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Research Article

GEOMORPHOLOGY APPROACH IN LANDSLIDE VULNERABILITY, TANJUNG PALAS TENGAH, EAST KALIMANTAN, INDONESIA

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ABSTRACT
Abstract Landslide hazard occurs almost in every area in Indonesia. About 45% of land in Indonesia is mountainous area with steep slopes. Lack of knowledge about landslide hazard and its mitigation in an area can result in poor land-use decisions. Therefore, it is very important to give good information, knowledge, and education for people about landslides for promoting community awareness. This research aims to get information of geomorphological condition in research area and for determining the location that has high vulnerability of landslide. The product of this research is geomorphological map. This research is expected could be input for land use regulation of research area in order to pay more attention to landslide hazard issues. Method used in this research is divided into two kinds, *i.e.,* office method and field method. Office method consists of morphometric analysis, morphographic analysis, morphogenetic analysis, and data processing for generating the geomorphological map. This research used GIS software for generating the morphometric and morphographic data. Field method was done for getting data of structural geology, lithology, and geomorphology features. Morphography analysis has shown that research area consists of two landscapes (van Zuidam 1985), i.e.: lowland and inner lowland also one drainage pattern i.e. sub-dendritic. Morphometric analysis has shown that research area consists of three classes of slope i.e. very gently sloping, gently sloping, and rather steep. Morphogenetic analysis has shown that research area consists of three lithology units, i.e.: fine soil unit, coarse soil unit, and organic soil unit. According to the analysis of morphometric, morphographic, and morphogenetic analysis it can be concluded that research area consist of four geomorphologic units. The location that is prone to landslide is area that included in geomorphologic unit of rather steep sediment terrain.

Keywords*: Landslide, Morphography, Morphogenetic, Morphometric, Geomorphological Map*

INTRODUCTION
Landslide hazard occurs in almost every area of Indonesia. About 45% of land in Indonesia is mountainous with steep slopes. This situation is exacerbated by high rainfall factor in the various regions of Indonesia. Therefore, good knowledge about landslide hazard is necessary to avoid negative impacts (Susilo 2008).

Determining the vulnerability models of landslide is necessary as a form of simplification of the real condition. This modelling can provide information on areas prone to landslide. By knowing the vulnerability of landslide, we can determine the land planning. One of the initial modelling to do is perform geomorphological mapping. Geomorphological mapping will provide information about the shape and slope of land. This information can be used as a reference in classifying an area based on its susceptibility to landslide (Susilo 2008).

The research was conducted in the District of Tanjung Palas Tengah, Bulungan Regency, North Kalimantan. Conducted a comprehensive study of the parameters related to landslide and slope stability. This study aims to: (1) knowing the condition of geomorphological in research area and (2) determine the location which is prone of landslide occurrence.

Landslide
According to Griffiths (2005) in Bell (2007), landslide is manifestation of rapid movement toward the bottom of the material of slope. The movement may be falling, slip, flow, or in certain circumstances a combination of all three. The slope material movement involves the development of its slip surface, i.e.

the separation of the masses in the material. Force which is most commonly found in a slope is formed by gravitational weight of the material.

Landslide can also be triggered by a steep slope. Steep slopes can reduce the stability of the slope. This is caused by the safety factor is influenced by the slope. So that a region with a steeper slope will tend to be more susceptible to landslide hazard (Zakaria 2009).

Geomorphological Map

Geomorphological map is a map that contains information about the condition of the area landscape. Component of geomorphological maps are the aspects of: morphography, morphometry, morphogenetic, morphocronology, and morpho arrangements. This research limits the mapping study on aspects morphography, morphometry, and morphogenetic (van Zuidam 1985).

Morphography

Morphography is feature of the Earth's surface or architectural shape of the Earth's surface. In general, morphography can be divided into landform hills/ mountains, volcanoes, valleys, and plains. Several other approaches for mapping geomorphological landforms are in additon to the pattern of ridges and drainage.

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Morphography aspects are reviewed by analysing topographic conditions in the field. It is in the form of landform and patterns that may appear on the display of contour density on the map. It will help us in determining the landform, whether hills or plain. The changes in the pattern of ridge and river drainage can identify tectonic activity in the mapping area (van Zuidam 1985).

Land form is difference in elevation. It is usually measured from sea level, because the sea level is considered as an area that has zero elevation. Pattern of river drainage is a pattern that formed by confluent to the water course. Howard (1967) in van Zuidam (1985) divided the patterns of drainage into two kinds, i.e.: basic and modification patterns.

Morphometry

Morphometry is quantitative assessment of landforms. Classification of slope and landform quantitatively, grouped based on the number and percent of the slope angle. The formula for determining the value of slope is:

$$S = \left(\frac{(n-1).Ic}{dx.sp} \right) \cdot 100\% \qquad [1]$$

Where,
S = Slope
n = Numbers of contours
Ic = Interval contour
Dx = lateral distance
Sp = Map scale
(van Zuidam, 1985)

Morphogenetic

Morphogenetic is geomorphological aspect which discuss about the origin and occurrence of landforms. It will be related with lithology, geological structure, and forces involved in landscape formation (van Zuidam 1985).

MATERIALS AND METHODS

The methods used in this research is divided into two kinds, they are: office methods and field methods.

Office methods consist of morphometry and morphography analysis and also data processing for creating gemorphological map. Office methods require materials such as: (i) regional topographic map of research area, (ii) GIS software (in this research is Map Info 11.5), and (iii) counting tools (Ms. Excel).
Field methods are used to obtain the data of geological structure, lithology, and features of geomorphological appearance in the field. Tools and materials required in the method include: (i) geological hammer, (ii) geological compass, (iii) HCl solution, (iv) camera, and (v) sample plastic.
All of maps that have been generated (morphometric map, morphograpic map, and morphogenetic map) are overlaid. The result is geomorphological map that divide research area into several geomorphological units. Area that is prone of landslide determined based on these units.

RESULTS AND DISCUSSION

Morphographic Aspect

Based on morphographic analysis, research area was divided into two kinds of landforms, they are: (a) Lowland: occupies 55% of research area and cover the southwestern and northeastern of research area. Its elevation is about 3-50m, and (b) Inner lowland: occupies 45% of research area and cover the central part of the study area. Its elevation is about 50-116m. Map of landform zone is shown in Fig. 1.
Drainage pattern that developed in research area is sub-dendritic. Rivers are spread in northern and southern part of research area. River drainage map is shown in Fig. 2.

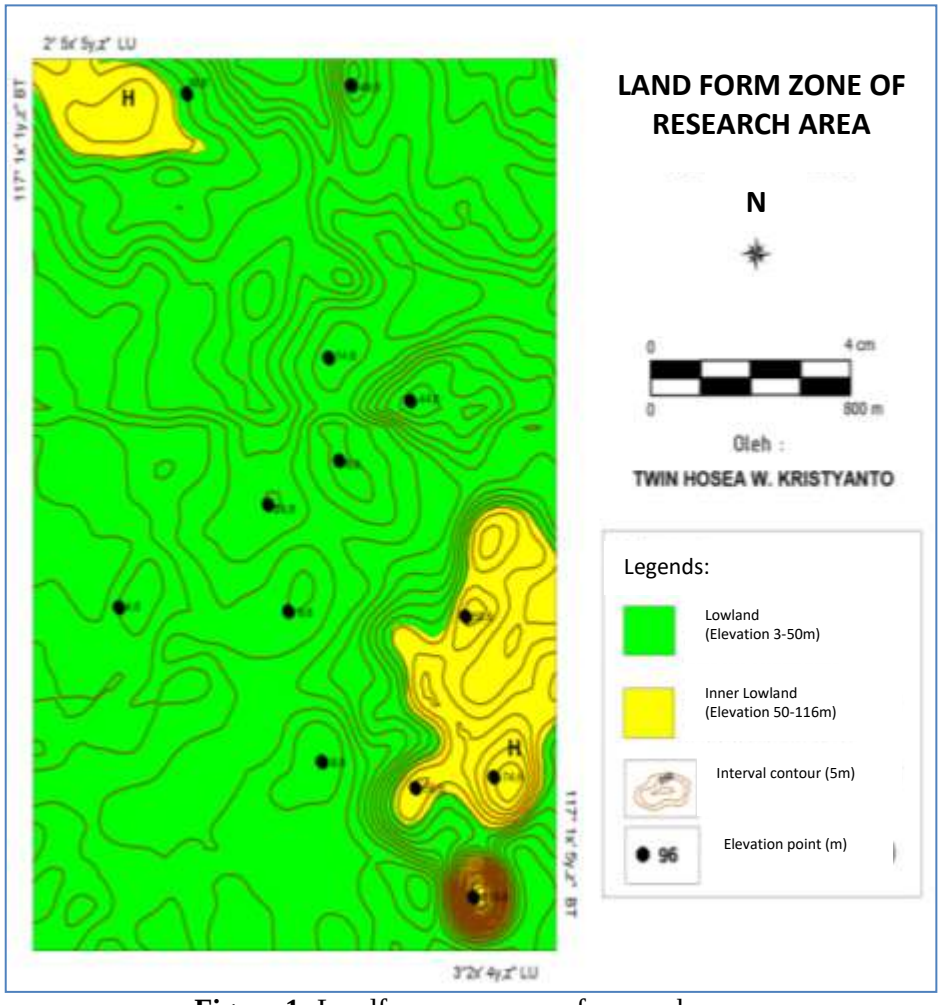

Figure 1: Landform zone map of research area

Morphometric Aspect

Based on morphometric analysis, research area is divided into 3 slope classes, they are: (a) very gently sloping (the slope is about 2-7%); (b) gently sloping (the slope is about 7-15%), and (c) rather steep (the slope is about 15-30%). Slope map of research area is shown in Fig. 3.

Morphogenetic Aspect

Based on distribution soil mapping, research area can be divided into 3 soil units (based on USCS). They are: fine soil unit, coarse soil unit, and organic soil unit. Geological structure that developed in research area is joints and syncline.

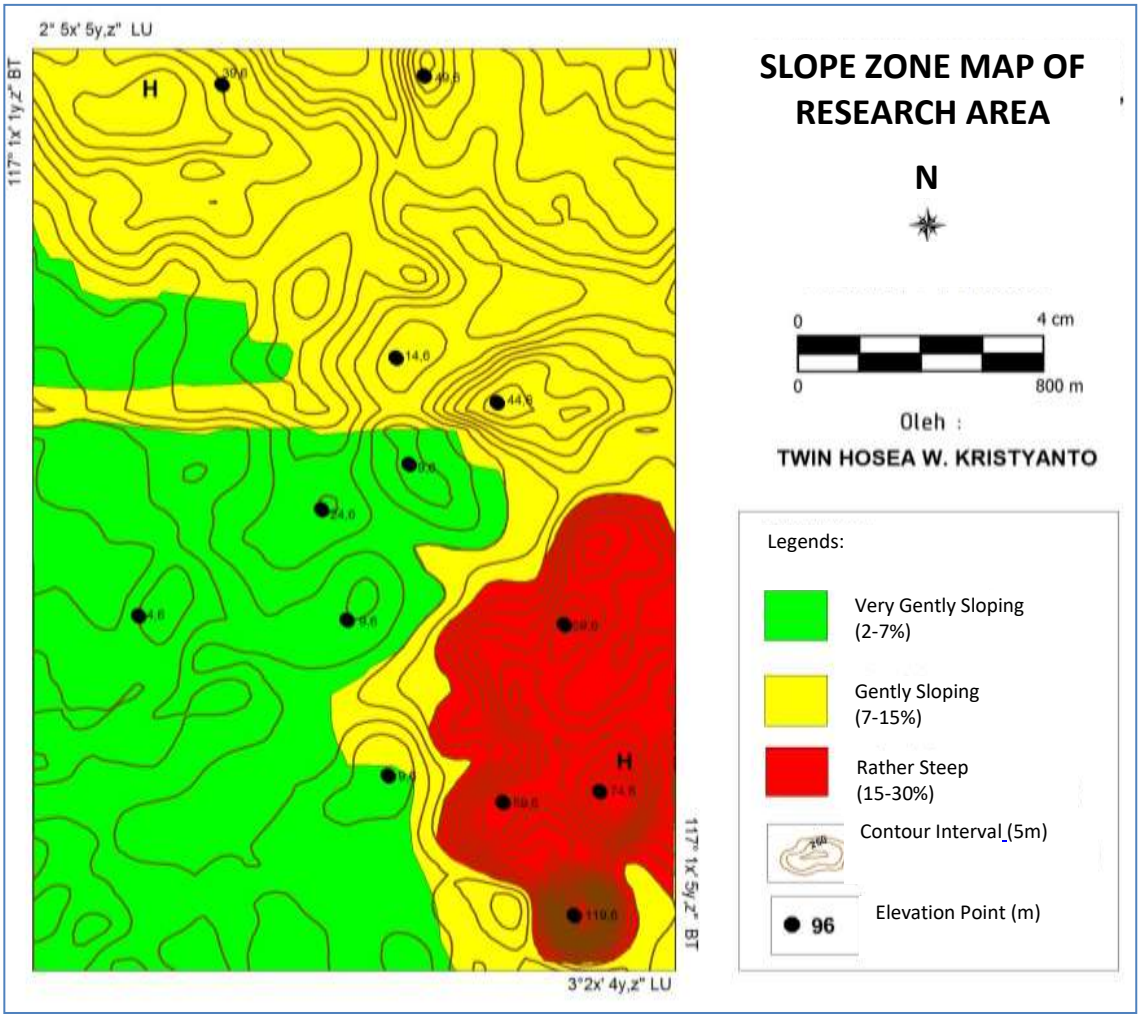

Figure 2: Slope zone map of research area

Geomorphological Units of Research Area

Based on analysis of morphometry, morphography, and field checking, research area is divided into 4 geomorphological units. They area:

a. Very gently sloping sedimentry lowland unit (Fig. 4).
b. Gently sloping sedimentary lowland unit (Fig. 5).
c. Gently sloping sedimentary inner lowland unit (Fig. 6).
d. Rather steep sedimetary inner lowland unit (Fig. 7).

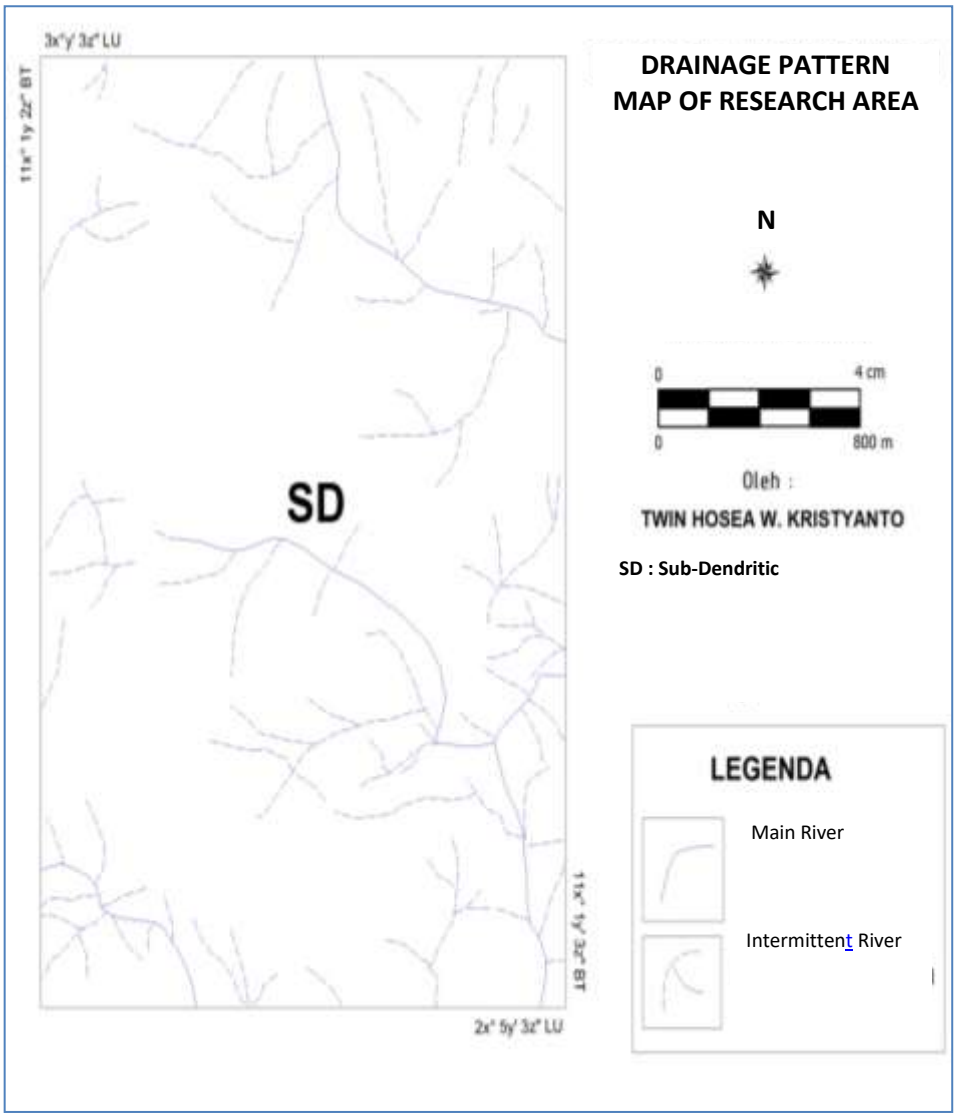

Figure 3: Drainage pattern of research area

Figure 4: Feature of geomorphological unit of very gently sloping sedimentary lowland

Figure 5: Feature of geomorphological unit of gently sloping sedimentary lowland

Figure 6: Feature of geomorphological unit of gently sloping sedimentary inner lowland

Figure 7: Feature of geomorphological unit of rather steep sedimentary inner lowland

The characteristics of each units are explained in Table 1. That also explains the legends of geomorphological map (Fig. 8). Figure 9 shows morphology feature of research area that generated from digital elevation model (DEM).

Prone of Landslide Location

Based on geomorphological map of research area, it is can be determined the area which is prone of landslide. Area that prone of landslide is area that include in geomorphological unit of rather steep sedimentary inner lowland. It is caused by this area has rather steep slope i.e. 15-30%.

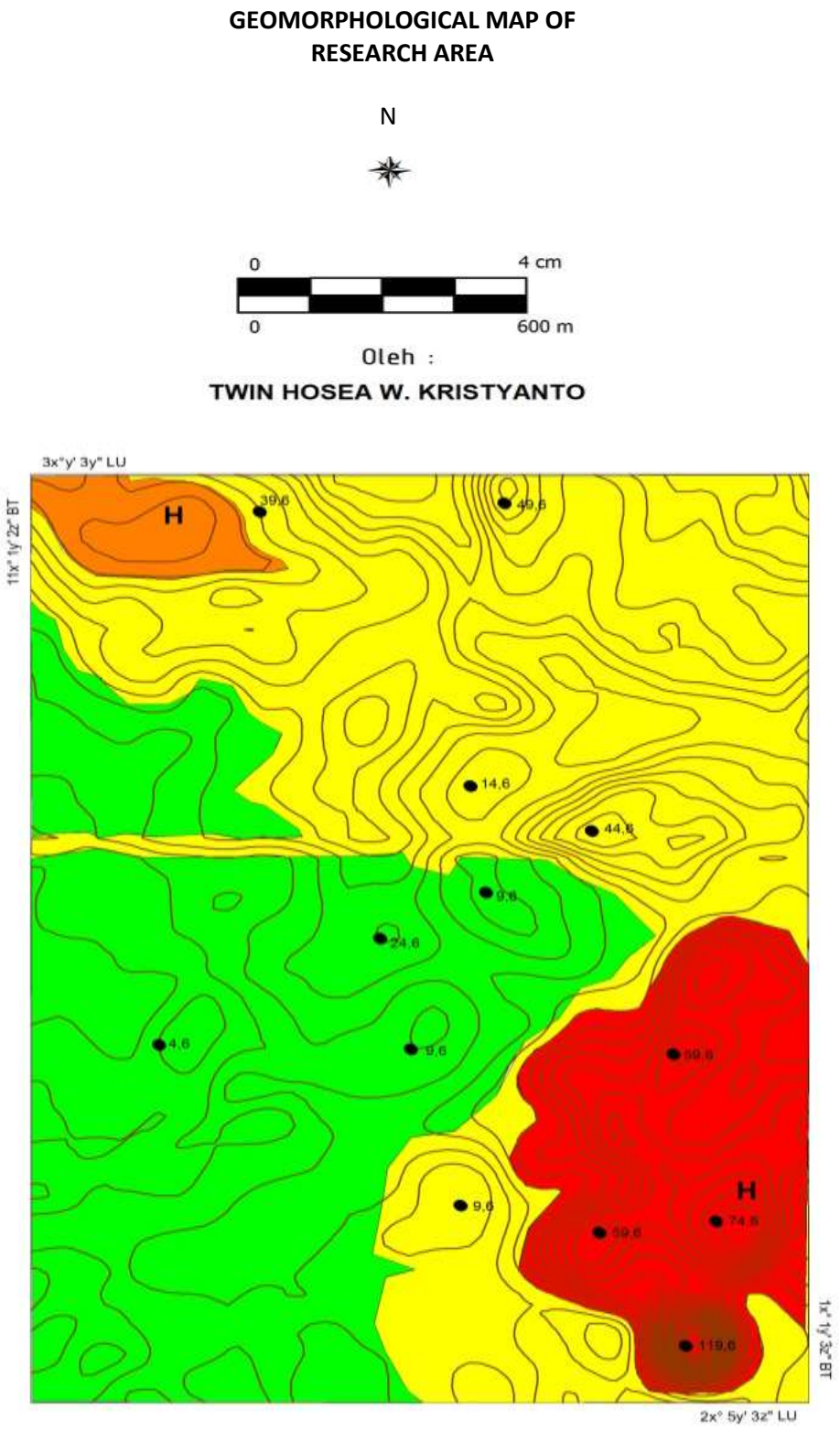

Figure 8: Geomorphological map of research area

Table 1: Legend of the Geomorphological Map

Geomorphological Unit	Color Symbol	Geomorphological Aspect						
		Morphography			Morphogenetic			Morphometry
		Landform	Drainage Pattern	Elevation	Lithology	Endogenic Force	Exogenic Force	
Very gently sloping sedimentry lowland		Lowland	Sub-Dendritic	3-50 (m)	CL-CH,	Structural	Weathering	2-7%
Gently sloping sedimentary lowland		Lowland	Sub-Dendritic	3-50 (m)	CL-CH,	Structural	Weathering	7-15%
Gently sloping sedimentary inner lowland		Inner Lowland	Sub-Dendritic	50-89 (m)	ML-MH, Coal	Structural	Weathering	7-15%
Rather steep sedimetary inner lowland		Inner Lowland	Sub-Dendritic	89-116 (m)	CL-CH, Coal	Structural	Weathering	15-30%

CONCLUSION

Based on result and discussion of this research, it can be concluded that the esearch area is divided into 4 geomorphological units, they are: (a) geomorphological unit of gently sloping sedimentary lowland, (b) geomorphological unit of sloping sedimentary lowland, (c) geomorphological unit of sloping sedimentary inner lowland, and (d) geomorphological unit of rather steep sedimentary inner lowland.

It also could be mentioned that area which prone of landslide is area that include in geomorphological unit of rather steep sedimentary inner lowland.

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