Evaluation of Landslide Based Settlement Distribution in Manado City

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Abstract. This research was conducted in Manado with the aim of identifying factors that could potentially cause landslide susceptibility, mapping the distribution of potential landslides, and evaluating the distribution of landslide-based settlements. The materials used in this study are daily rainfall maps, slope maps, geological / rock maps, fault maps, soil solum depth maps, land use maps, infrastructure maps and population density maps on a scale of 1:75 000. The map used as research material sourced from documentation studies and interpretation of maps of the earth and satellite imagery. Likewise, other data needed to support this research was obtained through documentation studies and field measurements. Each variable is used to determine landslide scaling and weighting vulnerability. The sum of the multiplication scores and weights of each variable is categorized into five classes of landslide susceptibility levels, which are very light, mild, moderate heavy and very heavy. Settlement distribution analysis is carried out by overlapping between landslide maps and settlement maps using geographic information system (GIS) technology with ArcView GIS 3.3 software. The results of the study indicated that there were three factors that triggered landslide susceptibility in Manado that had a significant effect, namely geological / rock constituent factors, fault factors, and depth of soil solum. Other factors both physical and management factors have a weak influence on landslides because they are on slopes <25%. Most (91.57%) of the study area had very low to low landslide susceptibility. Therefore, the distribution of settlements in the study area is generally in areas that are safe from landslides. Only about 46.12 ha or around 1.17% of settlements in Manado are located in high landslide susceptibility areas. Settlements located in areas with high landslide susceptibility are spread across seven sub-districts, which are located in Bunaken, Tuminting, Mapanget, Sinkil, Pal Dua, Wanea and Malalayang Districts.

Keyword: Evaluation, settlement, landslide, geographic information system

1. Introduction

The mass movement is often called the landslide is one of the natural disasters that frequently hit the hilly areas in the tropics. Landslide is a mass movement of land in large quantities that focuses on the specific slide, which in the field of land in arresting the slide detention exceeded (Kodoatie 2009). Landslide could occur if fulfilled all three states (1) rather steep incline so that the volume of soil to move or slide down, (2) there is a layer below the ground surface watertight as the glide plane, and (3) there is enough water in the soil so that the soil layer becomes saturated and heavy. Areas that have a steep slope (> 25%) plus high rainfall is a potential for the occurrence of the mass movement of soil and eventually cause landslide Land (Paimin, 2009). Cutting the hillside for construction of roads in
areas of steep slopes or other activities are often the cause of the landslide. Likewise, the construction of buildings or settlements on steep slopes will also increase the weight of the soil layer above the glide plane. Common symptoms include the appearance of landslide cracks in the slope parallel to the direction of the cliff, the emergence of new springs sudden and brittle rock and gravel began to fall.

Manado is one area that many have the potential landslide, because the vast majority (59.84%) territory has wavy, hilly topography with the majority of 92.15% at an altitude of 0-240 m above sea level (BPS Kota Manado, 2019). Landslides area in Manado were allegedly distributed in some of the districts, such as Sub Wanea, Winangun, Singkil, Tuminting, Tikala, Mapanget, Bunaken and Malalayang. Landslide vulnerability will increase during the rainy season, because the land mass will be more severe as a result of infiltration. Human activity in the form of land use is one of the important factors that play a role in triggering the landslide. Landslide disaster that occurred in Manado not only cause loss of property but also casualties. In 2012 claimed the lives of as many as 3, 2014 6, and in 2016 The victims were mostly buried by landslides in their homes, as happened in Winangun, Paal 4, Tikala, Singkil, Ternate Baru and Wanea.

Landslide in Manado, usually occurs in areas with unstable geological conditions and often triggered by heavy rains that exceeded the highest point, especially the months at the end of the year until the beginning of the year (December to March). The Flood and Landslide in Manado in January 2014 caused by extreme rainfall, far exceed the normal limits (> 50 mm/day) that is equal to 230 mm/day in DAS Tondano and 200 mm/day in the watershed Tomohon (BNPB, 2014). Another factor is the deviation of the function of the area for other designated functions, especially regarding the “spot” of residential land which occupies an area with a slope of more than 15% (not recommended according to applicable regulations). It shows there is a deviation from the standard required occupancy theoretically and also a deviation from the rules. Land use is not as intended and the high intensity of human activity in changing the land use would increase the level of risk on landslide areas.

In connection with many potential areas to landslide and magnitude of the effects of a landslide, it was necessary to the identification and mapping of landslide potential areas of the land. Likewise, the growth of settlements continues to grow along with population growth should be evaluated to determine the extent of its distribution pattern of the area potentially to landslide. Based on two reasons as mentioned above, it is necessary to do research to evaluate the extent of the growth of settlements in Manado grown on land that has the potential to landslide. In connection with this aim, the study aims to (a). Identify factors that potentially cause landslide Land, (b). Potential distribution landslide mapping the land and (3) to evaluate the distribution of landslide based residential land. The study is important as a first step for local government, especially the National Agency for Disaster (BNPB) the city of Manado in preparing the land landslide natural disaster mitigation.

2. Literature Review

Soil mass movement or often called landslides is the process of moving rock debris on a large scale down the slope slowly to fast by the direct influence of gravity (Suprapto Dibdyosaputro, 1999). Landslides can also be expressed as the movement of a large amount of land mass moving in a certain shear plane, in which the soil resistance to resist shear is exceeded. (Kodoatie, 2009). These landslides can occur because they are triggered by factors such as rainfall, geology, landforms, slopes, soil, and land use / land cover (Hermon, et al., 2010; Danang, et al., 2010 and Kundu, et al., 2011). The land use / land cover factor is one of the triggers that can easily be changed or changed as a landslide control function.

Changes in land use can increase or decrease the potential for landslides, which also affects the level of landslide vulnerability. Changing land use in areas with the potential for landslides to use land that can control landslides is an action that can prevent landslides from occurring. Based on these assumptions, landslide potential mapping can be used to evaluate the feasibility of settlements in an area. Potential landslide detection can be done directly and indirectly. Indirectly, it can be done by overlapping the parameter maps of landslide triggers using the Geographic Information System (GIS)
and remote sensing techniques. The parameters used to determine landslide susceptibility according to Paimin (2012) are divided into natural parameters and management parameters. The natural factors in question are: (1) cumulative daily rain for 3 consecutive days, (2) slopes of land, (3) geology / rocks, (4) presence of faults / fractures / gawirs, (5) soil depth (regolite) to impermeable layers; while management factors include: (1) land use, (2) infrastructure, and (3) density of settlements. Each of these parameters is weighted and classified into five landslide hazard classes with low to high vulnerability values. Determination of the location or area of landslide vulnerability can be done using GIS technology through modeling with spatial query analysis and map overlapping analysis (Demers, 1997; Borrough, 1988 in Sulistyo, 2016).

Population growth that continues to increase and the availability of limited land are the main problems in settlement development, so that it does not rule out the possibility of developing settlements in areas that are not suitable for habitation, such as areas with landslide hazards. Khadiyanto (2018) states that everyone has the right to live in a habitable area, therefore developers and city governments are obliged to provide land and settlements that are suitable for habitation. The question is whether the distribution of settlements in the city of Manado is appropriate in terms of landslide hazard. The reason that underlies this research attempts to evaluate the suitability of landslide-based settlements.

3. Method
This research was conducted in Manado North Sulawesi province, which is geographically situated on 1°.30 '1°.40' N and 124°.40 ' - 126°.50' BT. The approach used to assess the potential landslide in this study is a unit of land (land units) obtained from the overlaying maps of landslide trigger parameters. Variable trigger landslide is (1) daily rainfall cumulative 3 consecutive days, (2) the slope of land, (3) the geological, (4) the depth of the soil (regolith) until the impermeable layer, (5) the existence of fault escarpment, (6) land use, (7) infrastructure and (8) the population density (Paimin, et al., 2012). Each of these variables is weighted and scored according to its role in determining susceptibility to landslides.

The materials needed in the study include: Map RBI Indonesia, Soil Map, Map Geology, Data Digital Elevation Model (DEM), Google Earth image, Books Manado in number in 2019, and the rainfall data for 15 years. The instrument used was a set of computers with GIS software ILWIS (Integrated Land and Water Information System) and ArcView, Garmin Global Positioning System (GPS), digital camera, drill soil and analysis laboratory equipment for physical and chemical properties of soil.

Landslide vulnerability analysis done by giving weight and dignity to the landslide trigger parameters. Summation of weights and dignity multiplication results are classified into five classes, and categorized from very mild to very severe using the following formula:

\[
\text{Interval} = \frac{Hmak (5.00) - Hmin (1.00)}{K1 (5)} = \frac{4.00}{5} = 0.8
\]

Evaluation of the spatial distribution pattern of residential land based on potential landslide done by using the overlay of the settlement distribution map with a map of potential landslide using ArcView GIS Software version 3.3 extention geoprocessing.

4. Results and Discussion
4.1. Result
Appropriate research objectives, as stated in the introductory chapter, the results obtained are as follows:

4.1.1. Control factors for landslides in Manado
Of the eight parameters are used as inputs in the formulation of landslide models as mentioned above, not all parameters triggers the landslide susceptibility contribute in the study area. The identification results showed as follows:

a. **Average daily rainfall** Factors cumulative relatively very low to low in contributing to the landslide susceptibility of land in the whole area of research. Except for the rains in December-January accounted for landslide susceptibility moderate.

b. **Slope Factors** most of the study area (98.24%) is very low - low in contributing to landslide susceptibility land. Only in the area of 242.68 ha (1.76%) on a slope > 25%, which contributed to the landslide susceptibility.

c. **Geological factors** 95.15% shows the rock conditions in the study areas of high potential causes landslide susceptibility if they are found on slopes above 25%. The rock types are volcanic rocks (QV) and Tufa Tondsno (QTV).

d. **The existence of a normal fault** that leads from the bay of Manado - Kema can be triggered landslide susceptibility Land along the fault measuring 1000 meters on either side of the fault.

e. **Soil depth Factors**, The majority (76.82%) extensive research lie within the region has a depth of regolith which belong to, so as to trigger the landslide susceptibility of high land.

f. **Land use factor** that triggered the landslide susceptibility of land categories were - very high occupies an area of 90.99%, with details of land use, the vulnerability was covering 50.24%, higher susceptibility covering 9.88% and very high susceptibility covering 26.36%.

g. **Infrastructure Factors** a road that cut the slopes of > 25% and triggered a landslide vulnerability is very high land area occupies only 8.86%. The rest area of 91.14% is not to be triggered landslide because of roads that cut the slopes are on the slope <25%

h. **Population density factor** with the density of 5000-15000 people / km2 located on the slope> 25% trigger landslide susceptibility was very high in residential areas covering an area of 176.68 ha (1, 30%)

Of the eight factors triggering the landslide as it turned out potential factors that could trigger a landslide susceptibility categories were - very high in most areas of research are geological factors, the existence of fault depth of soil and land use. Other factors, such as rainfall, slope, infrastructure and relatively very low population density - low in triggering the landslide susceptibility.

4.1.2. Distribution potential landslide in Manado

The results of the analysis of eight parameters overlaying triggers landslide susceptibility showed the majority (86.52%) research areas have relatively low landslide susceptibility (Table 1). Only an area of 1115.55 ha (8.09%), which has the potential landslide susceptibility classified as moderate to high.

4.1.3. Distribution of Settlements on landslide areas in Manado

Results of the analysis showed that the distribution of settlements in Manado mostly safe from the threat of landslide, as they are distributed in areas with landslide potential is very low - low. That's because the settlement in Manado mostly located on the slope <25%, and the mean cumulative daily rainfall is low.

Based on Table 2 turned out to be largely 3409.22 ha (93.84%) settlements in Manado are in the secure area of the landslide hazard, because it is located in areas that have land landslide susceptibility is very low-low. Instead settlements scattered in areas with high land landslide vulnerability can be found in the seven districts with a total area of 46.12 ha, is Bunaken, Tuminting, Mapanget, Singkil, Paal Dua, Wanea and Malalayang. Distribution of the widest in the District Bunaken(13.35 ha), following Singkil (9.64 ha) and Paal Dua (8.61 ha).
Figure 1. Distribution Map Insecurity landslide in Manado

Table 1. Distribution of level of Insecurity landslide in Manado

| level of Insecurity | Area (ha) | Percent (%) |
|---------------------|-----------|-------------|
| Very low            | 695.96    | 5.05        |
| Low                 | 11926.48  | 86.52       |
| moderate            | 1115.55   | 8.09        |
| High                | 46.12     | 0.33        |
| amount              | 13784.11  | 100.00      |

Source: The level of vulnerability analysis results Map landslide Land

Table 2. Distribution of Settlements at Various Vulnerability Levels Landslides in Manado

| Districts  | Insecurity potential landslide | Amount |
|------------|--------------------------------|--------|
|            | Very Low | Low | Moderate | High |        |
| Bunaken    | 0.36     | 117.03 | 13.85    | 13.35 | 144.59 |
| Tuminting  | 0.00     | 265.27 | 13.06    | 0.16  | 278.50 |
| Mapanget   | 0.81     | 581.05 | 61.35    | 3.37  | 646.58 |
| Sinkil     | 0.38     | 255.56 | 6.26     | 9.64  | 271.84 |
| Wenang     | 0.00     | 330.28 | 0.00     | 0.00  | 330.28 |
| Tikala     | 0.03     | 199.88 | 4.68     | 0.00  | 204.59 |
| Pal Dua    | 1.73     | 354.30 | 13.38    | 8.61  | 378.02 |
| Sario      | 0.00     | 141.70 | 0.00     | 0.00  | 141.70 |
| Wanea      | 5.55     | 460.24 | 19.60    | 5.23  | 490.61 |
| Malalayang | 2.32     | 692.72 | 45.40    | 5.77  | 746.21 |
| amount     | 11.19    | 3398.03 | 177.58   | 46.12 | 3632.92 |

Source: The results of the analysis of landslide susceptibility maps overlaying land and settlements map
4.2. Discussion
The eight factors triggering landslide was only three were significantly potentially affecting landslide susceptibility, is a geological, the presence of faults, and the depth of soil that could potentially trigger a landslide susceptibility. Geology in Manado mostly from young volcanic rocks (Qx) and Tufa Tondano (QTV). Conditions young volcanic rocks (Qx) compacted yet powerfully, high erodibility, and the porosity make high permeability, so can trigger landslide. Likewise, tuff rocks have experienced weathering is up as early as the form of land. Young volcanic rocks and tuff Tondano Manado occupies an area of 13115.04 ha (95.15%). These rocks are generally obsolete, do not compact and easily separated. Both of these rocks have a high vulnerability to the value category landslide. Fault is a fracture in the earth layers form that allows the rock block moves down relative to other blocks, so that this zone into a zone of weak and vulnerable to landslide. The fault zone resulted in rock strength is reduced, causing many cracks that facilitate water is absorbed (Surono, 2003). Fault in Manado extends from Manado bay until Kema form weak zones which can be triggered landslide.
The depth of the solum is a measure of depth of soil that can absorb water. The deeper solum a land, the more prone to avalanche danger. This is because solum (regolit) which may add weight to the ground when the volume of pores filled with water. Increasing the volume of water will result in the slopes is not able to withstand the land mass that slopes prone to landslide hazard. Bedrock in the research area is dominated by old volcanic rock (tuff tondano) who have deep solum thickness. Most of the (76.82%) own research area solum thickness in the above 90 meters.
Potential distribution landslide in Manado region Evidently large part (91.57%) had a landslide susceptibility level of land classified as very low - low. The main cause of the low threat of landslide because the vast majority (98.24%) of land in Manado has a slope <25% and the cumulative daily rainfall for three consecutive days was low (<100 mm/3 days). High landslide susceptibility Land area 46.12 ha or approximately 0.33% of the total area of Manado generally spread over an area that has a slope> 25% and along the fault zone. High vulnerability to landslide in seven districts, is Bunaken, Tuminting, Mapanget, Singkil, Paal Dua, Wanea and Malalayang.
Most settlements in research within the region are at a slope <25%, and only a portion of the settlement traversed by fault lines. Both of these factors that led to the distribution of settlement in the region is relatively narrow high vulnerability. Likewise, the distribution of settlements that are in the category of vulnerability was only 4.89%, or about 177.58 ha. Settlements located on landslide susceptibility was high there are in almost all districts, except the district and sub-district Wenang Saro. This means that the settlement in the two districts are free from the threat of landslide.

5. Conclusion
In accordance with the purpose of the research is expected and the results of the analysis of this study concluded three outcomes research as follows:

a. Identified three dominant factors affecting the distribution of the level of vulnerability landslide land in Manado, the geological dominated by volcanic rocks that have high vulnerability, the factor of fault through the city of Manado which could weaken the layering of rock and factor layer solum in potentially increasing volume of water in the soil that trigger. On the other hand identified two factors that weaken the landslide susceptibility, that the cumulative daily rainfall is low and slope < 25%.

b. As a result of daily rainfall is low and most of the slope in Manado less than 25% causing potential vulnerability of landslide in the study area mostly relatively very low-low, only about 46.12 ha (1.27%) settlements in Manado that are in areas that have high landslide susceptibility.

c. The potential threat of high landslide against settlements scattered sporadically in Manado in seven districts, although the coverage area of its spread is relatively narrow. Distribution is located in the District of Bunaken, Tuminting, Mapanget, Singkil, Paal Dua, Wanea and Malalayang.
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