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Soil Erodibility Mapping for Soil Susceptibility in the Upstream of Kelara Subwatershed in Jeneponto Regency

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Abstract. Landslides and flash floods in Rumbia Village, Rumbia District, Jeneponto Regency on June 11-12, 2020, have caused material and non-material losses to the local population. The incident occurred very quickly with an area with a disaster impact on seven sub-districts and 18 villages. This study aims to map soil erodibility to assess soil susceptibility to landslides in the Upper Kelara Sub-watershed. Calculate soil erodibility using the Wischmeier and Smith method, texture with hydrometer method, c-organic with Walkley and Black, and mapping of soil erodibility with the kriging approach. The results showed that c-organic value content (1.19 to 2.47%) has low in landslides areas, with soil permeability ranging from 0.23 to 1.16 cm/hour and soil texture dominated silty clay. Soil erodibility in the landslides area reaches a value of 0.4. This value impacts the increased value of soil erodibility at the bottom of the Upper Kelara Sub-Watershed to increase soil susceptibility. Soil erodibility mapping showed a distribution of erodibility index increase in the bottom of the Subwatershed.

Keywords: landslide, Jeneponto, soil, Watershed

1. Introduction

Based on BNPB data for 2020, it is known that the risk index value for disaster events in 2015-2020 is still relatively high at 159.49 [1]. The number of landslides and flash floods in South Sulawesi is increasing every year. Although the incident data in Jeneponto Regency is classified as a moderate risk class, the events cause losses and casualties [2]. The data of landslides and flash floods in Rumbia Village, Rumbia District, Jeneponto Regency on June 11-12, 2020, have caused material and non-material losses to the local population. The incident occurred very quickly with an area with a disaster impact on seven sub-districts and 18 villages.

Disaster events are triggered by various things, such as changes in land use from forest to plantation [3], extreme rainfall anomalies [4,5], tectonic earthquakes, and volcanic earthquakes [6]. Various regional susceptibility maps related to landslides and flash floods have been made by ESDM [7] to take early mitigation actions against disaster events. However, the potential and magnitude of the event cannot be estimated because the geobiophysical conditions of each region are different [8] and very dynamic [9], so the extent of the impact cannot be evaluated at this time. For this reason, it is necessary to map the soil physical condition, especially the soil ability not to experience landslides that can trigger flash floods.

This study aims to create a soil erodibility map to predict the vulnerability of the soil in the banjir bandang-prone area upstream of the Kelara sub-watershed in the Jeneponto Regency.

2. Material and methods

Soil sampling was carried out on several slope classes in the Kelara watershed (Figure 1) in Jeneponto Regency at a 0-40cm depth at 24 soil sampling points. Soil analysis was carried out following the procedures of the Soil Research Institute [10] include; analysis of soil texture (sand, fine sand, silt and clay) with the hydrometer method, analysis of c-organic walkley and Black soil, permeability with permeameter, and direct observation for soil structure. Map created with Arc-GIS 10.3 software.
The calculation of the value of the soil erodibility index follows the procedure of Wischmeier and Smith [11], with the equation:

$$K = \frac{1.292[2.1M^{1.14}(10^{-4})(12-a) + (3.25(b-2) + 2.5(c-3)]}{100}$$

where:
K = index of soil erodibility
M = $percent\ of\ fine\ sand + percent\ of\ silt\ \times (100 - percent\ of\ clay)$
a = percent of organic matter
b = the code of soil structure
c = the code of permeability class

Soil erodibility mapping in the Kelara sub-basin was carried out by kriging interpolation with semivariogram value [12], with the equation:

$$\gamma * (h) = \frac{1}{2Nh}\sum_{i=1}^{Nh}[z\ (xi) - Z\ (xi + H)]^2$$

where:
Nh = The number of pairs
H = lag distance

Validation with root mean square error (RMSE), with the equation:

$$RMSE = [\frac{\sum_{i=1}^{n}(z(xi) - ž(xi))^2}{n}]^{1/2}$$

where:
z(xi) = the height value at reference data
ž = predited height of value

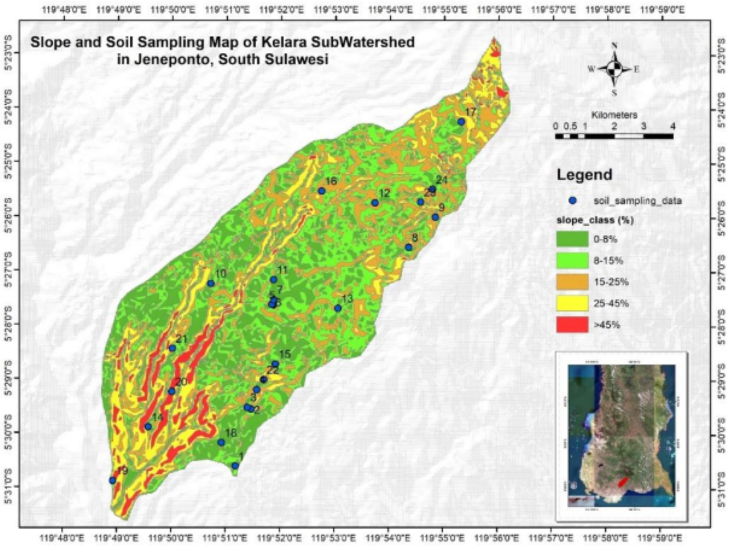

Figure 1. Slope and soil sampling map of the Kelara Subwatershed in Rumbia District, Jeneponto Regency

3. Results

The results showed that c-organic value content (1.19 to 2.47%) has low in landslides areas. The soil permeability ranged from 0.23 to 1.16 cm/hour in the very slow to slow category of permeability [13]. The soil texture dominated silty clay, with a silt fraction average is 49%; this value will reduce soil cohesion [14]. Slope classes vary widely and spread locally from the bottom to the upstream part of the SubWatershed. The dominant slope classes are 8-15% and 15-25% (figure 1).

Soil erodibility index in the landslides area reaches a value of 0.4 at slope 15-45% at sampling point 4 and sampling point 22, while on gentler slopes with higher erodibility values, no landslide triggers flash floods (figure2). The model of soil erodibility index in the upstream of Kelara Subwatershed in Jeneponto Regency showed the distribution of the erodibility index increases in the northeastern and eastern part of the subwatershed locally and increases at the bottom of the Subwatershed so that the accumulation of rain in the upstream area can cause landslides and flash flood at the bottom of the Subwatershed in line with the increase in the value of soil erodibility and the percent of the slope.

Validation data with RMSE show a value of 0.106, close to 0, which indicates the data used is accurate and precise to predict the spread of the erodibility index value in the upstream area of the Kelara sub-watershed in Rumbia District, Jeneponto Regency. The normal distribution of data value with plot distribution close to the model (straight line) can be seen in Figure 3.

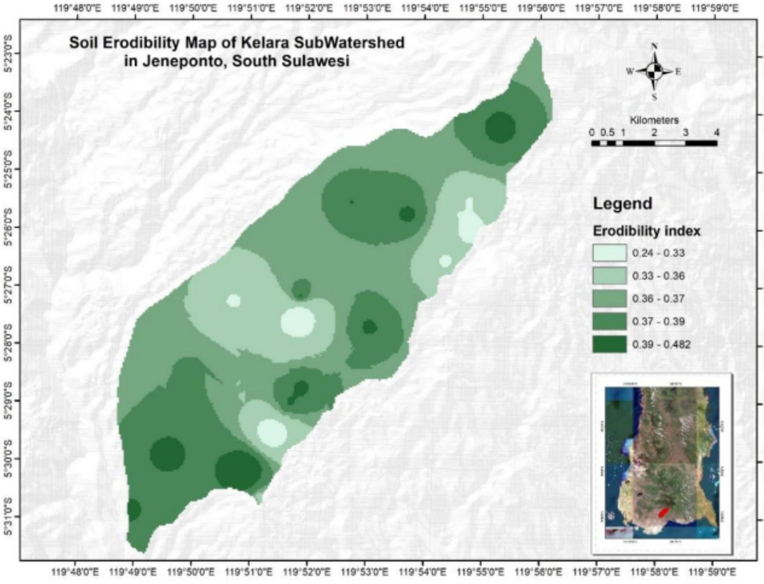

Figure 2. Soil erodibility map of the Kelara Subwatershed in Rumbia District, Jeneponto Regency

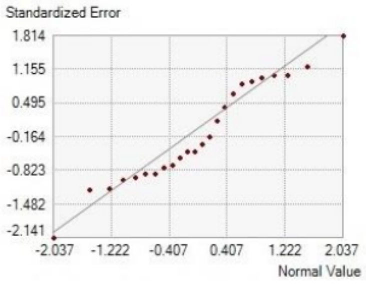

Figure 3. Normal distribution of plot data value closed to the model

Table 1. Soil characteristic in Kelara Subwatershed in Rumbia District of Jeneponto Regency

Soil sampling	Texture				Texture class	Soil organic matter	M	Soil Structure	Code of soil structure	Soil permeability	Class of soil permeability	Code of soil permeability	Soil Erodibility
	sand	fine sand	silt	clay		%				cm/hour			K
1	10	5	43	42	silty clay	3.07	2524	granule medium-coarse	3	0.99	slow	5	0.29
2	5	8	34	54	clay	4.26	1575	blocky	4	0.42	very slow	6	0.27
3	6	4	12	78	clay	3.45	268	blocky	4	0.71	slow	5	0.16
4	6	6	35	53	clay	2.05	1651	blocky	5	0.27	very slow	6	0.40
5	7	0	55	38	silty clay loam	4.22	3426	granule fine-medium	2	0.99	slow	5	0.29
6	12	0	30	65	clay	3.41	1050	blocky	4	1.39	slow	5	0.21
7	4	8	40	48	silty clay	3.62	2088	granule fine-medium	2	1.16	slow	5	0.20
8	7	8	45	40	silty clay	3.26	2708	granule fine-medium	2	0.76	slow	5	0.26
9	7	0	47	46	silty clay	3.43	2518	granule fine-medium	2	1.07	slow	5	0.24
10	5	0	43	52	silty clay	2.48	2064	granule fine-medium	2	0.31	very slow	6	0.25
11	4	3	67	26	silt loam	2.97	4961	granule fine-medium	2	0.56	slow	5	0.46
12	2	3	61	34	silty clay loam	2.65	4029	granule medium-coarse	3	0.41	very slow	6	0.47
13	6	5	62	26	silt loam	2.24	4593	granule fine-medium	2	0.5	slow	5	0.46
14	9	10	60	21	silt loam	2.09	4750	granule fine-medium	2	0.51	slow	5	0.48
15	3	0	60	37	silty clay loam	2.34	3780	granule medium-coarse	3	0.36	very slow	6	0.45
16	4	0	57	39	silty clay loam	2.09	3477	granule medium-coarse	3	0.36	very slow	6	0.43
17	8	11	63	18	silt loam	2.74	5177	granule fine-medium	2	0.94	slow	5	0.50
18	7	5	71	17	silt loam	2.31	5898	granule fine-medium	2	0.61	slow	5	0.59
19	8	13	59	20	silt loam	3.45	4733	granule coarse	3	1.16	slow	5	0.47
20	5	7	57	31	silty clay loam	3.14	3940	granule medium-coarse	3	0.51	slow	5	0.41
21	12	9	47	32	clay loam	3.34	3205	blocky	4	0.48	very slow	6	0.41
22	7	13	43	37	silty clay loam	2.09	2722	blocky	5	0.28	very slow	6	0.44
23	7	0	47	46	silty clay	2.10	2518	granule fine-medium	2	0.31	very slow	6	0.30
24	3	7	43	47	silty clay	2.09	2286	granule fine-medium	2	0.23	very slow	6	0.28

4. Discussion

The high slope classes at the bottom of the upstream Kelara Subwatershed trigger landslides that enter the river and induced flash floods. This is supported by the results of interviews with local communities, where before the flash flood, it was preceded by hillside landslides from riverbanks that entered the striped river flow and obstructed river flow. Continuous rain events had resulted in the overflow of river flows carrying material as flash floods and caused fatalities on June 12, 2021.

The decrease in soil carbon content in sloped areas of >15% occurred in all study locations. This triggers an increase in the value of soil erodibility. In this study, soil erodibility values that reach an index value of 0.4 have triggered landslides and flash floods. The decrease in soil carbon content and the high content of soil silt and clay fractions are the causes of increased soil erodibility and increasing soil saturation, and reducing soil cohesion values so that the soil is easily dispersed [15,16].

The increase in the value of soil erodibility in areas with small slopes (<15%) in hilly regions (highlands) is caused by an increase in land-use intensity. This situation results in a decrease in soil carbon content, which binds the soil fraction to compact the soil quickly [17], inhibits infiltration, increases runoff, and triggers flooding in lower areas. The decrease in soil carbon content can trigger flooding in flat areas, and this is following the results of research from Saint-Laurent [18] in southern Quebec, where floods often happen in lower areas with less organic carbon content.

Soil erodibility value mapping can be a solution in disaster mitigation. The mitigation process can be carried out immediately, especially for areas with high erodibility values, by applying vegetative and mechanical conservation techniques in the form of civil buildings to prevent the collapse of riverbank walls, especially in the lower area of the Kelara watershed.

5. Conclusions

Soil erodibility in the landslides area reaches a value of 0.4. This value impacts the increased value of soil erodibility at the bottom of the upstream of Kelara Sub-Watershed map to increase soil susceptibility, and it's connected to the slope of ≥15%.

Acknowledgment

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