Volume 4, Issue 9, September – 2019 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165

Utilization of the Storie Method to Analyze the Spatial Distribution of Ground Movement Vulnerability in the Limboto Watershed Area, Gorontalo Province

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Abstract:- Critical land due to land damage in watersheds area is mainly caused by the loss of topsoil, this is driven by the large carrying capacity of surface runoff flush from rainfall. The Limboto watershed area is one of the 15 national priority areas because it has a high level of sedimentation and is vulnerable to natural disasters. In addition, the area is also classified as critical land. Information regarding the spatial distribution and areas vulnerable to land movement is crucial to preserve the watershed area surrounding the lake and to mitigate the risks of natural disasters. With that being said, the purpose of this study is to use the storie method to analyze the level of vulnerability of ground movement in the Limboto watershed and its spatial distribution. Limboto Watershed has 4 level of ground movement vulnerability from low to very high. The dominant level of ground movement vulnerability is moderate with an area of 45.27% of the entire watershed. Spatial distribution from very high level of vulnerability is distributed in 3 subdistrict, there are Limboto Barat, Limboto and Tibawa Subdistrict.

I. INTRODUCTION

Critical land due to land damage in watersheds area is mainly caused by the loss of topsoil, this is driven by the large carrying capacity of surface runoff flush from rainfall. This damage is caused by various human activities that are not paying attention to the sustainability of the environment. A layer of fertile soil underutilized without the techniques of soil and water conservation as an effort to preserve its productivity. Logging of forest vegetation and fields that do not apply the principles of soil conservation is one of the main factors the causes of damage to the catchment. Conversion of agricultural land to reach around 4.2 percent per year is also a factor join make things worse [1].

This is when supported by rainfall is high enough then it can cause flooding. Gorontalo province had a relatively high air humidity, humidity average reach 80.17%. The highest rainfall (400 mm) occurred in December with the number of rainy days as many as 24 days [1].

Limboto Watershed is one of 15 national watershed priorities that should be addressed seriously and is one of the contributing watershed of sediment in the Limboto Lake and national disaster-prone. The area categories include Limboto watershed is critical land. Most of the population works in agriculture so as to spur the process of opening of the farmland to the upstream watershed areas which is a catchment, resulted in a decrease in the total area of the forest. This happens due to deforestation and illegal land conversion into agricultural land to plant corn. Community land extending more effort (extensification) without seeing the ability of power support the quality of the environment.

Therefore information about the spatial distribution as to the level of vulnerability of ground movement is required to support the conservation efforts of Limboto Lake and disaster in Limboto watershed. The purpose of this study is to use the storie method to analyze the level of vulnerability of ground movement in the Limboto watershed and its spatial distribution. Watershed physical characteristics in the form of usage of land, topography, soil type, precipitation, and used as an input parameter of the index calculation is the vulnerability of ground movement.

Ground movement is a process that generates movement towards the bottom and out of the materials forming the slopes include rock, ground or a combination of both. This material can move in the form of ruins, avalanches, flow, and a complex movement [2]. In the guidelines of Spatial Areas prone to Landslide, ground movement is defined as the period of displacement of soil or rock by the direction of the upright, horizontal, tilted from its original position, due to the influence of gravity, water currents and load.

One of the important factors is the ground movement caused by precipitation [3]. High rainfall intensity in a long time, it can cause water to seep into the ground would go down thereby damaging the structure of the rocks of the compact and waterproof. The rock will break and rock fragments of material will be carried away by the flow of water so that the landslide occurred. The factor causes landslides become inside and outside factors [4]. Inside factors consist of the depth of weathering of rocks comprise, structure of geology, thick solum, ground, soil texture, and soil permeability. While outside factors which act against the occurrence of landslides include slope slope, density of nicks, many say the least steep walls, and land use.

Storie index known as assessment methods (rating) based on characteristics of the land that relates to land use potential and productive. This assessment method does not consider the physical and economic factors relating to plant growth in a particular location. Characteristics of soil that is evaluated, it consists of 4 element; element A is the character of physical soil profile, element B is soil texture , element C is slope, and the X element which could be another element for example, drainage, salinity, alkalinity, erosion, micro-relief. Each of these elements are ranked (rating) then multiplied and the result is the value of the index Storie. Storie index = elements A x elements B x elements C x element X [5]. In 2005, USDA NRCS have published concerning the revision of the index Storie method. Revised method is intended to reduce the element of subjectivity associated with the assessment of the land/land use classification. The value of the parameters in the assessment score is determined using fuzzy logic functions and discrete [6].

II. DATA AND METHOD

Spatial distribution mapping vulnerable areas of ground movement is carried out using the method of index Storie. This method is used in addition to the assessment of classification of agricultural land, has also been implemented in determining areas vulnerable ground movement [7-10], with the index parameter modification Storie equation is as follows:

$$L = A \times \frac{B}{10} \times \frac{C}{10} \times \frac{D}{10} \quad (1)$$

Description:
L = Vulnerability of ground movement;
A = land use;
B = slope;
C = soil type ;
D = rainfall

Based on the previous equation, the order-parameter used to determine the level of ground movement vulnerability consists of classification of land use, distribution of soil types, slope classification, and distribution of rainfall. Data collection and processing are based on these four parameters.

A. The Stage of Data Collection

The data collected is a Digital Elevation Model (DEM) of SRTM data. The value that is contained in this data is the value of altitude. This data is remote sensing data in raster format which has a spatial resolution of 30 m and is available free of charge. Land use classification data were obtained from Topographical Maps (RBI) digital 1:50,000 scale, downloaded from the pages of the Geospatial Information Agency (BIG) are available in vector format (shapefile).

Distribution of soil types and rainfall data obtained from soil maps and digital rainfall BPDAS Bone Bolango Gorontalo Province. This data is available in vector format (shapefile). In addition there are other data as supporting analysis, which are available in the form of documents, data and coordinate digital map sourced from the results of previous research. Data processing parameters of physical or supporting data is done with the use of some application processing geospatial data, namely Quantum GIS 2.18 and office applications LibreOffice 6.0.3.2. Both of these applications are free and open source.

B. The Stage of Data Processing

This stage begins with the first adjust the coordinate system from the available data and determine areas of study in all the data. Slope data obtained by extracting the data DEM raster analysis using Terrain Models application on QGIS. The output of this process is data slope in percent (%) are next in classification and given appropriate weight classification.

The next stage of processing is process land use, soil type and rainfall data. This data is converted in a raster format with a resolution of DEM data. Next follows the determination of weights for each data is done based on the level of sensitivity to erosion. As can be seen in the following tables :

Land Use	Errotion level	score
Heterogeneus Forest	Insensitive	1
Homogeneus Forest	Less sensitive	2
Farm	Fair sensitive	3
Occupation, Rice fields	Sensitive	4
Moor, Open land	Very sensitive	5

Table 1:- Land use classification

Slope (%)	Slope class	Morphology	Score
0-8	Flat	Plain	1
9-15	Sloping	Soft relief hills	2
16-25	Rather steep	Medium relief hills	3
26-45	Steep	Rough relief hills	4
>45	Very steep	Very rough relief hills	5

Table 2:- Slope classification

Soil type	Errotion level	Score
Alluvial, Glei	Insensitive	1
Latosol	Less sensitive	2
Brown forest, mediteran	Fair sensitive	3
Andosol, grumosol, podsol	Sensitive	4
Regosol, litosol, organosol	Very sensitive	5

Table 3:- Soil type classification and score to errotion level

Rainfall intensity (mm/year)	Parameters	Score
<2000	Insensitive	1
2000-2500	Fair sensitive	2
2500-3000	Sensitive	3
>3000	Very sensitive	4

Table 4:- Rainfall intensity classification.

C. The Data Analysis Phase

This stage starts by doing a multiplication of the parameter Index Storie, utilizing the tools of raster calculator. The expression being entered in the analysis of these data follow the equation (1) above. The output of this process is a raster format file that contains the results of the multiplication order-parameter Index Storie. It was created based on the value of the next level of vulnerability as much as 4 classes, low, moderate, high and very high.

Further cross-tabulations of spatial-based methods (cross tab) will be conducted to clarify the relationship between two data/information. This process is done between vulnerability distribution map with the map slope, soil type and rainfall.

III. RESULT AND DICUSSION

First storie index parameters is the kind of land use in Limboto watershed, is classified into 5 class of land use. There are heterogeneus forest that insensitive to errotion, homogeneus forest that less sensitive to errotion, farm that rather sensitive to errotion, occupation and rice fields that sensitive to errotion, then moor and open land that very sensitive to errotion. The classification of land use in the Limboto watershed shown in figure 1.

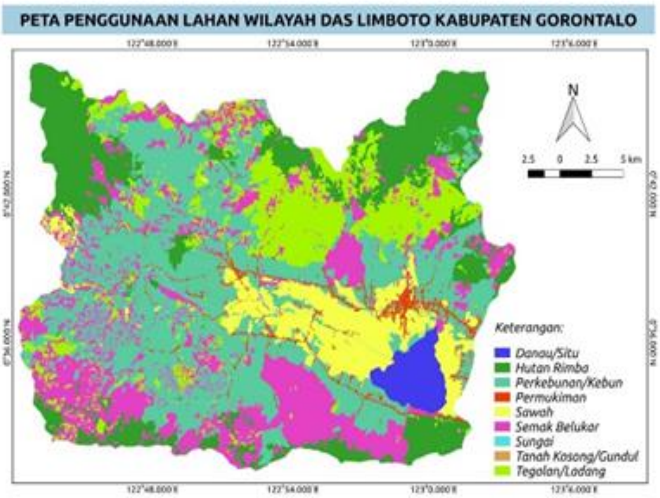

Fig 1:- Map of land use classification of the Limboto watershed.

The land use map showing that farm is dominating land use in Limboto Watershed, then following with jungle, then rice fields. Change in land use can be destroy the precipitation of ground water that can cause the land movement is more sensitive to happen in Limboto watershed.

ISSN No:-2456-2165

Then, for the second parameters of storie index is slope classification to the errotion level in Limboto Watershed. The slope class classification is classified into 5 class. Its classified using the percentage of slope. 0-8 % is categorized as flat class, 9-15 % is categorized as Sloping class, 16-25 % is categorized as rather steep, 26-45 % is categorized as steep, and >45 % is categorized as very steep. The slope classification in the Limboto watershed is shown in Figure 2.

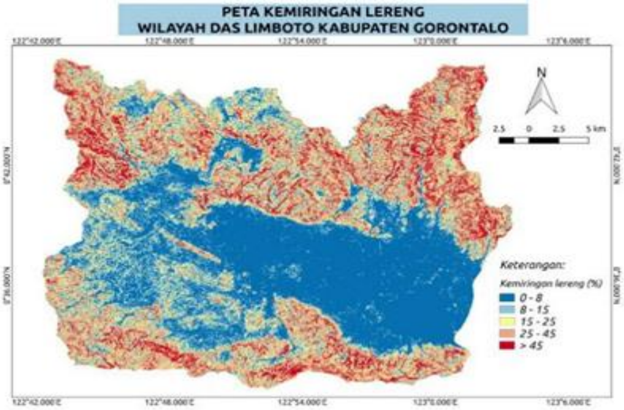

Fig 2:- Map of slope classification of the Limboto watershed.

The slope class map showing that Limboto watershed is dominated by flat slope class with 0-8 % slope in the middle part of Limboto Watershed. But very steep slope class is also dominating after flat slope class. We can see in the map, the red colour is also dominating the north and south part of the Limboto watershed.

For the third parameters, we have soil type classification to errotion level in Limboto Watershed. The soil type in classified into 5 class of soil. There are Alluvial and Gleil that insensitive to errotion, Latosol that less sensitive to errotion, Brown forest and mediteran that rather sensitive to errotion, Andosol, Grumosol, and Podsol that sensitive to errotion, Regosol, Litosol and Organosol that very sensitive to errotion. The distribution of soil type in the Limboto watershed is shown in Figure 3.

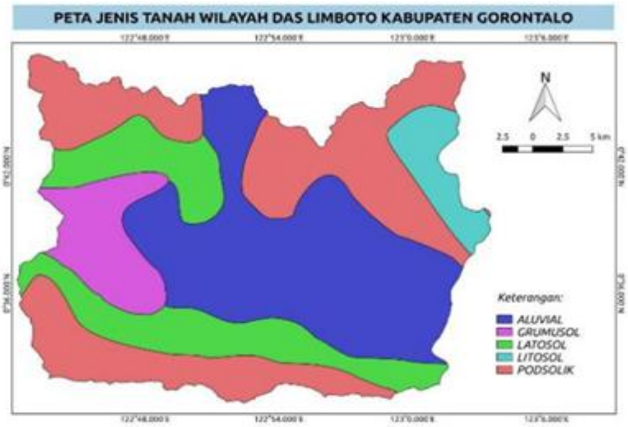

Fig 3:- Map of soil type of Limboto watershed.

The soil type map of Limboto Watershed showed that Alluvial type of soil is dominating the middle part of Limboto watershed which classified as insensitive to errotion level. Than continued by the Podsolik type of soil that classified as sensitive to errotion level in the north and south part of Limboto watershed.

Then for the last parameters of storie index is rainfall intensity classification to the errotion level in Limboto Watershed. The rainfall class is classified into 4 class. There are >2000 mm/year is categorized as insensitive level of errotion level, 2000-2500 mm/year is categorized as rather sensitive level of errotion level, 2500-3000 mm/year is categorized as sensitive level of errotion level, and >3000 mm/year is categorized as very sensitive level of errotion level. The distribution of rainfall intensity in the Limboto watershed is shown in Figure 4.

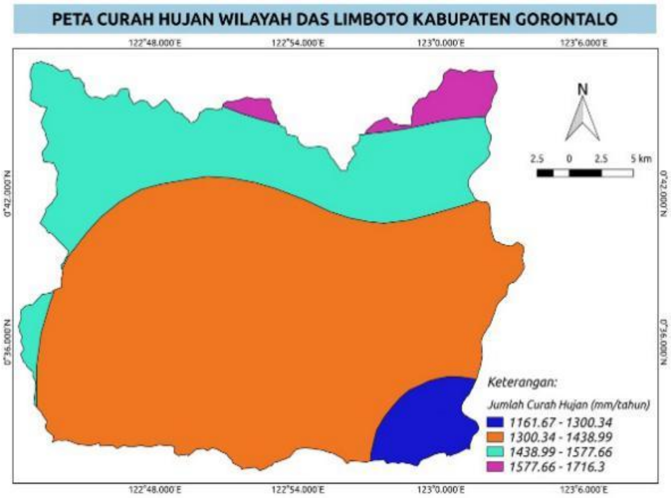

Fig 4:- Map of rainfall distribution of Limboto watershed.

The rainfall class map showing that Limboto watershed is insensitive to errotion level because the rainfall intesity is < 2,000 mm/year. We can see in the rainfall map, 1,300.34 – 1,439.99 mm/year is dominating the rainfall in the middle part of limboto watershed, and continued by 1,438.89 – 1,577.66 mm/year in north part of Limboto Watershed. In this case, rainfall is not the main reason of Land movement in Limboto Watershed, because the rainfall intensity is < 2,000 mm/year.

Based on the results of the multiplication of the Storie Index parameters, an index value of 0.001 s.d 0.125 is obtained. The results of the Index obtained, the limboto watershed area has 4 levels of ground movement vulnerability, namely Low, Medium, High, and Very High, can be seen in table 5 and figure 5 surface area of body area as follows :

The level of vulnerability	Area (Ha)
Low	30,770.37
Moderate	40,468.50
High	13,242.87
Very High	4,910.22
Total	89,391.96

Table 5:- The broad level of ground movement vulnerability

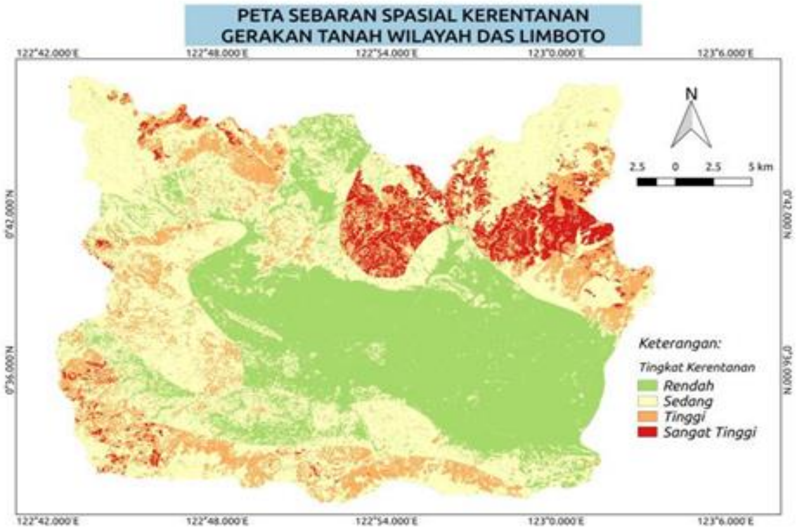

Fig 5:- Map of spatial distribution of ground movement vulnerability in Limboto watershed.

Analysis result of cross tabulation between spatial distribution of ground movement vulnerability and sub district administration map, we can get the vulnerability area per subdistrict. There are 13 subdistrict in Gorontalo Regency, 1 subdistrict in North Gorontalo, and 1 subdistrict in Gorontalo city. The vulnerability area per subdistrict in Limboto watershed showed in table 6 as follows :

No	Sub District	Area (ha) Vulnerability Level				
		Low	Mod	High	Very High	Total
1	Tabongo	2,791.98	1,217.43	116.10	0	4,125.51
2	Telaga	3.33	147.96	45.09	281.25	477.63
3	Dungaliyo	2,071.35	2,066.76	885.51	9.63	5,033.25
4	Batudaa Pantai	0.36	3.78	0	0	4.14
5	Talaga Jaya	482.31	16.56	0	0	498.87
6	Danau	2,203.47	0	0	0	2,203.47
7	Batudaa	1,484.64	2,024.73	484.02	0	3,993.39
8	Tilango	240.75	8.55	0	0	249.30
9	Limboto Barat	3,705.66	3,385.26	1,087.74	1,423.89	9,602.55
10	Pulubala	3,067.02	11,392.38	2,251.62	146.70	16,857.72
11	Limboto	3,461.85	1,382.58	1,103.22	1,298.61	7,246.26
12	Bongomeme	2,995.92	8,210.16	2,904.12	297.54	14,407.74
13	Tibawa	6,233.49	5,625.54	2,703.06	1,043.01	15,605.10

Table 6:- The vulnerability area per subdistrict in Limboto watershed.

ISSN No:-2456-2165

A. Very High Vulnerability Distribution Area

Spatial distribution of very high level of vulnerable area is dominated in North part of Limboto watershed, and mainly distributed into 3 subdistrict, which percentage area is Limboto Barat 29 %, Limboto 26.45 % and Tibawa 21.24 %. Land use in this class is dominated by moorfields 95.77 %. Slope class in this class is 95.39 % steep to very steep with rough hills relief to rough. Soil type that dominating by Podsolik and Litosol.

Disaster data of land movement is in land movement coordinate from BNPB Indonesia, overlayed with vulnerability level map. The result showed that land movement in Mulyonegoro Village in 2013, Pulubala subdistrict is in very high vulnerability class. Pulubala subdistrict has 2.99 % of very high vulnerability level.

B. High Vulnerability Distribution Area

High level of ground movement vulnerability is 14.81 % from Limboto Watershed area in west part of Limboto watershed, and distributed in Bongomeme subdistrict, Tibawa, Pulubala and Telaga Biru. According data and information in Sulawesi Agroforestry and Forest document that land movement happen in Labanu village, Tibawa Subdistrict in 1999 and 2000.

Therefore, land use that dominating in this class is field, shrubs and moorfields. Slope is sloping to very steep with almost same percentage. Soil type on this class is dominated by Podsolik. There also Grumusol, Litosol and Latosol with almost same percentage.

C. Low and Moderate Vulnerability Distribution Area

Low and moderate level of ground movement vulnerability each 45.27 % and 34.42 % and the most dominant class of vulnerability level in Limboto watershed. The distribution of this 2 class is available in all subdistrict with different percentage. Vulnerability level in dominated distributed in the middle part of Limboto Watershed. Land use in this area is dominated by field and jungle with sloping to very steep slope. Soil type in this class is Alluvial.

Disaster data of land movement is in land movement coordinate overlayed with vulnerability level map. The result showed that land movement in Pilolodaa village, Kota Barat Subdistrict in 2015, is in low level of vulnerability.

IV. CONCLUSION

Limboto Watershed has 4 level of vulnerability from low to very high. Moderate area of vulnerability level is dominant, 45.27% from watershed area. Spatial distribution from very high level of vulnerability is distributed in 3 subdistrict, there are Limboto Barat, Limboto and Tibawa Subdistrict.

ACKNOWLEDGMENT

The authors are grateful to several institution, to BIG for providing digital topographic map data, to BPDAS Bone Bolango for providing soil map and digital rainfall data, to U.S. Geological Survey for providing SRTM data. The authors are also grateful to all colleagues who cannot be mentioned one by one for all encouragement and support in this research.

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