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## Identification of Landslide Disaster Potential based on Weathering Grade of Rock in Parepare City South Sulawesi, Indonesia

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## Identification of Landslide Disaster Potential based on Weathering Grade of Rock in Parepare City South Sulawesi, Indonesia

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**Abstract**, The purpose of this research is to identify the potential of landslide disaster based on weathering grade of rocks from selected areas. There are three aspects of field observation method used in this research, consist of slope geometry, lithology, and weathering grade of rocks aspects. The result shows that the rocks on research area have been slightly to completely weathered, some areas have became residual soil and slope angles of the research area varieties from steep to very steep. With those condition of weathering and slope angle, the research area will be slightly to very susceptible to landslide. The landslide models or types that will occur are debris slide and debris fall.

### 1. Introduction

Increase of population in a city or regency results in the expansion of land for housing and other infrastructures. Parepare City is an agrarian city that becomes city of service with high increase in population. For example, in 2017, population in Parepare increased to 142,097 people from 132,699 people in 2015. Increase of population affected the increase of residential land and other land needs such as road infrastructure, etc. [1]. Utilization of land from forest land into residential land can no longer be limited to land plains, mountainous land to coastal areas. Excessive use of the area has a negative impact, which results in disaster. One of the disasters that will occur if land extensification is carried out for infrastructure is the occurrence of landslides.

Parepare City is occupied by three rock formations namely: Parepare Volcanic Rocks, Camba Formation, and Alluvial Deposit [2]. Parepare volcanic rocks consist of breccia and tuff. Alluvial deposit consists of deposits of sand to clay-sized materials. Some of the rocks has been weathered into residual soil and alluvial.

Based on information above, it is very important to identify areas with landslide potential in Parepare and determine model or type of landslide that will occur. Based on background of the research, the problem equation of the research are: (1) how the weathering grade of the rocks affect the landslide disaster and, (2) what model or type of landslide will occur.

Therefore, the purposes of this research are to identify the effect of weathering grade on the susceptibility of landslide and to analyze and determine model or type of the landslide that will occur.



## 2. Literature Review

### 2.1. Geological Setting

Regionally, the research area belongs to geological map of Pangkajene and Western Part of Watampone in 1:250,000 [2]. The following is the explanation of the regional geology of the research area, consists of geomorphological conditions, stratigraphy, and geological structures. In Pangkajene and West Part of Watampone sheet, there are two rows of mountain that extend in north northwest and separated by Walanae River valley. Western part of the mountain occupies nearly half of the area, widen in southern part (50 km) and narrow in northern part (22 km). The highest peak of the area is 1694 meters, whereas average elevation of the area is 1500 meters. Forming rocks are mostly volcanic rocks. Northern part of this mountain has karst topography where the surface is mostly conical. The northern boundary of the area is Bone plain, which occupies nearly a third of northern area. Walanae Valley which separate the mountains is 35 kilometers wide, but only 10 kilometers in southern part.

Regional stratigraphy of research area is based on previous researchers, according to [2], regional stratigraphy of research area belongs to geological map of Pangkajene and Western Part of Watampone. Mostly mountains, both western and eastern part have volcanic rocks. Most of western part of the mountain formed from Camba Formation, which is approximately 5000 meters thick, unconformably laying above Tonasa Formation, meanwhile Walanae Formation is interfingering with upper part of Camba Formation.

**Alluvium and coastal deposit (Qac):** Clay, silt, sand, and gravel along the big river, and along the coastal line. At some areas, coastal deposits contains clam shell remains and coral limestone.

**Parepare Volcanic Rocks (Tppv):** Volcanic breccia consists of trachyte and andesite fragments; pumice, tuffaceous sandstone, conglomerate, and tuffaceous breccia; intruded by trachyte and andesite stocks. The age of this unit is Pliocene, based on radiometry dating on trachyte and tuff in Parepare, which results 4.25 and 4.95 Ma [2].

**Camba Volcanic Rocks (Tmcv):** Volcanic rocks alternating with marine sedimentary rocks; volcanic breccia, lava, and fine-grained to lapili tuff; lime sandstone, limestone, and marl. The rocks consist of andesite and basalt; intruded by basalt-composed sill and stock; light gray, dark gray, and brown in color. The rocks mostly deposited in neritic marine environment as Camba Formation volcanic facies, some volcanic breccias contain limestone.

Regional structure in research area is based on previous researcher, according to [2], belongs to geological map of Pangkajene and Western Part of Watampone. Developing structures are affected by Walanae regional fault in northwest – southeast direction, actively, resulting in deformation such as fold, joint, and fault. North northwest-directed major fault formed in Middle Miocene, and grew until Post-Pliocene. Fold directed in almost parallel with major fault estimated to be formed because of horizontal pressure in east – west direction before Upper Pliocene. The faulting relatively smaller in western part of west mountain directing in northwest – southeast and southwest; and have fault contact with surrounding rock units.

### 2.2. Grade of Rock Weathering

According to [3], stated that weathering is a changing and breaking down process of rocks and soil on the or near the surface of earth by physical, chemical, and biological process into clay, iron oxide, and other weathering products.

There are 3 types of weathering, those are physical (mechanical) weathering, chemical weathering, and weathering caused by organism activity. According to [4], weathering grade is divided into 6 grades, from fresh rocks (unweathered) to residual soil. Weathering grade will be explained in Table 1 as follows:

**Table 1.** Terminology of weathering grade of rocks [4]

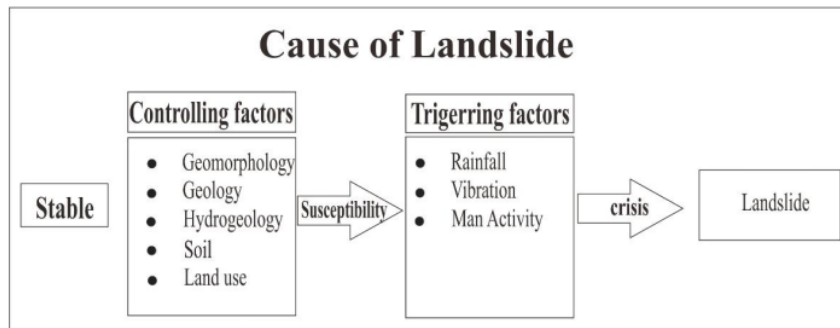
Grade	Term	Description
I	Fresh	No visible sign of rock material weathering; perhaps slight discoloration on major discontinuity surfaces
II	Slightly weathered	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than in its fresh condition.
III	Moderately weathered	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous frame work or as core stones.
IV	Highly weathered	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a discontinuous frame work or as core stones
V	Completely weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact
VI	Residual soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is large change in volume, but the soil has not been significantly transported.

According to [5], one of the causing factor of landslide is weathering because the higher the weathering grade, the more the rock forming minerals disintegrate and if that happens in a slope area, that area will be susceptible to landslide.

According to [6], landslide can be caused by interaction of some conditions like morphology, geology, hydrogeology, and land use. Those conditions affect each other, making a slope has a tendency to move. Furthermore [6] stated that such a slope condition is called susceptible to move. So, the definition of susceptible is when a slope has a potential or tendency to move, but has not moved yet.

Movement on a slope can happen when there is a movement trigger. Movement triggers are natural or unnatural processes that can change condition of the slope from susceptible to start moving. Movement triggers are rain, vibration, human activity on slope such as slope excavation and cutting, blasting, overburden, or water entering into slope through leaks on channel or ponds.

The causing factor of landslide [6] can be seen in Figure 1.



**Figure 1.** Causing factors of landslide (controlling factors and triggering factors) [6]

In Figure 1 above, we can see that there are 4 stage of the process of landslide, those are:

- Stable stage
- Susceptible stage

- Critical stage
- Landslide stage

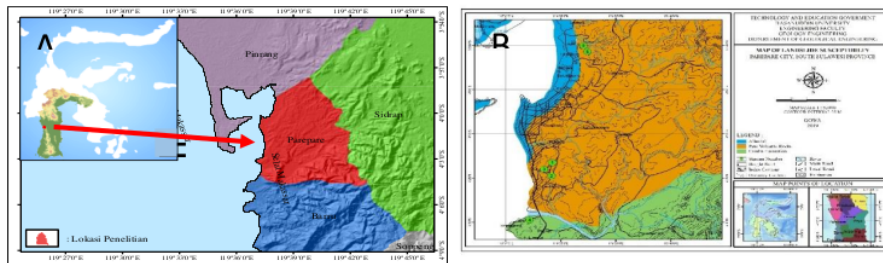
Furthermore, [6] explained that Figure 1 also shows that the cause of landslide can be divided into direct cause (controlling factors) and indirect cause (triggering factors). Landslide classification [7] is based on movement mechanism and moving materials. Classified the landslides into 6 types, those are fall, topples, slides, lateral spread, flow, and complex/compound [7].

According to [6], landslide susceptibility is a phenomenon that makes slope become potential or susceptible to move although it is stable at the moment (hasn't moving or land sliding yet). A slope susceptible to landslide will move when there is an interference triggering the movement.

### 3. Research Methods

#### 3.1. Research Area

The research area is located in Parepare City, about 150 km from Makassar City to the north.



**Figure 2.** (a) Administrative map of research area, (b) Geological map of research area

#### 3.2. Retrieving Field Data

This research is explorative, where all retrieved data are field data. Field data consist of:

1. Geomorphological Data  
 Geomorphological data contains slope geometry, such as slope height, slope length, slope width, and slope angle
2. Lithological Data  
 Lithological data contains: the position of the outcrops, rocks' type, and the name of the rocks
3. Weathering Grade Condition

Next observation is observing weathering, which is observing weathering such as fresh rocks, slightly weathered, moderately weathered, highly weathered, and completely weathered.

### 4. Result and Discussion

Result of observation and measurement of the slope geometry in research area is shown in Table 2 and Figure 2.

**Table 2.** Slope geometry data of research area

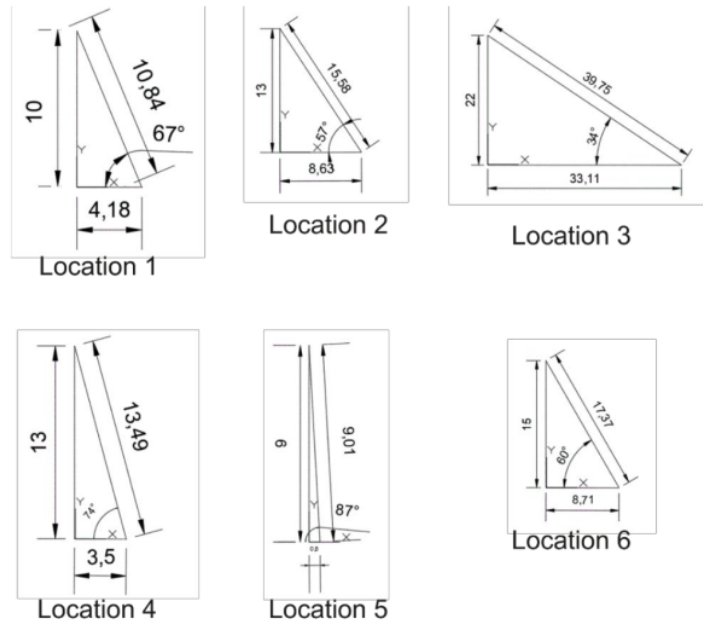
Location	Position		Slope Condition				Explanation
	x	y	Slope Height (Meter)	Slope Width (Meter)	Slope Direction (N....°E)	Slope Dip (....°)	
1	119°37'50.43 "	04°01'39.17 "	10	70	225	67	Jalan Patung Kuda
2	119°37'49.92 "	04°01'57.25 "	13	35	240	56	Geddongnge Bagian Timur

Location n	Position		Slope Condition				Explanation
	x	y	Slope Height (Meter)	Slope Width (Meter)	Slope Direction (N....°E)	Slope Dip (....°)	
3	119°37'41.76	04°01'48.17	22	100	60	34	Geddongnge Bagian Barat
4	119°37'26.10	04°02'57.04	13	20	305	75	Toraya Kel. Lumpue Bacukiki Barat
5	119°38'24.46	03°59'58.98	9	40	85	87	Jalan Lauleng (MAN 1)
6	119°38'30.45	03°59'07.67	15	45	180	48-60	Jalan Lauleng IAIN Parepare

The result of weathering grade observation of each observed location is shown in Table 3 below.

**Table 3.** Weathering grade of research area

Location of Observation	Grade of Weathering				
	Fresh	Slightly Weathered	Moderately Weathered	Highly Weathered	Completely Weathered
Location-1			√	√	√
Location-2			√	√	√
Location-3		√	√	√	√
Location-4		√		√	√
Location-5		√	√		
Location-6		√	√	√	√



**Figure 3.** Slope geometry of research area

Below is the explanation of each observed locations and potential of occurrence of landslide.

#### 4.1. Location-1

Location-1 is located in Patug Kuda Street with slope geometry consists of: (1) slope height: 10 meters; (2) slope width: 70 meters; (3) slope length: 10.84 meters; (4) slope direction: N225°E; and (5) slope angle: 67 degrees. Slope forming rocks are volcanic rocks, consist of alternating tuff, lapilli tuff, volcanic breccia, and agglomerate. Those rocks are moderately weathered and locally have completely weathered (Table 3), locally occurred residual soil were also found in this area.

Based on the data above, location-1 is moderately susceptible to landslide because of steep slope (67 degrees), but the weathering is not evenly distributed to completely weathered, and the soil is thin. If landslide is about to happen, the model/type of landslide that will happen is debris slide.

#### 4.2. Location-2

Location-2 is located in Northern Part of Geddonge with slope geometry consists of: (1) slope height: 13 meters; (2) slope width: 35 meters; (3) slope length: 15.58 meters; (4) slope direction: N240°E; and (5) slope angle: 56 degrees. Slope forming rocks are volcanic rock, consists of bedded coarse tuff, moderately to completely weathered and locally has become residual soil.

Based on the data above, location-2 is very susceptible to landslide because of steep slope angle (56 degrees) and evenly distributed weathering into completely weathered. Moreover, there are buildings like offices and residents' houses above the slope which became burden to the slope. If landslide is about to happen, the model/type of landslide that will happen is debris slide.

#### 4.3. Location-3

Location-3 is located in Western Part of Gaddonge with slope geometry consists of: (1) slope height: 22 meters; (2) slope width: 100 meters; (3) slope length: 39.75 meters; (4) slope direction: N60°E; and (5) slope angle: 34 degrees. Slope forming rocks are volcanic rocks, consists of bedded coarse tuff, slightly to completely weathered (Table 3).

Based on the data above, location-3 is moderately susceptible to landslide because of moderately steep slope (34 degrees) and unevenly distributed completely weathered rocks and also thin soil. If landslide is about to happen, the model/type of landslide that will happen is debris slide.

#### 4.4. Location-4

Location-4 is located in Tonraya Western Part of Bacukiki with slope geometry consists of: (1) slope height: 13 meters; (2) slope width: 20 meters; (3) slope direction: N305°; and (4) slope angle: 74 degrees. Slope forming rocks are volcanic rocks consists of lapilli tuff and agglomerate, moderately to completely weathered (Table 3).

Based on the data above, location-4 is very susceptible to landslide because of steep slope (74 degrees) and distributed weathering into moderately to completely weathered. If landslide is about to happen, the model/type of landslide that will happen is debris fall.

#### 4.5. Location-5

Location-5 is located in Luleng Street with slope geometry consists of: (1) slope height: 9 meters; (2) slope width: 40 meters; (3) slope length: 9.01 meters; (4) slope direction: N85°E; and (5) slope angle: 87 degrees. Slope forming are volcanic rocks, consists of coarse tuff, fine tuff, and locally lapilli tuff, slightly to moderately weathered (Table 3).

Based on the data above, location-5 is moderately susceptible to landslide because of very steep slope (87 degrees) and slightly to completely weathered rocks, but will be very susceptible if the weathering goes on until the rocks are completely weathered. If landslide is about to happen, the model/type of landslide that will happen is debris fall.

#### 4.6. Location-6

Location-6 is located in Lauleng Street (IAIN Parepare) with slope geometry consists of: (1) Slope height: 15 meters; (2) slope width: 45 meters; (3) slope length: 17.37 meters; (4) slope direction: N180°E; and (5) slope angle: 48 to 60 degrees. Slope forming rocks are volcanic rocks, consists of coarse tuff and fine tuff, slightly to completely weathered (Table 3).

Based on the data above, location-6 is very vulnerable to landslide because of very steep slope (48 to 60 degrees) and moderately to completely weathered. If landslide is about to happen, the model/type of landslide that will happen is debris slide.

#### 5. Conclusions

- Parepare City official or instances has to pay attention to all six of research location, because weathering will go on over time and will result in weaker slope strength into critical slope
- If landslide happens, the model/type of landslide that will happen is debris fall in location 1, 2, and 6 and debris slide in location 4 and 5
- To prevent the slope from becoming more critical, mitigation has to be done in all six locations, structurally and non-structurally.

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