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MAPPING OF LANDSLIDE POTENTIAL ZONE WITH FREQUENCY RATIO METHOD AND MITIGATION EFFORTS IN BANJARNEGARA REGENCY, CENTRAL JAVA, INDONESIA

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ABSTRACT

Indonesia is a country with a very high potential for disaster. This is supported by the existence of Indonesia which is surrounded by three world plates, namely the Eurasian plate, the Indian-Australian plate and the Pacific plate. One of natural disaster which occur in Indonesia is landslide. This situation has similarities with the research area located in the Banjarnegara Regency, Central Java. Aim of this research is to provide information on the level of influence of the class and conditioning factors of landslides, and a picture of areas that have vulnerability to landslides and as an effort to provide information to related parties. This research was conducted by geological mapping and remote sensing using DEM (Digital Elevation Model) and landsat-8 as field support data and visualization of the condition of the research area. The results of this study found that the results of mapping with frequency ratio method, the percentage of low insecurity is 66.83%, moderate insecurity is 17.94%, high insecurity is 1.87%, and very high insecurity is 0.02%. Areas with very high land movement potential are in karangkobar and pandanarum districts with a total area of 0.094589 km². The area has a very high potential because it has litology with volcanic rock types, very low vegetation and the presence of straightness. Therefore, various mitigations are needed both structural and non-structural.

INTRODUCTION

Indonesia is a country with a very high potential for disaster. Large archipelago Indonesia is frequently affected by climate and weather-related disasters such as landslides, volcanic eruptions, and tsunamis (Burrows et al., 2021). This is supported by the existence of Indonesia which is surrounded by three world plates, namely the Eurasian plate, the Indian-Australian plate and the Pacific plate (Suharini et al., 2020). The intensive interaction of the three plates makes Indonesia passed by the ring of fire, thus forming reliefs and topography in Indonesia to be diverse. Climate and human factors are very influential in forming new topographical results with conditions that have differences in elevation. As a result, the intensity of soil and rocks becomes unstable due to the difference in elevation produced, and disasters can occur in the form of land movements, especially in the form of landslides. Landslides are a type of movement of soil or rock masses that generally occur at a slope of 20°-40° with moving masses in the form of residual soil, coluvial deposits and weathered

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volcanic rocks (Storie et al., 2018). Moreover, due to global climate change and demographic pressure, the likelihood of landslides is growing (Nugraha et al., 2015). Thus, Rough soil will be more at risk of landslides because the land has low soil aggregate cohesion.

This situation has similarities with the research area located in the Banjarnegara area, Central Java. Banjarnegera is one of the districts that has historically experienced landslides (Hidayat, 2020). Data and information on landslide disaster events in Banjarnegara Regency for example, from January to September 2016, there have been 12 landslide disaster events with 7 deaths, 7 injuries and 1,237 displaced people (Dyah Susanti et al., 2017). In addition, landslide conditioning factors that affect soil vulnerability include slope, elevation, slope direction, land cover, soil type, fault distance, and geological rocks (Nugroho & Nugroho, 2020). Based on this condition, research is needed to analyze landslide-prone areas. This research was conducted as an effort to provide information on the level of influence of the class and conditioning factors of landslides, and a picture of areas that have vulnerability to landslides and as an effort to provide information to related parties, such as local governments, which have the authority to provide planning advice in the construction of houses or residential areas.

One method that can be used to determine the vulnerability zone of ground movement is the Frequency Ratio method. Frequency Ratio method is a method based on the assumption that, the occurrence of soil movement in the future will occur in conditions similar to the conditions of soil movement in the past (Yan et al., 2019). Frequency ratio is the relationship between the occurrence of ground movement and the parameters that control the occurrence of soil movement. The results of this method will be obtained a map of the potential of land movement which is the result of calculations from the parameter map. In addition, through these results, a socialization and training were carried out to the community to prevent land movement.

METHOD

Research was conducted for two weeks, starting from September 1-4, 2021 in the Banjarnegara Regency area. This research was conducted by geological mapping and remote sensing using DEM (Digital Elevation Model) and landsat-8 as field support data and visualization of the condition of the research area. DEM is a digital representation of the earth's surface elevation (Hidayat et al., 2016). In this study, various data are needed such as slope data from DEMNAS data, rainfall data from CHIRPS data in 2017 - 2021, fault fracture density data (FFD), land use processed data from Landsat imagery with guided classification maximum likelihood method processed from Landsat imagery, NDVI processed from Landsat imagery, disaster point events from geological mapping.

The method used is frequency ratio (FR). The frequency ratio method is based on the assumption that the future land movement events will occur under the similar condition to the past landslide movement (Darminto et al., 2021; Silaban, 2021). The parameters used in this study are slope, lithology, land use, vegetation index, rainfall, and fault fracture density. The parameters are then processed using ArcGIS into a thematic map, then calculated the number of ground movement points in each class of each parameter to get a frequency ratio (FR) value (Sukristiyanti et al., 2020).

After the mapping results are obtained, it is necessary to prepare a mitigation strategy. The mitigation is in accordance with mitigation theory which divides mitigation into 2 forms, namely: Structural mitigation, in the form of making infrastructure as a driver of impact minimization and the use of technological approaches and non-structural itigation, in the form of spatial management and training to increase community capacity. The research flow is presented in figure 1.

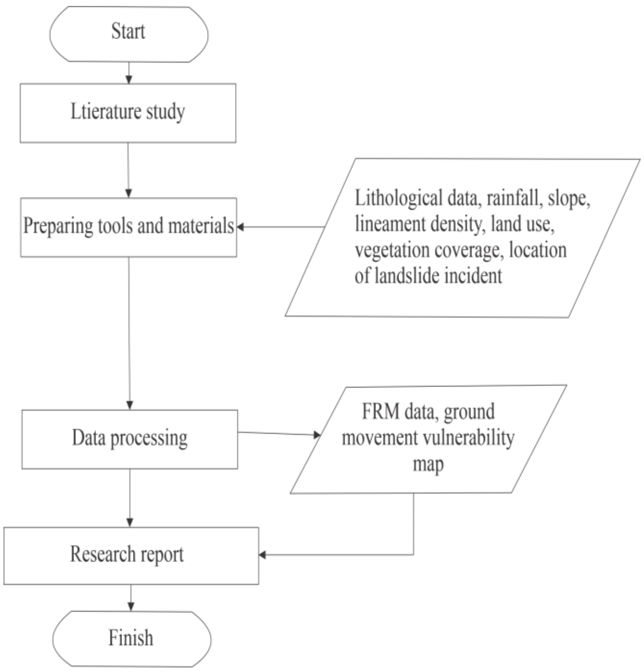

Figure 1. Research Flow Diagram

RESULTS AND DISCUSSION

A. Landslide Vulnerability

Banjarnegara is one of the regencies in Central Java Province with news of land movements frequently appearing. Moreover, there were 149 landslides in Banjarnegara Regency in 2018 (Kuntjorowati, 2020). Therefore, the purpose of using the method is to determine the potential distribution of ground motion. In this FRM processing, several parameters are used. These parameters include lithology, slope, lineament density, rainfall, land use, and vegetation cover.

Based on the regional geological map, the plots located in Banjarnegara Regency are composed of several types of lithology. The lithology is composed of alluvium, agglomerates, reef limestones, tuffaceous claystone, sandstones, breccias, polymeric volcanic breccias, alternating sandstones with flysch, conglomerate, marl, lava, ophiolite, mélange, diorite intrusion, diorite/porphyry intrusion/porphyry gabbro. Based on the lithology, they are grouped into several types of rock and then assigned a value based on their influence on soil movement by determining, the following division of class values: alluvium is worth 1, sedimentary rock is worth 2, and volcanic rock is worth 3.

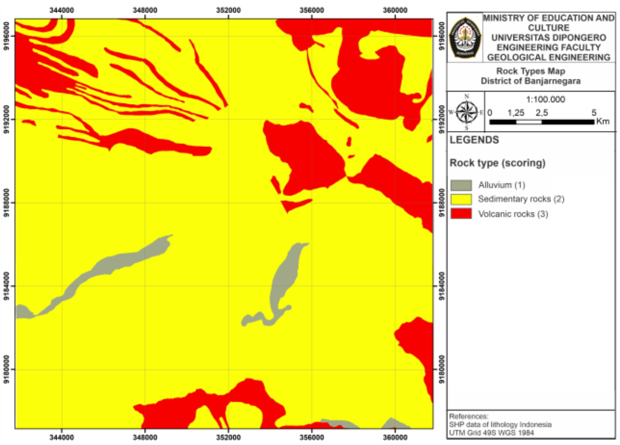

Figure 2. Litology Map

Scoring from the slope map (figure 3), the plot area consists of flat slopes with a slope percentage of 0% – 8%, gentle slopes with a slope percentage of 8% – 15%, wavy slopes with a slope percentage of 15% –30%, steep slopes with a slope percentage of 30% – 45%, and slopes very steep with a slope percentage of more than 45%. Based on the level of the slope, a value is given based on its effect on landslides, following the division of class values: flat slopes are worth 1, gentle slopes are worth 2, wavy slopes are worth 3, steep slopes are worth 4, and very steep slopes are 5.

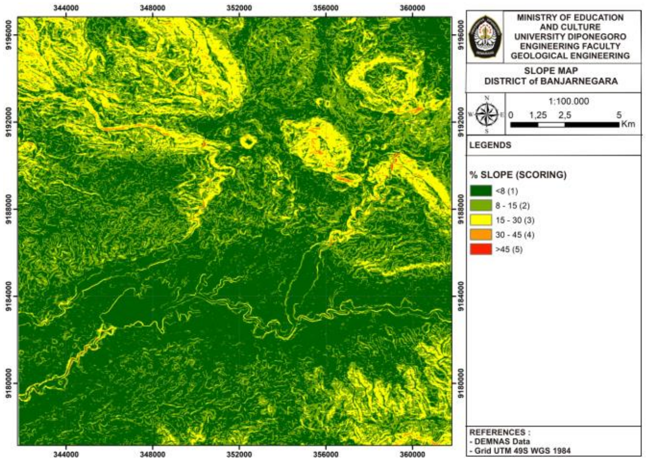

Figure 3. Slope Map

Based on the rainfall map from CHIRPS data processing from January 2017 to divided into three classes, 3100–3400 mm/year, 3400 – 3700 mm/year, and more than 3700 mm/year. Based on the rainfall, a value is given based on its effect on landslides, the following is the division of class values: rainfall ranging from 3100 – 3400 mm./year is worth 1, rainfall ranging from 3400 – 3700 mm/year is worth 2, and rainfall is around 3700 mm/year is 2.

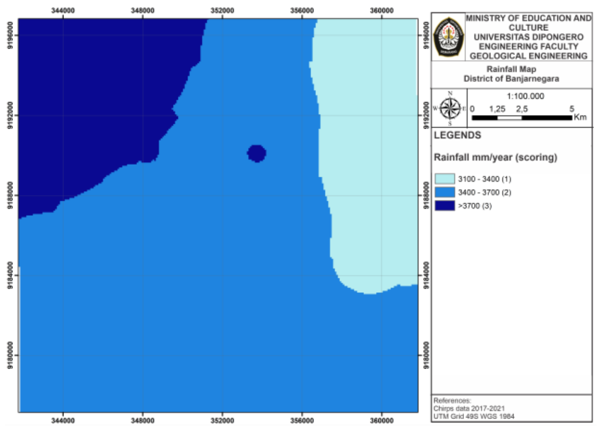

Figure 4. Rainfall Map

For the lineament density map of the plot area, there are several levels of lineament density. The alignment is divided into 5 classes or levels. The levels consist of very low level (0 – 0.0004), low level (0.0004 – 0.0009), medium level (0.0009 – 0.0013), high level (0.0013 – 0.0018) and very high level (0.0018 – 0.0022). For the distribution of the straightness/straightening itself, most of the straightness/straightening is found in the southeast and northwest areas of the plot area. Based on the straightness density level, a value is given based on its effect on landslides, following the division of class values: a very low level is worth 1, a low level is worth 2, the medium level is worth 3, a high level is worth 4, and very high level is 5.

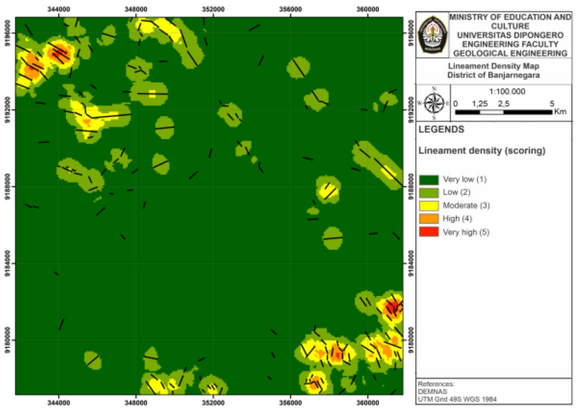

Figure 5. Lineament Density Map

Based on Landsat 8 on September 3, 2019, land use classification was carried out using a guided classification using the maximum likelihood method. Based on this process, the results were obtained in the form of seven land covers. The land cover includes forests, gardens, fields, housing, rice fields, shrubs, and bodies of water. Based on the land use, a value is given based on its effect on landslides, following the division of class values: water bodies are worth 1, settlements are worth 2, forests & gardens are worth 3, bushes are worth 4, and fields & rice fields are worth 5.

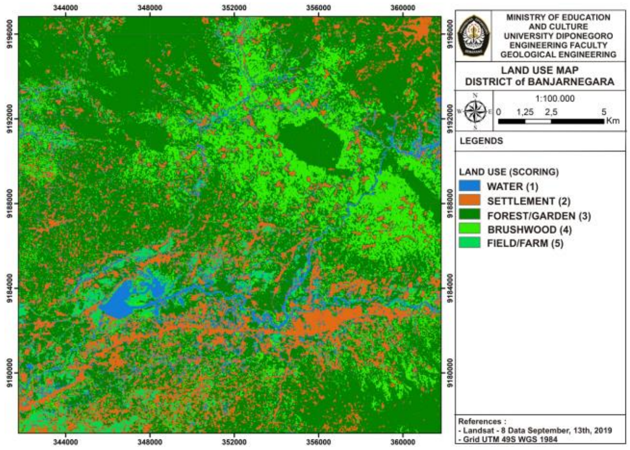

Figure 6. Land Use Map

Viewed from the cover map In terms of vegetation, the plots are divided into five classes based on the NDVI classification according to Wahyunto (2003) which consists of unvegetated land (-1 – -0.03), very low vegetation (-0.03 – 0.15), low vegetation (0 .15 – 0.25), medium vegetation (0.26 – 0.35), and high vegetation (0.36 – 1). Based on the level of vegetation cover, a value is given based on its effect on landslides: unvegetated land is worth 1, very low vegetation is worth 2, low vegetation is worth 3, moderate vegetation is worth 4, and high vegetation is 5.

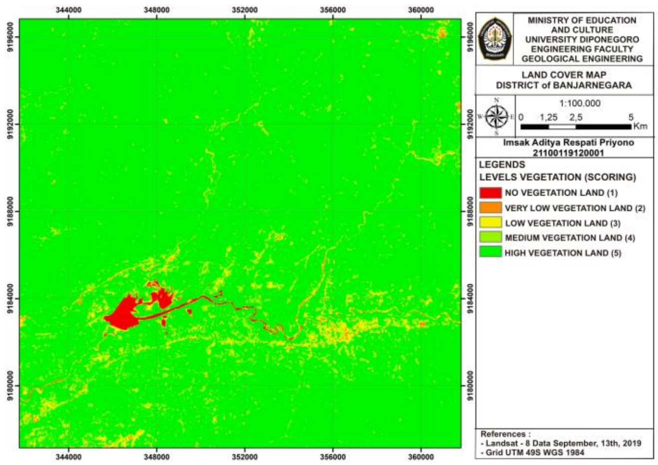

Figure 7. NDVI Map

Thus, from these parameters then FRM processing is carried out and the results of the FR calculation are obtained as follows at Table 1.

Table 1
FR Calculation Result

Parameter	Class	Pixels	% Class Pixels	Landslide Pixels	% Landslide Pixels	FR	RF	RF (Non%)	RF (INT)
Litology	Alluvial	122640	2.12	20.000027	1.22	0.58	0.19	18.56	18.00
	Sedimentary Rocks	4693260	81.09	1165.001599	71.08	0.88	0.28	28.26	28.00
	Volcanic Rocks	971751	16.79	454.000623	27.70	1.65	0.53	53.18	53.00
Total						3.10			99.00
Slope	0 - 8 %	3183689	55.01	958.001315	58.45	1.06	0.31	31.17	31.00
	8 - 15%	1778718	30.73	542.000744	33.07	1.08	0.32	31.57	31.00
	15-25 %	792354	13.69	133.000183	8.11	0.59	0.17	17.39	17.00
	25 - 45 %	31282	0.54	6.000008	0.37	0.68	0.20	19.87	19.00
	> 45 %	1617	0.03	0	0.00	0.00	0.00	0.00	0.00
Total						3.41			98.00
Rainfall (mm//year)	3100 - 3400	949078	16.38	333.000457	20.32	1.24	0.40	39.67	39.00
	3400 - 3700	3824098	66.02	1039.001426	63.39	0.96	0.31	30.72	30.00
	>3700	1019553	17.60	267.000366	16.29	0.93	0.30	29.61	29.00
Total						3.13			98.00
Fault Fracture Density	Very Low	4940245	84.29	1434.001968	87.49	1.04	0.12	12.21	12.00
	Low	658077	11.23	170.000233	10.37	0.92	0.11	10.87	10.00
	Medium	197929	3.38	11.000015	0.67	0.20	0.02	2.34	2.00
	High	56183	0.96	10.000014	0.61	0.64	0.07	7.49	7.00
	Very High	8782	0.15	14.000019	0.85	5.70	0.67	67.09	67.00
Total						8.50			98.00
Land Use	Water Body	371689	6.336	112.000154	6.83	1.08	0.20	19.90	19.00
	Settlement	1000554	17.057	886.001216	54.06	3.17	0.58	58.49	58.00
	Forest/Garden	3193333	54.437	501.000688	30.57	0.56	0.10	10.36	10.00
	Bush	998366	17.019	127.000174	7.75	0.46	0.08	8.40	8.00
	Fields	302142	5.151	13.000018	0.79	0.15	0.03	2.84	2.00
Total						5.42			97.00
Vegetation Index	No Vegetation	40044	0.68	0	0.00	0.00	0.00	0.00	0.00
	Very Low Vegetation	27627	0.47	34.000047	2.07	4.40	0.52	51.79	51.00
	Low Vegetation	119839	2.04	52.000071	3.17	1.55	0.18	18.26	18.00
	Medium Vegetation	288568	4.92	208.000285	12.69	2.58	0.30	30.33	30.00
	High Vegetation	5389990	91.96	1345.001846	82.06	0.89	0.11	10.50	10.00
Total						9.42			109.00

The frequency ratio method is based on the relationship between the distribution of ground motion points with each controlling factor of ground motion. From this data, it is known that the RF value will be used in determining the class value of each parameter. The RF value varies in each class in each parameter. Next, a raster calculator is used to create a landslide susceptibility map, so that the area of the vulnerability level and the map is as follows (Silalahi et al., 2019).

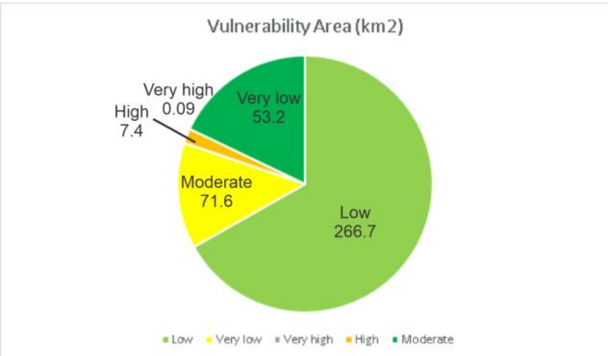

Figure 8. Vulnerability Area of Landslide

Based on the results of processing parameters with the FRM method, the results obtained are maps of ground motion susceptibility. Judging from the area, areas in Banjarnegara Regency are dominated by the potential for low ground movement followed by the potential for moderate ground movement. The result of landslide map is presented in figure 9.

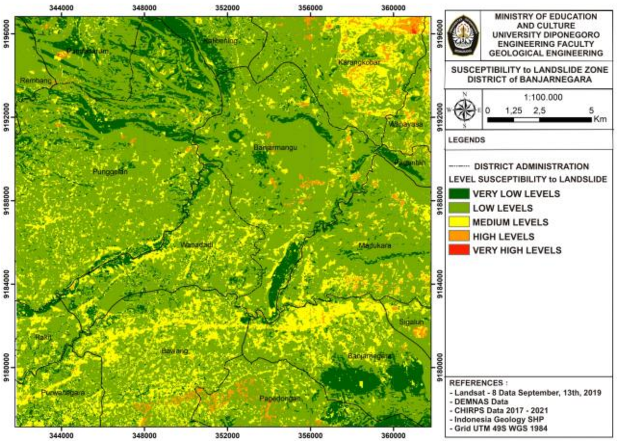

Figure 9. Landslide Potential Zone Map

1. **Areas with Very High Landslide Potential**
   Areas with very high ground movement potential are in Karangkobar and Pandanarum sub-districts with a total area of 0.094589 km² or about 0.02%. This area has a lithology with volcanic rock types, very low vegetation, and straightness.
2. **Areas with High Landslide Potential**
   Areas with very high ground movement potential are Karangkobar District, Wanayasa District, Pagentan District, Banjarmangu District, Madukara District, Punggelan District, Sigaluh District, and Pagedongan District, with a total area of 7.455772 km² or about 1,87%. This area has a lithology with volcanic rock types, rainfall with an intensity of 3400 – 3700 mm/year and many alignments are found, and has wavy to very steep slopes.
3. **Areas with Medium Landslide Potential**
   Areas with moderate soil movement potential are in Bawang District, Rakit District, Banjarnegara District, Purwanegara District, Wanadadi District, Karangkobar District, Wanayasa District, Pagedongan District, part of Sigaluh District, part of District, part of Kalibening District, and part of Banjarmangu District, with a total area of 71.606354 km² or about 17.94%. The area has a lithology with sedimentary rock types, rainfall with an intensity of 3400 – 3700 mm/year, low vegetation, and sloping to wavy slopes.
4. **Areas with Low Landslide Potential**
   Areas with low ground movement potential are located in Banjarmangu District, Punggelan District, Madukara District, Kalibening District, Karangkobar District, Pandanarum District, Banjarnegara District, and Rembang District, with the total area of 266.736396 km² or about 66, 83%. The area has moderate rainfall, there is straightening but not as much as in areas with moderate potential for soil movement has gentle to wavy slopes, and is widely used as forest plantations.
5. **Areas with Very Low Landslide Potential**
   Areas with very low ground movement potential are located in a part of Punggelan District, part of Banjarmangu District, part of Banjarnegara District, part of Pandanarum District, and Kalibening District. little housing.

B. Landslide Disaster Mitigation in Banjarnegara Regency

Disaster prevention using satellite imagery can be used for landslide inventory or knowing the characteristics of landslides, determination of landslide-prone areas, mapping of factors associated with landslides (Zakaria et al., 2018). Factors of occurrence or landslide parameters include slope, lithology, land use, vegetation index, rainfall, and fault fracture density. The results of the risk assessment showed that Banjarnegara Regency was at low to moderate risk of landslides. The results of the risk mapping showed that in Banjarnegara Regency, 17.94% were classified as areas with moderate landslide risk and 66.83% were at low risk of landslides.

As for thestrategy of disaster mitigation of landslides, among others:

1. Management of areas with steep marbles and unstable soil
2. Reduction of population activity in areas with a high risk of disaster
3. Determination of evacuation routes and places
4. Structural mitigation by development is not at the site of high disaster risk
5. Non-structural mitigation by creating rules that can reduce the risk to the medium disaster risk area
6. Carrying out mixed planting patterns such as agricultural crops and deep-rooted trees
7. Provision of relevant disaster-related information that can be accessed by all stakeholders
8. Preparation of early warning information systems
9. The participation of disaster communities and communities

10. The existence of socialization of landslide disaster simulations to society

CONCLUSION

Banjarnegara regency is an area that is vulnerable to landslides. Natural factors such as high slope slopes, high rainfall, faults, geological conditions and land use are influential factors in this region. The potential vulnerability of landslides in this region is increasing with the infrastructure, namely buildings due to population density in areas that are vulnerable to landslides. Based on the results of mapping with the frequency ratio method, the percentage of low insecurity is 66.83%, moderate insecurity is 17.94%, high insecurity is 1.87%, and very high insecurity is 0.02%. Areas with very high land movement potential are in karangkobar and pandanarum districts with a total area of 0.094589 km². The area has a very high potential because it has litology with volcanic rock types, very low vegetation and the presence of straightness. Therefore, various mitigations are needed both structural and non-structural.

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