SUSCEPTIBILITY OF LANDSLIDE IN THE FOREST REGION OF THE CIMANUK RIVER CATCHMENT AREA, WEST JAVA, INDONESIA

Dicky Muslim
Laboratorium Geologi Teknik, Fakutas Teknik Geologi, UNPAD

ABSTRACT

In Indonesia, a program in rehabilitation of forest region on destructed land had become a national movement (GNRHL) by the central government on the river catchment area since 1999. Destructed forest implies to the decreasing its natural function which physically related with geological hazards such as erosion, landslide, etc. In the forest region of the Cimanuk River catchment area, landslide frequently occurs every year. As an initial step to build the early warning system, mapping of landslide susceptibilityis necessary. In this study, landslide susceptibility is approached through analysis of Geological map, rock/soil engineering formation, quantitative analysis of slope stability (SF) and plotting of previous reported landslides in the forest region.

Result of analyses shows that there are 4 types of susceptibility on the study area. Highly susceptible is characterized by mountainous to hilly area on thick soil of fine grain sedimentary rocks with high density lineations representing geological structures. Medium susceptibility is characterized by hilly area on thick to thin soil of coarse grain rocks with medium density lineations. Low susceptibility is characterized by hilly area on thin soil of coarser grain from sedimentary and volcanic rocks. Very low susceptibility area is characterized by soil on alluvial plain. Special attention is carried out on swelling-shrinking type of soils, neotectonism and bare forest area on the toe of slope.

***Keywords**: Landslide Susceptibility, Slope Stability, Cimanuk River, Neotectonism*

ABSTRAK

Di Indonesia, sebuah program rehabilitasi kawasan hutan pada tanah yang rusak menjadi sebuah gerakan nasional (GNRHL) oleh pemerintah pusat di daerah tangkapan air sungai sejak tahun 1999. Hutan rusak berimplikasi pada penurunan fungsi alaminya yang secara fisik terkait dengan bahaya geologis, seperti erosi, tanah longsor, dll. Di wilayah hutan daerah tangkapan air Sungai Cimanuk, longsor sering terjadi setiap tahun. Sebagai langkah awal untuk membangun sistem peringatan dini, pemetaan kerentanan longsor diperlukan. Dalam studi ini, kerentanan longsor didekati melalui analisis dari peta Geologi, batuan / tanah teknik formasi, analisis kuantitatif stabilitas lereng (SF) dan plotting tanah longsor dilaporkan sebelumnya di kawasan hutan.

Hasil analisis menunjukkan bahwa terdapat 4 jenis kerentanan pada wilayah studi. Sangat rentan ditandai oleh pegunungan ke daerah berbukit di tanah tebal dari batuan sedimen butir halus dengan kepadatan tinggi kelurusan-kelurusan mewakili struktur geologi. Kerentanan sedang dicirikan oleh daerah perbukitan di tanah tipis untuk batuan butiran kasar dengan kepadatan kelurusan-kelurusan menengah. Kerentanan rendah dicirikan oleh daerah perbukitan di tanah tipis dari tanah berbutir kasar dari batuan sedimen dan vulkanik. Daerah kerentanan sangat rendah ditandai dengan tanah di dataran aluvial. Perhatian khusus dilakukan pada tipe tanah mengembang-menyusut, neotektonisme dan kawasan hutan gundul di ujung lereng.

Kata kunci: Kerentanan Longsor, Stabilitas Lereng, Sungai Cimanuk, Neotektonisme

INTRODUCTION

Background

The Government of Indonesia launched a programme for rehabilitation of forest region on destructed land. This programme had been designated to become a national movement by the government (Gerakan Nasional Rehabilitasi Hutan dan Lahan – GNRHL) since 1999. The programme is mainly carried out on the river catchment area where the forest region exists. This program is performed and maintained by the Ministry of Forestry and its subsidiary in each region.

The Cimanuk River catchment area lies on the eastern part of West Java Province. The main river flows from mountainous area in the central part (around Garut Regency) to the coastal plain of Java Sea in the north. On the surface, this catchment area is mainly covered by forest region, which has currently undergone intensive

deforestation in many places due to urban development process (Sugalang *et al*., 1995). Destructed forest implies to the decreasing its natural function which physically related with the occurrence of geological hazards such as erosion, landslide, flash flood, etc.

West Java Province in Indonesia is famous for the most frequent landslide occurrence region, especially during the rainy season (Hirnawan, 1998). In the study area, earthquake also frequently occurs, which is potential to become the trigger for geological hazard such as landslide (Syarief *et al*., 2001; Tobing *et al*., 2002).

Objective

Landslide is one type of geoclimatic hazard, which occurs on a unique geological condition (Dearman, 1992). As a part of rock and/or soil mass movement, landslide occurrences in forested area are controlled by many factors such as conditions of geology, geomorphology, climate, hydrology, etc (CDMG, 1999). The aim of this paper is to elucidate the interaction of those factors producing landslide susceptibility area. To map landslide susceptibility as an initial step to build the early warning system is necessary.

Tectonics & Stratigraphy

The study area lies in the continental margin of Eurasian Plate and relatively close to the subduction zone, where Eurasian and Indo-Australian Plates subduct each other below the Indian Ocean. There are several major geological structures across the study area. Their azimuths in general are in-line with the azimuth of subduction zone, suggesting recent driving-force working on them.

In the Cimanuk River catchment area, stratigraphical arrangement consists of lithologic units from Tertiary (Oligocene) to Quaternary and Recent deposits. The Tertiary units compose of limestone, sandstone, claystone, marl, mudstone, conglomerate and breccia. The Quaternary units compose of andesitic lava and intrusion, volcanic breccia, pyroclastic rocks, alluvium, terrace (beach & river) deposits. In general, lithologic units in the study area can be classified into sedimentary rocks (from deep marine to fluvial environment) and igneous rocks with volcanic products (Budhitrisna, 1992; Djuri, 1995).

Geomorphology & Hydrogeology

The Cimanuk River catchment area geomorphologically consists of mountainous to hilly land on the upstream and gentle hill to lowland on the downstream. On the upstream part, it is common to find high geomorphologic relief with steep slope indicating intensive vertical erosion in "youth" stage, composing harder lithologic units. On the downstream, low relief is common with gentle slope to plain area indicating lateral erosion in "mature" stage, composing softer lithologic units.

According to Sutrisno (1983), groundwater resource in the study area varies hydrogeologically based on the aquifer productivity (very high to low). The Cimanuk as main river is a perennial type with fluctuative volume between dry and rainy seasons. Its tributaries distribute over large area covering 6 regencies (i.e. Garut, Tasikmalaya, Majalengka, Kuningan, Cirebon and Indramayu).

METHODOLOGY

In this research, the engineering properties of material (rocks and soil) are approached through analysis of engineering formation according to Anon (1976) and Dearman (1992). The engineering formation map is produced by combining 4 aspects, namely; surface morphology (steep – gentle – plain), mass movement (active – less active – passive),

deformation (strong – medium – weak), erosion (high – middle – low).

Engineering formation map was produced from geological map by putting the material characteristics (physical and engineering properties) onto the map and considering the conditions of geomorphology, tectonics (minor and major geological weaknesses), hydrogeology and current land-use. Results of quantitative analysis of slope stability were mapped (SF mapping) and locations of previous landslides occurrences were plotted on the engineering formation map to produce slope stability map of the study area. Units on the engineering formation map, which have high similarities in terms of material properties and slope stability factor (SF), were then grouped into 4 types based on the SF values of the slope to produce landslide susceptibility map of the Cimanuk River catchment area.

To obtain the engineering properties of material for this research, rock and soil sampling were carried out in the field. Disturbed (DS) and Undisturbed (US) soil sampling were obtained around the area where landslides previously occur. It is followed by soil testing in the laboratory according to ASTM methods to obtain physical and mechanical properties of soil. Data of physical and mechanical properties of soil from several terrains were used to calculate (quantitatively) the stability factor (SF) of each slope. Basically, the SF is a value representing the resultant ratio of resisting force with driving force acting in the body of slope.

RESULT AND DISCUSSION

Burbank and Anderson (2002) explained that landslides result from interactions between rock strength (c), angle of internal friction (ϕ), slope gradients (β) and geometry, morphological relief, pore water pressure and seismic accelerations. This complex interaction produces SF values of hillslope, which dynamically degraded from stable to critical and finally unstable when landslide occurs.

This phenomenon in an area is implemented into susceptibility zones, which can be classified into several ranks to produce landslide susceptibility map.

Muslim and Sophian (2007) discussed the rock engineering formation of the Cimanuk River catchment area and explained the engineering characteristics of several rock formations in the study area.

Result of analyses shows that there are 4 types of susceptibility on the study area. Explanation of each susceptibility type is as follows: 1) High susceptibility is characterized by mountainous to hilly area on thick soil of fine grain sedimentary rocks with high-density lineations on the ground surface representing geological structures. The material generally is composed of swelling-shrinking type of thick soil on high-angle slope (30 - 50 % & partly > 50 %), fine grain residual soil with montmorilonitic contents about 14-43 % (Hirnawan, 1998). It has high run-off from the surface water caused by drainage on the top of slope (ponds, paddy fields, etc). The land-use of this type consists of forest, agriculture and rural area; 2) Medium susceptibility is characterized by hilly area on thick to thin soil of coarse grain rocks with medium density lineations. It has gentle slope of hilly to mountainous land (10 – 30%), fine grain thick soil of sedimentary or volcanic rocks origin (tuff, breccia, sandstone and mudstone). It shows medium stage of weathering with medium annual rainfall and run off. It consists of forest, agriculture and urban development area. 3) Low susceptibility is characterized by low-land to plain area, with slope 5 – 10%, consist of volcanic material (breccia, conglomerate, etc), alluvium and terrace deposits. On the surface, it is composed of thin, coarse grain,

mainly transported soil. Mature stage of weathering. It mainly belongs to urban development area in the northern part of the study area.5)Very Low susceptibility is characterized by soil on alluvial and coastal plain with slope less than 5%. The land-use of this type consists of agriculture and urban development area in the northern part of the study area

Due to the intensive and frequent landslide in the study area, special attention was paid to the occurrence of expansive (swelling-shrinking type) soils and active structures in the medium and high susceptibility types, neotectonism and bare forest area on the toe of slope.

The expansive soil is characterized by high mud content (finer grain fraction) and certain clay mineral composition. Decomposed fine-medium marine sedimentary rocks will produce montmorilonite and illite minerals, which can significantly swell when water content is high (in the rainy season) and shrink when dry. While decomposed Quaternary volcanic material will produce halloysite and metahalloysite minerals, which also belong to expansive soil type.

The occurrence of several major structures in the study area (fault, folds and joints) mainly characterize the high susceptibility types. The high density of (active) fault in this zone suggests that the area is undergoing active deformation (neotectonism).

CONCLUSION

A study to analysis the distribution of landslide susceptibility on the Cimanuk River catchment area is carried out as an initial step to build the early warning system. We noted on the high susceptibility type, which is contributed by bare condition of forest caused by deforestation as well as geo-climatological factors (rock and soil materials, tectonics and rainfall). This implies on the land planning system, especially to the rehabilitation efforts to maintain the natural function of the forest. It is suggested to keep the forest in its natural environment not only by the government but also by all stakeholders to avoid the occurrence of landslide hazard for the people who live in/around the forest area.

ACKNOWLEDGEMENT

The author would like to express his deep gratitude to Prof. Dr. Febri Hirnawan, Mr. Irvan Sophian and Mr. Zufialdi Zakaria for valuable comments and suggestions. He also conveyed best appreciation to Dr. Motohiko Shibayama of Natural Environment Institute in Osaka, Japan and fellows from the Faculty of Geology, University of Padjadjaran, Bandung, Indonesia.

REFERENCES

Anon, 1976, *Engineering Geological Maps, A Guide to Their Preparation*, the UNESCO Press, Paris, p 79

Budhitrisna, T, 1990, *Geologic Map of Tasikmalaya Quadrangle, West Java, scale 1:100.000, 2nd Ed.*, Geol. Res. Dev. Centre, Bandung, Indonesia

Burbank DW and Anderson RS, 2001, *Tectonic Geomorphology*, Blackwell Science, Massachusets, p274

California Division of Mines and Geology (CDMG), 1999, *Factors Affecting Landslides in Forrested Terrain*, California Department of Conservation, Division of Mines and Geology, Note 50, p 5.

Dearman WR, 1992, *Engineering Geological Mapping*, Butter-worth-Heinemann, London, p 231.

Djuri, 1995, *Geologic Map of Arjawinangun Quadrangle, West Java, scale 1:100.000, 2nd Ed*, Geol. Res. Dev. Centre, Bandung, Indonesia

Hirnawan, F., 1998, The Behavior of Expansive Soil and Increment of Strength Parameters by Vegetation, Bulletin of Environmental

Geology, v.45, Bandung, Indonesia, pp 1-12.

Muslim D & Sophian I (2007), Landslide Susceptibility Map of Forest Region on the Cimanuk River Catchment Area, West Java, Indonesia, *Proceeding of the 10th Indonesia-Malaysia Symposium (SKIM X), Kuala Lumpur, p 76.*

Sugalang, Usman B., and Sugiyanto, 1995, *Map of Landslide Susceptibility Zone around Ciamis, West Java, scale 1:100.000*, Report of the Directorate of Environmental Geology, Bandung, Indonesia. *)

Syarief EA., Tobing, THML and Murdohardono, D., 2001, *Engineering Geologic Evaluation of Erosion Hazard in the Upstream of Cimanuk River Catchment Area, West Java,* Report of the Directorate of Environmental Geology, Bandung, Indonesia.*)

Tobing, THML and Murdohardono, D., 2002, Engineering Geologic Evaluation of Erosion Hazard in the Downstream of Cimanuk River Catchment Area, West Java", Report of the Directorate of Environmental Geology, Bandung, Indonesia.*

*) In Indonesian with English abstract

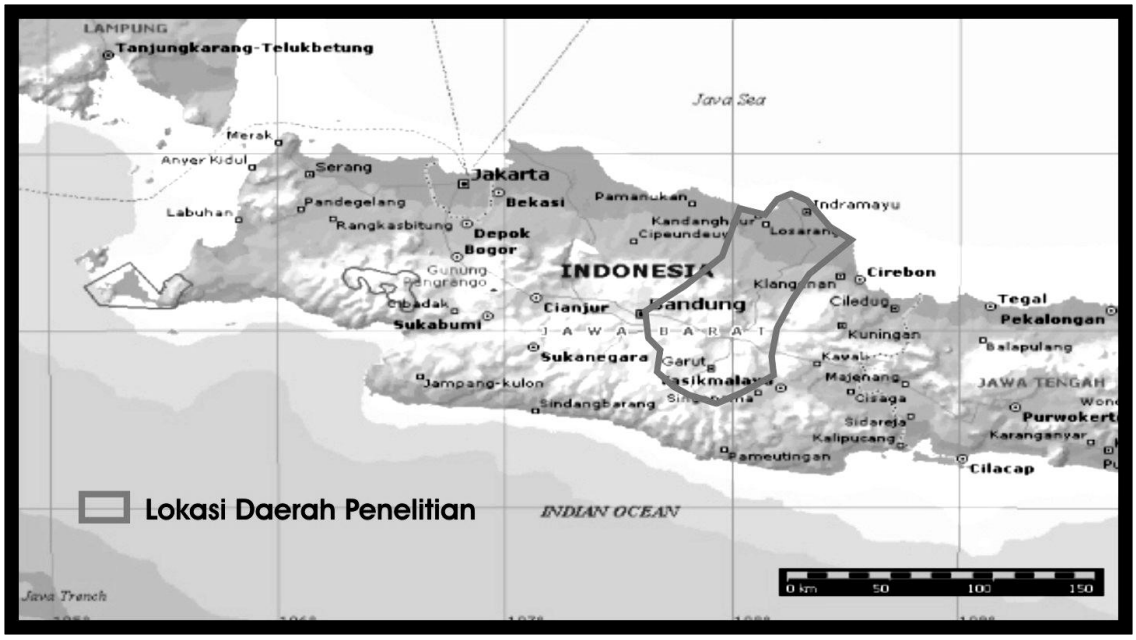

Figure 1. Location of the Study Area

Table 1. Landslide susceptibility of the Cimanuk River CA

No	Types of Susceptiblity	Distribution
1	High (red)	Mountainous to hill, steep morphology and relief, fine grained soil, landslide frequently occurs, high density of lineation/ geological structures
2	Medium (yellow)	Hill, gentle morphology and relief, fine to moderate grained soil, landslide moderately occurs, moderate density of lineation/ structures
3	Low (blue)	Lowland to plain, moderate to coarse soil, landslide rarely occurs, almost no lineation/ geological structures
4	Very Low (green)	Alluvial to coastal plain, coarse soil, landslide never occur except in the river-wall

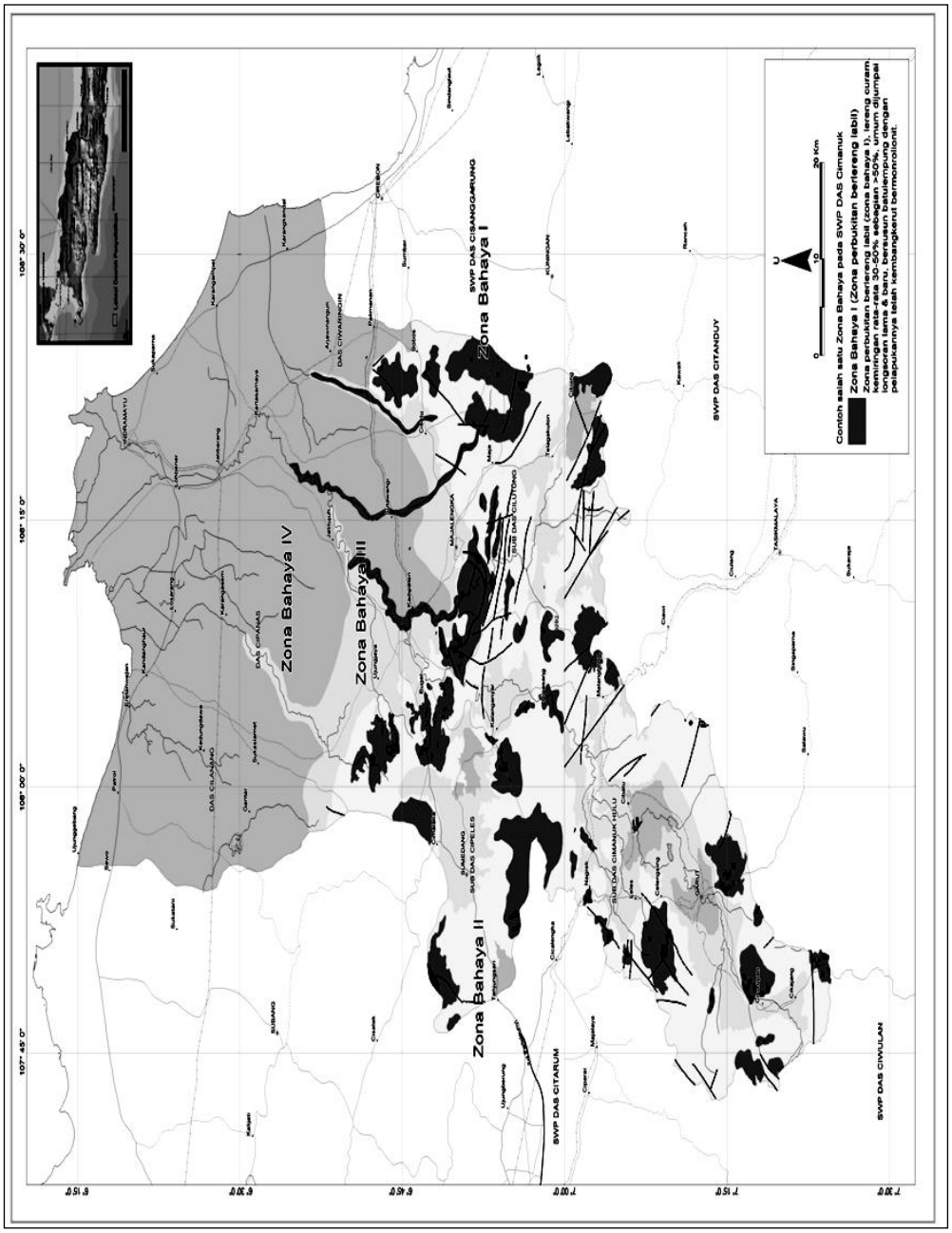

Figure 1. Location of the Study Area