

LANDSLIDE SUSCEPTIBILITY MAPPING IN BERASTAGI DISTRICT KARO REGENCY BASED ON GEOGRAPHIC INFORMATION SYSTEMS

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Abstract

This study aims to describe the spatial distribution of landslide prone areas in Berastagi District, Karo Regency with a Geographic Information System approach. Determination of the level of landslide susceptibility is obtained based on the method of scoring and weighting and overlaying of parameters including slope, rainfall, land use, soil type, rock type, and landform. The results showed that there were 4 levels of landslide susceptibility in Berastagi District, Karo Regency, namely low level of susceptibility 1,036.76 Ha (33.16%), medium level of susceptibility 772.02 Ha (24.69%), high level of susceptibility 1,055.53 Ha (33.76%), and very high level of susceptibility 262.13 Ha (8.38%). The low level of susceptibility is dominated by Guru Singa Village (10.83%), Raya Village (8.66%), and Rumah Berastagi Village (3.72%). The medium and high level of susceptibility were dominated by Sempajaya Village at 4.51% and 3.68%. The very high level of susceptibility to landslides is dominated by Doulu Village, which is 17.40%. Meanwhile, the other 5 (five) villages have varying levels of susceptibility to landslides. Thus, 33.16% of the Berastagi District area is still safe from landslides, while the remaining 66.83% is prone to landslides.

Key words: Mapping, Susceptibility, Disaster, Landslide, GIS

INTRODUCTION

According to Law Number 24 of 2007, a disaster is an event or series of events that threatens and disrupts people's lives and livelihoods caused by both natural and/or non-natural factors as well as human factors, resulting in human casualties, environmental damage, property losses, and psychological impacts. Based on this definition, according to the causal factors, disasters can be categorized into three types, namely natural disasters, non-natural disasters, and social disasters.

Landslides are included in the category of natural disasters caused by geological factors. Nohani et al. (2019) revealed that based on a report from the Center of Research on the Epidemiology of Disasters, landslides are the cause of 17% of all victims of natural disasters in the world. Landslides cause the evolution of landscapes and are considered the greatest threat in a large number of areas around the world. The tendency of damage caused by this disaster will increase in the future along with increasing urbanization, population growth, development of residential areas, deforestation, and climate change. According

to Aversa et al. (2016), although they cause fewer casualties than other hazards, landslides are responsible for massive economic damage worldwide. Even small-scale landslides are a serious threat and greatly affect transportation corridors and disrupt human mobility and the distribution of goods.

Indonesian territory is not immune from the threat of landslides. Its position above the confluence of three of the world's major plates, namely the Eurasian plate, Pacific plate and Australian plate, has resulted in collisional activity between plates which then forms a subduction zone that stretches along the Indonesian archipelago. Starting from the west of the island of Sumatra, south of the island of Java to Bali and the Nusa Tenggara Islands, and north of the Maluku Islands to the north of Papua. This subduction zone gives rise to hills with slopes varying from steep to gentle. Such conditions cause Indonesia to have a fairly high threat of natural disasters from landslides (BNPB, 2016).

According to Damanik and Restu (2012), North Sumatra Province is one of the areas on the island of Sumatra that is affected by the

subduction zone with the main threat of landslides. There are 15 districts/cities prone to landslides out of 78 districts/cities in North Sumatra Province. The area includes Central Tapanuli Regency, South Tapanuli Regency, Mandailing Natal Regency, Padang Sidempuan City, Sibolga City, Dairi Regency, Humbang Hasundutan Regency, Nias Regency, South Nias Regency, Karo Regency, Dairi Regency, West Pha-phak Regency, Samosir Regency, Toba Samosir Regency, and Simalungun Regency.

Karo Regency is one of the landslide-prone areas in North Sumatra Province because most of its territory is a highland located in the Bukit Barisan Mountains range with hilly and undulating topography. The area has cold air with air temperatures ranging from 17.4°C to 23.6°C and an average air humidity of 88.39% which produces a fairly high average rainfall of around 1,000 - 4,000 mm/year (Profile Karo Regency 2015-2019).

Based on data from the Center for Volcanology and Geological Hazard Mitigation (2017), Karo Regency has several potential areas for landslides. The potential areas for landslides in Karo Regency can be seen in Table 1. There are 107 villages/kelurahan that were recorded as experiencing landslides in the three years of enumeration. The top five sub-districts with villages that experienced the most landslides were Barusjahe Subdistrict with 16 villages, Juhar Subdistrict with 15 villages, Munte Subdistrict with 14 villages, Merdeka Subdistrict and Tigapanah Subdistrict with 10 villages, and Berastagi District with 7 villages.

Table 1 Potential Land Movement Areas in Karo Regency, North Sumatra Province

No	Subdistrict	Potential for Land Movements
1.	Barusjahe	Medium - High
2.	Berastagi	Medium - High
3.	Dolarakyat	Middle - High
4.	Juhar	Medium - High
5.	Kabanjahe	Medium
6.	Kutabuluh	Medium
7.	Laubaleng	Medium - High
8.	Mardingding	Medium
9.	Merdeka	Medium - High
10.	Brand	Medium - High
11.	Munte	Medium
12.	Namanteran	Medium - High
13.	Umbrella	Medium - High
14.	Simpangempat	Intermediate
15.	Tigabinanga	Medium - High
16.	Tiganderket	Medium - High
17.	Tigapanah	Medium

Source: PVMBG, 2017. Accessed on December 20, 2019

Berastagi District is one of the sub-districts in Karo Regency that has medium to high landslide potential. Berastagi District

occupies the top 5 (five) rankings for landslides, covering 7 out of 10 villages/kelurahan. The topography of Berastagi District is flat to choppy (65%), wavy to hilly (22%), hilly to mountainous (13%). The air temperature level is 19°C to 26°C with air humidity ranging from 79% and an average rainfall of 2,100 to 3,200 mm per year (BPS Berastagi District, 2019).

Berastagi is the second largest city after Kabanjahe City, but the sub-district with the smallest area is in Karo Regency, which is 3,126.44 Ha. Berastagi is also the sub-district with the second highest population density after Kabanjahe, reaching 1,575.41 people/km². The number of human activities drives the high level of land use. Areas with rice fields and cultivation make the soil soft and saturated with water because plant roots are not strong enough to bind soil grains so landslides are easy to occur. The presence of additional loads in the form of residential buildings and transportation infrastructure on the slopes will increase the driving force for landslides (Anonymous, 2006).

Based on the description of physical conditions, human activities, and landslides that have occurred in Berastagi District, it is necessary to identify and map landslide-prone areas that are able to provide an overview of the existing condition of the area based on the driving factors for landslides. Landslide hazards can be identified quickly through the Geographic Information System through mapping the spatial distribution of landslide-prone areas using the method of overlaying the parameters of landslide susceptibility. Mapping activities are an initial mitigation effort to identify disaster-prone areas in order to minimize the risks caused by landslides.

METHODS

This research is located in Berastagi District, Karo Regency. The population in this study includes all land that is included in the administrative area of Berastagi District, Karo Regency. The sampling technique used is purposive sampling. The samples in this study were the locations of landslides in Berastagi District, Karo Regency.

The equipment used in this research include: hardware (laptops and printers), software (ArcGIS 10.1 and Microsoft Office 2010), GPS, Abney Level, meters, digital cameras, and stationery. The materials needed in this study include: Quickbird image of Berastagi District, Digital Map of the Administrative Area of Berastagi District, Digital Map of Slope of Berastagi District,

Digital Map of Rainfall in Berastagi District, Digital Map of Land Use in Berastagi District, Digital Map of Soil Types in Berastagi District, Digital Map of Geology of Berastagi District, and Digital Map of Landforms in Berastagi District.

The data collection technique in this research is a documentary study to obtain secondary data and observation to collect primary data and determine the level of accuracy of the mapping using the following formula.

$$\text{Tingkat kebenaran interpretasi} = \frac{\sum \text{Titik benar}}{\sum \text{Titik survei}} \times 100 \%$$

The data analysis technique used in this study is the method of scoring and weighting the parameters of landslide susceptibility (Tables 2-7), overlay, and presented in the form of descriptive analysis.

Table 2. Slope Classification (%)

Parameter	Weight	Score
<8	30 %	1
8 - 15		2
15 - 25		3
25 - 45		4
>45		5

Source: Minister of Agriculture (1980)

Table 3. Classification of Rainfall (mm/year)

Parameter	Weight	Score
(0 - 1000)	20 %	1
1000 - 1500		2
1500 - 2000		3
2000 - 2500		4
>2500		5

Source: BMKG (2020)

Table 4. Land Use Classification

Parameter	Weight	Score
Ponds, reservoirs, waters	15%	1
City /settlement		2
Forests and plantations		3
Shrubs		4
Upland, rice fields		5

Source: Quickbird image (2020)

Table 5. Soil Type Classification

Parameter	Weight	Score
Histosol	15 %	1
Entisol		2
Inceptisol		3
Moltisol		4
Alfisol		5
Ultisol		6

Parameter	Weight	Score
Oxisol		7

Source: Nurwihastuti, et al (2016)

Table 6. Classification of Rock Type

Parameter	Weight	Score
Alluvial rock	10 %	1
Sedimentary rock		2
Volcanic rock		3

Source: BNPB (2016)

Table 7. Landform classification

Parameter	Weighting	Score
Alluvial plain	10 %	1
Highlands		2
Karst hills		3
Volcanoes		4
Remaining hills		5
Denudational hill slopes		6
Denudational hills		7
Slopes contemplation denudasional		8
Mountains denudasional		9
Slope mountains structural denudasional		10
Structural Mountains denudasional		11

Source: Nurwihastuti, et al (2016)

These tables are a classification of parameters landslide susceptibility that has been given a score and weighting. The next action is to overlay the thematic maps (figures 2 - 7). The total score of the landslide susceptibility parameter is calculated based on the following formula.

$$\text{TOTAL SCORE} = 0.3SKL + 0.2SCH + 0.15SPL + 0.15SJT + 0.1SJB + 0.1SBL$$

Description:

- SKL = Score Slopes
- SCH = Score Rainfall
- SPL = Score Land Use
- SJT = Score Soil Type
- SJB = Score Type rocks
- SBL = Score landforms

Final classify of landslides susceptibility grouped into four (4) class intervals, namely low, medium, high, and very high with the following formula.

$$\text{Class} = \frac{\text{Highest score} - \text{Lowest score}}{\text{Number of classes}}$$

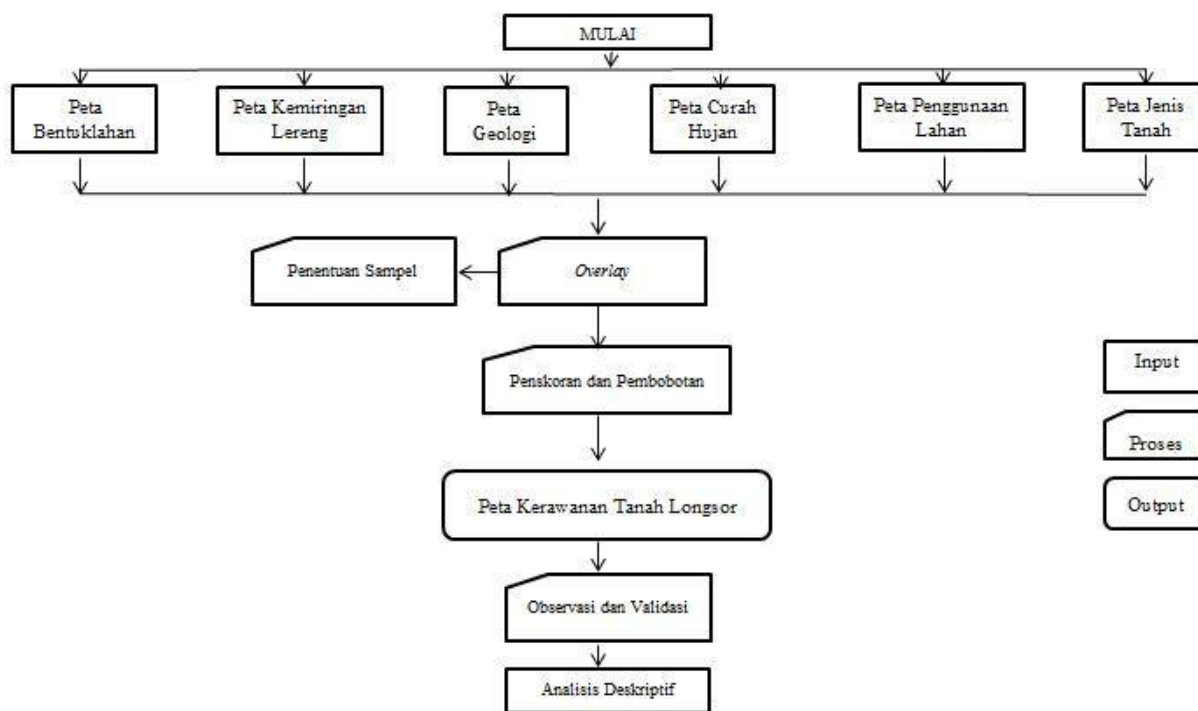


Figure 1. Research Flowchart

RESULTS AND DISCUSSION

Area Description

Astronomically the area of Berastagi District is located between 03° 9' - 03° 11' North Latitude and 98° 30' - 98° 31' Longitude East. Geographically, the area of Berastagi District is bordered by the following areas, in the north with Deli Serdang Regency; to the south with Kabanjahe District; in the west with Simpang Empat and Merdeka sub-districts; in the east with Tigapanah District and Dolat Rayat District.

Berastagi District consists of 10 (ten) villages, namely Guru Singa, Raya, Rumah Berastagi, Sempajaya, Doulu, and Lau Gumba,

namely Gundaling I, Gundaling II, Tambak Lau Mulgap I, Tambak Lau Mulgap II, with a total area of 3,126.44 Ha.

Slope Parameters

Most of the Berastagi District is located on a stretch of plateau with an elevation ranging from 1,265 - 1,417 meters above sea level. The topography of Berastagi District varies from flat - choppy ($\pm 65\%$), choppy - hilly ($\pm 22\%$), and hilly - mountainous ($\pm 13\%$). By using the Digital Elevation Model (DEM) classification, Berastagi District can be classified into 5 (five) slope classifications which are described in Table 8.

Table 8. Area and Distribution of Land Slope in Berastagi District

No	Village	Area Slope (Ha)				
		Flat (<8%)	Ramps (8-15%)	A bit steep (15-25%)	Steep (25-45%)	Very steep (> 45%)
1	Guru Singa	339.83	66.34	38.39	43.38	64,35
2	Raya	271.73	52.50	32.29	32.69	59.82
3	Rumah Berastagi	111.36	28.95	21.73	20.02	25.33
4	Tambak Lau Mulgap II	67.24	25.92	19,07	23.86	29.36
5	Gundaling II	56.09	14.05	7.84	14.31	15.90
6	Gundaling I	46.39	44.49	31.75	28.96	19.81
7	Tambak Lau Mulgap I	16,46	12.90	14.11	15.87	14.29
8	Sempajaya	66.58271.74	68.85		37.53	113.04
9	Doulu	162.81218.09	90.22			153.63

No	Village	Area Slope (Ha)				
		Flat (<8%)	Ramps (8-15%)	A bit steep (15-25%)	Steep (25-45%)	Very steep (> 45%)
		323.72				
10	Lau Gumba	21.06	28.19	27.91	16.00	4.48
Total		1,196.88	432.48	422.64	479.80	594.64

Source: Research Data Processing Results (2020)

Rainfall Parameters

According to Junghuhn climate classification theory, the region subdistrict Berastagi is included in the temperate climate zone (700 - 1,500 meters above sea level) because it is located at an altitude between 1,265 - 1,417 meters above sea level. Meanwhile, according to the Schmidt-Ferguson theory, based on the calculation of the comparison of the number of wet months with dry months, the Berastagi sub-district is included in the tropical climate type A (very wet) with air temperatures ranging from 19 to 26 °C. The calculation of this rainfall distribution is based on data obtained from 2 (two) rainfall stations that cover the research area, namely Kuta Gadung and Tongkoh (Berastagi) Stations.

The intensity and distribution of rainfall in Berastagi District is influenced by location factors in mountainous areas. Based on data obtained from observation stations, rainfall in

the Berastagi sub-district is medium to very high, namely between 1500 to more than 2500 mm/year. Rain factors such as rain intensity, amount of rainfall, and distribution of rainfall can determine the location of the opportunity for landslides to occur and how big the danger of landslides is.

Based on the results of the classification of annual rainfall parameters, the intensity of very high rainfall (>2500 mm/year) has the highest distribution area, with an area of 1,436.27 Ha or 45.93% of the research site area. The second order is followed by the intensity of medium rainfall (1500 - 2000 mm/year) with a distribution area of 1,151.46 Ha or 36.82% of the research site area. Meanwhile, the high rainfall intensity (2000 - 2500 mm/year) has the narrowest distribution area, which is 538.71 or 17.23% of the research location area.

Table 9. Classification of Annual Rainfall in Berastagi District

No.	Rainfall	Parameter	Area (Ha)
1	1500 - 2000 mm/year	Medium	1,151.46
2	2000 - 2500 mm/year	High	538.71
3	>2500 mm/year	Very High	1,436.27
Total			3,126,44

Source: Research Data Processing Results (2020)

Land Use Parameters

Aspects of land use in an area are closely related to economic conditions and the type of community living in the area. Land cover types have different contributions in determining the area's vulnerability. Things that contribute to the formation of landslide-prone areas from land use, for example the nature and conditions of land cover, such as buildings or plants, types and characteristics of plants, as well as the extent of closure and location of closure. The area and distribution of land use in Berastagi District can be seen in Table 10 and Figure 4.

The most extensive type of land use found in Berastagi District is land use for dry fields/fields with an area of 1,428.73 Ha or

45.69% of the total area research sites. This type of land use is mostly found in Guru Singa Village, namely 425.49 (Ha) while the narrowest is in Tambak Lau Mulgap I village, which is 9.59 Ha.

Furthermore, the most extensive use of forest land is in Doulu Village, which is 755.80 ha, while in Raya Village, Berastagi House, Lau Mulgap II, Gundaling II, Gundaling I, Lau Mulgap I, Sempajaya, Doulu, Lau Gumba, there is no forest land use. The total area of land in the forest sector is 809.75 Ha. There are many forest vegetation in the research area, including Pine, Meranti, Mahogany, and so on.

In the land use for residential areas, the most extensive is in Gundaling I Village, which

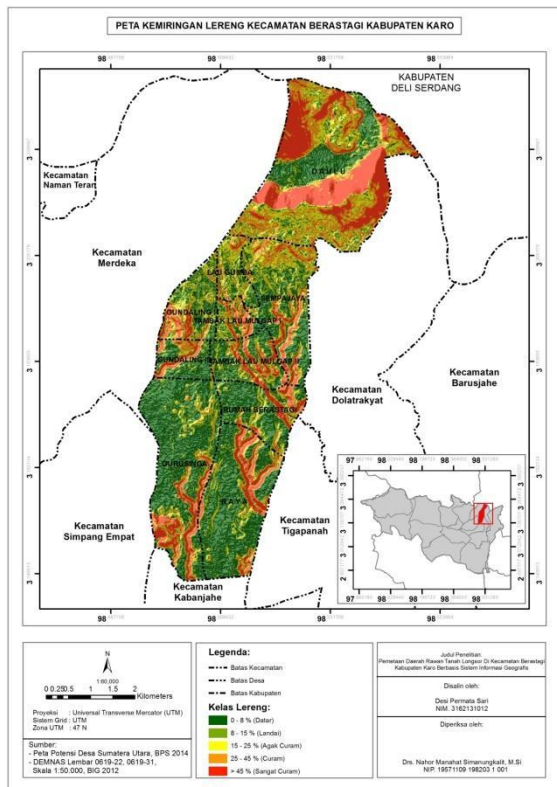


Figure 2. Slope Map of Berastagi Subdistrict, Karo Regency

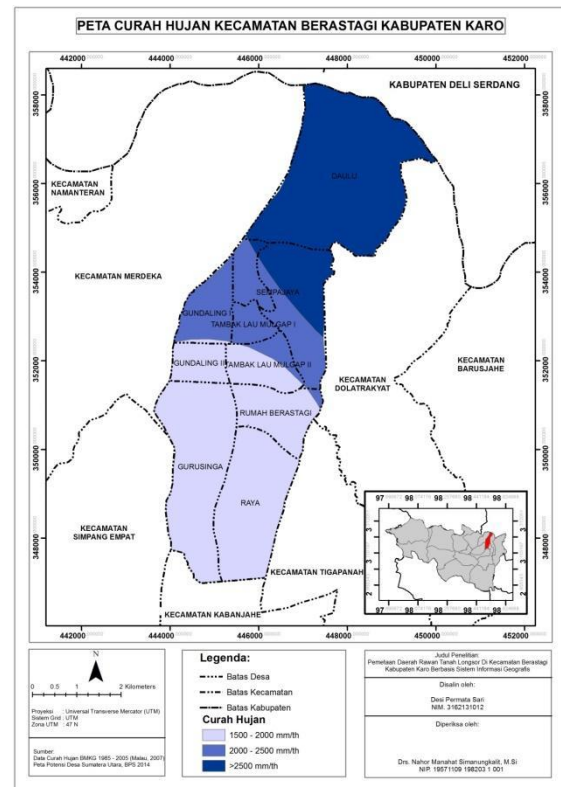


Figure 3. Annual Rainfall Map of Berastagi Subdistrict

is 59.30 Ha. Meanwhile, the area with the narrowest settlement is in Doulu Village, which is only 7.89 ha. The total area of land use for settlements in Berastagi District is 272.98 Ha.

The most extensive use of land for rice fields is in Doulu Village, which is 131.36 Ha. While in Gundaling II and Gundaling I villages

there is no use of paddy fields. The total area of paddy field use is 259.01 Ha.

The most extensive shrubs are in Guru Singa Village, which is 75.10 Ha. While the narrowest use of bushland is in Lau Gumba Village. The total area of shrubs is 355.95 ha. The shrubs are overgrown with types of weeds such as reeds, shrubs, ferns, and others.

Table 10. Area and Distribution of Land Use in Berastagi Subdistrict

No	Village	Area Type of Land Use (Ha)				
		Upland/Fi eld	Forest	Settlement	Rice	Bushes
1	Guru Singa	425.49	31.26	20.11	0.43	75.10
2	Raya	311.29	0	38.22	62.80	36.80
3	Rumah Berastagi	128.64	0	14.71	17.73	46.62
4	Tambak Lau Mulgap II	85.95	0	25.69	24.95	28.86
5	Gundaling II	68.30	0	14.44	0	25.46
6	Gundaling I	59.30	0	84.39	0	29.1
7	Tambak Lau Mulgap I	28.88	0	22.32	12.84	9.59
8	Sempajaya	210.72	16.25	44.52	8.83	73.14
9	Doulu	43.31	755.80	7.89	131.36	8.30
10	Lau Gumba	61.00	6.43	25.70	0.03	4.56
Total		1,428.73	809,75	272.98	259.01	355.95

Source: Research Data Processing Results (2020)

Soil Type Parameters Soil

Types at the research site are classified based on the Soil Map of the Research and Development Center for Agricultural SDL

consisting of Inceptisol and Ultisol soils. The spatial distribution of soil types at the study site is shown in Table 11 and Figure 5. Inceptisol soil types have the widest

distribution of 3,113.39 Ha. Inceptisol soil belongs to the category of alluvial soil and has a dusty loam texture. Meanwhile, the Ultisol soil type is only found in a small part in Doulu Village with an area of 13.05 Ha. Ultisol soil type belongs to the red yellow podzolic soil category. Its characteristics include deep soil cross-section, acid soil reaction so that it is easily washed off by rainfall, and clay accumulation in the lower horizon. This causes reduced water absorption capacity and increased surface runoff and soil erosion.

Parameters of Rock

Types Volcanic rock types are the most dominant rock types in this region (95.27%).

The type of rock QTvk which is part of the Takur-takur formation with pyroclastic material and is most abundant in Gundaling I village is 88.70 Ha. The total area of this rock type is 138.04 Ha or 4.41% of the total area of the study area. In other volcanic rock types, namely Qvba, it is part of the Sibayak unit formation with andesite lava material. This type of rock is only found in Doulu village, which is 300.15 ha. Meanwhile, the rock type Qybs (Unit Singkut) consists of tuff rock material spread throughout the villages in Berastagi District with a total area of 2,540.66 Ha or 81.26% of the total area of the study area.

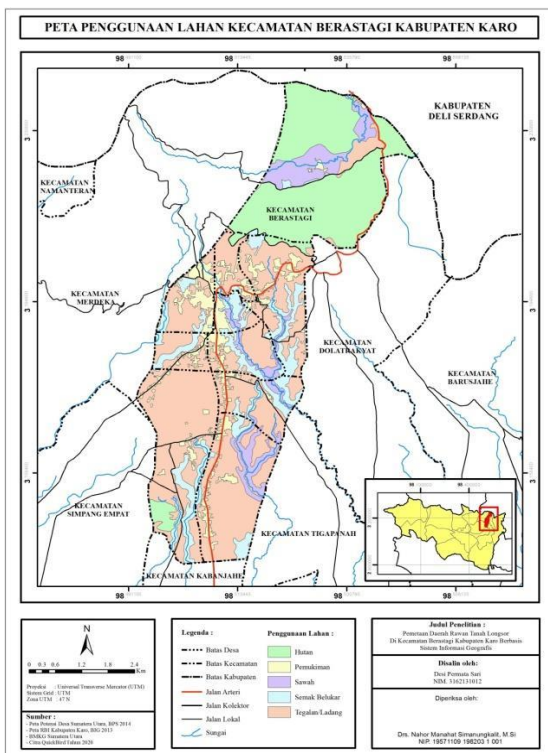


Figure 4. Land Use Map of Berastagi Sub-district, Karo Regency

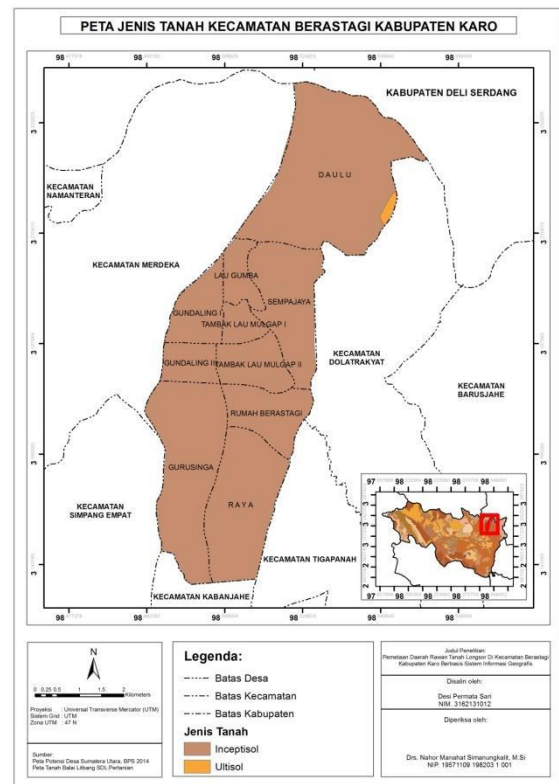


Figure 5. Map of Soil Types in Berastagi Sub-district, Karo Regency

Table 11. Area and Distribution of Soil Types in Sub-district Berastagi

No.	Village	Area Soil Type (Ha)	
		Inceptisol	Ultisol
1.	Guru Singa	552.40	0
2.	Raya	449.13	0
3.	Rumah Berastagi	207.72	0
4.	Pond Lau Mulgap II	165.47	0
5.	Gundaling II	108.22	0
6.	Gundaling I	171.87	0
7.	Pond Lau Mulgap I	73.65	0
8.	Sempajaya	353.50	0
9.	Doulu	933.62	13.05
10.	Lau Gumba	97.75	0
Total		3,113.39	13,05

Source: Research Data Processing Results (2020)

The next rock type, namely Alluvial, has a

total area of 147.59 Ha or 4.73% of the total

area of the study area. The rock type Qh is a young alluvium rock with loose sedimentary material located mostly in Doulu village, which is 81.46 Ha. While in the villages of Guru Singa, Raya, Gundaling II, Gundaling I, Tambak Lau Mulgap I and Lau Gumba there is no distribution of this rock type.

Parameters of Landforms

The research area only has 1 (one) type of

landform, namely volcanic fallout deposits. Berastagi area is part of the accumulation of volcanic material. The area of the volcanic fall sediment landform in Berastagi District is adjusted to the area of the research area itself, because the entire area of Berastagi District with an area of 3,126.44 Ha is included in the same landform.

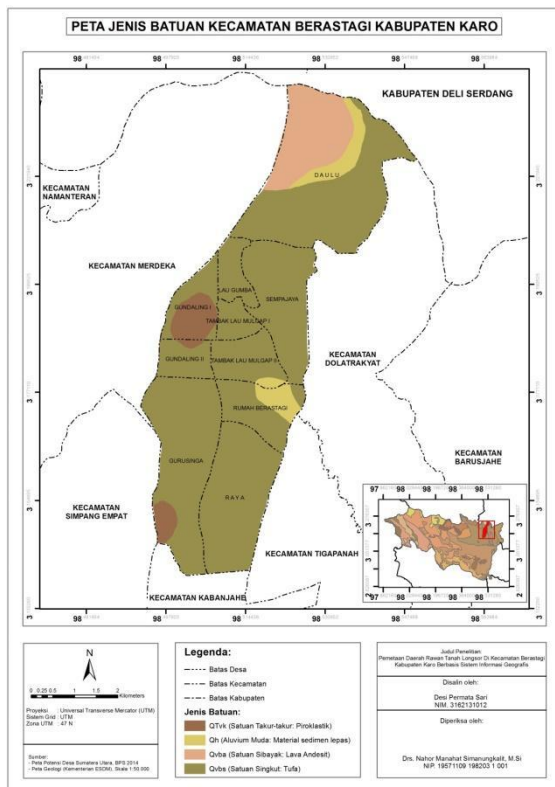


Figure 6. Map of Rock Types, Berastagi District, Karo Regency.

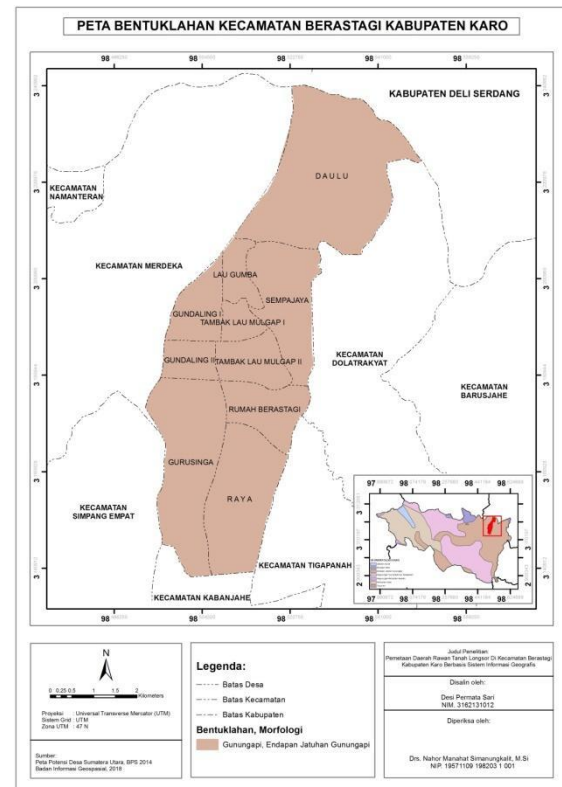


Figure 7. Map of landforms in Berastagi Sub-district, Karo Regency

Table 12. Area and Distribution of Rock Types in Berastagi Sub-district

No.	Village	Area of Rock Type (Ha)			
		Qvka	Qh	Qvba	Qvbs
1.	Lion Master	40.60	0	0	511.81
2.	Raya	0	0	0	449.13
3.	Berastagi House	0	53.02	0	154.69
4.	Tambak Lau Mulgap II	0	12.61	0	152.86
5.	Gundaling II	8.73	0	0	99.49
6.	Gundaling I	88.70	0	0	83.18
7.	Mulgap Lau pond I	0	0	0	73.65
8.	Sempajaya	0	0.49	0	353.01
9.	Doulu	0	81.46	300.15	565.05
10.	Lau Gumba	0	0	0	97.75
Total		138.04	147.59	300.15	2.540,66

Source: Research Data (2020)

Landslide Vulnerability

Based on the results of secondary data analysis, research uses a scoring and weighting method based on the Geographic Information System on 6 (six) landslide

susceptibility parameters, namely Slope, Rainfall, Land Use, Soil Type, Rock Type, and Landform, obtained 4 (four) levels (classes) of landslide susceptibility found in Berastagi District, Karo Regency. Based on the data

shown in table 13, the high level of landslide susceptibility has the widest distribution, which is 1,055.53 Ha or 33.76% of the research area. This is followed by a low grade landslide susceptibility level, which is 1,036.76 Ha or 33.16% of the total area of the research area. Furthermore, the moderate level of vulnerability to landslides has an area

of 772.02 Ha or 24.69% of the research area. Meanwhile, the very high level of vulnerability to landslides has a distribution with the least area, which is 262.13 Ha or 8.38% of the total area of the research area.

Table 13. Landslide Vulnerability Level in Berastagi Sub-district, Karo Regency

No.	Vulnerability Level	Interval	Area (Ha)	Percentage (%)
1.	Low	0.30 - 1.28	1.036.76	33.16
2.	Medium	1.29 - 2.25	772.02	24,70
3.	High	2.25 - 3.23	1,055.53	33.76
4.	Very High	3.24 - 4.20	262.13	8.38
Total			3,126.44	100

Source: Research Data Processing Results (2020)

Spatial Distribution of Land Prone Areas Landslide

Based on the data presented in Table 14, it can be described the distribution of landslide-prone areas and the area of vulnerability classes based on each administrative area of 10 villages in Berastagi District as follows.

a. Low-level landslide susceptibility

Distribution of areas with low-level landslide susceptibility in Berastagi District has a total area of 1,036.75 Ha or 33.72% of

the total area of the study area. Areas with a low level of vulnerability to landslides are mostly located in the western part of Berastagi District, especially in Gurusinga Village with an area of 338.60 Ha. Meanwhile, the village with the narrowest distribution of areas with a low level of vulnerability to landslides is Lau Gumba Village with an area of 9.66 Ha.

Table 14. Spatial Distribution of Landslide Prone Areas Based on Administrative Areas of Berastagi Subdistrict

No	Village	Area of Class Vulnerability							
		Low		Medium		High		Very High	
		Ha	%	Ha	%	Ha	%	Ha	%
1.	Guru Singa	338,60	10,83	69,99	2,23	98,41	3,14	45,40	1,54
2.	Raya	270,95	8,66	54,56	1,74	63,79	2,04	59,81	1,91
	Rumah Berastagi	116,53	3,72	32,38	1,03	51,00	1,63	7,81	0,24
4.	Tambak Lau	68,22	2,18	29,38	0,93	41,69	1,33	26,18	0,83
	Mulgap II								
5.	Gundaling II	54,85	1,75	15,82	0,50	21,62	0,69	15,89	0,50
6.	Gundaling I	40,34	1,29	60,73	1,94	51,27	1,63	19,54	0,62
7.	Tambak Lau	14,79	0,47	20,15	0,64	24,54	0,78	14,15	0,45
	Mulgap I								
8.	Sempajaya	43,94	1,40	141,17	4,51	115,10	3,68	14,79	0,47
9.	Doulu	78,82	2,52	306,42	9,80	544,03	17,40	17,39	0,55
10.	Lau Gumba	9,66	0,30	41,40	1,32	44,03	1,40	2,64	0,08
Total (Ha)		1.036,75	33,16	772,02	24,70	1.055,53	33,76	262,14	8,38

Source: Research Data Processing Results (2020)

b. Medium-level landslide susceptibility

Distribution of areas with a high level of vulnerability Landslide fields in Berastagi District have a total area of 772.02 Ha or 25.11% of the total area of the study area. Areas with a medium level of vulnerability to landslides are mostly located in the northern part of Berastagi

District, especially in Doulu Village with an area of 306.42 Ha. Meanwhile, the village with the narrowest distribution area with a moderate level of vulnerability to landslides is Gundaling II Village with an area of 15.82 Ha.

c. High level of landslide susceptibility

Distribution of areas with a high level of landslide susceptibility in the District of Berastagi has a total area of 1,055.53 ha or 34.33% of the total area of the study area. Areas with a high level of vulnerability to landslides are mostly located in the northern part of Berastagi District, especially in Doulu Village with an area of 329.77 Ha. Meanwhile, the village with the narrowest distribution area with a high level of vulnerability to landslides is Lau Gumba Village with an area of 14.62 Ha.

d. Very high landslide susceptibility

Distribution of areas with a very high level of vulnerability to landslides in the Berastagi District has a total area of 262.13 Ha or 6.81% of the total area of the study area. Areas with a high level of vulnerability to landslides are mostly located in the eastern part of Berastagi District, especially in Raya Village with an area of 59.81 hectares. Meanwhile, the village with the narrowest distribution area with a very high level of vulnerability to landslides is Lau Gumba Village with an area of 2.64 Ha.

Landslide Characteristics in the Research Area

There are 2 (two) types of landslides found, namely translational type and rockfall type. The type of translational landslide is the most common type of landslide found in the study area. This type of landslide is a type of landslide movement in the form of displacement of rock material from a high place to a lower place through a slip plane in the form of a basin. The composition of rock and clay material will be saturated during the rainy season. This causes the binding force (cohesive) of the soil to weaken so that the shear force of the soil is getting stronger. In addition, land use factors and vegetation damage also affect the high risk of landslides.

This type of rockfall landslide is only found in Doulu Village with a fairly steep hilly area. Rock slope avalanches usually occur due to an misalignment between rock bonds during the slope formation process or also known as a *Discontinuity Pattern*. This misalignment can affect the value of the shear strength of the slope-forming material. Several factors triggering the occurrence of this type of landslide include the weathering process of rocks, the interaction of water with the slopes, and vibrations caused by earthquakes.



(a)



(b)

Figure 5.8 Types of landslides (a) Rockfall in Doulu Village and (b) translation in Tambak Lau Mulgap I Village

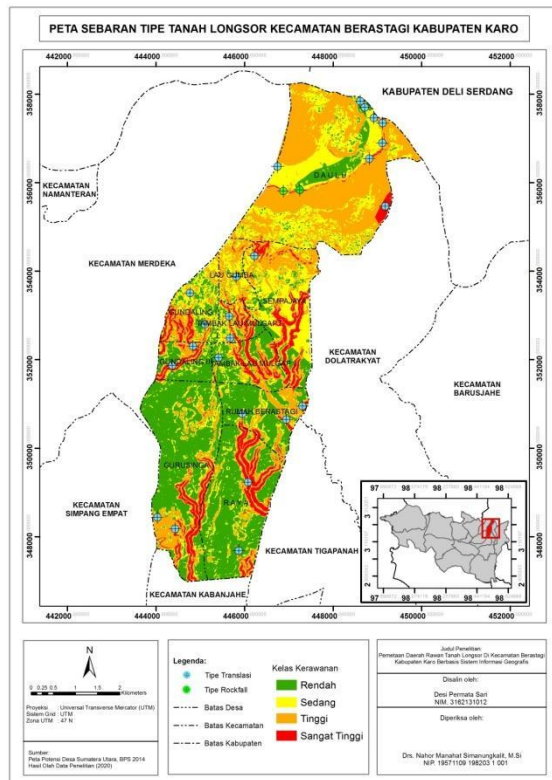


Figure 8. Distribution Map of Landslide Prone Areas Based on Village/Kelurahan Administrative Areas and Landslide Types in Subdistricts Berastagi Karo Regency

CONCLUSION

Based on the results and discussions that have been described, the conclusions of this study are the results of the study indicate that there are 4 (four) levels/classes of landslide susceptibility in Berastagi District, Karo Regency, namely the low level of vulnerability level 1,036.76 hectares (33.16 %), the medium level of vulnerability area is 772.02 Ha (24.69 %), the high level of vulnerability is 1,055.53 Ha (33.76%), and the very high level of vulnerability is 262.13 Ha (8.38 %).

The low landslide susceptibility level is dominated by Guru Singa Village (10.83%), Raya Village (8.66 %), and Rumah Berastagi Village (3.72%). The medium and high landslide susceptibility levels were dominated by Sempajaya Village at 4.51% and 3.68%. The very high level of vulnerability to landslides is dominated by Doulu Village, which is 17.40%. Meanwhile, the level of vulnerability to landslides in the other 5 (five) villages varies. Thus, 33.16% of the Berastagi District area is still safe from landslides, while the remaining 66.83% have varying levels of vulnerability. There are 2 (two) types of landslides in Berastagi District, namely translational landslides and rockfalls. Doulu Village is the

village with the most landslide cases found.

Based on the conclusions of the results and discussion of the research, some suggestions that can be put forward by researchers are people need to strengthen disaster mitigation actions before landslides occur so that they can reduce the risk due to landslides. Among the landslide disaster mitigation actions that need to be considered are the application of soil conservation techniques on agricultural land, selection of plant types that are in accordance with the physical conditions of landslide-prone areas, engineering of slope cutting techniques, improving drainage systems, and socializing landslide disaster mitigation to be more massive to all residents of Berastagi District. More complete historical data of landslide events is needed for further research using landslide prediction modeling with different methods.

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