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Spatial Analysis of Landslide Potential Using Modification of the Storie In-dex Method in the Wae Batu Gajah Watershed, Ambon City, Indonesia

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A B S T R A C T

Based on data on landslide disaster events in 2022, it shows that the Wae Batu Gajah watershed is a land-slide-prone area in Ambon City. The development of increasing population settlements in this area will cer-tainly increase the risk of landslides that are getting higher and higher. Based on this, it is necessary to con-duct spatial analysis of landslide-prone areas in the Wae Batu Gajah watershed. This study aims to analyze the potential for landslides and their exposure to settlements in the Wae Batu Gajah watershed, Ambon City using the Storie Index method. The results showed that the potential for landslides in the Wae Batu Gajah watershed is a hazard class, namely not potential, low, medium, high. The high landslide potential class dom-inates the Wae Batu Gajah watershed, covering an area of 280.19 ha or 43.67% spread across the middle and upper reaches of the watershed. An area of 98.05 ha or 47.82% of the area of residential land located in land-slide-prone areas with low potential located in the lower reaches of rivers with marbles of 0-2% and 2-8% which are relatively sloping and flat. The results of the study are expected to help the Ambon City govern-ment in efforts to mitigate landslide disasters in the future and in spatial planning efforts based on disaster mitigation

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INTRODUCTION

Landslides are one of the natural disasters that result in property losses, casualties, and cause damage to infrastructure such as housing, industry and agricultural land which have an impact on social conditions and economic decline in an area (Shinohara & Kume, 2022). Landslides that occur in Ambon City are caused by natural factors and human factors. Natural factors consist of climate change, high rainfall, steep topography, geological activities such as earthquakes, unstable soil conditions and human factors that can cause landslides in an area are agricultural activities, mining, deforestation, development that does not pay attention to environmental aspects. In many cases, landslides are the result of interaction between natural and human factors. Therefore, it requires good management and handling from the authorities and local communities to prevent landslides and reduce their impacts. The danger of landslides in Ambon City from time to time increasingly threatens the lives of residents living in mountainside areas (Rakuasa & Rifai, 2021; Rakuasa et al., 2022).

The condition of Ambon City which is hilly and has a steep slope makes Ambon City often occur landslides (Sugandhi et al., 2023). The research conducted by Rakuasa et al., (2022) used a variety of slopes and slope shapes in a row and generally illustrated that the city of Ambon is a landslide-prone area with. Geographically, the Wae Batu Gajah watershed (DAS) is on the slopes of the mountain where there are frequent landslides in the rainy season. The increase in population and the development of built-up land that is increasing in the Wae Batu Gajah watershed (Rakuasa et al., 2022), which is a landslide-prone area, will certainly increase the risk of landslides which is getting higher. Based on this, it is necessary to conduct spatial analysis of landslide-prone areas in the Wae Batu Gajah watershed.

Based on data on landslide events in Ambon City in 2022, it is known that there are 13 (thirteen) landslide points. Landslide disasters that occurred in 13 (thirteen) points, among others, in Batu Merah Sirimau District (In front of the PPN Tantui Mosque), RT 031 / RW 011 Halong Baru Baguala District, RT 005 / RW 007 Batu Meja, Sirimau District, RT 005 / RW 003 Karpan Sirimau District, RT 004 / RW 004 Batu Gajah Sirimau District, RT 006 / RW 016 Batu Merah Negeri Sirimau District, RT 004/RW 004 Batu Gajah Sirimau District (BPBD Ambon, 2022). Based on landslide data in 2022, it is known that Batu Gajah and Batu Meja Villages are villages geographically located in the Wae Batu Gajah watershed. This shows that the Wae Batu Gajah watershed is an area prone to landslides. Spatial analysis of landslide prone has an important role to map landslide-prone areas as the first step in efforts to mitigate landslide disasters in the future (Hamida & Widyasamratri, 2019). Geographic Information System is a tool that plays an important role in identifying potential landslide areas spatially and temporally in Ambon City (Bhunia & Shit, 2022; (Pakniany et al., 2023)

One method that is quite effective for analyzing landslide-prone areas is the stories index method. The storie index method is a grouping of variables that affect the occurrence of landslides, namely, land use, slope, soil type and rainfall

(Ristya et al., 2019). Based on this background, it is necessary to carry out a disaster mitigation effort by identifying landslide-prone areas in South Leitimur District and is expected to be used to minimize the dangers and losses from landslide disasters in the future. This study aims to analyze the potential for landslides and their exposure to settlements in the Wae Batu Gajah watershed, Ambon City using the Storie Index method.

METHODOLOGY

This research was conducted in the Wae Batu Gajah watershed, which is geographically located in Ambon City, Maluku Province. The modeling used in the study is modeling with the Stories Index.The data used for this study included National DEM data to process slope variables, rainfall data obtained from the Ambon City BMKG, ambon city soil type map data scale 1; 50,000 were obtained from BAPEKOT Ambon, and land cover data were obtained from the results of the interpretation and classification of SPOT 7 images of Ambon City obtained from BAPEKOT Ambon. The software used for the process of processing and analyzing data in this study is Microsoft Office 365 and ArcGIS 10.8. Based on the data obtained, it is then processed into variables that affect the potential for landslides in the Wae Batu Gajah watershed, Ambon City uses the Index storie method modified from the research of (Ristya et al., 2019; Somae et al., 2022). These variables were then carried out spatial analysis using weighting and scoring methods referring to the studies of Ristya et al., (2019). Data processing using Index Stories starts from; Determination of the dignity of each variable used, more research variables can be seen in Table 1. After all variables are given a score / dignity before combining using the tool union.

Table 1. Landslide Potential Variables

Variable	Class	Skor
Land Cover	Not Agricultural Land	1
	Agricultural Land	3
	Built-up Land	4
	Water Body	5
	Open Field	5
Slope	0-2 %	1
	2-8%	3
	8-15%	4
	15-45%	5
	45-65%	5
	>65%	6
Soil Type	Kambisol	4
	Rendzina	2
Rainfall	>3,000 mm/month	6

Source; (Ristya et al., 2019)

The classification of potential landslides begins with calculating the total value using the following Stories Index forecasting.

$L = A \times B/10 \times C \times 10 \times D/1$……..(1)

L= Landslide Potential Level
A= Land Cover
B= Slope
C= Soil Type
D= Rainfall

Then the stories index values will be classified based on the classification of potential landslides in table 2. The map of existing landslide potential areas is then overlaid with built-up land/settlement data obtained from land cover data to find out the distribution of built-up land/settlements that are in the landslide potential class.

Table 2. Classification of Potential Landslides in the Stories Index method

Rainfall	Soil Type	Slope	Land Cover	Weight Analysis	Weight Class Value	Landslide Potential Level
1	1	1	1	0,001	<0,001	No Potential
2	2	2	2	0,016	0,001 - 0,016	Low
3	3	3	3	0,081	0,016 - 0,081	Medium
4	4	4	4	0,256	0,081 – 0,256	
5	4	5	5	0,4	>0,256	High
5	4	6	5	0,48	>0,256	

Source; (Sobirin & Ramadhan, 2017)

RESULTS

Landslide Potential Variables

Variables of landslide potential in the Wae Batu Gajah watershed, Ambon City consist of rainfall, soil type, slope slope, land cover. The marble factor is the main factor in determining the degree of vulnerability (Ristya et al., 2019). Based on the results of the slope classification in Figure 1, it is known that the Wae Batu Gajah watershed has various slope classes, starting from slopes between 0-2% with an area of 74.57 ha, slopes of 2-8% covering an area of 155.17 ha, slopes of 8-15% covering an area of 202.62 ha, slopes of 15-45% covering an area of 209.15 ha. According to Rakuasa & Rifai (2021), the steeper the slope of the slope, the greater the potential for landslides in an area to occur, and vice versa, the smaller the magnitude of the slope, the smaller the potential for landslides that occur in an area.

The land cover of the Wae Batu Gajah watershed in Figure 2 consists of built-up land covering an area of 205.01 ha, open land covering an area of 4.20 ha, agricultural land consisting of 201.83 ha, non-agricultural areas covering an area of 227.19 ha and water bodies covering an area of 3.27 ha. Land cover is one of the variables for landslide potential analysis. According to Firdaus & Usman, (2022), stated that land use can be a factor controlling soil movement and

increasing the risk of land movement because land use will affect existing land cover. Rakuasa et al., (2022), stated that a good ground cover vegetation such as thick grass or dense jungle will eliminate the influence of rain and topography on landslides.

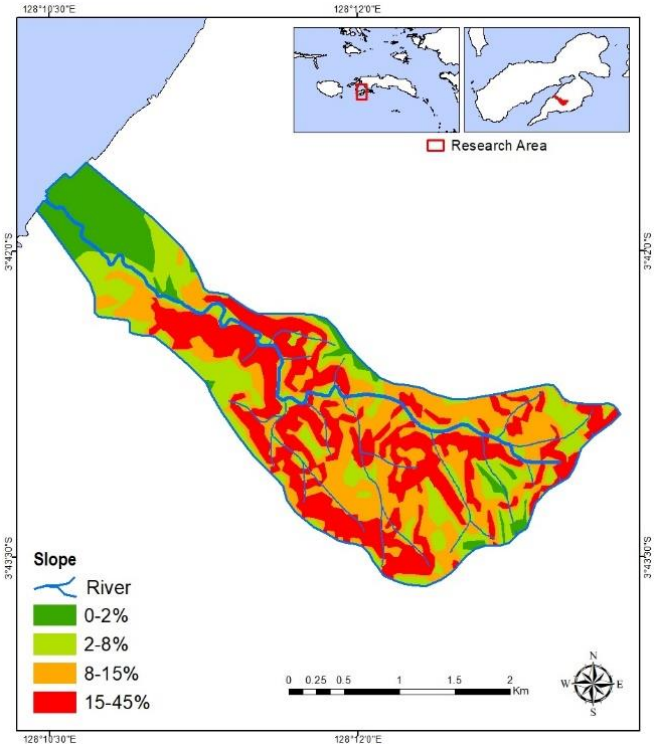

Figure 1. Slope Map

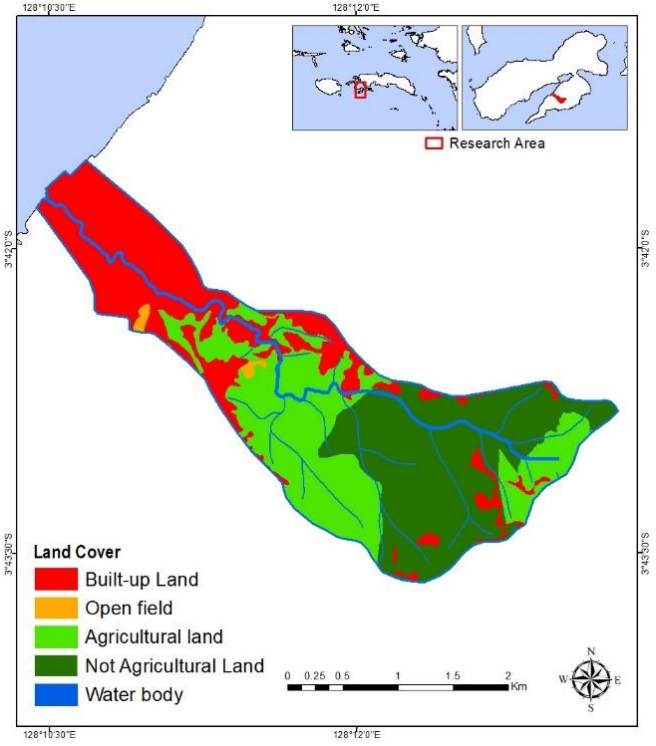

Figure 2. Land Cover Map

Based on the soil type map in Figure 3, it is known that most of them are dominated by the Kambisol soil type with an area of 499.55 ha and Rendzina with an area of 141.95 ha. In his research Lestari et al., (2022) soil type is one of the factors that affect landslides. Kambisol soil type is a type of soil that is relatively easy to trigger landslides according to the characteristics of soil movement (Priyono, 2015).

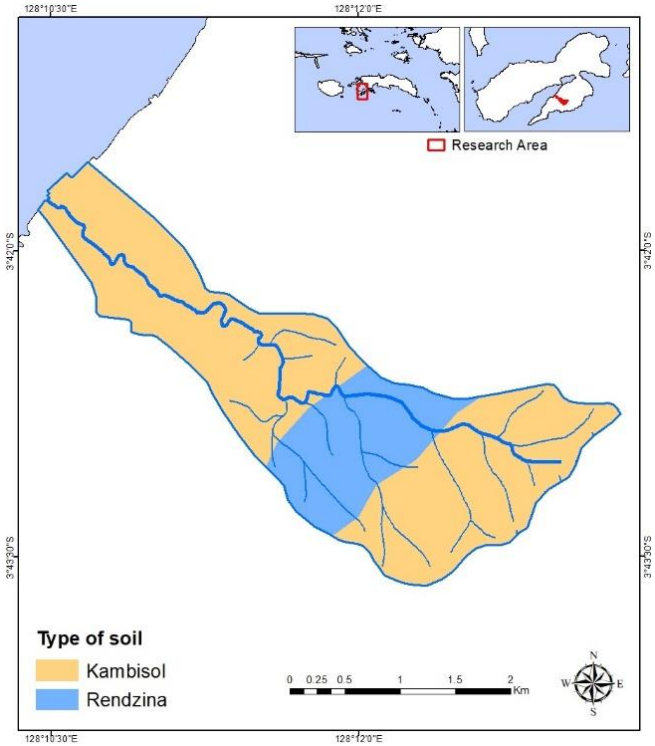

Figure 3. Soil Type Map

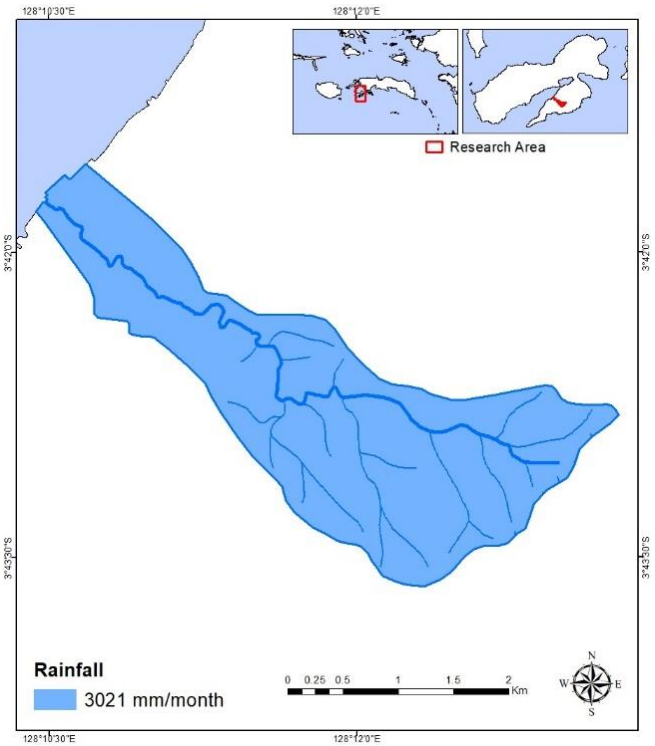

Figure 4. Rainfall Map

Based on the rainfall map of the Wae Batu Gajah watershed in Figure 4, the total average rainfall in the Teluk Das Wae Batu Gajah District from 2014-2022 is 3021 mm/month. According to Triwahyuni et al., 2017) one of the important factors that can cause landslides is rainfall, where when the intensity of rainfall is high for a long time, causing rainwater that falls and seeps into the ground will damage the.

Landslide Potential Level

Landslide potential is defined as the movement of a mass of rock or soil that moves due to gravitational forces pulling downwards. A landslide occurs when the pushing force on the slope is greater than that of the built-in material. Based on four parameters of landslide potential using the modification of the Stories Index method, a map of the potential landslide of the Wae Batu Gajah watershed was obtained. The landslide potential map is then classified into four classes, namely no potential, low potential, medium and high potential. Based on the results of the classification of the wae Batu Gajah watershed landslide potential area, the area that does not have the potential for landslides covers an area of 68.79 ha or 10.72%. The area is dominated by flat slopes and sloping slopes, land cover dominated by settlements. Areas that do not have the potential for landslides are in the lower reaches of the watershed.

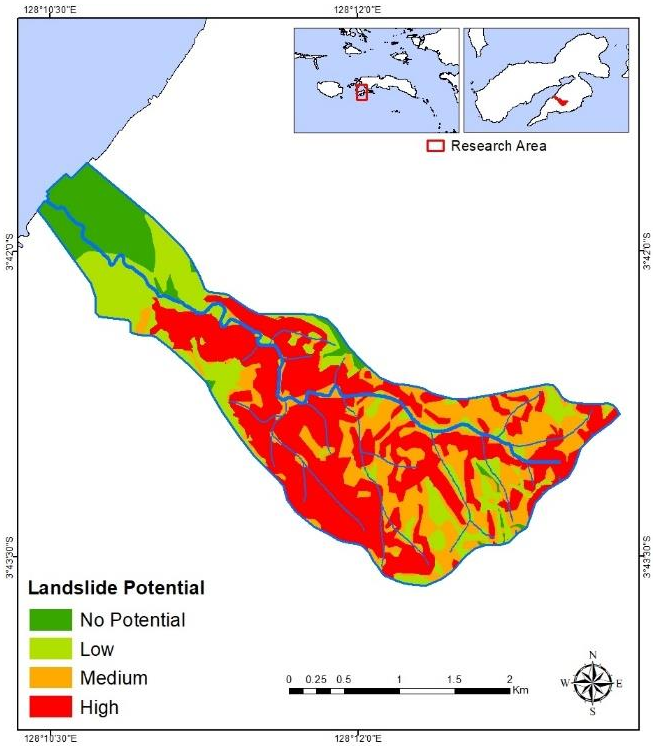

Figure 5. Map of Potential Landslide of the Wae Batu Gajah Watershed

The low potential class covers an area of 140.50 ha or 21.90% spread across the lower reaches of the watershed. The land cover is dominated by residential areas in this area as well as the relative slope is dominated by slopes of 0-2% and 2-8%. The potential for moderate landslides in the Wae Batu Gajah watershed has an area of 152.06 ha, or 23.70%. The high landslide potential is dominated by slopes with a slope of 8-15% and 15-45%. Slope is one of the factors that affect

landslides in an area, where the steeper the slope, the greater the potential for landslides in an area to occur, and conversely, the smaller the size of the slope, the smaller the potential for landslides that occur in an area. The high landslide potential has an area of 280.19 ha, or 43.67%. Spatially, the map of potential landslides in the Wae Batu Gajah watershed can be seen in Figure 5.

Prediction of Residential Areas Located in Landslide-Prone Areas

Based on the results of the analysis of potential landslide hazards in Figure 5 and Figure 6, it is known that landslides with high potential have a percentage of the area of 45% of the total area of the Wae Batu Gajah watershed, therefore landslide disaster mitigation must be carried out to anticipate the impacts and losses caused, both material losses and casualties. Landslide hazard is a condition where material from a landslide disaster harms the community. The affected aspects of a potential landslide are called landslide hazards if landslide material falls in settlements, physical and socioeconomic means, as well as economic activity.

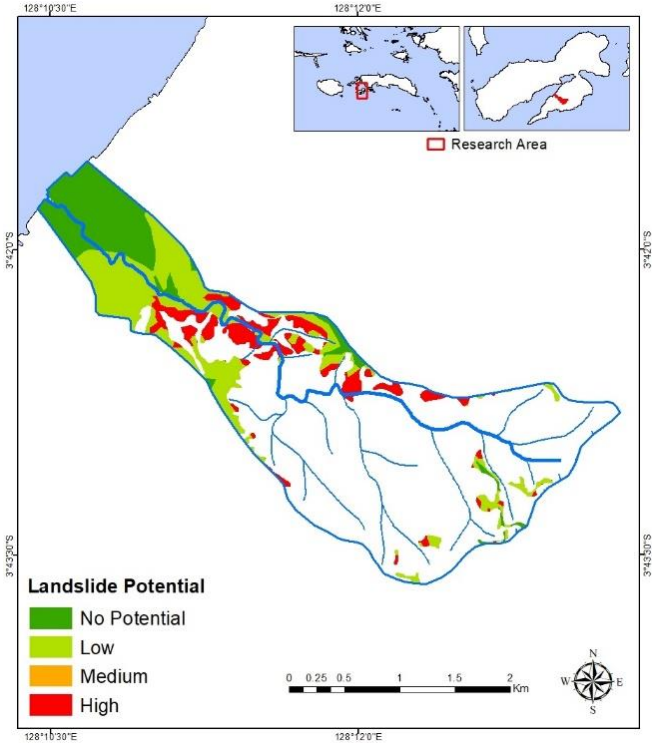

Figure 6. Map of the Distribution of residential land in landslides

According to Asmare, (2022) one form of anticipation is to predict how large the area of built-up land / settlements is in flood-prone areas. Based on Figure 6, it can be seen that the area of built-up land / settlements in the Wae Batu Gajah watershed which is in an area with a high landslide potential level of 39.22 ha or 19.13%, predictions of settlements that are in the potential for moderate landslides, namely an area of 0.02 ha, by 0.01%, in the low landslide potential class covering an area of 98.05 ha or 47.82% and settlements that are in areas that do not have the potential for landslides, namely an area of 39.22 ha of 19.13%.

CONCLUSIONS AND RECOMMENDATIONS

The results showed that the potential for landslides in the Wae Batu Gajah watershed is a hazard class, namely not potential, low, medium, high. The high landslide potential class dominates the Wae Batu Gajah watershed, covering an area of 280.19 ha or 43.67% spread across the middle and upper reaches of the watershed. An area of 98.05 ha or 47.82% of the area of residential land located in landslide-prone areas with low potential located in the lower reaches of rivers that are 0-2% and 2-8% which are relatively landau and flat. The research results can be used as a reference for the Ambon City government for landslide mitigation in the future. The results of this research are expected to be useful and a reference for academics who will conduct similar research in the future.

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