Determination of landslide susceptibility level using scoring method in Pugung Area, Tanggamus

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Abstract. Landslide is one of the most common disasters, especially in Indonesia. Pugung as a bumpy area with a fairly steep slope and coupled with the number of settlements around the hillsides makes it an area with a potential disaster is large enough, so it takes action to overcome it. Disaster management can be carried out long before the incident occurred, making the evacuation route, mapping of landslide-prone areas and disaster socialization are some ways that can be done to overcome them. This research aims to define and classify Pugung Region based on the level of landslide susceptibility that may occur in this area to be an illustration for the government and communities around the dangers and as a reference for disaster mitigation. The research was done by analysis of the literature, analysis directly in the field and laboratory analysis. The data obtained from the field is processed and validated with the results of laboratory tests until the calculation of the importance values on each parameter using a scoring method to determine the susceptibility of landslide in each area. Based on analysis and calculation that has been done, the results obtained are quite diverse wherein the southeastern part of the study area had the highest risk, while for areas that have the smallest risk is the western region.

1. Introduction
Landslide is a prevalent disaster in Indonesia, and this incident frequently results in damage or even casualties. Rahman (2010) states that landslide is shifting or moving process of land with vertical or oblique direction from the initial position as a result of gravity. The existence of landslide event reveals the need to recognize the landslide characteristics, particularly in term of mechanism and its spatial probability that can be identified through landslide susceptibility mapping (Wati, et al., 2010). Landslide susceptibility basically can be defined as quantitative and qualitative assessment including classification, volume and spatial variability which exist or potentially occur. In term of susceptibility, time frame is not explicitly considered and the susceptibility analysis brings the information about combination of several physical factors influencing landslide occurrence in a certain location (Fell, et al., 2008).

Pugung as a surging hill area with a fairly steep slope and coupled with the number settlements around the slopes of the hills, making it as an area with the sufficient potential of the landslide. A highly vulnerable disaster requires steps to solve this problem, one of which is to create a map out of the level of vulnerability of landslides in any potential areas landslides occur. This research will be done by observing the Pugung Region with the aim of classifying each area according to the susceptibility of landslide. After the completeness of the levels susceptibility landslide mapping, it is expected that the government and the society around the site can be more aware of the importance of protecting the environment and preparing the mitigation measures for possible disasters.
2. Literature Review
The initial phase of the study was accomplished by committing literature studies from various sources and research that has been done before. Supporting aspects such as soil type, rainfall, slope gradients, etc., in the use of scoring methods for the determination of landslide susceptibility levels are also studied. By doing this initial phase, it is expected to indicate the overview of the conditions in the area of research which would be very helpful in direct analysis activities in the field.

3. Field Analysis
The field analysis phase is carried out with a preliminary investigation aimed to identify the terrain. Perceiving prevalently the geological conditions, lithology, soil type, rainfall, slope and land use, so that charting the location of the observation post and the work strategy will be done in the field including things that need to be observed while at the observation post can be considered. The next phase is to collect data conducted by field observation, where necessary data are collected for laboratory and studio analysis activities.

4. Laboratory Analysis
Laboratory analysis is done by remote sensing using several supporting applications such as Google Earth Pro, Global Mapper, ArcGIS and Map Source. The results of remote sensing analysis are compared with data that had been obtained in the field and calculated using the scoring method. The calculation process is done by overlaying the six maps generated from the data that had been obtained by considering the value of their respective interests. The overlayed map is then given a limit on each unit of land and is calculated. After the calculation is done then will be obtained the results in the form of units of land with various potential landslides.

5. Scoring Technique and the Determination of Landslide Potential
The scoring method is a method that assesses a parameter based on its weightiness value. In determining the potential of land, in this case, the determination of landslide susceptibility level is presented by six parameters, namely the type of lithology, soil type, slope, land use and rainfall. The six parameters that have been obtained data have their respective weightiness value and will be calculated as their power value (Table 1).

| Parameter and Weighted Factor | Score |
|-------------------------------|-------|
| Litho Type – Weight : 24.2    |       |
| Pyroclastic rocks with Andesite Fragment | 1 |
| Sedimentary rocks (Sandstone) | 2 |
| Sedimentary rocks (Mudstone)  | 3 |
| Soil Type – Weight : 6.1      |       |
| Alluvial                      | 1     |
| Andosol                       | 2     |
| Soil Permeability – Weight : 2.8 |   |
| Moderately fast, fast (> 6.25 cm per hour) | 1 |
| Moderate (2.0 – 6.25 cm per hour) | 2 |
Based on table 1 it will be calculated by considering the value of each parameter and also the value of the weight. This conversion is done to get the value of the interval which will become the reference to classify the level of landslide knowledge. In each parameter given the maximum and minimum values to be calculated to produce an interval value, the two values will be calculated using the formula:

$$X = \frac{MaxV - MinV}{5}$$  \hspace{1cm} (1)

with : $X = $ Interval Score,

$MaxV = $ Maximum Value,

$MinV = $ Minimum Value.

The result of the calculation above will show the interval value which then will be used in classifying the potential landslide occurs in each unit of land located in the research area. From the calculation is obtained value $X = 10$.

$$X = \frac{78-23}{5} = 13$$

From the value of intervals that have been obtained then made a classification that is used to determine the potential landslide on each unit of land in the Pugung Region (Table 2).
Table 2. The variable to classified the landslides susceptibility.

| Land Classification Towards landslide |  |
|--------------------------------------|--|
| Non Susceptible                      | 23 – 35 |
| Potential Susceptible                | 36 - 48 |
| Quite Susceptible                    | 49 - 61 |
| More Susceptible                     | 62 - 74 |
| Very Susceptible                     | 75 – 87 |

6. Result and Discussion

Based on the calculations that have been done, where each parameter is given weight and score determined by experts in the long term. Weight and a high score will show the large size of the parameter in causing the landslide. This weighting is generated from the ArcGIS. At this stage, rainfall is not presented as a parameter for the same regions, and it will not affect the calculation.

6.1. The Litho Type

Landslides are controlled by several factors, including the existence of a slip field. Besides for being a slip, rock resistance levels also play a role in the occurrence of landslides, where rocks with low levels of resistance have a high probability of landslides, rocks with high resistance withstand weathering and cause resistsants towards a landslide. Based on the literature study, field analysis, and studio analysis, three rocks are found in the research area, namely pyroclastic rocks with andesite fragments, sedimentary rocks such as Sandstone and Siltstone. The three types of rock are then classified into a table based on their respective values, which then will become the parameters in the calculation using a scoring method.

![Figure 1. The geological map](image)
6.2. The Soil Type
As the parameter of landslide susceptibility determination, there are two types of soil are found in the research area. The data is generated from the literature studies and direct analysis in the field. The two types of soil found are alluvial and andosol soils, this refers to the study of Nugroho et al., 2010. The data obtained were classified into the table for calculation using the scoring method as in the previous rock type data.

![Figure 2. The soil type map](image)

6.3. The Soil Permeability
Soil type will affect its permeability, where the soil with low ability to pass water will be more susceptible to landslides because there will be a buildup of water which causes a load of soil to increase. So, the slower the ground drains the water, in this calcification will have a more substantial score because it is more susceptible to landslides.

![Figure 2. The soil type map](image)
6.4. The Slope

The slope in the study area is quite diverse, ranging from flat to steep. The data used here is obtained from the analysis in the field, and through remote sensing, these are obtained by the classification of the slope that refers to the classification by Widyatmandi et al., 2016. The slope becomes the factor with the highest value of interest which is based on the moving lane of landslide material which will be higher possibly on a steep slope and otherwise. Of the six existing classifications, there are only five classifications found in the study area as presented in the table below.

![Slope Map of Pugung and Its Surrounding Areas](image)

**Figure 4 The slope map**

6.5. The Land Use

Land use in a region illustrates how the land tenacity. Areas used as plantation areas have high tenacity, especially to floods and landslides, differing on land with the use of settlements which is undergoing many changes by humans thus reducing their tenacity. The data used in this land-use classification is obtained from direct field and remote sensing analysis. Based on the analysis, there are three land-use in the research area had been included in the classification in the table below.
6.6. The Soil Depth

The soil depth as a parameter in this calculation has a considerable weight, where the depth of soil is in the shear stretch and the shear strength. The soil with a larger thickness will have a high weight and vice versa, so in the scoring thickness becomes the basis of its determination. In this classification, four different depths of soil also play a different role in the occurrence of landslides.
7. Discussion

Calculations that have been done using the scoring method on each of the parameters that affect the results show quite diverse. In the study area, each landslide susceptibility classification is scattered in every area, with varying extents. From the 5x5 km research area, only about 25% of the areas included in the classification are susceptible to landslides. The area with high landslide susceptibility is quite high in the research area dominated by a height of 300-400 m with a fairly steep slope, so it is appropriate to note that the results of the calculations have been kind enough to present the potential susceptibility.

7.1. Non-susceptible
There are six units of land that belong to the classification of no potential in the research area; this result is following the findings in the field. Based on the data that had been obtained, this area shows the plains of possibility to occur very small landslide; this is also reinforced by calculations made by entering other parameters as a validation step. These six units of land belonging to this possible classification account for about 8% of the total research area.

Land use in this area is dominated by settlements and plantations with several streams of small confluent. These parameters do not significantly affect the potential susceptibility of landslides in the area since the most critical aspects of slope and altitude are not fulfilled. Indirectly, it can be stated that this area is the safest in the study area.

7.2. Potential susceptible
Around 55 land units are included in potentially vulnerable classifications, of which the area is relatively wide with a percentage of about 37% of the total area of research. The spread of this classification is located along the western part which makes it quite extensive. This area is dominated by pyroclastic rocks that have andesite fragments, where the rock resistance is high enough to weather, thus making it strong enough to resist the movement of mudslides. In addition to rock resistance, the slope is also one of the factors that become the basis of this area, is quite safe to the danger of landslides, where the slopes contained here on average only 2 – 7%.

7.3. Quite susceptible
A total of 41 units of land belonging to the classification are quite vulnerable to the spread along the middle to the northeast or about 25% of the total area of research. Low rock resistance and slope higher than usual (7-30%) make it in a moderately vulnerable condition, which may increase due to plantations and settlements in some places. This area should have begun to receive attention from the government and especially the surrounding citizen so that things that can harm, even to take the casualties did not happen.

7.4. More susceptible
A more vulnerable classification is a potentially high degree of the landslide, especially in areas used as settlements. There are 53 units of land classified as more vulnerable or about 24% of the total research area. This is caused by the availability of rocks that have low resistance, so it is effortless to weather or form fractures that will be the beginning of the movement of rocks. Besides, the height of this area which ranges from 250-300 m and the slope of a reasonably steep slope makes it vulnerable to the occurrence of landslides. The government and the surrounding community must be severe in addressing this issue because landslide disaster is a hazardous event and often takes casualties as well as material.
7.5. Very susceptible
In the southeast of the study area, there are 12 units of land belonging to a very susceptible classification or about 6% of the total area. Based on field data that has been obtained, it was found that the rocks that make up this area have low resistance, so easily stuck and cracks that will become the path of water filling in the rain. Also, it can be seen that the height ranges from 300-400 m with a steep slope or about 30 - 70%. Disaster mitigation measures should be promptly undertaken in this area because omission will cause potential damage to be likely to increase due to several external factors. Many things can be done to prevent the occurrence of landslides, such as socialization to the community, making evacuation routes, maintaining the environment with no damage, etc.

7.6. Disaster Mitigation
After obtaining the landslide susceptibility map, one of the efforts in the mitigation activity has been achieved. Furthermore, many steps must be immediately undertaken by the local government and the community, to cope with the threat of landslide disaster. Each element relating to this activity should work in synergy and work together to overcome it. Mitigation strategies such as the development of landslide susceptibility maps, the creation of evacuation routes, socialization, etc. are required steps taken as quickly as possible to avoid disaster.

8. Conclusion
The research that has been done gives the result that in Pugung Region there are 5 classifications of landslide susceptibility level. From the results of calculations that had been done by using the scoring method in the study area are obtained 171 units of land representing each classification that existed. The five classifications that had been obtained show that the eastern to southeastern of the research area have the highest degree of susceptibility to the landslide which this area belongs to more vulnerable and
highly vulnerable classification. After obtaining the result of landslide susceptibility map, it is expected that the government and the local citizen can refer to carry out actions against disaster mitigation. Research that may be done next is expected to expand the scope of the area, to add other parameters, and to improve the accuracy.

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