Landslide Disaster Mapping in Silo District, Jember Regency

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Abstract. Silo District has land with mountainous contours that are relatively unstable and prone to landslides. The factors that cause landslides are complex factors, not only one factor that affects landslides but there are several factors that contribute to the occurrence of a landslide. The use of five landslide parameters, including rainfall, soil type, slope, land cover and geology. The use of this parameter is adjusted to the physical condition of the Silo sub-district. The purpose of this study was to analyze the level of landslide vulnerability in Silo District. The method used is the overlay method with scoring. The scoring of each parameter is based on previous research and the researcher's modifications are adjusted to the physical conditions of the research location. The data resulting from the overlay process is then classified into three classes, namely areas of landslide vulnerability: low, medium, and high. The low classification has a total area of 4266 hectares, the medium classification has an area of 5324 hectares, and the high classification has an area of 659 hectares. Areas with low classification are scattered in the central and northern part of Silo District, namely Silo Village, Sempolan Village and Sumberjati Village. Areas with Medium Classification are spread in the central to southern region which is an area with an old mountainous topography. Meanwhile, areas with a high classification are scattered in the eastern, southern and western regions right around the border with the Banyuwangi Regency border in the east and the old mountainous area in the south and west.

1. Introduction
Jember Regency is a district that has a diverse topography in the form of coastal, lowland and highland. The eastern part of Jember Regency is a mountainous area that has various contours ranging from gentle to steep. Silo Subdistrict has land with mountainous contours that are relatively unstable and prone to landslides. According to Suripin in [14] landslides are a form of erosion that occurs due to a process of lifting or movement of the soil mass that occurs at one time with a relatively large volume. The factors that cause landslides are complex factors, not only one factor that affects landslides but there are several factors that contribute to the occurrence of a landslide [13] in addition to physical, economic and mental losses can be caused by a landslide [18]. In 2006 in Harjomulyo Village there was a landslide disaster which was followed by flash floods, this was caused by the bare land on the slopes of Baban and Mayang mountains which caused landslides and flash floods[20]. In 2009 there was a landslide which was followed by a flash flood in Dosun Curah Wungkal, Pace Village, this can happen because the plantation area that used to be planted with rubber was converted into corn. Residents said they saw a landslide on the hill that blocked the flow of the river which caused flash floods[21]. In 2020, landslides and flash floods occurred in Sidomulyo Village which caused the interruption of access to the Jember Banyuwangi national road KM 34-38, in addition to flash floods and landslides in Sidomulyo Village in 2020 causing damage to SMPN 5 Silo[22].

Geographic Information Systems can be used for the basis of landslide-prone areas. Mapping of landslide-prone areas can be done using various applications or mapping software on GIS [14]. One of the studies conducted by [6] regarding the mapping of landslide-prone areas in Bondowoso Regency classifies landslide vulnerability levels into three vulnerability vulnerability, vulnerable and vulnerable. In this study using geological parameters, slope angle and rainfall. In line with this, the research conducted by [11] uses land use, geology, slope and rainfall parameters for landslide hazard mapping. The difference in these parameters will give different results. Parameters used in this study include parameters of rainfall, soil type, slope, land cover and geology. Rainfall is a factor in the level of vulnerability to landslides, the higher the amount of rainfall in a location, the higher the potential for landslides [8]. Low soil parameters are based on the ability of the soil to pass water, meaning that the easier it is for the soil to pass water, the risk of landslides will increase[10]. The slope is one of the factors that affect the danger of landslides, because with increasing slopes, the attraction of the earth or...
Gravity will pull the material down the hill, this will increase the potential for landslide hazards [15]. Land cover parameters affect the structure of the soil beneath it. Soil that has an unstable structure will cause a greater potential for landslide hazard in line with land cover if the type of land cover vegetation maintains the soil structure, the potential for landslides will be lower [1]. Geological parameters are determined from the geological structure which will be divided into several types of rock such as volcanic rock, alluvial, karst and so on. The division of this structure will later provide differences in the potential for landslide vulnerability [11].

The final result of data processing on each parameter in this study will later produce a map of landslide-prone areas in Silo District, Jember Regency. Mapping of landslide-prone areas is one of the preventions that can be considered in efforts to mitigate landslides that occurred in Silo District with later output of higher vulnerability classes, disaster mitigation must be more effective to reduce moral or material losses.

2. Methods

Landslide vulnerability can be analyzed through the Geographic Information System with the overlay method of landslide vulnerability parameters [13] The data used in this study is spatial data from various types of maps originating from various agencies. The parameters used in this study include: administrative maps, slope maps, rainfall maps, geological maps, land cover maps and soil type maps. The analytical method used is the overlay method. The overlay method is a method in ArcGIS applications that combines data from each parameter, then the results of these parameters are assessed or assessed to determine the vulnerability area. The overlay data is then crossed with administrative data for each village to determine the extent of landslide-prone areas.

2.1 Place and time of research

This research was carried out in Pace Village, Harjomulyo Village, Sidomulyo Village and Mulyorejo Village. Of the four villages, all of them are in Silo District, Jember Regency. Geographically, Silo District is bordered by Ledokombo District in the north, Banyuwangi Regency in the east, Tempurejo District in the south, Mayang and Mumbulsari Districts in the west. The eastern region of Silo District is the slope of Mount Raung which has steep slope characteristics. The southern region of Silo District is an old mountain that has a steep slope. The research was conducted from October to November 2021.

Figure 1. Silo District Administration Map
2.2 Tools and material

• Acer Aspire 3 . Laptops
• ArcGIS 10.8 . software
• Microsoft Office Word 2010
• Microsoft Office Excel 2010
• Village and District Administration Map
• USDA Land Map
• Geological Map
• Land Cover Map
• DEM SRTM data
• Rainfall data

2.3 Mapping of Landslide Prone Areas

Mapping of landslide-prone areas requires several maps of each parameter such as rainfall maps, soil maps, slope maps, land cover maps and geological maps.

2.3.1 Rainfall Map

Rainfall maps were obtained from the interpolation process using the IDW method of annual rainfall data for rain stations in the Silo District area. Then the rainfall map is scored according to Table 1.

| Rainfall          | Score |
|-------------------|-------|
| <1000 mm/year     | 1     |
| 1000-1500 mm/year | 2     |
| 1500-2000 mm/year | 3     |
| 2000-2500 mm/year | 4     |
| >2500 mm/year     | 5     |

Source: [18] with modification

2.3.2 Soil Map

Soil type maps are obtained from USDA data which are clipped according to the research area. The soil type map of Silo District was then scored according to Table 2.

| Soil Type | Laju Infiltrasi | Score |
|-----------|-----------------|-------|
| Andosol   | Sensitive       | 2     |
| Gleisol   | Somewhat sensitive | 4   |
| Kambisol  | Very sensitive  | 1     |
| Regosol   | Very sensitive  | 1     |

Source: [2]

2.3.3 Slope Map

The slope map was obtained from SRTM data extracted using slope tools in ArcGIS, then the slope map was reclassified to determine the number of slope classes in accordance with Kepmentan No 83 of 1980. The basis for the weighting score on the slope map is in accordance with table 3.
### Table 3. Slope Parameter Score

| Slope Class | Information     | Score |
|-------------|-----------------|-------|
| 0-8 %       | Flat            | 1     |
| 8-15 %      | Sloping         | 2     |
| 15-25%      | Slightly Steep  | 3     |
| 25-45%      | Steep           | 4     |
| >45%        | Very Steep      | 5     |

Source: [7]

#### 2.3.4 Land Cover Map

The land cover map data was obtained from the website of the Ministry of Environment and Forestry which was then adapted to the research area. Then the land cover map is scored based on table 4.

### Table 4. Land Cover Parameter Score

| Land Cover                     | Score |
|--------------------------------|-------|
| Forest                         | 1     |
| Settlements, rice fields       | 2     |
| Plantations, fields, fields    | 3     |
| Shrubs                         | 4     |
| Vacant land                    | 5     |

Source: [2] with modification

#### 2.3.5 Geological Map

The geological map is obtained by digitizing the geological map of the Jember sheet which is then filled in with attribute data. Then the geological map is given a parameter score according to table 5.

### Table 5. Geological Parameter Score

| Name of formation | Geology                                                                 | Score |
|-------------------|-------------------------------------------------------------------------|-------|
| Breakthrough Rock | Diorit, granodiorit, dasit                                              | 2     |
| Raung Volcano Rock, Tuff Argopuro | gray tuff, lava, volcanic breccia, lava breccia.                        | 3     |
| Merubetiri Formation, Batuampar Formation, Sukamade Formation | Volcano breccia, lava and tuff, sandstone dan batulempung,claystone with silt | 4     |
| Mandiku Formation | Andesit, basalt                                                          | 5     |

Source: [2] with modification

The scoring process for each parameter is then added up with the following formula:

After summing up each score, the total score is classified into 3 classes with the formula:

Maximum Value = 19
Minimum Value = 9
Interval Value = Maximum Value – Minimum Value

\[
\text{Interval Value} = \frac{19 - 9}{3} = 3.3
\]

Table 6. Distribution of Score Range

| Class   | Score Range |
|---------|-------------|
| Low     | 9 To 12     |
| Medium  | 13 To 16    |
| Height  | 17 To 19    |

Source: Researcher’s calculation results

3. Results and Discussion

3.1 Landslide Parameter Map

3.1.1 Rainfall Map of Silo District

The making of rainfall maps in Silo District utilizes data from the Jember Public Works and Irrigation Service, namely the annual rainfall at each rain station around Silo District. The use of the Inverse Distance Weighting (IDW) method is one of the interpolation methods to estimate a value at an unsampled location based on the surrounding data [12]. The basic data for interpolation is obtained from the results of interpolation of rainfall at rain stations scattered in the Silo District area. After the interpolation process is obtained, the Silo District area is divided into four classes of rainfall.

Figure 2. Rainfall Map of Silo District

Source: [3]
3.1.2 Soil Type Map of Silo District

Based on the USDA soil type map, it can be identified that the soil types at the study site consisted of andosols, gleisols, cambisols, and regosols. Andosol soil dominates the research site. Classification of soil types for landslide mapping is based on the sensitivity of the infiltration rate. The infiltration rate sensitivity was divided into four classes, namely insensitive, moderately sensitive, sensitive and very sensitive. The more sensitive the infiltration rate, the smaller the score for landslide classification. This is because when a runoff occurs, the potential for landslides will be even greater [19]. Andosol soil is a soil that is sensitive to infiltration, gleisol soil is a rather sensitive soil, while cambisol soil and regosol soil are very sensitive to infiltration.

![Soil Type Map of Silo District](image)

Figure 3. Map of Soil Types in Silo District

Source: [16]

3.1.3 Slope Map of Silo District

The slope map was obtained from the USGS SRTM DEM data extract process. The extracted DEM data was then divided into five classes based on Kepmentan no. 837 of 1980, the distribution of slope classes based on percentages included 0-8% Flat, 8-15% Sloping, 15-25% Slightly Steep, 25-45 % Steep, and >45% Very Steep. The determination of the slope of the slope is based on the influence of gravity or sliding along the slope. The steeper the slope, the gravitational force or sliding force will cause a horizontal shift so that the material that has a less strong structure will have the potential to slip down the slope. [9].
Figure 4. Slope Map of Silo District
Source: [4]

3.1.4 Land Cover Map of Silo District

Land cover data is a parameter used in determining areas prone to landslides. The land cover map serves to determine the land cover above the research area. Each land has the potential to increase the occurrence of landslides. With regard to land cover and vegetation cover, areas with hard vegetation will have a low score, because hard vegetation has roots that will maintain the soil structure. On the other hand, bare land cover will have a high score because bare soil is easy to pass water so that the soil structure will easily slip from the parent rock[5]. The land cover in the silo sub-district is divided into several land covers, including: shrubs, secondary dry land forest, plantation forest, settlements, dry land agriculture, mixed dry land agriculture and rice fields.
3.1.5 Geological Map of Silo District

The research location is an area that has rock structures that are influenced by Mount Argopuro and old mountain formations such as the Sukamade Formation, Batuampar Formation, Merubetiri Formation and Mandiku Formation. Based on the classification of bedrock types, the constituent rocks at the study site consist of breakthrough rock with rock types of diorite, granodiorite and dacite, raung volcanic rock and argopuro tuff which is volcanic rock with tuff rock type, ash tuff, lava tuff, volcanic breccia and lava breccia. Merubetiri Formation, Batuampar Formation and Sukamade Formation with interspersed rock types of volcanic breccia, lava and tuff, alternating sandstone and claystone, and claystone with siltstone inserts. Mandiku Formation with andesite and basalt rock types.
3.2 Map of Landslide Prone Areas in Silo District

Source: The results of the researcher's analysis
Table 7. The area of each village prone to landslides in hectares

| Village       | Class in (Hectares) |         |         | Total |
|---------------|---------------------|---------|---------|-------|
|               | Low                 | Medium  | Height  |       |
| Garahan       | 423                 | 120     | 543     |       |
| Harjomulyo    | 536                 | 1173    | 175     | 1884  |
| Karangharjo   | 345                 | 296     | 641     |       |
| Mulyorejo     | 153                 | 1313    | 276     | 1742  |
| Pace          | 394                 | 729     | 104     | 1227  |
| Sempolan      | 313                 | 940     | 104     | 1676  |
| Sidomulyo     | 632                 | 407     | 884     |       |
| Silo          | 477                 | 933     | 1247    |       |
| Sumberjati    | 993                 | 254     | 305     |       |
| **Total**     | **4266**            | **5324**| **659** | **10249** |

Source: The results of the researcher’s analysis

4. Conclusion

Based on the parameters of rainfall, soil type, slope, land cover and geology, landslide-prone areas in Silo District are divided into 3 classes of vulnerability, namely "Low", "Medium", and "High". The low classification has a total area of 4266 hectares, the medium classification has an area of 5324 hectares, and the high classification has an area of 659 hectares. Sumberjati village has the largest low vulnerability class, covering an area of 933 hectares. In the medium vulnerability class, the village area that has the largest area is Mulyorejo Village with an area of 1313 hectares, in the high classification Mulyorejo Village has an area of 276 hectares. Areas with low classification are spread in the central and northern part of Silo District, namely Silo Village, Sempolan Village and Sumberjati Village. Areas with Medium Classification are spread in the central to southern region which is an area with an old mountainous topography. Meanwhile, areas with a high classification are scattered in the eastern, southern and western regions right around the border with the Banyuwangi Regency border in the east and the old mountainous area in the south and west.

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