The potential of landslide in Lake Maninjau Catchment Area, West Sumatra

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Abstract. West Sumatra is amongst tectonically and volcanically active area, located at the interface of Indo-Australia and Eurasia plates. The movement of plates triggers many natural disasters, one of them is landslides. Especially Lake Maninjau that located in Tanjungraya District, Agam Regency, West Sumatra that often experience the landslide. This landslide caused physical damage and loss of life. The direct research was conducted in the field by mapping rock types, soil types, slope and then other factors such as rainfall and landuse, using Geographic Information System (GIS) based analysis using the weighted method with spatial analysis, and weighting for each parameter. The higher score and the weight, then the effect will be higher on the ground movement and vice versa. The purpose of this research is to get information about potential of landslide as the basis for the development of Lake Maninjau Watershed Area. Based on the result of DEM analysis the research area is dominated by a fairly steep slope (15%-30%) whereas the area with flat slope – very flat only 20% of 244,03 km². Land use as settlement, plantation, forest, water etc. Result of this research with spatial analysis is potential of ground motion in 20 locations with steep slopes around Koto Malintang Village and Tanjung Sani Village. The validation of calculation result shows 75% similarity with field data.

1. Introduction

Landslide disaster is one of the most frequent natural disasters in Indonesia and generally occurs in mountainous areas and in the rainy season. This disaster is closely related to natural conditions such as soil type, rock type, rainfall, land slope and land cover. In addition, the human factor is also very determine the occurrence of landslide disasters such as land use change that is not wise, deforestation, settlement development in areas with steep topography. Land landslide is a movement of land directly related to various physical properties such as geological structure, parent material, soil, drainage patterns, slopes/landforms, rainfall and non-natural traits that are dynamic such as land use and infrastructure [1].

Lake Maninjau located in Agam regency is one of the regencies in West Sumatra Province. The lake is characterized by steep cliffs around it in a circular shape. These cliffs often experience

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landslides, otherwise the plains on the slopes of his feet often experience flash floods. Major landslide disaster ever occurred in 1980 caused by high rainfall. After that another landslide in 2009 was triggered by high earthquake and rainfall, which destroyed more or less four hamlets with heavy casualties of 80 deaths, 90 seriously injured, and 47 minor injuries [2]. Based on statistics data of Tanjung Raya district have the number of resident 34,791 populations.

Geomorphology of Lake Maninjau is very closely related to volcanic and tectonic formed that has happened, morphological condition of Maninjau catchment area can be separated form volcanic origin, fluvio-volcano, fluvial, denudation, structure and volcano denudation [3]. This lake is formed from the caldera which then filled with water furthermore filled also by the material from the caldera wall. The rest of the caldera wall that is straight in some places has experienced landslide, Then the area is growing settlements in several locations so that identification of avalanche potential becomes important to avoid disaster [4]. Given the number of landslide events that bring disaster in Tanjung Raya District, the study of landslides and dangers is very necessary. The results of this study are expected to be used by the government and by stakeholders to cope with this disaster more thoroughly.

2. Materials And Methods

2.1 Study Area
Lake Maninjau Located at 00° 01' 34" - 00° 28' 43" S and 99° 46' 39" - 100° 32' 50" E, administratively Lake Maninjau is included in Tanjung Raya District, Agam Regency, West Sumatra Province. The Catchment area only including one district that is Tanjung Raya District consisting of 12 villages. Base on statistical data total population in Tanjung raya district is 34,791 People in 2016. Figure 1 Shows the study area.

2.2 Geology Setting
Geology of Lake Maninjau based on geological map of Padang, West Sumatra [5], composed of tuff and andesite (pink) and andesite rock from caldera maninjau (brown) age of Pleistocene or 1.8 million years ago. Tuff and andesite generally consist of glass fibers and 5 - 80% of white-clay fragments, measuring from 1 – 20 cm, compact, Maninjau Ignimbrite Deposition characterized by the occurrence of high Kryolite to calcalkaline andesite [6]. This tuff deposit may be the result of eruptions associated with the Great Sumatara Fault [7]. The study area lies in a large segment of the Sumatran active fault oblique system known as The Great Sumatra Fault. Figure 1 shows the geology condition of Lake Maninjau Catchment Area.

Figure 1. Study Area Map
This study uses weighted methods with GIS applications, data obtained from field mapping such as; lithology, geological structure, landslide location, besides that also used secondary data such as; Digital Elevation Model (DEM), soil type and rainfall. The DEM used SRTM with 30 x 30 m resolution. The research tools to be used include computer hardware and software. Software such as Microsoft Office, ArcGIS 10.2 with tools 3DAnalysis and SpatialAnalysis While the hardware used includes Global Positioning system (GPS), digital cameras, printers, and stationery.

The first step in this research is to make the boundary of the study area by using 30 x 30 meter SRTM data which can be downloaded at USGS Website, Catchment boundary is developed by ArcHydro Tools on ArcGIS Application. Then the result data is DAS Map is used to cut other spatial data, namely lithology map, slope map, land use map, soil map and rainfall distribution map.

From the data DEM (SRTM 30x30), it can be seen the slope and watershed area. Supported by data on lithology, soil, landuse and rainfall. The stages of combining existing data are carried out, so that data can be weighted. After that the data is processed using the Arcgis 10.2 application. the results of data processing, we can classify the vulnerability zones of the ground movement according to the Puslittanak (2004) and then get the landslide prone-map of the earth From the prone-map landslide, recommendations were made for the community in determining which areas were safe to occupy.

2.3 Data Analysis
Analysis data performed includes spatial, attribute, and descriptive analysis. Spatial analysis and attributes utilize Geographic Information System (GIS), using weighting and scoring on each parameter specified. In this case the higher score and weight of the parameters, then the effect will be greater against the hazard or risk of landslides, and vice versa. The classification for hazards, vulnerabilities, capacities and risks is divided into five classes, ie very low, low, medium, high and very high. The descriptive analysis is conducted to describe the relationship between spatial arrangement and landslide risk that is used to formulate spatial planning as an effort to minimize the impact of landslide disaster.

2.4 Data Processing
Preparation of landslide hazard maps with overlap of the landslide parameter maps. In the overlapping process, the parameters are scored and weighted according to their potential in contributing to the landslide. The higher the score and weighting, reflecting the greater the potential to contribute to the occurrence of landslides, and vice versa. Determination of weights using several causes of landslide parameters include rainfall, slope, geology and soil type. The use of weight and scores of landslide hazard parameters refers to the Puslittanak parameter score (2004) [8]. The landslide hazard rate is semi-quantitatively analyzed using a combination of scoring and weighting based on the relative contribution of parameters to landslide hazard.

3. Results and Discussion
Stages of research conducted to determine the potential of ground motion in Lake Maninjau Catchment Area through Geographic Information System Approach among others by:

(1) Analysis of each parameter in accordance with Puslittanak [8], to determine the potential for land movement such as slope, rainfall, soil type, geology, and land use. Figure 3 shows the spatial data for calculation process.

(2) The next step by overlaying the basic maps of each parameter in accordance with the score and weight so that it gets a potential map of the movement of the land in Tanjung Raya Subdistrict to see the spread of potential disaster prone zone of land movement in Tanjung Raya Subdistrict
Based on the mapping in Tanjung Raya District has 2 types of rocks namely Volcanic Rock and Alluvial Rock. Alluvial rock types spread on six nagari namely Koto Malintang, Bayua, Koto Gadang, Anam Koto, Koto Kaciak, Duo Koto and Paninjaun while volcanic rock types scattered in all nagari in Tanjung Raya District. Figure 3 Shows the types of rock. The validation of these parameters by weighting the field:

Table 1. Type of Rock

| No | Rock Type     | Score | Weight | Total  |
|----|--------------|-------|--------|--------|
| 1  | Volcanic Rocks | 3     | 30%    | 13.3%  |
| 2  | Alluvial Rocks | 1     |        |        |

Based on the mapping in Tanjung Raya District the potential for soil movement hazards is very high, an area with a slope of 30 - 45%. On the slopes of 15 - 30% can have a high landslide impact, these slopes are found in Nagari Koto Malintang and Nagari Tanjung Sani. Figure 3 Shows the types of slope.

Table 2. Type of Slope

| No | Slope       | Score | Weight | Total |
|----|-------------|-------|--------|-------|
| 1  | 30% – 45%   | 4     | 20%    | 14%   |
| 2  | 15% – 30%   | 3     |        |       |

The type of land located in Tanjung Raya Sub-district is Gley Humus. Type of soil Gley Humus according to the old soil classification system included into the soil Alluvial or Regosol. Regosol soil type spread throughout in Tanjung Raya District which means it can give a high influence on the occurrence of land slide. Figure 3 Shows the types of soil.
Table 3. Type of Soil

| No | Soil Type | Score | Weight | Total |
|----|-----------|-------|--------|-------|
| 1  | Regosol   | 5     | 10%    | 9%    |
| 2  | Andosol   | 4     |        |       |

Tanjung Raya District Land Use consists of seven uses of land that are Settlement, Forest and Plantation, Shrub, Rice Field, Road, and River. The most extensive land is a forest with 6,870 hectares and the smallest is a river with an area of 25 hectares. Figure 3 Shows the types of landuse.

Table 4. Landuse

| No | Landuse               | Score | Weight | Total |
|----|-----------------------|-------|--------|-------|
| 1  | Forest and Plantation | 3     | 20%    | 10%   |
| 2  | Settlement            | 2     |        |       |

Based on the use of land located in Tanjung Raya Subdistrict, the use of land that gives a high influence on the occurrence of land movement is forest and plantation because in view of the points of movement of so much land in forests and plantations.

Table 5. Rainfall

| No | Rainfall (mm/yr) | Score | Weight | Total |
|----|------------------|-------|--------|-------|
| 1  | 2501 – 3000      | 4     | 30%    | 24%   |

Average rainfall in Tanjung Raya district is 2707.75 Millimeters per year based on Regulation of Minister of Public Works No 22 / PRT / M / 2007 on Landslide Prone Areas in very high level of vulnerability [9]. Based on map calculation on soil map, rainfall map, rocks map, slope map and landuse map by weighting method resulted produces landslide-prone maps that are divided into 4 classes are low, medium, high and very high in the show in different colors, that in the Tanjung Raya district have a high landslide potential (Figure 5). The calculation result also validated by ground check mapping for landslide location, 20 location was encountered in Lake Maninjau Catchment Area. The validated result for landslide is similarity (75%). The result shows very higher landslide located on steep slope around Lake Maninjau, and several settlement very near from very height landslide, mainly on South part of Lake Maninjau Catchment Area, this condition as input for local government in spatial planning for urban location and infrastructure.

Figure 3. Landslide Prone Map
4. Conclusion and Recommendation

The lake Maninjau volcano-tectonic is volcano tectonic, almost around the lake has a steep slope. Maninjau cathment area (24,800 Ha) have a lot of potential soil movement events, the results of calculations indicate very high potential grade almost found around Lake Maninjau. Some locations are very close to the residential location.

Further research is needed using more detailed data and incorporating structural geology factors lake as fault and joint to obtain better results.

Acknowledgment

The author is grateful to Research Center for Limnology, Indonesian Institute of Sciences, for financial support, LATPD Maninjau and team from Pakuan University, who have been involved in full paper done.

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