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Analysis of soil permeability and C-Organic in landslide events in Tangka Sub-Watershed

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Abstract. One of the areas in South Sulawesi Province classified as prone to landslides is the Tangka Sub-watershed in the West Sinjai Sub-District. The factors used in making the susceptibility map in the West Sinjai area mostly use general characteristics, such as slope, slope shape, distance from the river, lithology, land cover, and rainfall. Several previous research results stated that internal soil factors significantly affect the occurrence of landslides. Therefore, this study aims to determine the internal characteristics of the soil, especially the permeability and C-organic soil, which affects the occurrence of landslides and create a susceptibility map based on the resulting frequency ratio value. Soil permeability analysis using permeameter method, C-Organic analysis using Walkley and Black method, and susceptibility maps using frequency ratio method. The results showed that the low permeability and c-organic level of the soil increased the soil susceptibility to landslide events and produced a more detailed map of the area susceptibility than using only general factors.

1. Introduction
One of the areas in South Sulawesi Province prone to landslides is the West Sinjai sub-district, especially in the Tangka sub-watershed. Landslides are disasters that have a major impact on human life and safety. From 2008 to 2017, there have been 55 landslides in South Sulawesi, resulting in 38 deaths or missing [1].

One of the causes of landslides is weak soil or rock structure conditions that allow the soil mass above to move [2]. Some of the common factors that cause landslides are slope, slope shape, distance from the river, lithology, land cover, and rainfall [3]. Several previous research results state that internal soil factors greatly affect landslide events such as permeability and soil c-organic [4]. Therefore, this study aims to determine the internal soil factors (permeability and C-organic soil) that affect the occurrence of landslides by adding the permeability and C-Organic soil parameters to built up a susceptibility map.

2. Methods
The research location is in the Tangka Sub-watershed, South Sulawesi Province (Figure 1.). Data processing with ArcGIS 10.8 and data validation with SPSS (Statistical Product and Service Solution).

Soil samples were taken at the top layer (0-20cm). There are two methods for soil sampling i.e. undisturbed soil with ring samples for permeability analysis and disturbed soil for c-organic analysis.

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Measured soil permeability uses the permeameter method and c-organic analysis using the Walkley and Black method. The rainfall data used in this study is CHIRPS (Climate Hazards Group InfraRed Precipitation) for the period 2011-2020, which was analyzed using ArcMap 10.8. Analysis of the distance from the river was made using ArcMap 10.8 using the National DEM. There are several distance classes from the resulting river.

Soil susceptibility mapping uses the frequency ratio (Fr) method is based on the observed relationship between the distribution of landslide points and each landslide controlling factor, thus revealing the correlation between the location of the landslide and the factors causing the landslide [3]. The frequency ratio built up from parameters; lithology, land cover, rainfall, slope, curvature, distance from the river, soil permeability, and c-organic. Value Fr ratio is greater than 1.0 then the relationship between landslide incidence and causal factors is strong, and if the ratio is less than 1.0 then the relationship between landslide incidence and causal factors is weak [5]. The analysis of the landslide susceptibility index from all raster maps of the factors causing landslides with the ratio frequency value was carried out based on natural breaks in ArcMap 10.8. The ratio value in each class shows the degree of relationship between the frequency ratio values calculated by the formula [6]:

$$Fr = \frac{Pxcl\ (nm)/\sum PnxL}{Pixel\ (nm)/\sum Pnx} \quad (1)$$

Where, pixel (nm) number of pixel with landslide within class n of j parameter, Pixel (nm) Number of pixel in class n of m parameter, ΣPnxL total pixel of m parameter, and ΣPnx whole pixel of the area. To create an index susceptibility to landslides, all causative factors were charted in the form of raster maps of the value FR then summed by using Equation.

$$LSI = FR1 + FR2 + \ldots + FRn \quad (2)$$

Where FR1, FR2, FR3… FRn is the frequency ratio raster maps of landslide causative factors.

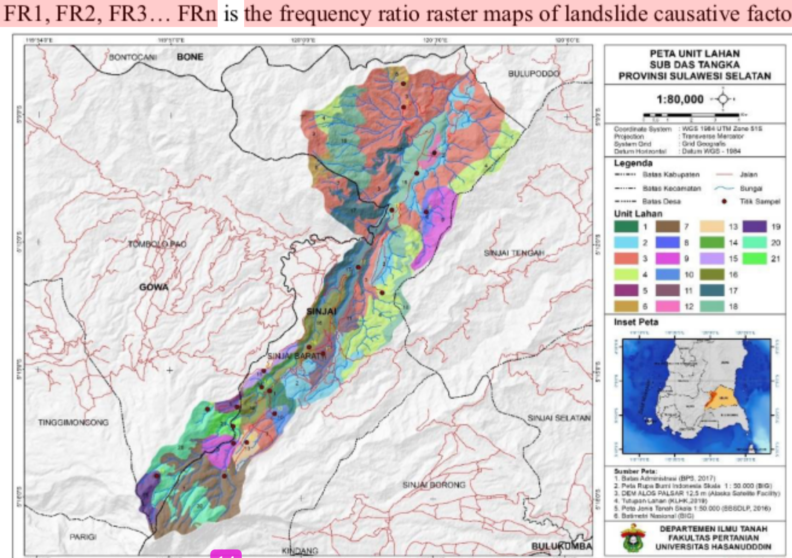

Figure 1. Map of the Research Location.

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3. Results and discussion

3.1. The frequency ratio of landslide

The frequency ratio from the parameter of lithology, land cover, rainfall, slope, curvature, distance from the river, soil permeability, and c-organic are presented in Table 1.

Table 1. The frequency ratio value with the factors that cause landslides.

Factor	Class	Number of Landslide Pixel in Class	Number of Landslide Pixel in Class % (a)	Number of Pixel in Class	Number of Pixel in Class % (b)	Frequency Ratio (a/b)
Lithology	Qlv Formation	481	57.74	346,270	43.49	1.33
	Camba Formation	350	42.02	225,806	28.36	1.48
	Granodiorite	0	0.00	44,849	5.63	0.00
	Baturape Formation	2	0.24	179,323	22.52	0.01
Land cover	Primary Dryland Forest	6	0.72	111,391	13.99	0.05
	Secondary Dryland Forest	0	0.00	16,990	2.13	0.00
	Shrubs	6	0.72	61,698	7.75	0.09
	Paddy field	5	0.60	65,133	8.18	0.07
	Mixed Dryland Farming	816	97.96	541,036	67.95	1.44
Rainfall	2,506-2,600mm/yr	0	0.00	106,687	13.40	0.00
	2,600-2,700mm/yr	712	85.47	253,072	31.78	2.69
	2,700-2,800mm/yr	66	7.92	186,781	23.46	0.34
	2,800-2,900mm/yr	55	6.60	205,889	25.86	0.26
	2,900-3,000	0	0.00	43,819	5.50	0.00
Slope	0-8%	0	0.00	42,292	5.31	0.00
	8-15%	5	0.60	75,740	9.51	0.06
	15-25%	34	4.08	130,328	16.37	0.25
	25-45%	89	10.68	296,861	37.28	0.29
	>45%	705	84.63	251,027	31.53	2.68
Curvature	Concave	512	61.46	487,059	61.17	1.005
	Convex	321	38.54	309,189	38.83	0.992
Distance from river	0-100m	476	57.14	362,218	45.49	1.26
	100-200m	322	38.66	231,340	29.05	1.33
	200-300m	30	3.60	135,356	17.00	0.21
	300-400m	4	0.48	51,888	6.52	0.07
	400-500m	1	0.12	13,434	1.69	0.07

	>500m	0	0.00	2,012	0.25	0.00
Soil permeability	slow	421	50.54	309,088	38.82	1.30
	slightly slow	0	0.00	85,398	10.73	0.00
	moderate	6	0.72	53,569	6.73	0.11
	Very slow	406	48.74	348,193	43.73	1.11
C-Organic	low	432	51.86	393,003	49.36	1.05
	moderate	401	48.14	403,245	50.64	0.95

Lithology affects landslides based on the type of rock [7]. In line with Raja et al. (2017) [8] stated that rock strength is the main geological character reflected by lithological conditions and its structure. So that information is needed in the form of the distribution and limits of the rock ability to withstand the destructive forces that naturally exist in nature when doing landslide analysis. In the study area, there are four rock formations, namely, Quarter Lompobattang Volcanic Rock (Qlv), Camba Formation (Tmcv), Granodiorite (gd), and Baturape Volcanic Rock (Tpbv) (Table 1).

The dominant rock types in the Tangka sub-watershed are Quarter Lompobattang Volcanic Rocks (Qlv) and the Camba Formation with a frequency ratio value of > 1, which means the possibility of landslides is high. One of the factors that cause landslides is rocks, which are generally in volcanoes such as volcanic deposits that have easily weathered characteristics. This is following the opinion of Imran et al. (2012) [9], they stated that tuff is one of the easily weathered volcanic deposits from highly weathered to completely weathered so that during the rainy season, air will seep into the rock and cause the rock mass to get heavier so that landslides may occur.

Land cover, could trigger a landslide due to improper use of land [4]. Such settlements with inappropriate land conditions are located in areas with high landslide susceptibility. In addition, improper land use will impact the occurrence of landslides [10]. The source of land cover data used is KLHK (2019). There are five land covers in the research area: primary dryland forest, secondary dryland forest, shrubs, rice fields, and mixed dryland agriculture (Table 1).

Land cover on mixed dry agricultural land has a frequency ratio value of > 1 which means it is prone to landslides, and other land cover shows a high ratio value. Dryland provides high land management, thereby reducing soil. According to Tazik et al. (2014) [11], landslides occur naturally and due to human behavior; of course, human activities can trigger landslides. Chen et al. (2019) [12] explained that changes in land use would affect slope stability and impact hydrological processes in the form of infiltration, surface runoff, and soil strength.

Rainfall, the trigger factor for landslides that needs to be considered is rainfall. According to Effendi (2016) [10], the threat of landslides usually occurs when the intensity of rainfall increased in an area. The higher the rainfall in an area, the possibility of landslides will be greater. The Fr value of rainfall can be seen in Table 1.

The average rainfall of 2600-2700mm/year shows the highest ratio compared to other rainfall averages. Rainfall affects the slopes; this occurs through a decrease in the shear strength of the soil and the addition of slope loads. This is following Hidayat (2018) [13] statement, where rainwater causes an increase in soil mass and has soil particles to trigger landslides. The intensity of rainfall can also affect the slopes of the slopes.

Slope, spread over the Tangka Sub-Watershed, have a very varied class ranging from flat, sloping, slightly steep, steep to very steep. The higher Fr value is a slope of >45% (Table 1). The Fr value of slope > 45% has a frequency ratio of 2.68, which indicates a very high potential for landslides. While the slope class 0-8% with a frequency ratio value of 0 indicates low landslides. Landslides are strongly influenced by

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the level of steepness and the driving force against the material on the slope. If the steepness of a slope is very high, the driving force will also be greater. Sobirin et al. (2017) [14] suggest that the chance of landslides in an area if the slope is higher, and vice versa, the smaller the possibility of landslides if the slope is in the area.

Curvature, the shape of the slope, divided into three classes, namely convex, flat and concave [15]. According to Shaw and Putra (2014), the process accumulating soil mass is influenced by water and the shape of the slope to trigger a landslide. The Fr value shows that the flat area has a frequency ratio value of 0 which indicates the occurrence of low soil movement and the shape of the slope of the basin has a value of > 1, which indicates the occurrence of landslides sufficient. In accordance with Putra's (2014) [16] statement, slopes with a basin shape are more common in landslide events. Concave slopes (such as valleys) tend to form overhanging soils and collect groundwater, surface water, sediment, and organic matter.

Distance from river is one of the causes of landslides. According to Wang et al. (2017) [17], areas close to rivers with steep slopes will experience heavy erosion, which in case of high intensity rain and sloping topography will cause landslides potential. The distance of the river of 0-100 m and 100-200 m has a frequency ratio value > 1, indicating a high occurrence of landslides. The 200-300 m class and the other three classes with a frequency ratio value of < 1 indicate a low probability of landslides. These results indicate that the higher the occurrence of landslides, the higher it is. This is in line with Fadilah opinion (2019) [18], which states that landslides are higher if they are near rivers because in areas close to rivers that usually have high humidity, soil conditions become less strong.

Permeability, one of the physical properties of the soil that affects the occurrence of landslides, is soil permeability Ahmad et al. (2018) [19]. Several classes of permeability were obtained, including rather slow, slow, very slow, and moderate (Table 1). The slow and very slow permeability values show the frequency ratio value >1, indicating the possibility of landslides. For slow and medium permeability has a <1, which means the possibility of landslides is low. High permeability will reduce the possibility of landslides compared to low permeability. This is according to Ahmad et al., (2018) [19], which states that areas with landslides with different physical properties are most common on soils with very slow permeability and low porosity.

C-Organic has two classes of c-organic analysis results obtained, namely low and medium (Table 1). the c-organic of low soil has a ratio value of <1 which means the possibility of landslides is high. One of the characteristics of the former landslide has a low c-organic content. New soils formed due to landslides have lower organic matter content than soils that have not / have not experienced landslides. Following the opinion of Cheng et al. (2015) [20], the soil in areas that do not occur in landslides contains higher levels of organic matter content because landslide events play a role in reducing organic content in the soil.

3.2. Landslide susceptibility mapping

The landslide map built based on lithology, slopes, land cover, rainfall, slope shape, and distance from the river resulted in a map with a susceptibility area with a low-class hazard level, which was higher than the medium-high susceptibility level. However, by including the permeability factor and c-organic soil, the moderate susceptibility level decreased from 27.48% to 24.7%, but still the same category in high-class hazard (Figure 2-5). This proves that the internal factors of the soil influence susceptibility. This is in accordance with the results of research by Ahmad et al. (2019) [21] that the soil factor has a significant influence on the occurrence of landslides. Many landslides occurred in Bonto Salama village, Terasa village, Arabica village, and Tassililu village; this area included in the low category of a landslides hazard class.

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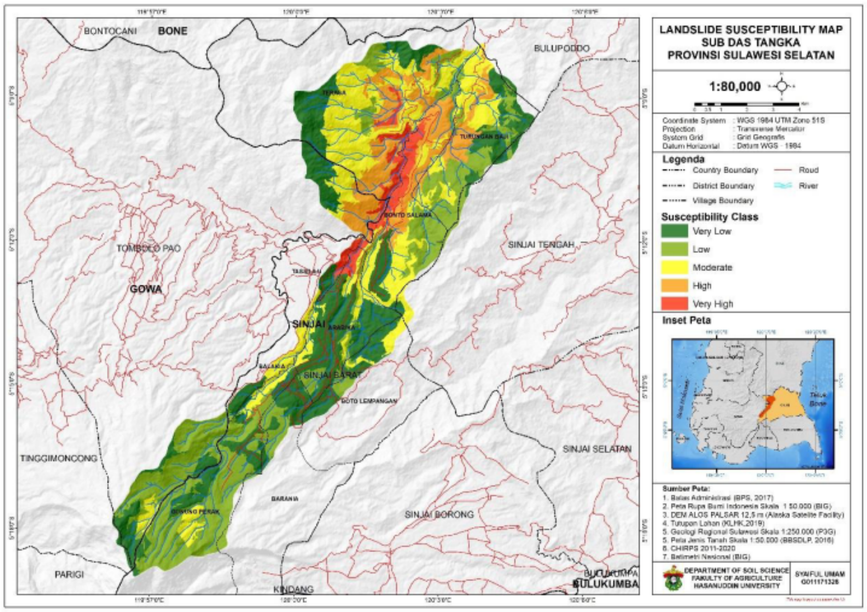

Figure 2. Landslide susceptibility map from factors; lithology, land cover, rainfall, slope, curvature, distance from the river, soil permeability and c-organik.

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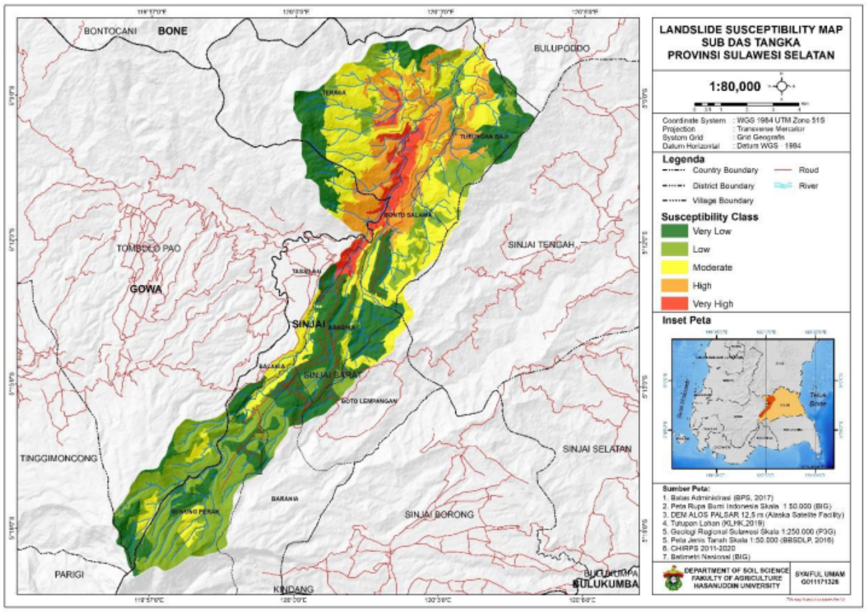

Figure 3. Landslide susceptibility map from factors; lithology, land cover, rainfall, slope, curvature, and distance from the river.

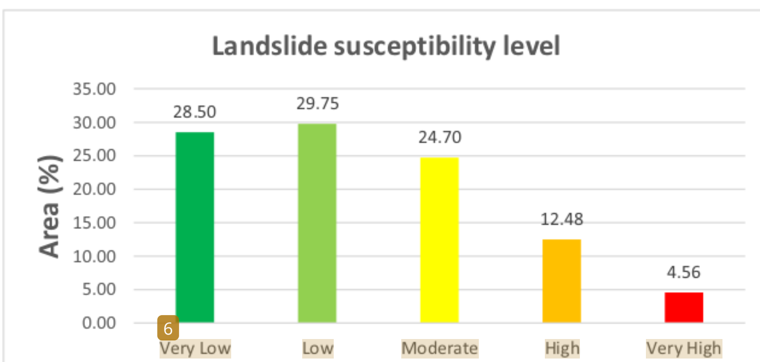

Figure 4. Landslide susceptibility level (%) from factors; lithology, land cover, rainfall, slope, curvature, distance from the river, soil permeability, and c-organic.

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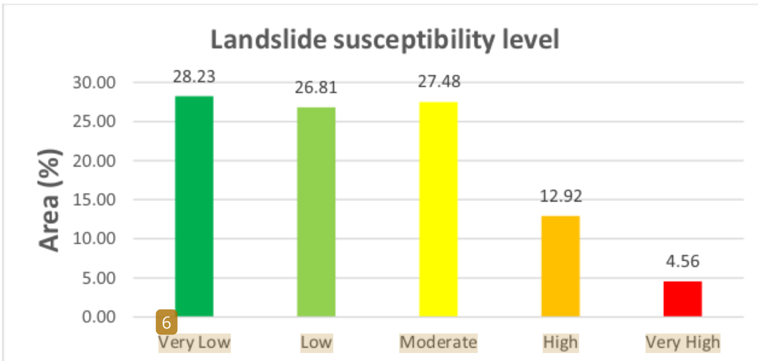

Figure 5. Landslide susceptibility level (%) from factors; lithology, land cover, rainfall, slope, curvature, and distance from the river

4. Conclusion

The low of permeability and c-organic level of the soil increased the soil susceptibility to landslide events with Fr value >1 and produced a more detailed map of the area susceptibility than using only general factors.

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