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Landslide Hazard Analysis Based on Geomorphological Approach in Karo Highland, North Sumatra Province, Indonesia

Dwi Wahyuni Nurwihastuti
Department of Geography Education
Faculty of Social Sciences
State University of Medan
Medan, Indonesia
Corresponding email: nurwihastuti@gmail.com

Anik Juli Dwi Astuti
Department of Geography Education
Faculty of Social Sciences
State University of Medan
Medan, Indonesia

Eni Yuniastuti
Department of Geography Education
Faculty of Social Sciences
State University of Medan
Medan, Indonesia

***Abstract*—The research is conducted in Karo District, North Sumatra Province, Indonesia. Landslides often occur in the research area. The research objectives are to analyze landslide hazard based on geomorphological approach and to illustrate the distribution of landslide hazard. The landslide hazard was analyzed based on geomorphological approach. The factors causing landslide can be determined by geomorphological approach. The techniques of Geographic Information System (GIS) and remote sensing were applied to analyze the distribution of landslide hazard. The results showed that the factors causing landslide in the research area are geomorphological characteristics such as slope and landform. Additionally, the distribution of landslide hazard is variety. The landslide hazard can be divided into 5 classes, i.e. very low, low, moderate, high, and very high. The 19% of research area is safe from landslide hazard while 81% of research area is potential to occur landslides. Consequently, the research area is prone to landslide.**

Keywords—Landslide hazard, geomorphological approach, Karo

I. INTRODUCTION

Landslide is one of natural disaster which often afflict in some regions in Indonesia. This event was increase dramatically in the last decade. Landslide caused 1.670 deaths from 1998 to 2012 (BNPB, 2012). Moreover, the increasing of landslide events due to human activities can cause property damage and negative affect a variety of resources. This damage can be minimized by landslide risk mitigation. Landslide risk mitigation must be based on physical characteristics. Physical characteristics of land can be studied by geomorphological approach. It is because the object of geomorphology are physical characteristics consists of landforms as constituent of the earth's surface (Verstappen, 1983).

Landslide also happened in Karo Regency, North Sumatra. Some regions in Karo were struck landslide in February 2013 and it caused road damage (Metronews, 2013). The physical condition of Karo consists of hills and mountains that cause landslide in this area.

The research objectives are (1) to analyze landslide hazard based on geomorphological approach and (2) to illustrate the distribution of landslide hazard.

II. METHOD

The methods of this research are surveying, sampling and qualitative. The whole region of Karo Regency was became as population. Sample of this research was taken by stratified purposive sampling. This sample was used to check and verify the data. The landslide hazard was analyzed based on geomorphological approach. The zonation of landslide hazard was analyzed based on the factors causing landslide which consists of causative factors (slope, landform), dynamic trigger factors (rainfall, land use) and static trigger factors (lithology and soil). All factors were assigned a certain weight and score based on expert judgment. The techniques of Geographic

Information System (GIS) and remote sensing were applied to analyze landforms and the distribution of landslide hazard.

III. FINDING AND DISCUSSION

A. Landslide hazard based on geomorphological approach

Karo Regency is a region in North Sumatra which prone to landslide events. Landslide occurred due to geomorphological characteristics of land such as slope, geology condition, and landform. Geomorphological characteristics cover four geomorphological aspects consist of morphology, morphogenesis, morphology, and morpho arrangement (Van Zuidam, 1985). In this research, morphology in Karo Regency was interpreted by using Digital Elevation Models (DEM). The morphology of Karo Regency can be classified as plains, hills, and mountains. The plain areas was located in the middle of Karo Regency as a highland while the hills and mountains areas cover west, north, east, and south part of Karo. The morphogenesis aspect consist of active and passive morph structure Passive morph structure which can be found in Karo are volcanic, fault, lineament, and fault scarp. Morphodynamic is related to exogenous dynamics. In Karo, morphodynamic was driven by water in the forms of erosion and sedimentation. Meanwhile, morpho arrangement describes spatial aspect and interrelation among landforms.

Furthermore, the study of geomorphological processes can not be separated from landform characteristics because it will develop in accordance with landform characteristics (Thornbury, 1969). In Karo, based on the genesis, there are 5 main landforms as structural, volcanic, fluvial, sollutional as well as denudational landform. The 5 main landforms can be divided into 30 landform units.

Structural landform consists of Toba Tuff Highland, Butar Denudation Structural Mountain, Bahorok Denudation Structural Mountain, Alas Denudation Structural Mountain, Metamorphosed Limestone Denudation Structural Mountain, Limestone Members Denudation Structural Mountain, Slope of Toba Tuffs Denudation Structural Mountain with a total area of 720.15 km2 (33.85%). Structural landform in Karo was showed in Fig. 1.

Fig. 1. a) Fault in Sipiso-piso Waterfall, b) Karo Highland

Structural landform were composed by old rocks which intensively weathered and resulted thick soil layer. In structural landform, there are some landslide events such as slump (soil rotational slide), soil creep, debris slide, and rock fall which can be seen in Fig. 2.

Fig. 2. a) Soil creep in Jalan Medan – Kutacane, b) Debris slide in Karo

Volcanic landform in this area consists of Sinabung Volcano of Andesite, Dacites and Pyroclastic and Sibayak Volcano of Andesite, Dacites and Pyroclastic. Both Sinabung and Sibayak volcanoes are Pleistocene-Holocene in age. This landform has areas of 58.58 km^2. In some slope in Sibayak Volcano, there were landslides which endangered to local community. Fig. 3 show volcanic landform in Karo.

Fig. 3. a) Crater of Sibayak Volcano, b) Slope of Sibayak Volcano

In Karo, Fluvial landform unit consists of alluvial plain which took place in Mardinding as well as Merek Districts and covers areas of 114.46 km^2. For example, Alluvial plain which is located in Tongging and Mardinding can be seen in Fig. 4. In this landform, landslide event is very often happened.

Fig. 4. a) Alluvial Plain in Tongging, b) Alluvial Plain in Mardinding

Denudational processes related to erosion and mass wasting. In Karo, denudational landform consists of Toba Tuffs Denudational Mountain, Takur-Takur Denudational Mountain, Singkut Denudational Mountain, Sibutan Denudational Mountain, Mentar Denudational Mountain, Binjai Denudational Mountain, Keteran Granite Denudational Mountain, Kluet Denudational Mountain, Haranggaol Volcano Denudational Mountain, Butar Denudational Mountain, Bohorok Denudational Mountain, Sipiso-piso Volcano Denudational Mountain, Barus Volcano Denudational Mountain, Slope of Singkut Denudational Mountain, Butar Denudational Hill, Slope of Toba Tuffs Denudational Hill, Takur-Takur Isolated Hill, Limestone Metamorphosed Isolated Hill. Denudational landform covers areas of 1193.31 km^2 and spreads in some districts namely Juhar, Munte, Merdeka,

Barusjahe, Merek, Tigapanah, Namanteran, Kutabuluh, Tigabinanga, Tigandreket, Dolatrayat, Mardinding, Laubaleng, Simpang Empat and Berastagi district. The example of denudational landform is showed in Fig. 5.

Fig. 5. (a) Residuall hill in Berastagi Karo Highland, (b) Eroded Hills in Karo

In denudational landform, it can be found some types of landslides such as debris fall, rock fall, and soil slide. Soil slide and debris fall can be presented in Fig. 6.

Fig. 6. a) Soil slide, b) Debris fall

Solutional landform in Karo has areas of 40,54 km^2 (1.91%) and it took place in Kutabuluh, and Tigadreket districts. Solutional landform unit consists of Batumilmil Limestone Karst Hill as shown in Fig. 7. The distribution of landform in Karo can be seen in Fig. 8.

Fig. 7. (a) Solutional landform in Karo, (b) Rock outcrops of solutional landform in Kutabuluh District

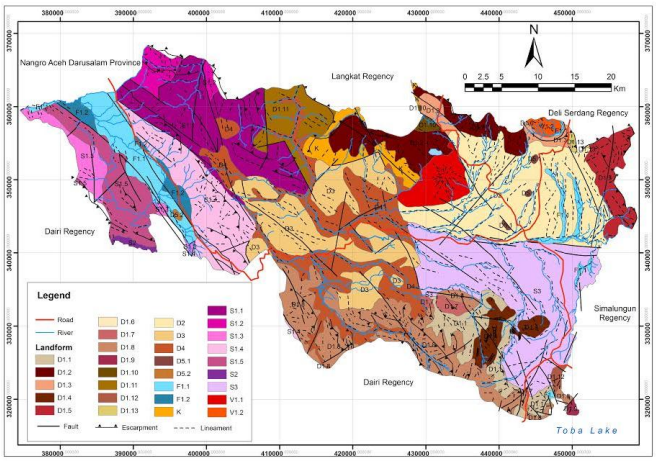

Fig. 8. The Distribution of Landform in Karo

B. *Distribution of landslide hazard*

Based on geomorphological approach, landslide hazard in Karo can be divided in 5 categories: very low, low, moderate, high, and very high. Very low landslide hazard can be found in the west and east part of Karo Regency and it covers fluvial landform while very high landslide hazard covers west-part of Karo Regency in structural landform. In Karo, landslide hazard in volcanic landform are low and moderate. It is slightly different with landslide hazard in solutional landform and denudational landform which both of solutional and denudational landform are moderately occurred. Spatially, the distribution of landslide hazard in Karo is showed in Fig. 8.

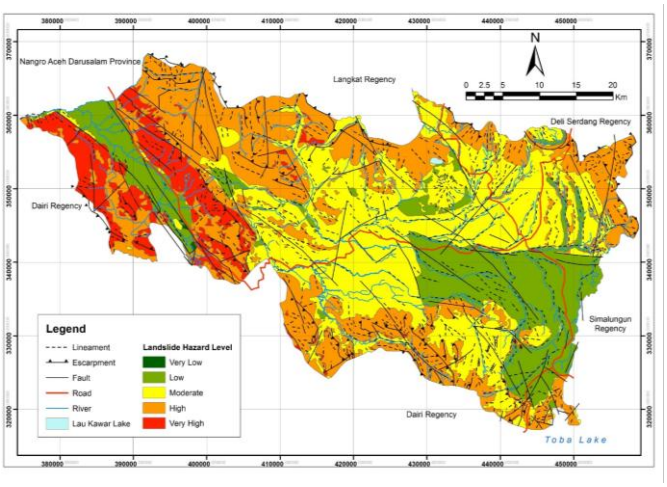

Fig. 8. Landslide Hazard Map of Karo Regency

IV. CONCLUSIONS AND SUGGESTIONS

Mitigation of landslide risk based on physical characteristics. The studied of physical characteristics can be used by geomorphological approach. Physical characteristics of Karo consists of hills and mountains area. It has consequens to landslide prone area. Based on the genesis in Karo, there are five main landforms as structural, volcanic, fluvial, solutional as well as denudational landform. Structural landform in Karo are some landslide events such as slump (soil rotational slide), soil creep, debris slide, and rock fall. In denudational

landform, it can be found some types of landslides such as debris fall, rock fall, and soil slide. Landslide prone also found in Volcanic landform and Fluvial landform such as in Sibayak Volcano and Alluvial plain located in Tongging and Mardinding. Based on geomorphological approach, landslide hazard in Karo can be divided in five categories: very low, low, moderate, high, and very high.

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