Landslide Susceptibility in Majalengka Regency, West Java Province

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Abstract. Majalengka is one of districts in Indonesia which is susceptible to landslides. Landslides in Majalengka caused enormous losses such as damage to infrastructure, loss of property, and even human fatalities. Seeing of the impact, mitigation efforts are needed to reduce risks and losses by making landslide susceptibility maps. This study aims to map areas landslide susceptibility and as a reference for the government and related agencies to reduce losses. The method used overlay using Spatial Multi-Criteria Evaluation (SMCE), using weighting values from the Minister Public Works Regulation NO.22/PRT/M/2007, Puslittanak Bogor (2014) and Directorate Volcanology and Disaster Mitigation (DVMBG) (2004). Then comparison of these sources is carried out to determine weighting value with the highest accuracy. The variables are slope, rainfall, soil type, lithology, and land use. The results of this study indicate that landslide susceptibility areas are divided into non-susceptible, low, moderate, and high areas. Where areas Majalengka Regency is dominated by moderate susceptibility level. For the accuracy value of the landslide susceptibility map produced by the weighted value source from the Minister of Public Works Regulation NO.22/PRT/M/2007 has the highest accuracy value of 76%. For weighting from the Bogor Puslittanak is 73%, while weighting source from DVMBG is 68%.

Keywords: Majalengka Regency, Landslide Susceptibility, Overlay, SMCE

1. Introduction

Landslides are one of the disasters in Indonesia, many factors affect the stability of the land making up the slopes, causing landslides in one area. Landslide is a type of soil movement, both rock, and mixture that moves down or out of the slope caused by disturbing the stability of the soil or rock making up the slope [1]. Landslide as a land movement and is a natural phenomenon in the form of soil mass moving rapidly following the slope [2]. The steeper the slope, the more likely the material will fall to a lower place [3]. Factors that cause landslides naturally include the morphology of the earth's surface, land use, lithology, geological structure, rainfall, and seismicity. Apart from natural factors, human activity factors also cause landslides such as agricultural activities, slope cutting, plantations, and mining [4].

The Regional Disaster Management Agency (BPBD) of Majalengka Regency, West Java, noted that the largest contributor to the disaster came from landslides, namely 82 incidents in 2018 - 2019. There are 19 sub-districts from 24 sub-districts that have the potential to experience landslides and land movements, especially in peak rainy season. Where the landslides that occur cause infrastructure damage such as cut off-road access, damaged houses, and even casualties.

Seeing the impact of the losses caused by landslides in Majalengka Regency, it is necessary to carry out disaster mitigation efforts. One of the mitigation efforts that can be done to reduce the
risk and impact of landslides is by making a landslide susceptibility map. Making landslide susceptibility maps using a Geographic Information System (GIS) can provide convenience in providing information and perform repeated, continuous, fast, and accurate spatial analysis. Landslide susceptibility in an area can be identified through a Geographic Information System (GIS) overlay using the Spatial Multi-Criteria Evaluation (SMCE) method. SMCE is a qualitative and quantitative analysis approach to identify disaster zones and can facilitate a sustainable disaster mitigation process and assist decision-makers based on predetermined criteria based on priority values [5]. Spatial Multi-Criteria Evaluation is a process that can combine and converting some data (input) into a decision (output) generated [6]. The variables used in this study are slopes, rainfall, soil type, lithology, and land use which will be given a weighting value that comes from the Minister of Public Works Regulation NO.22 / PRT / M / 2007 [7], Puslittanak 2004 [8], and the Directorate of Volcanology and Geological Disaster Mitigation in 2004 [9].

This research was conducted in the Majalengka Regency, which is located in the eastern part of West Java Province with a total area of 134,585 hectares or about 2.71% of the area of West Java Province. There are 26 sub-districts, 13 wards, and 334 villages. Majalengka Regency has very diverse topographical conditions, in the southern part, the topography is hilly and has high rainfall. The purpose of this study is to map the distribution of landslide susceptibility areas in Majalengka Regency by comparing the sources used in determining the weighting value so that the most relevant weighting values can be found that can be applied to the same physical conditions so that they can be used as a reference in mitigation. landslide disasters to reduce the number of victims and losses caused by landslides.

2. Data and Method

2.1. Data
The data needed in this study are primary data and secondary data in the form of spatial data and other supporting data obtained from websites, institutions, related institutions, and direct observations in the field when conducting validation tests at the point of landslides. The data needed during the research process and analysis to get the results of landslide susceptibility areas in the Majalengka Regency are data on slopes, lithology, rainfall, soil types, land use, and landslide locations.

2.2. Method
In this study, the method used is the Spatial Multi-Criteria Evaluation (SMCE). SMCE is used to process physical factors in the form of drought, rainfall, soil type, lithology, and land use and conducts multi-criteria assessments using weighted values derived from the Minister of Public Works Regulation NO.22/PRT/M/2007, Puslittanak Bogor in 2004, and the Directorate of Volcanology and Geological Disaster Mitigation in 2004.

2.2.1. Model 1 is sourced from the Minister of Public Works Regulation NO.22/PRT/M/2007.
Model 1 which is used to analyze the susceptibility of landslides in Majalengka Regency is an estimator model which refers to the Minister of Public Works Regulation NO.22/PRT/M/2007 type A with the following values:
Table 1. The Weighted Value of Model 1 is sourced from the Minister of Public Works Regulation NO.22/PRT/M/2007.

| Indicator          | Weighted (%) | Scoring | Classification      |
|--------------------|--------------|---------|---------------------|
| Slope Inclination  | 30           |         |                     |
|                    | 5            | > 40°   |                     |
|                    | 4            | 35° - 40°|                     |
|                    | 3            | 20° - 30°|                     |
|                    | 2            | 15° - 20°|                     |
|                    | 1            | 0° - 15° |                     |
|                    | 5            | > 5.500 mm/year |           |
|                    | 4            | 4.500 - 5.500 mm/year |     |
| Rainfall           | 15           |         |                     |
|                    | 3            | 5.500 - 7.500 mm/year |       |
|                    | 2            | 5.000 - 5.500 mm/year |       |
|                    | 1            | < 2.500 |                     |
| Lithology          | 20           |         |                     |
|                    | 1            | Limestone and igneous rock |   |
|                    | 5            | Regosol |                     |
|                    | 4            | Andosol, grumosol |        |
|                    | 3            | Volcanic |                   |
|                    | 2            | Sediment |                  |
| Soil Type          | 15           |         |                     |
|                    | 3            | Podsolik |                  |
|                    | 2            | Latosol  |                  |
|                    | 1            | Alluvial |                  |
|                    | 5            | Irrigated rice fields |      |
|                    | 4            | Rain-fed rice fields |      |
| Landuse            | 10           |         |                     |
|                    | 3            | Plantations, fields |      |
|                    | 2            | Forest   |                  |
|                    | 1            | Rocky ground, bush, savanna |  |
2.2.2. Model 2 originated from the Puslittanak Bogor in 2004.
Model 2 used to analyze the susceptibility of landslides in Majalengka Regency is an estimator model that refers to the 2004 Puslittanak with the following values:

| Indicator           | Weighted (%) | Scoring         | Classification          |
|---------------------|--------------|-----------------|-------------------------|
| Slope Inclination   | 20           | 5               | > 45°                   |
|                     |              | 4               | 30° - 45°               |
|                     |              | 3               | 15° - 30°               |
|                     |              | 2               | 8° - 15°                |
|                     |              | 1               | < 8°                    |
|                     |              | 5               | > 2,500 mm/year         |
|                     |              | 4               | 2,000 – 2,500 mm/year   |
| Rainfall            | 30           | 3               | 1.500 – 2.000 mm/year   |
|                     |              | 2               | 1.000 – 1.500 mm/year   |
|                     |              | 1               | < 1.000 mm/year         |
|                     |              | 3               | Volcanic                |
| Lithology           | 20           | 2               | Sediment                |
|                     |              | 1               | Limestone and igneous rock|
|                     |              | 5               | Regosol                 |
|                     |              | 4               | Andosol, Podsolik       |
| Soil Type           | 10           | 3               | Litosol                 |
|                     |              | 2               | Latosol                 |
|                     |              | 1               | Alluvial                 |
|                     |              | 5               | Fields, Rice fields     |
|                     |              | 4               | Shrubs                  |
| Landuse             | 20           | 3               | Forests, Plantations    |
|                     |              | 2               | City/Settlement, Airport |
|                     |              | 1               | Water body              |
2.2.3. Model 3 is sourced from the Directorate Volcanology Geological Disaster Mitigation in 2004. Model 3 which is used to analyze the susceptibility of landslides in Majalengka Regency is an estimator model that refers to the Directorate of Volcanology and Geological Disaster Mitigation in 2004 with the following values:

| Indicator     | Weighted (%) | Scoring       | Classification       |
|---------------|--------------|---------------|----------------------|
| Slope Inclination | 15          | 5             | > 45°                |
|               |              | 4             | 30° - 45°            |
|               |              | 3             | 15° - 30°            |
|               |              | 2             | 8° - 15°             |
|               |              | 1             | < 8°                 |
| Rainfall      | 30           | 5             | > 3000 mm/year       |
|               |              | 4             | 2500 – 3000 mm/year  |
|               |              | 3             | 2000 – 2500 mm/year  |
|               |              | 2             | 1000 – 2000 mm/year  |
|               |              | 1             | < 1000 mm/year       |
| Lithology     | 20           | 2             | Volcanic             |
|               |              | 1             | Limestone and igneous rock |
|               |              | 5             | Regosol, Litosol     |
|               |              | 4             | Andosol, Laterik, Grumosol, Podsolik |
| Soil Type     | 15           | 3             | Mediteran            |
|               |              | 2             | Latosol              |
|               |              | 1             | Alluvial             |
|               |              | 5             | Empty land           |
|               |              | 4             | Industrial and residential areas |
| Landuse       | 20           | 3             | Plantation and irrigated rice fields |
|               |              | 2             | Garden and scrub mix |
|               |              | 1             | Water Body, Forest   |

2.3. Accuracy Test
The results of the landslide susceptibility map model were tested using the accuracy assessment. Accuracy assessment is a method used to validate data by comparing landslide susceptibility map data with field survey results [10]. The purpose of the accuracy assessment is to determine the accuracy of the classification of landslide incident points with field data. Landslide susceptibility maps that have been overlaid with the distribution of landslide event points will be tested by comparing the actual landslide event data, with the following formula:

\[
\text{Accuracy Assessment} = \frac{\sum \text{Point In Accordance With Ground Check}}{\sum \text{Observation Point}} \times 100\%
\]
3. Result and Discussion

Landslide susceptibility maps processed using the Spatial Multi-Criteria Evaluation (SMCE) method will produce 4 classifications of landslide susceptibility in Majalengka Regency, namely areas not susceptible, low, medium, and high. Determinants of landslides such as slopes, rainfall, lithology, soil types, and land use that have been given weighted values will affect the area of each resulting landslide classification.

3.1. Landslide susceptibility Model 1 (Minister of Public Works NO.22/PRT/M/2007).

The landslide susceptibility area model 1 in this study is the result of an overlay of the ILWIS software SMCE method with a weighted value that has been determined by Minister of Public Works Regulation NO.22 PRT/M/2007 as follows: 30% slope, 15% rainfall, type soil 15%, 20% lithology, 10% land use. Based on the results of the data processing that has been carried out, it is known that in model 1, Majalengka Regency is dominated by the classification of moderate susceptibility which is found with an area of 57,666 hectares or about 42.85%.

![Landslide Susceptibility Map Model 1 Based on Minister of Public Works Regulation NO.22 PRT/M/2007.](image)

**Figure 1.** Landslide Susceptibility Map Model 1 Based on Minister of Public Works Regulation NO.22 PRT/M/2007.

| Classification   | Area (Ha) | Percentage (%) |
|------------------|-----------|----------------|
| Not Susceptible  | 774       | 0.58           |
| Low              | 41.006    | 30.47          |
| Moderate         | 57.666    | 42.85          |
| High             | 35.139    | 26.11          |
| Total            | 134.585   | 100            |

**Table 4.** The total area in Majalengka Regency based on the landslide susceptibility class model 1
3.2. Landslide Susceptibility Model 2 (Puslittanak, 2004).
The susceptibility of the landslide area model 2 in this study is the result of an overlay of the ILWIS software SMCE method with the weighting value determined by Puslittanak in 2004 as follows: 20% slope, 30% rainfall, 10% soil type, 20% lithology, usage land 20%. Based on the results of the data processing that has been carried out, it is known that in model 2, Majalengka Regency is dominated by low susceptibility classifications which are found with an area of 63,737 Ha or around 47.4%.

![Figure 2. Landslide Susceptibility Map Model 2 Based on Puslittanak 2004.](image)

| Classification   | Area (Ha) | Percentage (%) |
|------------------|-----------|----------------|
| Not Susceptibility | 890       | 0.7            |
| Low              | 63,737    | 47.4           |
| Moderate         | 62,120    | 46.2           |
| High             | 7,600     | 5.7            |
| Total            | 134,585   | 100            |
3.3. Landslide Susceptibility Area Model 3 (Directorate of Volcanology and Geological Disaster Mitigation, 2004).

The susceptibility of the landslide area model 3 in this study is the result of an overlay of the ILWIS software SMCE method with a weighted value that has been determined by the Directorate of Volcanology and Geological Disaster Mitigation in 2004 as follows: 15% slope, 30% rainfall, 20% soil type, lithology 20%, land use 15%. Based on the results of the data processing that has been carried out, it is known that in model 3, Majalengka Regency is dominated by the classification of moderate susceptibility which is found with an area of 85,055 hectares or about 63.23%.

![Landslide Susceptibility Map Model 3](image)

**Figure 3.** Landslide Susceptibility Map Model 3 Based on the Directorate of Volcanology and Geological Disaster Mitigation in 2004.

**Table 6.** The total area in the Regency of Majalengka is broken down based on the landslide Susceptibility class model 3

| Classification | Area (Ha) | Percentage (%) |
|----------------|-----------|----------------|
| Not Susceptible| 5.361     | 3.99           |
| Low            | 36.535    | 27.16          |
| Moderate       | 85.055    | 63.23          |
| High           | 7.555     | 5.62           |
| Total          | 134.585   | 1000           |
3.4. Accuracy Test of Landslide Susceptibility Map in Majalengka Regency

Based on Figure 4, in Majalengka Regency in 2018-2019 there were 82 landslide incident points spread across 19 sub-districts. Argapura Kecamatan had the most landslide incidents, namely 12 events.

![Landslide Location Map in Majalengka Regency](image)

**Figure 4. Landslide Location Map in Majalengka Regency**

To find out the level of accuracy of the landslide-prone maps that have been generated from 3 sources, the Accurate Assessment method is used, namely by calculating the points that correspond to the ground check then divided by the number of landslide events and multiplied by 100.

The point that matches the ground check is known by looking at what variables are present at the landslide point, then calculating the standardization for each variable then matching it with the classification of susceptible areas from the map that has been generated, if it matches the standardization value with the classification of susceptible areas, then that point matches the ground check. The following is a table of the accuracy of the resulting landslide-prone area map:

| Landslide Susceptibility Map Model | Number of Points Corresponding | Accuracy Results |
|-----------------------------------|-------------------------------|-----------------|
| Model 1 (Minister of Public Works Regulation NO.22 / PRT / M / 2007) | 64 | 76% |
| Model 2 (Puslitnank, 2004) | 60 | 73% |
| Model 3 (DVMBG, 2004) | 56 | 68% |
There is a difference between accuracy result carried out in this study and the research of INengah Sinarta et all [11]. In research of INengah Sinarta, the accuracy result derived from Minister of Public Works Regulation NO.22 / PRT / M / 2007 produces an accuracy value of 71.4% while in this study the accuracy reaches 76%.

4. Conclusion

Based on the three landslide susceptibility maps produced using different sources, it can be seen that Majalengka Regency is dominated by moderate susceptibility areas that are scattered in the central to western parts of the Majalengka Regency. Increased incidence of landslides also caused by rainfall, steep slopes and utilization activities land above it [12]. This region has a slope of >30% with rainfall >1,500 mm / year. Slopes that have a high degree of steepness cause the location of rainwater is close to the maximum so that it can lead to possibilities landslides [13]. The types of soil contained in it are regosol, latosol, and andosol, where these soil types have a high erodibility level. Loose soil has high permeability so that water will be easy to pass, so that it will have more potential landslides occur compared to dense soils [14]. This area contains lithology in the form of volcanic and sedimentary rocks and uses of land in the form of rice fields, moor, and settlements. Based on the three sources used to determine the weighting value of the landslide susceptibility map in Majalengka Regency, the source of the Minister of Public Works Regulation NO.22 / PRT / M / 2007 model has a higher accuracy rate of 76% compared to the 2004 Puslittanak 2 model with a value of 73% and model 3 of the Directorate of Volcanology and Geological Disaster in 2004 with a value of 68%.

Evaluation in this study for further research is to determine the weighting value for each variable, you should pay attention to the physical condition of the research area, because each source of weighting values does not necessarily correspond to the conditions of the research area to be studied, and it is better to use the point of landslides 3 or 4 years earlier, so that the accuracy value is more accurate. Based on the research results, the SMCE method has a better accuracy value by using a weighted value than other weighting value methods[15].

Acknowledgments

The author would said thank you for the Universitas Indonesia who supported and funded this international conference, and thanks to Regional Disaster Management Agency Majalengka Regency which helps in providing information and data on landslides disaster

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