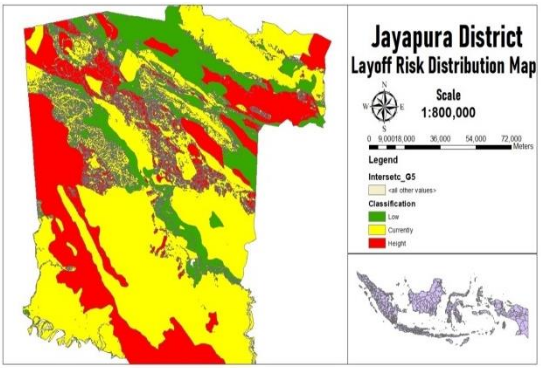

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Figure 8. Longsor Risk Spread Map with Parameter Bombing

Based on landslide risk analysis, the Jayapura Regency area has 16.34% low-risk areas, 53.26% medium-risk areas, and 30.38% high-risk landslides.

Distribution of Risk Areas Based on the BNPB Inarisk Method

The BNPB Inarisk method is a risk assessment and mapping technique used to analyze and predict the distribution of areas prone to landslides. This method involves collecting relevant data, using spatial modeling and mapping techniques, assessing risk levels, and validating the results.

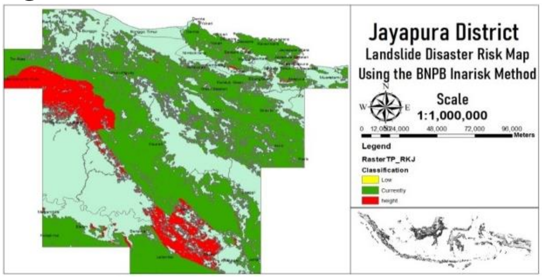

Figure 8. Landslide Risk Map based on BNPB's Inarisk method

Based on the results of landslide risk analysis using the Inarisk method, BNPB showed that the Jayapura Regency area has a low risk of 4.47%, a medium risk of 77.95%, and a high risk of 17.75 area of Jayapura Regency.

CONCLUSION

This study successfully mapped landslide vulnerability in Jayapura Regency using a parameter-weighting GIS approach, identifying key risk factors like steep slopes, sandy clay soils, high rainfall, and geological susceptibility. The analysis revealed significant medium to high-risk areas, with variations compared to the BNPB Inarisk method, emphasizing the need for diverse assessment techniques. The findings underscore the importance of integrated, multidisciplinary strategies for landslide risk management, highlighting the necessity of accurate data, proper land use planning, and targeted mitigation. The 2019 Sentani disaster reinforces the urgency for enhanced preparedness and risk reduction, with this research providing valuable insights for policymakers to minimize future landslide impacts and promote sustainable development.

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