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SPATIAL DISTRIBUTION OF LANDSLIDE PRONE AREAS IN THE WAE BATU MERAH WATERSHED, AMBON CITY

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ABSTRACT

High Community needs of land for settlements encourage prone land to remain inhabited around the Wae Batu Merah watershed which is used as a place to live. This is very risky and can cause the loss of life and property in the event of an inevitable natural disaster. The objectives of this research were to: 1. Identify factors that cause landslides in Wae Batu Merah watershed, and 2. Determine the distribution of landslide-prone areas in the Wae Batu Merah watershed. This research used Geographic Information System approach model which is given the value of each parameter (Souisa, et al, 2016) after being modified by researchers, and Remote Sensing approach for satellite image processing. Field data collection was carried out on 34 sample areas which represent 100 observation samples to obtain actual land cover data. Factors causing landslides analyzed include slope, rainfall, land cover, geology, soil type, seismicity, fault, and each has a score and weight then overlaid to produce a map of landslide prone distribution areas. The results shows that Wae Batu Merah watershed was included in the high landslide prone class which dominated 544.86 ha (51.41%) while the low prone class area was 92.53 ha (8.73%).

Keywords: *Landslide, Prone, GIS, Spatial, Watershed*

INTRODUCTION

As the capital of the Maluku Province, Ambon City in a national space designated as the National Activity Center in the province of a thousand islands. Viewed from the geological and geographical aspects, Ambon City consists mostly of hilly terrain with steep slopes of ± 186.90 Km^2 or 73% and highland areas with a slope of around 10% covering ± 55 Km^2 or 17% of the total mountainous area. Such conditions make this region vulnerable to various disaster threats, both natural disasters caused by anthropogenic factors and disasters arising from social, cultural and political differences, one of which is landslides (Ambon City Regional Disaster Management Agency, 2012).

Landslides are a type of natural disasters that often occur in Indonesia. Data from the National Disaster Management Agency (BNPB) in 2017 noted that there were around 577 landslide events across Indonesia (Suryowati, 2018). The damage caused by the landslide is not only direct damage such as damage to public facilities, agricultural land, or the existence of human casualties, but also indirect damage that paralyzes development activities and economic activities in the area and its surroundings. The landslides tend to increase along with the increase in human activities (Hardiyanto, 2006).

The Directorate of Volcanology and Geological Disaster Mitigation (2015) explained the occurrence of landslides, one of which, was caused by soil types from volcanic eruptions. This soil has a composition of mostly clay with little sand and is fertile. Weathering soils that are above water-resistant rocks on hills with moderate to steep slope have the potential for landslides in the rainy season with high intensity rainfall. If the hills do not have deep-rooted perennials, the area is prone to landslides.

The Ambon City Disaster Management Agency (BPBD) noted that during 2012 there had been 22 catastrophic events that affected many lives and damage. One of them was the landslide that occurred in mid-2012 that left 35 people dead, 22 injured and hundreds of houses and several other public facilities damaged. It was also explained that in 2012 out of 22 events, floods / landslides dominated disaster events, namely 12 times (55%), followed by Windstorms 6 times (27%) and Earthquake events 2 times (9 %) and Social Conflict disaster 2 times (9%). For 2013, out of 18 occurrences, the Flood / Landslide disaster occupies the highest position with 10 occurrences (56%), then Fire disasters totaling 6 occurrences (33%) and Tidal Wave disasters totaling 1 occurrence (6%) and the last is a Social Conflict disaster 1 time (6%) (Ambon City BPBD, 2012).

The state of the disaster that occurred in Ambon City is inseparable from the geographical condition of this region which is 75% is a hilly area (Putuhena 2013a). This is a consideration in planning protection and safety for the community. This condition is due to the fact that most of the people build in areas with slopes> 20% and have the potential to threaten life safety in the event of a landslide.

Regional watersheds as regulators of the hydrological cycle determine the effect of soil and water conservation, and also the value of environmental services in this case (Putuhena 2013; Putuhena 2014: Latuihamallo and Putuhena 2016; Oszaer and Putuhena 2017, Latuconsina el all 2020). Good soil and water conservation will determine the size of the critical occurrence of a watershed including erosion and landslide disasters. This certainly occurs in watersheds in Ambon City including Batu Merah watersheds.

The purpose of this study was to identify the factors causing landslides and determine the distribution of landslide prone areas in the Wae Batu Merah watershed

RESEARCH METHODS

Research Location and Time

This research was conducted in the Wae Batu Merah Watershed (DAS), Sirimau sub-district, Ambon City. This research activity was conducted in September to October 2018.

Tools and Materials

The equipment used in this research was the Garmin 76Csx GPS, ArcGIS software, ENVI, digital cameras and writing stationery. The materials used in this study included Landsat 8 OLI / TIRS C1 satellite image data Level-1 Path 109 / Row 62 Records 28/10/2017, DEM SRTM 30m resolution data, rainfall data, soil type maps Ambon Island sheets, geological maps scale 1: 250,000, seismicity data, and fault map scale 1: 250,000.

Data collection technique

The data collection carried out in this study used secondary data in the form of Landsat 8 satellite imagery of 30m resolution, and SRTM DEM data from the United States Geological Survey (USGS). The rainfall, seismicity and fault data were from the Ambon City Climatology and Geophysics Meteorology Agency (BMKG), soil type data was from the Ambon Island Sheet Soil Type Map and the geologic data was from the Maluku Province Office of Energy and Mineral Resources, and information related to landslide events from the Agency for Mitigation Regional Disaster (BPBD) Ambon City.

Observation Variable

Observational variables consist of independent and dependent variables. Independent variables include: 1. Slope, 2. Rainfall, 3. Land Use, 4. Soil Type, 5. Slope Composite (Geology), 6. Seismicity, and 7. Fault. The dependent variable is: Landslide occurrence in Wae Batu Merah watershed.

Pre-Processing Satellite Image Data

The process of pre-processing satellite imagery data used the Remote Sensing approach with ENVI 5.2 software to make corrections to images. The corrections include: 1. Geometric Correction, 2. Radiometric Correction, and 3. Cropping Image.

Data processing

This data processing used the Geographic Information System (GIS) approach with ArcGis 10.1 software, which is carried out on the seven (7) research variables / parameters of the weights and the scores of each parameter are determined based on the influence of landslide events, from the smallest influence in the class 1 to the largest, class 5 that means it is very influential on landslides. Then, the seven (7) variables were overlaid to determine the level of landslide vulnerability which was divided into 4 classes, including: 1. Low, 2. Medium, 3. High, and 4. Very High.

The following are parameters for determining landslide vulnerability as shown in

Table 1. Determination of Landslide Vulnerability Parameters

Variable	Clasifications	Weight	Score
Slope	> 40 % 20 – 40 % 10 – 20 % 0 – 10 %	30 %	5 4 3 2 1

Rainfall	> 200 180-200 160-180 140-260 < 140	20 %	5 4 3 2 1
Land Cover	Settlement Secondary Dry Land Forest Shrubs Primary Dry Land Forest	15 %	5 4 3 1
Rock Forming Slope (Geology)	Alluvium, Ambon Volcano Rock, Coral Limes, Kanikeh Formation and Ultramafic Rock	10 %	5 1
Type of soil	Podsolic Kambisol Alluvial	10 %	5 3 1
Seismicity	> 2.9 SR 1 – 2.9 SR	10 %	5 4
Fault	Yes No	5 %	5 1

Source*: Souisa, et al. (2016) after being modified.*

Data analysis method

Determination of Landslide Vulnerability Level

Measurement of the level of landslide prone can be determined based on seven parameters consisting of slope, rainfall, soil type, land use, rock compilers (geology), seismicity and faults. This parameter was then weighted according to the size of the effect of each parameter on the landslide which refers to the Ministry of Public Works in 2007. Furthermore, the method used refers to (Souisa, et al 2016) after being modified by researchers as follows;

$$LHZ = (0.2 \times FLE)+(0.2 \times FCH)+(0.15 \times FGL)+ (0.1 \times FG)+ (0.1 \times F\pi)+ (0.1 \times FG)+ (0.05 \times FP)$$

Where: LHZ: landslide vulnerbaility, FLE: slope, FCH: rainfall, FGL: land use, FG: rocks forming the slope, FJT: soil type, FG: seismicity, and FP: fault.

After generating new spatial data, the classification of data was carried out on certain criteria of the data studied by giving a score divided into four classes, then in total and by dividing the difference between the values of the four classes (zones), the level of vulnerability to landslide vulnerability in landslide-prone areas was obtained with the formula referring to (Souisa, et al 2016);

$$\text{Interval Class} = \frac{Nt - Nr}{n_{class}}$$

Where Nt: maximum data, Nr: minimum data and n*class*: number of classes desired. Landslide vulnerability distribution map was used as a reference mapping for landslide prone.

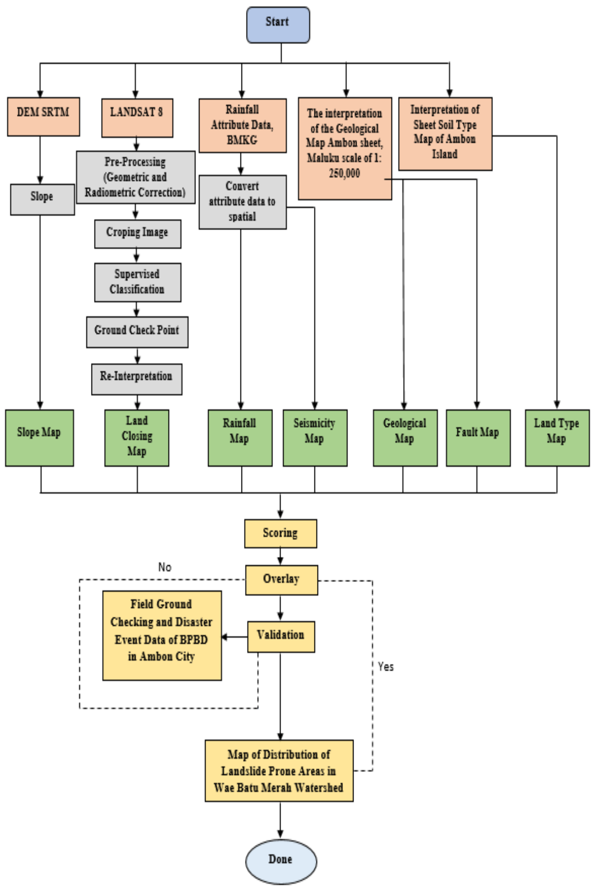


Figure 1. Research Flow Diagram

RESULTS AND DISCUSSION

Analysis of the Causes of Landslides

Slope

Table 2. Slope Class and Spread Area in Wae Batu Merah River Watershed

No	Slope	Class Slope	Area	
			(Ha)	(%)
1	0 - 10 %	Flat	528.378,67	49.85
2	10 - 20 %	Sloping	438.747,46	41.40
3	20 - 40	Steep	78.636,39	7.42

	%			
4	> 40 %	Very Steep	14.140,26	1.33
Total			1.059,90	100

Source: *Primary Data (Analysis Results) 2018*

Based on the percentage of area, Wae Batu Merah watershed is dominated by flat topography of 49.85% and narrow area is dominated by very steep topography of 1.33%.

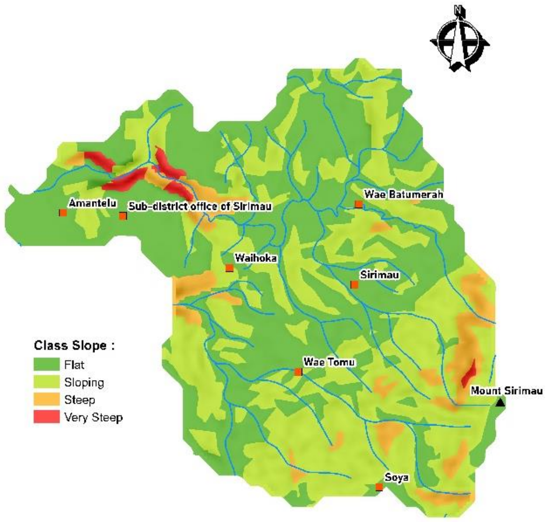
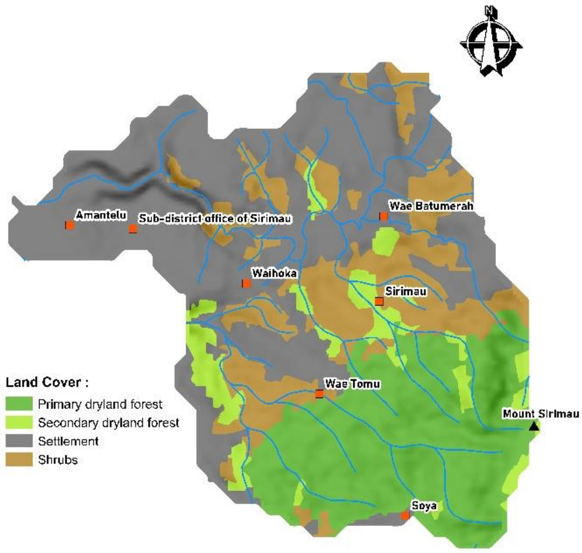
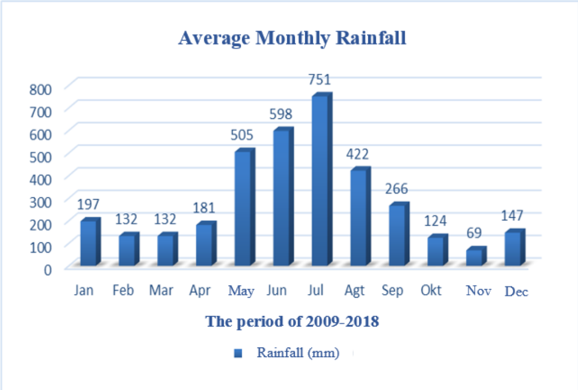


Figure 2. Slope Map



Rainfall



Source: *Pattimura Ambon Class II Meteorological Station, 2018*

Figure 3. Graph of Average Monthly Rainfall
Wae Batu Merah watershed

Analysis results show that, Wae Batu Merah watershed has the highest average rainfall in the last 10 years. It is occurred in July of 751 mm and the lowest in November of 69 mm with an average monthly rainfall of 293.66 mm.

Land Cover

Table 3. Land Cover Class and Spread Area in Wae Batu Merah River Watershed
Source: *Primary Data (Analysis Results) 2018*

Based on the percentage of area, Wae Batu Merah watershed is dominated by settlement land cover by 45.57% and small percentage for secondary dryland forest cover is 6.83%.

No	Land Cover	Symbol	Area	
			(Ha)	(%)
1	Primary Dry Land Forest	Hp	289.283,12	27.29
2	Secondary Dry Land Forest	Hs	72.392,44	6.83
3	Shrubs	B	215.265,96	20.31
4	Settlement	Pm	482.961,24	45.57
Total			1.059,90	100

Figure 4. Land Cover Map

Geology

Table 4. Geological Formation and Spread Area in Wae Batu Merah River Basin

No	Geological Formation	Compiler Material	Area	
			(Ha)	(%)
1	TrJk	Kanikeh Formation: alternating sandstone, shale, siltstone, with conglomerate and limestone inserts	57.995,21	5.38
2	JKu	Ultramafic Rock: Harzburgite, dunit, serpentinite, gabbro	34.852,67	3.29
3	Ql	Coral Limestone: Coral, algae and bryozoan colonies	166.347,24	15.69
4	Tpav	Ambon Volcano Rock: Andesite, dacite, breccia and tuff	801.707,63	75.64
Total			1.059,90	100

Source: *Secondary Data (Geology Map of Ambon Island Sheet) 2018*

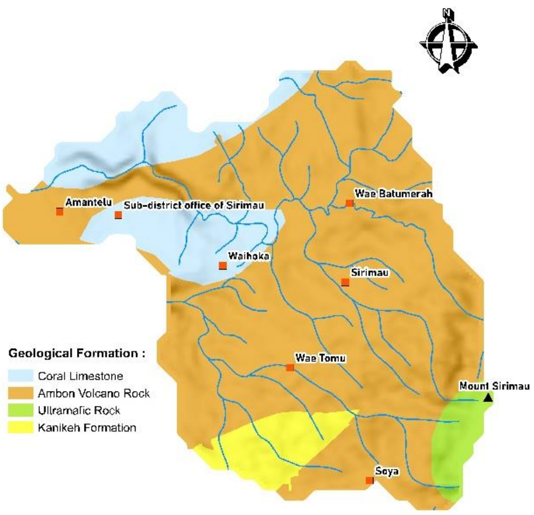


Figure 6. Soil Type Map

Based on the percentage of area, Wae Batu Merah watershed is dominated by the Tpav geological formation (Ambon Volcano Rocks) of 75.64% and a small percentage of the Jku geological formation (Ultramafic Rock) of 3.29%.

Type of soil

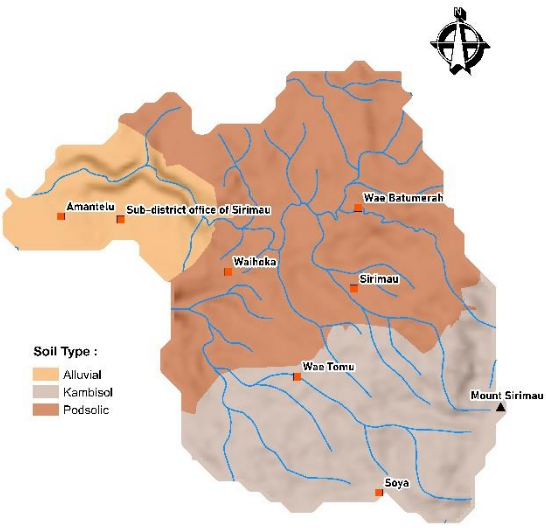
Table 5. Soil Type and Spread Area in Wae Batu Merah River Watershed

No	Type of soil	Area	
		(Ha)	(%)
1	Alluvial	153.125,28	14.45
2	Kambisol	365.287,19	34.46
3	Podsolic	541.490,30	51.09
Total		1.059,90	100

Figure 5. Geological Map

Source*: Secondary Data (Ambon Island Land Sheet Map) 2018*

Based on the percentage of area, Wae Batu Merah watershed is dominated by Podsolic soil types by 51.08% and small percentage for Alluvial soils by 14.36%.



Seismicity

Table 6. Earthquake Data in Wae Batu Merah Watershed

No	Magnitude	Depth	Date	Buffer

				Distance
1	2.3	10	05/6/2012	500
2	2.5	20	29/07/2012	500
3	3.6	28	29/07/2012	500
4	1.8	10	01/08/2012	500
5	2	10	06/09/2012	500
6	2.9	10	15/02/2014	500
7	2.3	33	21/05/2016	500

Source: *Secondary Data (Ambon Class I Geophysical Station) 2018*

Based on data from Ambon Class I Geophysics Station from 2009 - 2018 (seen in **Table 6**). The analysis showed that there were 7 earthquake events, especially in the Wae Batu Merah watershed on a scale of 1.8 - 3.6 Magnitude with varying depths.

Source: *Secondary Data (Ambon Class I Geophysical Station) 2018*

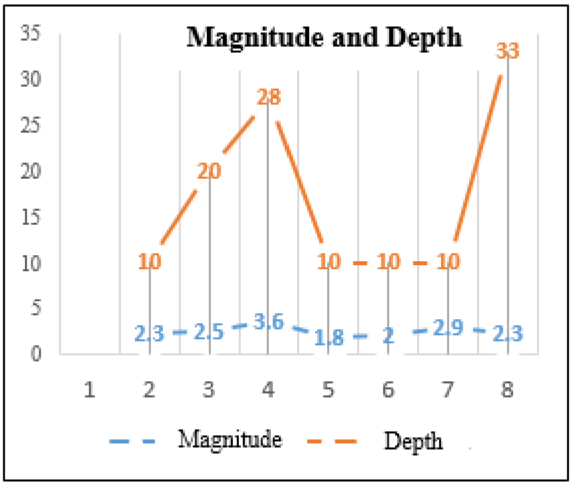


Figure 7. Magnitude and Depth Diagram of Seismicity in Wae Batu Merah Watershed

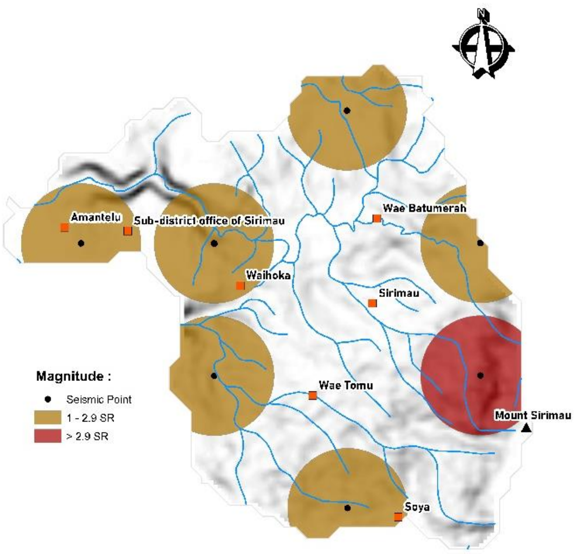


Figure 9. Fault Map

Fault

Fault is a shift in part of the rock mass from its original position caused by the forces acting on the rock. Based on the Geological Map of Ambon Maluku sheet scale of 1: 250,000 (Director General of Geology and Mineral Resources, 1993) Wae Batu Merah watershed itself has a fault with a length of ± 2.40 Km dividing the Leitimur Peninsula in Ambon Island with a type of fault; the up fault and the down fault.

0 = No is > 500m
1 = Yes is 0 – 500m

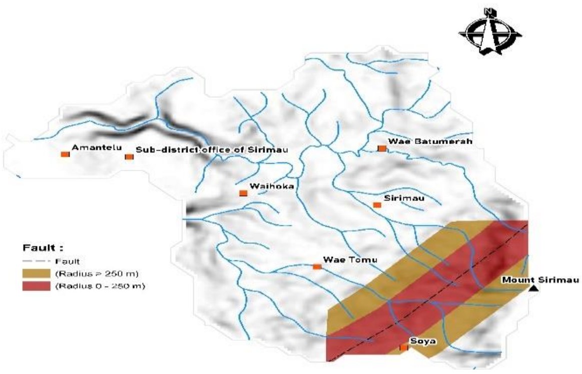


Figure 8. Seismicity map

Spatial Model for Landslide Prone Areas

Based on the results of the spatial model research that was built from each of the factors causing landslides to produce a landslide prone map in the Wae Batu Merah watershed (see **Figure 10**)

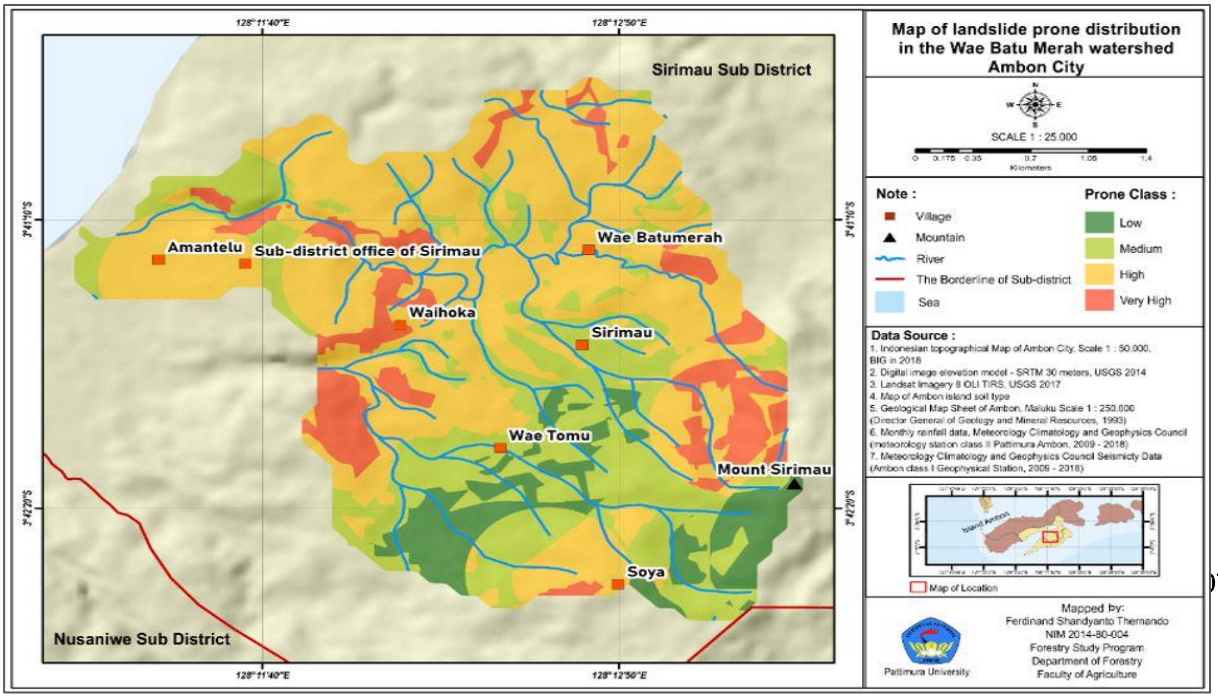


Figure 10: Map of Landslide Prone Distribution in Wae Batu Merah Watershed

The results showed that the landslide-prone areas in the Wae Batu Merah watershed vary in their landslide susceptibility (see **Table 7**). The level of landslide vulnerability is influenced by seven parameters namely slope, rainfall, land cover, geology, soil type, seismicity and faults. Each parameter has a dominant influence on landslides. For the vulnerable class itself, the dominant one is the high vulnerable class with an area of around 544.86 ha (51.41%) of the watershed area and for the small vulnerable class is the low class of 92.53 ha (8.73%).

No	**Prone Class**	**Area**	
		(Ha)	(%)
1	Low	92.53	8.73
2	Medium	302.90	28.58
3	High	544.86	51.41
4	Very High	119.61	11.29
Total		1.059,90	100

Source: Analysis Results, 2018

Table 8. The Relationship of Slope Class to Slides

Slope	Landslide Prone Class				***Slope Class Size (Ha)***
	Low	**Medium**	**High**	**Very High**	
0 - 10 %	54.37	164.03	309.98		528.38
10 - 20 %	38.16	122.87	202.86	74.86	438.75
20 - 40 %		16.01	28.44	34.19	78.64
> 40 %			3.58	10.56	14.14
Total Class Prone (Ha)	**92.53**	**302.90**	**544.86**	**119.61**	**1059.90**

Based on the table of the relationship between the slope classes and landslides for the slope class varies. However, it has high effect on specific landslides in the Wae Batu Merah watershed for the dominant slope is on the slope of 0-10% with an area of about 309.98 ha in high-prone classes and for slopes with a slight effect on the slope> 40% with an area of about 3.58 ha or very small against landslides (seen in **Table 8**).

Table 9. Relationship of Land Cover Class to Landslide

Land Covers Class	Landslide Prone Class				***Cover Class Area (Ha)***
	Low	**Medium**	**High**	**Very High**	
Primary Dry Land Forest	86.04	123.49	60.34	19.41	289.28
Secondary Dry Land Forest	6.49	24.18	16.79	24.93	72.39
Settlement		58.04	358.11	66.81	482.96
Shrubs		97.19	109.61	8.46	215.27
Total Class Prone	**92.53**	**302.90**	**544.86**	**119.61**	**1059.90**

Source: *Analysis Results, 2018*

Geology	Landslide Prone Class				**Geological Area (Ha)**
	Low	**Medium**	**High**	**Very High**	
Coral Limestone		30.88	117.19	18.27	166.35
Ambon Volcano Rock	38.65	235.29	426.43	101.34	801.71
Ultramafic Rock	25.08	9.77			34.85
Kanikeh Formation	28.80	26.96	1.24		57.00
Total Class Prone (Ha)	**92.53**	**302.90**	**544.86**	**119.61**	**1059.90**

Table 10. Geological Relations to Landslides

Source: *Analysis Results, 2018*

Based on the table of the relationship between land cover class for landslides, the settlement land cover class has a big influence, which is around 358.11 ha to the high vulnerable class that is dominant in the spread of landslides. The settlement land cover class is very influential if it is on a slope of > 20% range. As for the slight effect on the class of forest cover secondary dryland forest land around 6.49 ha in the low prone class. (seen in **Table 9**).

Seen on the rocks forming the slope or geology known in the Wae Batu Merah watershed, the geological type of Ambon Volcano Rock has a fairly wide area of about 426.43 ha in high-prone classes while for a small area that is the type of kanikeh formation in high-prone classes is in an area of about 1.24 ha. Alluvium types were eliminated when spatial data analysis because the area <1ha.

Table 11. Relationship between Soil Classes and Landslides

Type of soil	Landslide Prone Class				***Land Type (Ha)***
	Low	**Medium**	**High**	**Very High**	
Alluvial		44.30	96.68	12.14	153.13
Kambisol	92.53	169.85	72.38	30.53	365.29
Podsolic		88.75	375.80	76.94	541.49
Total Class Prone (Ha)	**92.53**	**302.90**	**544.86**	**119.61**	**1059.90**

Source: *Analysis Results, 2018*

Based on the Ambon Island Sheet Map, the type of soil contained in the Wae Batu Merah watershed that dominates the watershed is Podsolic soil type with the general characteristics of clay and sandy soil and very low water retention. The area of the soil type is about 375.80 ha in high prone classes and a small area is found in alluvial soils with an area of around 12.14 ha. It is the type of soil that also affects landslides if the slope is> 20%.

The rainfall also has an effect on landslides if rainfall> 500 mm / month.In the rainy season for a long time can cause landslides if the land cover in the form of settlements with a slope of > 20%. There are also soil types that are sensitive to landslides such as podsolic (seen in **Table 11**) and their geology also influence the formation of special slopes for the geological type of alluvium and ambon volcanic rocks. The presence of seismic points spread over the seven points in the whole watershed with a different magnitud. The fault factor also has an influence but not too significant if the fault is not on a slope <20% which can disturb the stability of the soil with the type of up and down faults in the Wae Batu Merah watershed. (According to Puturuhu, 2016) in his research the types of landslides and locations contained in the Wae Batu Merah watershed consist of: 1. Soil rotational slides landslide type, location: kanawa clove and soya gardens 2. Earth slide Landslides Type, location: Batu Merah Atas.

CONCLUSION

From the results of research and data analysis it can be concluded as follows:

1) Factors that cause landslides in Wae Batu Merah watershed in Ambon City are influenced by slopes > 20%, land cover in the form of settlements, rainfall > 500 mm / month, soil types that are sensitive to landslides such as podsolic, ambon volcanic rocks as rock forming slope or geology, seismicity or earthquake events, 7 seismic points spread with varying magnitude and the faults are the up and down faults in the watershed.
2) Spatial distribution for landslide-prone classes in Wae Batu Merah watershed, widely distributed in the High Class around 544.86 ha (51.41%) and a small distribution in the Low Class around 92.53 ha (8.73).

SUGGESTIONS

1. Based on the results of research conducted, it can be seen that landslide-prone areas are classified as high and very high classes, the majority of which occur in residential areas and shrubs. Seeing the results of the study, the authors suggest that relevant parties in this case stakeholders pay more attention to the areas that have been identified as priority areas in landslide disaster mitigation efforts.
2. In the effort to mitigate landslides, the authors used the approach of mapping spatially landslide-prone areas so that in the future it becomes a material consideration in spatial planning that must pay more attention to the natural physical aspects by not building on the steep terrain.
3. Need to do studies and further research on the physics condition of the field and more accurate data to support the acquisition of better information in terms of landslide vulnerability.

REFERENCES

BPBD. 2012. *Data Bencana Kota Ambon Tahun 2012 – 201*3 [Ambon City Disaster Data, 2012 – 2013]. Ambon City Regional Disaster Management Agency. Ambon. 74 Halaman

Direktorat Vulkanologi dan Mitigasi Bencana Geologi. 2015. *Booklet "Gerakan Tanah"["Land Movement" booklet]*. Kementerian Energi Dan Sumber Daya Mineral. 14 Halaman.

Hardiyanto, H.C. 2006. *Penanganan Tanah Longsor Dan Erosi [Management of Landslides and Erosion]*. Gajah Mada University Press. Yogyakarta. 450 Halaman.

Latuconsina R, G. Mardiatmoko, Jusmy D. Putuhena, 2020. Variation of NDVI Vegetation Index In Land Use Change of Ambon City, Maluku Province. Jurnal Hutan Pulau Pulau Kecil. Vol 4 Nomor 1, Halaman 1-13.

Latuihamalo J., Jusmy D. Putuhena. 2016. Analisis Nilai Guna Hutan Sebagai Penyedia Air Bersih dan Implementasi PES (Payment for Ecosystem Sevices) bagi Pemilik Dusun di Hutan Lindung Sirimau Kota Ambon [Analysis of Forest Use Value as a Provider of Clean Water and Implementation of PES (Payment for Ecosystem Services) for Hamlet Owners in the Sirimau Protected Forest in Ambon City]. Jurnal Hutan Pulau Pulau Kecil. Vol 1 Nomor 1, Halaman 44-52.

Oszaer R., J. D. Putuhena. 2017. Analysis of Sustainability Management of River Flow of Wae Batu Gajah City Ambon. International Journal of Science and Research (IJSR). Vol 6. Issu 10. www.ijsr.net.

Putuhena J. D. 2013. Model Dinamik Pengelolaan Daerah Aliran Sungai (watershed) dalam upaya penyediaan Air yang Berkelanjutan Di semenanjung Leitimor Pulau Ambon [Dynamic Model of Watershed Management in Efforts to Provide Sustainable Water in the Leitimor Peninsula Ambon Island]. Disertasi Institut Pertaian Bogor.

Putuhena J. D., A. Sapei., M. T. Y. Purwanto., L. B. Prasetyo 2014. Sustainable Water Supply Model in Ambon Island. Journal of Environmental and Ecology. Vol 5 No. 2. Page 292-306. www.macrothink.org/jee.

Puturuhu, F. 2016. Pengembangan Metode Penginderaan Jauh Dan Sistem Informasi Geografis (SIG) Untuk Pemetaan Kerawanan Longsorlahan Di Jazirah Leitimur Pulau Ambon [Development of Remote Sensing Methods and Geographic Information Systems (GIS) for Landslide Hazard Mapping in Leitimur Peninsula, Ambon Island]. Disertasi. Yogyakarta: Sekolah Pascasarjana, Universitas Gadjah Mada.

Souisa, M., Hendrajaya, L., & Handayani, G. 2016. Landslide Hazard and Risk Assessment for Ambon City using Landslide Inventory and Geographic Information System. *Journal of Physics: Conference Series 739.*

Suryowati, E. 2018. Sepanjang 2017, BNPB Mencatat 2.175 Kejadian Bencana di Indonesia [Throughout 2017, BNPB Records 2,175 Disasters in Indonesia]. (https://nasional.kompas.com/read/2017/12/05/17200331/sepanjang-2017-bnpb-mencatat-2175-kejadian-bencana-di-indonesia) Diakses: 1 Maret 2018.