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IDENTIFICATION OF VULNERABILITY AREA OF MASS MOVEMENT USING STORIE METHOD IN BONE BOLANGO REGENCY, GORONTALO PROVINCE

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Abstract

Mass movement occurs due to the natural process in the changes of surface structure, in which there is a disturbance of stability in the soil or rocks making up the slope. The disturbance is caused by some conditions such as a relatively steep slope, the condition of rock or soil making the slope, high rainfall intensity, uncontrolled human activity in exploiting the nature as well as the state of geological structures. The research site is located in three sub-districts in Bone Bolango District; Suwawa Timur, Suwawa Tengah, and Suwawa Selatan. These three sub-districts have a history of mass movement during the rainy season. The availability of up-to-date data is required to reduce the impact caused by the mass movement. This research aims to identify the areas prone to mass movement. One of the approaches applied to identify the areas prone to mass movement is Storie Index method by calculating the parameter, which is considered influencing the mass movement. Among others, the parameters are steepness of the slope, rainfall, type of soil, land usability, and lineament density as the parameter of geological structures. Based on the analysis result, the research sites are divided into three levels of mass movement vulnerability; low as much as 10,98, moderate as much as 84,41, and high as much as 4,61% out of the entire research areas.

Keywords: Mass Movement, Lineament Density, Bone Bolango

A. Introduction

Mass movements occur due to disturbance of slope stability on the ground or mountain slope compiler which is a natural process of surface structure changes. This can be caused by several factors that affect geomorphology, especially the slope, the condition of the land or mountains making up the slope, and the geological structure that develops to form a stocky and fault in the area. Although mass movement is a natural phenomenon, some of the results of uncontrolled human activities in exploiting nature are one of the factors causing slope stability so that ground motion can be carried out (BNPB, 2012).

Regional Disaster Management Agency (BPBD) of Bone Bolango Regency noted that there had been a land movement disaster in April 2019 in Suwawa Selatan Sub District. This incident resulted in one house in Bondawuna Village being damaged by an avalanche. In 2016 Gorontalo Province Social Service established East Suwawa District as a Kampung Siaga Bencana (KSB) because this area was considered vulnerable to disasters in the land movement in terms of geographical conditions.

The Storie Method is one of the methods that is easy to implement and the data needed is easy to obtain. In Indonesia, the Storie method is used for agricultural purposes, in addition it can be applied to determine the level of landslide vulnerability (Arifin, et al, 2006). The Storie Method is a function of several parameters that are factors in the occurrence of mass movement, namely the slope, land use, soil type, rainfall, and geological factors (lithology and geological structure).

B. Methodology

1. Storie Index

The Storie Index is a semi-quantitative method for rating (rating) land based on soil characteristics, generally this method is used to determine the potential for land use and soil productivity capacity (Storie, 1978). In its application this method does not take into account other physical or economic factors that might affect the suitability of plants in an area. The analysis is easy to do, from various categories then grouped into several categories.

There are four to five parameters that are usually taken into account, namely:
A: Soil depth and texture;
B: Soil permeability;
C: Chemical properties of soil;
D: Drainage, surface runoff;
E: Climate.
The index is calculated by multiplying the parameters, i.e.:
S index = A x B x C x D x E........................(1)

The disadvantage of this method is that if one of the parameter categories is zero, the result of the multiplication (Storie Index) will be zero. Then the land will be considered to have physical limitations, so it is not suitable for agricultural land needs. The Storie Index Method was originally used to classify soil types on agricultural land. But in its development this method was used in several studies, one of which was conducted by Arifin et al. (2006) for the determination of landslide prone areas in Lampung Province with the arithmetic parametric model of the Storie Index multiplication using the formula:
L = A x B/10 x C/10 x D/10 x................... (2)
explanation:
L : prone to landslides
A : slope
B : land use
C : rainfall
D: type of soil

2. Lineament Density Analysis (LDA)

Generally, there are two methods used to detect and extract lineament features from satellite image data:

a. Extraction Based on Visual Observation: this method begins with a number of image processing techniques to improve the edge quality of an object (edge enhancement). The lineament feature can be visually clarified using image enhancement techniques with directional and non-directional filters, such as contrast stretching, Sobel, Laplacian, and PCA (Principal Component Analysis). Then an observation is made of the image data, which is then digitized manually.

b. Automatic Extraction: several methods used with the help of computer hardware have been proposed to extract lineament features. Generally, these methods are based on filtering and edge filtering techniques, such as the Canny, START and EDISON algorithms. This of course requires help from software that can be used to extract lineament (straightness) automatically. Software that is commonly used to detect and extract lineament features automatically is PCI Geomatics.

Table 1. Use of parameter values for lineament extraction in the LINE Algorithm Module in PCI Geomatica.

Parameter		Score
Name	Description	
RADI	*Filter Radius*	5
GTHR	*Gradient Threshold*	75
LTHR	*Length Threshold*	10
FTHR	*Line Fitting Error Threshold*	2
ATHR	*Angular Difference Threshold*	20
DTHR	*Linking Distance Threshold*	1

Source: Thannoun R.G. 2013

To get the right lineament features according to the tectonic state of the study area, the optimal value for the LINE Module parameters must be determined. Then the values (table 1) are used as input data to the LINE Module to calculate and estimate length, orientation, numbers, and line density.

C. Findings and Discussion

1. Parameter Identification and Classification

a. Slope

The slope data obtained from the analysis of the Digital Elevation Model (DEM) data downloaded via the Earth Explorer website The U.S. Geological Survey (USGS). The initial step taken is to input data using the add data tool then create the value of the slope using the Slope tool in ArcGIS 10.3 software. After that, the slope data are classified according to the Guidelines for the Preparation of Land Rehabilitation and Conservation Patterns (1986).

Table 2. Classification and slope score of the study site

Slope (%)	Class	Score
0 – 8	Flat	1
8 – 15	Sloping	2
15 – 25	Rather steep	3
25 – 45	Steep	4
>45	Very Steep	5

Source: Guidelines for the Preparation of Land Rehabilitation and Conservation Patterns (Direktorat Jendral Reboisasi dan Rehabilitasi Lahan, 1986).

The research location has a slope of 0 - 8%, 8-15%, 15-25%, 25 - 45%, and> 45%. Each class has a slope based on the degree of slope starting from flat, sloping, rather steep, steep, and very steep.

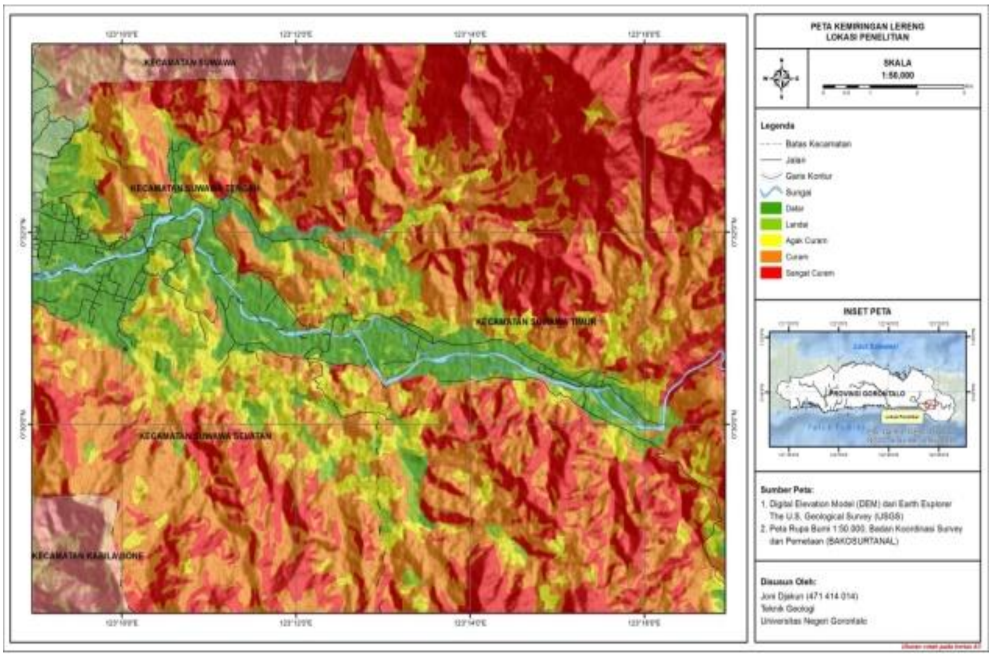

Figure 1. Map of the slope of the study site

b. Rainfall

Rainfall data were obtained from the Climatology and Geophysics Meteorological Agency of Gorontalo Province. The data obtained in the form of monthly rainfall data for the period 2018 at three observation stations namely, Tulabolo station, Bone Raya Station, and BP3K Bone Station. The three data from each station are then averaged. The isohyet method is a method used to interpolate rainfall data. The isohyet method calculates the actual influence of a rain gauge. This method is suitable for irregular hilly areas with an area more than 5000 km2. The data is classified based on reference and converted into vector data so that it can be given a score value and calculated as a ground motion parameter as table 3.

Table 3. Classification and rainfall scores of study sites.

Intensity (mm/year)	Intensity Level	Score
900	Very Dry	1
1100	Dry	2
1300	Moderate	3
1500	Wet	4
1700	Very Wet	5

Source: Data Analysis (2019)

This shows that rainfall in 2018 is not so intensive as its impact on soil movements in certain periods. The research location consists of only one rain class, which is very dry.

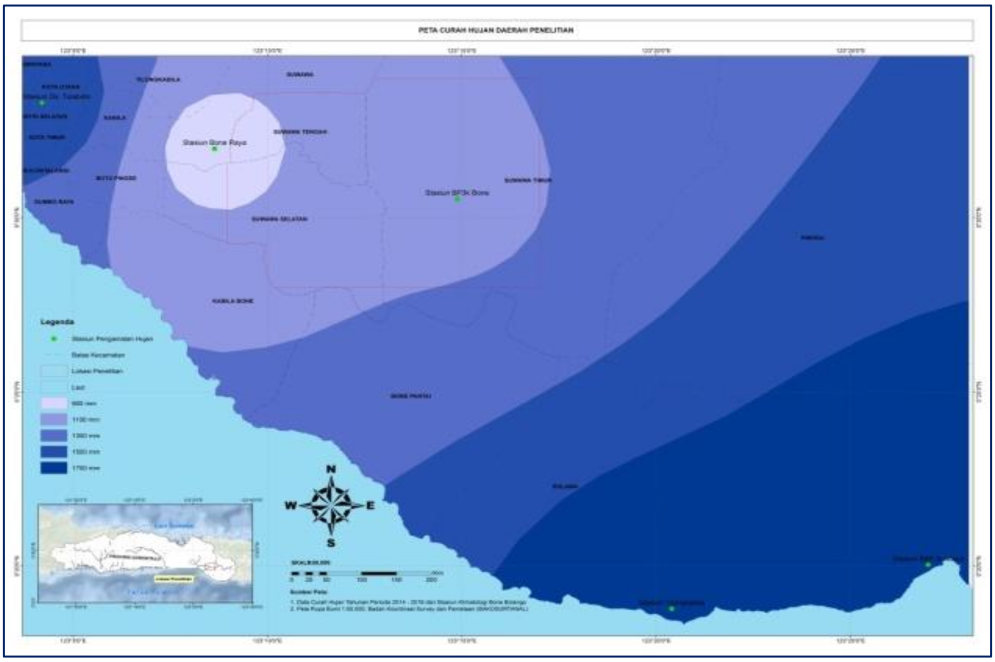

Figure 2. Map of rainfall in the research location

c. Land Use

The land use data used is the Bone Bolango District Land Use Data. The data obtained in the form of Shapefile data which is then inputted into ArcGIS 10.3 software and classified according to table 4

Table 4. Classification and land use score of the study location

Land type	Sensitivity level	Score
Jungle	Not sensitive	1
Shrubs	Less sensitive	2
Plantation	Rather sensitive	3
Settlement	Sensitive	4
Fields, vacant land	Very sensitive	5

Source: (Karnawati, 2003 in Sugianti, 2014)

The research location has land use which is divided into five types of land, namely jungle, shrubs, plantations, settlements, fields and vacant land.

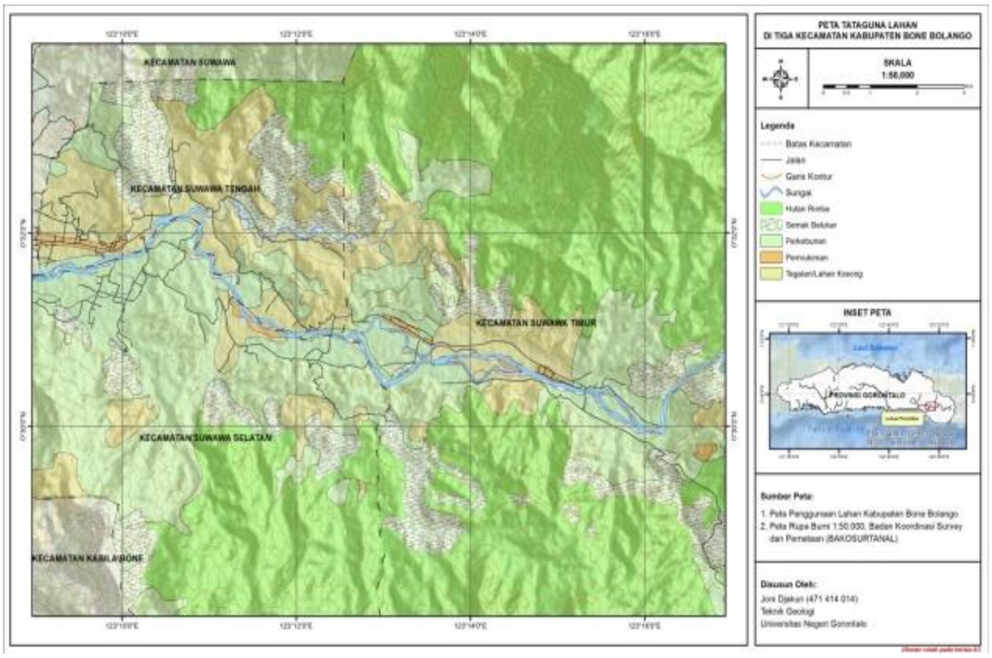

Figure 3. Map of land use for the study location

d. Type of Soil

Data on soil types were obtained from the Indonesian Center for Agricultural Land Resource Research and Development (BBSDLP). The data obtained in the form of image data (JPEG), which then made Shapefile data by manually digitizing the boundaries of the area of the type of soil and adjusted to the study location as table 5.

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Table 5. Classification and score of soil types of study sites

Type of Soil	Sensitivity	Score
Alluvial, Glei	Not sensitive	1
Latosol	Less sensitive	2
Brownforest, Mediteran	Rather sensitive	3
Andosol, Grumosol, Podsol	Sensitive	4
Reogosol, Litosol, Organosol	Very sensitive	5

Source: Sobirin (2013)

The location of the study was based on a map of soil types by the Indonesian Center for Land Resources and Agriculture (Figure 4) consisting of four types of soil. Yellow indicates alluvial soil types, green indicates brown forest soil types, purple indicates latosol soil types, while blue indicates Mediterranean soil types.

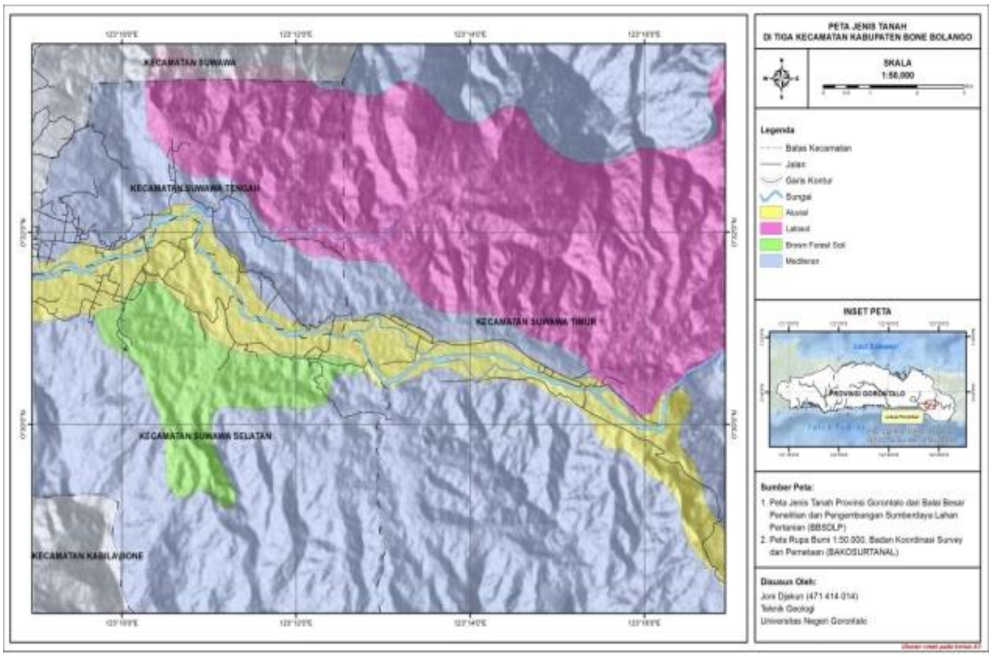

Figure 4. Map of soil type research location

e. Lineament Density Analysis

Spatial analysis using Digital Elevation Model (DEM) data downloaded via the Earth Explorer website The U.S. Geological survey (USGS) with a resolution of 30 × 30 meters (Figure 3.1). This analysis is assisted by using ArcGIS 10.3 software.

The initial step starts with making a shaded relief with four irradiation angles 0º, 45º, 90º, and 135º using the Image Analysis menu. This is done so that the resulting lineament can represent data from each irradiation angle. The shaded relief data is then stored in the .tif file format so that it can be imported into the PCI Geomatica software program for further analysis.

The shaded relief data is then extracted into a lineament feature using the help of PCI Geomatica Software. Lineament extraction process using LINE Algorithm based on Thannoun R.G. (2013) on PCI Geomatica 2015. The results of lineament extraction in the form of lines showing ridges, valleys, rivers, and contacts of rocks in the study area. Data that has been extracted into a lineament feature is then exported into shapefile format so that it can be imported later into the ArcGIS 10.3 software for further analysis.

The next process is to import the four data lineament into ArcGIS 10.3 software. Lineament from the four illumination angles is then selected lines that have the same value using the Erase tool. The four selected data lineaments are merged into one data using the of rocks in the study area. Data that has been extracted into a lineament feature is then exported into shapefile format so that it can be imported later into the ArcGIS 10.3 software for further analysis.

The next process is to import the four data lineament into ArcGIS 10.3 software. Lineament from the four illumination angles are then selected lines that have the same value using the Erase tool. The four selected data lineament are merged into one data using the Merge tool for further processing. Then the density is calculated using a grid measuring 1 × 1 Km^2.

Table 6. Classification and lineament density scores of study sites

Total length (km)	Density level	Score
0 – 0,420491	Very Low	1
0,420492 – 0,904692	Low	2
0,904693 – 1,376151	Moderate	3
1,376152 – 1,885837	High	4
1,885838 – 3,249246	Very high	5

Source: Analysis (2019)

So the research location is divided into five classes of structural density, which are tenuous, slightly tenuous, rather tight, tight, very tight. The higher the density value, the higher the influence there is ground motion.

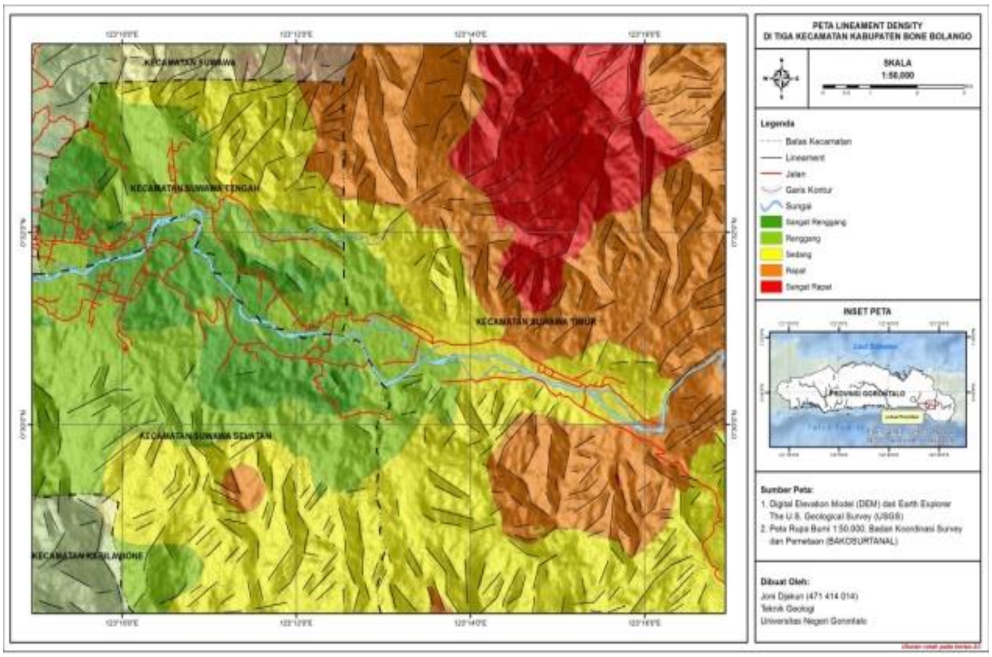

Figure 5. Lineament density map of study sites

2. Identification of Soil Prone Areas Based on the Storie Index

This analysis was carried out with the help of ArcGIS 10.3 software to determine areas prone to ground motion using the Storie Index calculation**.**

L = A x B/10 x C/10 x D/10 x E/10………(3)

explanation:

A : slope
B : rainfall
C : landuse
D : type of soil
E : lineament density
L : land movement

The results of the analysis showed the value of the Storie Index which ranged from 0,0001 to 0.06. Therefore, the researchers divided the area of soil movement hazard in the study site into three levels of vulnerability, namely low level of vulnerability, moderate level of vulnerability and high level of vulnerability (see Figure 6).

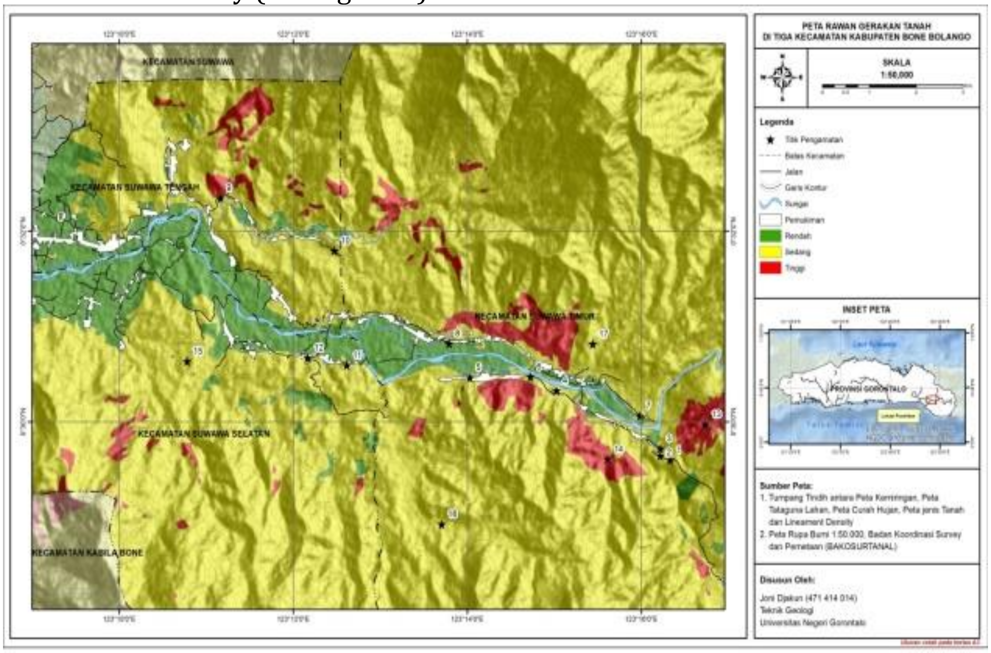

Figure 6. Map of soil movement prone at the study site

The results of the mapping of mass movement-prone areas using the Storie index method show areas with high levels of vulnerability are in areas with steep to very steep slopes with a slope between 25% -> 45%, with mountainous landforms and undulating hills. Areas with a high level of vulnerability are in the west. Areas with low levels of vulnerability are in the middle which are alluvial plains and flood plains along the Bone river

The map of the ground movement prone areas can illustrate potential areas for land movement at the study site. The occurrence of ground motion is very dependent on rainfall. Rain data for 2014 - 2018 shows very low intensity in the dry to very dry category. However, rainfall in certain periods resulted in several points in the study site occurring ground movement events although still on a small scale.

Although the density factor (lineament density) shows a high-density value in the north and south, however, this area is categorized as a medium hazard level. This does not forget the landuse factor which is still dominated by jungles and soil types that are not too sensitive to erosion. Unlike the case in dry fields, plants that are usually found in the form of plants with fibrous roots that are not penetrated deeply in the soil layer, so that the roots of plants are less functioning as a reinforcement of soil aggregates. The area with a high level of a vulnerability is in the southern part shown on the land use map, that this area is upland or empty land.

Vulnerable areas for land movement are divided into three levels of vulnerability or class, namely a low vulnerability level of 10.98%, a moderate level of vulnerability 84.41%, and a high level of vulnerability 4.61% of the entire study area.

D. Conclusion

1. Based on the results of the analysis using the Storie Index method, the value of the Storie Index obtained ranged from 0,0003 to 0.06 (attachment). If this value is converted into the level of vulnerability, the research location consists of three levels of soil movement vulnerability, namely low level of vulnerability, moderate level of vulnerability and high level of vulnerability. Where each classification has an area including a low vulnerability rate of 10.98%, a medium vulnerability rate of 84.41%, and a high vulnerability rate of 4.61% of the entire study area.
2. The map of land movement prone areas illustrates that South Suwawa Subdistrict has a low vulnerability level of 5.01%, moderate 22.32% and high of 0.5% of the total area of the study. Meanwhile, Central Suwawa Subdistrict has a low vulnerability level of 3.37%, moderate at 11.02% and high at 0.82% of the total area of the study. Finally, East Suwawa Subdistrict has

a low vulnerability level of 2.6%, 51.03% medium and high 3.31% of the total area of research.

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