Geographical information system and satellite imagery for landslides analysis in Karo Regency based on human factors

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Abstract. Mapping of landslide potential areas was carried out in Karo Regency using an estimation model based on the Minister of Public Works Regulation No.22 of 2007. This regulation states that human activity is one of the aspects that causes landslides to occur. There are 7 factors in human activity that can cause landslides, namely; cropping patterns, excavating and cutting slopes, pond construction, slope drainage, building construction, population density, and mitigation efforts. All of these indicators are searched for their respective scores using the Q-Gis application which produces a total score to determine the class of landslide hazard levels. Based on the analysis, the level of landslide hazard in Karo Regency is divided into 3 classes, namely; low hazard level with an area of 1699.01 km$^2$ covering the sub-districts of Mardingding, Laubelang, Tigabinaga, Juhar, Munte, Kutabuluh, and Tiganderket. The moderate hazard level with an area of 259.34 km$^2$ covers the sub-districts of Payung, Simpang Empat, Naman Teran, Merdeka, Brand, and Barusjahe. The high hazard level with an area of 168.77 km$^2$ includes the sub-districts of Kabanjahe, Berastagi, Tigapanah, and Dolat Rayat.

1. Introduction

The geographical location of Indonesia, which is between two continents and two oceans, makes Indonesia has great potential in the economy as well as being prone to natural disasters. One of disasters that often occur in Indonesia is landslide. Landslides themselves occur due to loss of stability on the slopes caused by natural and human activities [1][2][3][4].

Bitra Indonesia stated that 19 out of 25 regencies and cities in North Sumatra Province have the potential to experience landslides, one of which is Karo Regency. Karo Regency is located at an altitude of 200 - 1500, is flanked by two active volcanoes, and is on the Bukit Barisan plateau with hilly and undulating topography. In this area, there are many valleys and steep hillsides. So it does not rule out that Karo Regency is very vulnerable to landslides [2].

Apart from geographical factors, human activities also give some effects on landslides, such as inappropriate land use and uncontrolled exploitation of nature which can also increase the threat of landslides. So it is necessary to do the mapping to determine the distribution of the potential regions that have the potential to experience landslides by utilizing the Geographic Information System (GIS) and Satellite Imagery applications [5][6].

2. Literature Review

2.1 Landslides
Landslides is a disaster that threaten and disrupt people's lives and livelihoods caused by the movement of land from the top to the bottom of the slope, resulting in human casualties, environmental damage, property loss, and psychological impacts [3].

2.2 Geographical Information System (GIS)
Geographical Information System, hereinafter referred to as GIS, is a computer-based information system used to process and store geographic data or information. [4] In general, the data model in GIS is divided into two, namely, spatial data models such as vector data and raster data, and attribute data models [5].
2.3. Satellite Imagery

Satellite imagery is a picture of the earth's surface from remote sensing satellites orbiting the earth in the form of a digital image. An example of application that has been developed by utilizing satellite imagery is Google Earth.

3. Research methods

The data was collected by using quantitative methods and data analysis using the scoring method and overlay union. Secondary data that have been obtained are processed with a scoring system. Scoring is done to give value to each parameter used.

Landslide mapping uses an estimation model based on the Minister of Public Works Regulation No.22 of 2007. Based on this prediction model, the indicators used to estimate landslide vulnerability according to human factors are divided into 7 indicators, namely cropping patterns, slopes excavation and cutting, pond construction, slope drainage, building construction, population density and mitigation efforts, which can be formulated as follows

$$NBT = 0.1(PT)+0.2(PPL)+0.1(PK)+0.1(DL)+0.2(K)+0.2(KP)+0.1(UM)$$

Where:

$PT$ = Cropping Patterns, $PPL$ = Slopes Excavation and Cutting, $PK$ = Pond Construction, $DL$ = Slope Drainage, $K$ = Building Construction, $KP$ = Population Density, $UM$ = Mitigation Efforts [7]

The value of landslides proneness consists of 3 categories as in Table 1 below

| No. | Proneness Level | Score |
|-----|----------------|-------|
| 1   | Low            | 1.00-1.69 |
| 2   | Moderate       | 1.70-2.39 |
| 3   | High           | 2.40-3.00 |

4. Results and Analysis

4.1. Landslide Proneness Mapping

4.1.1. Cropping Patterns

At least 10% of the causes of each landslide that occur are uneven cropping patterns. Slope forests are continuously cut down without replanting trees and many of the slopes have been converted into plantations and rice fields. So that when it rains there is no barrier that will stop the land movement which eventually causes landslides.

| Cropping Patterns | Category | Score | % Weight (10% x Score) | Area (km²) |
|-------------------|----------|-------|------------------------|------------|
| Fields            | Low      | 3     | 0.3                    | 347.54     |
| Gardens           | Moderate | 2     | 0.2                    | 788.99     |
| Pine forests      | High     | 1     | 0.1                    | 990.72     |
4.1.2 Slopes Excavation and Cutting
The excavation and cutting of slopes is the biggest major factor that causes landslides. The excavation and cutting of slopes is generally carried out for the construction of road access. However, sometimes the construction does not pay attention to the structure of the soil or rocks on the slope and does not calculate the slope stability analysis. This has led to landslides along the roads that have been built. From the analytical results obtained, the area based on the indicators of slopes excavation and cutting can be seen in Table 3.

| Slopes excavation and cutting | Category  | Score | % Weight (20% x Score) | Area (km²) |
|------------------------------|-----------|-------|------------------------|------------|
| High                         | High      | 3     | 0.6                    | 139.34     |
| Low                          | Moderate  | 2     | 0.4                    | 1054.50    |
| No slopes cutting            | Low       | 1     | 0.2                    | 933.42     |

4.1.3 Pond Construction
When the pond is filled with water, the water in the pond will slowly seep through into the slopes. The wider and denser the pond is built, the higher possibility that water in the pond will seep through and penetrate the slope. If these activities are left without any effort to fix them, then it is possible that landslides will occur. From the analytical results obtained, the area based on the pond construction indicator can be seen in Table 4.
Figure 2. The excavation and cutting slopes map of Karo Regency

Table 4. Area based on pond construction

| Pond construction          | Category | Score | % Weight (10% x Score) | Area (km²) |
|---------------------------|----------|-------|------------------------|------------|
| High                      | High     | 3     | 0.3                    | 3.81       |
| Low                       | Moderate | 2     | 0.2                    | 97.04      |
| No pond construction      | Low      | 1     | 0.1                    | 2026.40    |
4.1.4. Slope Drainage

When it rains, some of the rainwater will be infiltrated into the soil and will cause slope collapse due to the formation of a slip plane along the water leakage layer, and some other rainwater will flow over the surface of the slope causing the slope to erode.

In Karo Regency, no drainage is found along the slope, it is caused Karo Regency to be included in the high category on the slope drainage indicator. From the analytical results obtained, the area based on the slope drainage indicator can be seen in Table 5.

Table 5. Area based on slope drainage

| Slope Drainage          | Category | Score | % Weight (10% x Score) | Area (km²) |
|-------------------------|----------|-------|------------------------|------------|
| Inadequate drainage     | High     | 3     | 0.3                    | 2127.25    |
| Adequate drainage       | Moderate | 2     | 0.2                    | -          |
| Very adequate drainage  | Low      | 1     | 0.1                    | -          |
4.1.5. Building Construction
Buildings built on the edge of the slope have the potential to cause landslides which are caused by the huge load that messes the stability of the slope. Also, the number of buildings built right along the slopes that do not follow the guidelines potentially affect slope stability. From the analytical results obtained, the area based on the construction development indicators can be seen in Table 6.

Table 6. Area based on building construction

| Construction Level     | Category  | Score | % Weight (20% x Score) | Area (km²) |
|------------------------|-----------|-------|------------------------|------------|
| High                   | High      | 3     | 0.6                    | 180.48     |
| Low                    | Moderate  | 2     | 0.4                    | 138.80     |
| No building construction| Low       | 1     | 0.2                    | 1807.97    |

Figure 4. The slope drainage map of Karo Regency

Figure 5. The Building Construction Map of Karo Regency
4.1.6. Population Density
According to the Central Agency on Statistics of Karo Regency (2019), the population of Karo Regency is 409,680 people spread across 17 sub-districts. From the analytical results obtained, the area based on the population density indicator can be seen in Table 7.

Table 7. Area Based on Population Density

| Population Density | Category  | Score | % Weight (20% x Score) | Area (km²) |
|--------------------|-----------|-------|------------------------|------------|
| High (>50 people/ha) | High      | 3     | 0.6                    | -          |
| Moderate (20-50 people/ha) | Moderate | 2     | 0.4                    | -          |
| Low (<20 people/ha)    | Low       | 1     | 0.2                    | 2127.25    |

4.1.7. Mitigation Efforts
Mitigation efforts really need to be done to reduce the impact caused by natural disasters. But in fact, in the results of the questionnaire, there are 2 sub-districts in Karo Regency which are included in the high category and only 1 sub-district which is included in the low category. This occurs due to the lack of public knowledge about the importance of disaster mitigation and the lack of socialization by the government. Table 8 shows the results of the analysis that has been carried out.

4.1.8. Landslide hazard level analysis
Landslide hazard analysis uses an estimation model based on the Regulation of the Minister of Public Works No.22 of 2007. After all indicators have been classified based on scores, then they are weighted according to their respective contributions, then the seven indicators will be overlaid to determine the hazard of landslides that have occurred. The results of the overlay analysis can be seen in Table 9.

5. Conclusion
Uncontrolled human activity in exploiting nature has a big share in the occurrence of landslides. The construction of building, excavation, and slope cutting are the parameters that influence the occurrence of landslides the most. The reason is because it has an indicator weight by 20%, so that the high landslide hazard level is mostly located in areas that have a high level of construction and slope
cutting. Based on the analysis, the level of landslide hazard in Karo Regency is divided into 3 classes, namely; low hazard level with an area of 1699.01 km$^2$ covering the sub-districts of Mardingding, Laubelang, Tigabinaga, Juhar, Munte, Kutabuluh, and Tiganderket. Moderate hazard level with an area of 259.34 km$^2$ covering the sub-districts of Payung, Simpang Empat, Naman Teran, Merdeka, Brand, and Barusjahe. High hazard level with an area of 168.77 km$^2$ includes the sub-districts of Kabanjahe, Berastagi, Tigapanah, and Dolat Rayat.

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