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Geomorphological Aspects in Determining the Landslide Risk Zones in Cisangkuy Watershed, Bandung Regency, West Java Province

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***Abstract*—** *The Cisangkuy sub-watershed has a hilly to mountainous landform, dominated by slightly steep to steep slopes. The area's characteristics cause the Cisangkuy sub-watershed to be a landslide-prone zone. This study aims to identify and analyze the landslide susceptibility zones based on geomorphological characteristics in the Cisangkuy sub-watershed by utilizing a Geographic Information System (GIS). Research activities are carried out through studio analysis using remote sensing methods and satellite imagery. The geomorphological aspects studied consisted of slope, drainage pattern, lithology, land use, and bifurcation ratio. Based on the results of the analysis, three levels of landslide susceptibility zone were obtained in the study area, including low, moderate, and high levels of landslide vulnerability. The results of the analysis show that the Cisangkuy sub-watershed is dominated by a high level of landslide susceptibility zone, with the morphological characteristics of the area having hilly to mountainous landforms with slightly steep slopes, volcanic rock types, and radial drainage patterns with a bifurcation ratio indicating that it has been controlled by faults. Land use is dominated by settlements, forests, rice fields, plantations, agricultural fields, and shrubs. Some of the main factors that cause landslides are slope, soil type, land use, and rainfall. Therefore, it is necessary to have good regional planning to minimize the impact of landslides in the future.*

***Keywords*—** *Sub-watershed, Cisangkuy, Landslide, Geomorphology, Remote Sensing.*

I. INTRODUCTION

The Cisangkuy Watershed is a sub-watershed of the Upstream Citarum which is administratively located in Bandung Regency. The Cisangkuy River is a tributary of the Citarum River which passes through several areas such as Pangalengan, Banjaran, Arjasari, Baleendah, Pameumpeuk, Kertasari, Pasirjambu, and Pacet sub-districts. Based on its geographical location, Bandung Regency is included in the category of landslide-prone areas, because the majority of its area is hilly and mountainous (Sawitri, 2021).

Regionally, the South Bandung area is part of the Quaternary Volcano Group, bounded in the northwest by the Sukabumi-Padalarang shear fault zone. Geologically, the Upstream Citarum area is dominated by quaternary volcanic products, such as the Malabar, Patuha, Tanjaknangsi, Kuda, and Pangalengan pyroclastic products. Lake deposits consist of loose clay, silt, sand, and gravel-sized tuffaceous rocks containing breccia inserts (Rohaendi, Sukiyah, Muslim, & Cipta, 2021). The Beser Formation, which consists of tuffaceous breccias, lava, sandstones, and conglomerates, is the oldest rock type in this region (Silitonga, 1973). The Cisangkuy sub-watershed has a high rainfall intensity of 2500–3000 mm/year (Siswanto & Sule, 2012).

Based on these facts, steps to reduce the risk of landslides need to be taken. This study aims to identify and analyze landslide susceptibility zone based on geomorphological characteristics along the Cisangkuy sub-watershed. Certain geomorphological characteristics can also affect land use conditions in an area. There are several geomorphological parameters that can be studied, such as slopes, rivers, landscapes, lithology, etc. Physically, it can be seen through various approaches through field observations and remote sensing (Rendra, 2022).

II. METHODOLOGY

Studio analysis was carried out by utilizing a Geographic Information System (GIS). The remote sensing method uses ArcGIS software, and the spatial data used includes the 1:25.000-scale Indonesian Topographical Map of Soreang, Pakutandang, Barutunggul, Pangalengan, and Lebaksari. Then the 1:100.000-scale regional geological maps of Garut and Pameungpeuk and DEM SRTM images with a spatial resolution of 30 meters. In addition, the results from relevant previous studies are also used and supported by field data in the form of landslides that have occurred in the study area.

In making a map of the estimated landslide susceptibility zone in the Cisangkuy sub-watershed, an analysis is first carried out, which is used as a reference for determining landslide-prone areas. Then interpret the topographic map and Google Earth satellite imagery of the research area. Satellite imagery are used to identify land use, and topographic maps are used to analyze the geomorphological characteristics of the study area, such as slope, drainage pattern, bifurcation ratio, and lithology.

III. RESULT AND DISCUSSION

A. Slopes

Based on the contour processing, the height and slope of the study area can be identified. The research area is a hilly area with an elevation of 700 to 2300 masl (meters above sea

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level). Slope conditions vary greatly, based on the classification of Guidelines for Compilation of Land Rehabilitation Patterns and Soil Conservation (1986), the slope in the study area consists of 5 areas, namely flat (0%-8%), sloping (8%-15%), slightly steep (15%-25%), steep (25%-45%) and very steep (>45%).

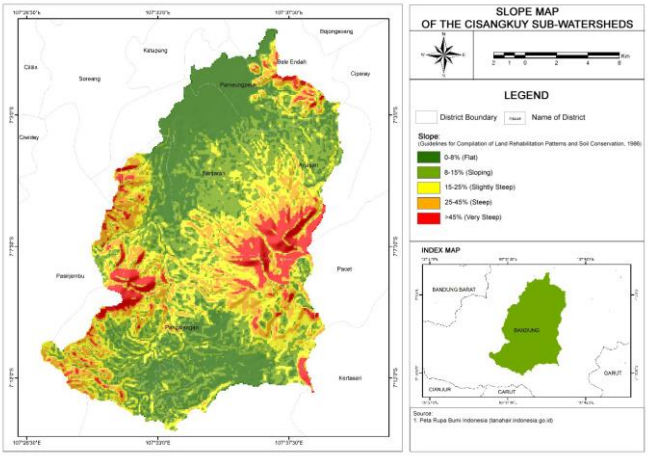

Fig. 1. Slope Map of the study area

B. Drainage Patterns

Several factors affect the pattern of drainage patterns in an area. This includes control of structure, rock type and hardness, initial slopes, geological history, and geomorphology of the area (Thornbury, 1969). Based on the analysis of the drainage pattern, the pattern that develops in the study area is included in the sub-parallel, radial, and dendritic drainage patterns that refer to Howard's classification (1967). In general, sub-parallel drainage patterns are drainage patterns that have relatively parallel directions controlled by slopes, lithology, and geological structures with homogenous rock layers. Meanwhile, the radial drainage patterns are circular or converging to an area. So that the tributaries go to one point in a circle. This pattern is formed following the convex formation of the earth's surface which is usually found in volcanic areas on dome landscapes. As well as sub-dendritic drainage patterns are a modification of dendritic drainage patterns that are influenced by topography and geological structures that develop in an area. Thus, forming a dendritic pattern that has more branches.

C. Lithology

Based on the regional geological map, the Bandung Regency area is composed of volcanic rocks originating from volcanoes, sedimentary rocks, metamorphic rocks, and alluvial. In terms of physiography, which belongs to the Bandung zone, is dominated by young volcanic deposits and old sedimentary deposits (Sawitri, 2021). The research area is composed of volcanic products such as Lake Deposits (Qd), which are tuffaceous clay, silt, sand, and gravel. The Malabar-Tilu Volcanic (Qmt) rocks are tuff, breccia and lava. Undifferentiated Efflata Deposits of Old Volcanics (Qopu), are tuff, breccia, and lava deposits. Waringin-Bedil Andesite, Old Malabar (Qwb) are lava, breccia, and tuff. Beser Formation (Tmb) are tuffaceous breccia and lava. This is also related to the characteristics of the rocks with the slope and drainage patterns. In addition, there are also indications of faults with varying orientations in the study area.

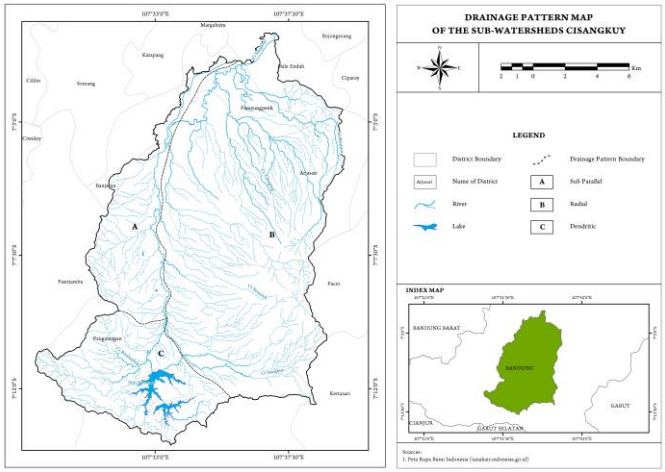

Fig. 2. Drainage Pattern Map of the study area

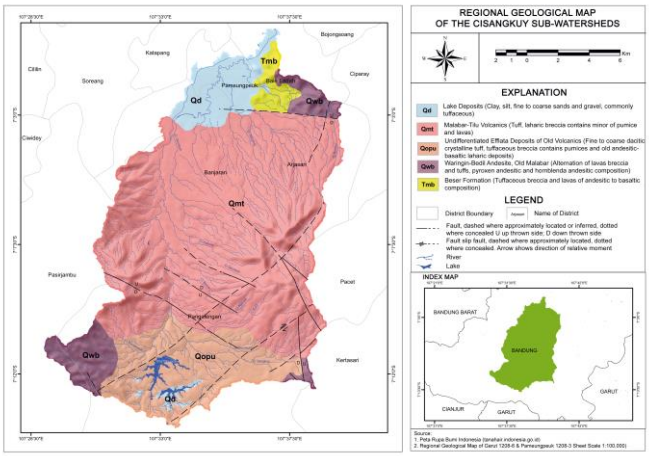

Fig. 3. Regional Geological Map of the study area

D. Land Uses

Based on the Indonesian Topographical Map (RBI), land use in the Cisangkuy sub-watershed area consists of settlements, rice fields, forests, shrubs, plantations, and agricultural fields. The land use that has the largest area in the Cisangkuy sub-watershed is forest, while the land use that has the smallest area is bare land (Julaeha, Kendarto, & Solihin, 2022). The sub-districts with the largest area of forest land use include Pangalengan and Banjaran sub-districts. Forested land produces lower amounts of surface run-off and has a higher infiltration rate than other types of land cover. Changes in land use occur due to an increase in population. In the upstream part, there is a change in the land use of forests into agricultural fields (Suriadikusumah & Herdiansyah, 2014).

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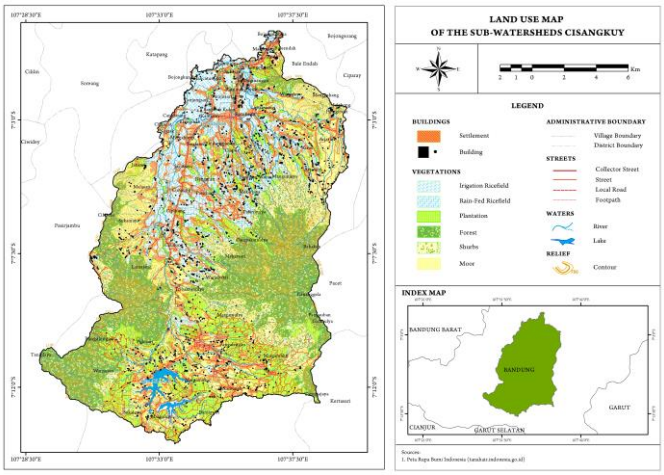

Fig. 4. Land Use Map of the study area

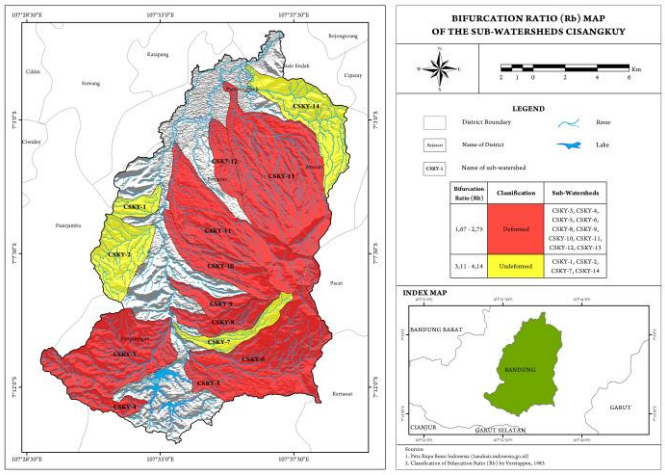

Fig. 5. Bifurcation Ratio Map of the study area

E. *Bifurcation Ratio (Rb)*

Based on the results of calculations carried out on 14 sub-watersheds in the study area, the value of the bifurcation ratio is dominated in the range of 1.67 to 2.75. Based on Verstappen's classification (1983), it can be concluded that the majority of the sub-watersheds in the study area have deformed. Areas with Rb<3 or Rb>5 values are controlled by active faults (Sukiyah, Agung, & Raditya, 2015). There are several sub-watersheds that have higher Rb values, which are in the range of 3.11 to 4.14 (CSKY_1, CSKY_2, CSKY¬_7, and CSKY_14 sub-watersheds) indicating that the sub-watershed undeformed.

F. *Landslide Susceptibility Level and Satellite Image of Study Area*

Based on the results of the landslide susceptibility analysis, three levels of landslide risk zones were obtained in the study area, including low, moderate, and high levels of landslide susceptibility. Figure 6 and Figure 7 show that areas with a low level of susceptibility include 3 sub-districts, namely Baleendah, Pangalengan, and Pameungpeuk sub-districts. This area has characteristics including flat-sloping slopes, dominated by lake deposits, and dendritic drainage patterns. Land use is dominated by settlements, lakes, and plantations. This area has a small possibility of landslides if there is instability on the slopes. Small-scale landslides can occur on riverbanks that are eroded by surface runoff.

Areas with a moderate level of susceptibility include 6 sub-districts, namely Baleendah, Pameungpeuk, Banjaran, Arjasari, Pasirjambu, and Pangalengan sub-districts. This area has characteristics including a slope dominated by sloping-slightly steep slopes, volcanic rock types, and a drainage pattern that is dominated by sub-parallel with a bifurcation ratio indicating deformed river branches. Land use is dominated by settlements, rice fields, plantations, and agricultural fields. This area can experience small to medium-scale landslides, especially in areas bounded by escarpments, river valleys, and lithological transitions. Landslides can also occur when there is instability on the road cliffs that cut the slope.

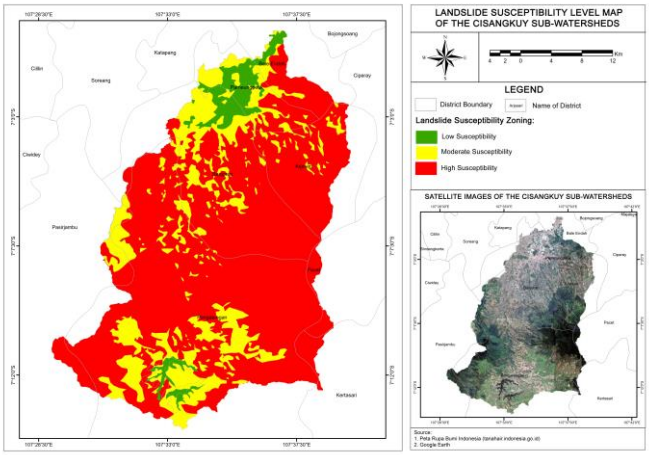

Fig. 6. Landslide Susceptibility Level Map and satellite imagery of the research area

Areas with a high level of susceptibility include 7 sub-districts, namely Baleendah, Pameungpeuk, Banjaran, Arjasari, Pasirjambu, Pacet, and Pangalengan sub-districts. This area has characteristics including slope dominated by slightly steep-very steep slopes, volcanic rock types, and dominated by radial drainage patterns with a bifurcation ratio indicating deformed river branching. Land use is dominated by settlements, forests, rice fields, plantations, agricultural fields, and shrubs. This area has a high potential for landslides. Landslides can occur due to steep slopes and triggered by heavy rainfall.

Rainfall intensity in the study area is 2500-3000 mm/year. The dry season occurs in July-September with an average rainfall of less than 100 mm/month, and the rainy season occurs in November-April. The average number of dry months is 1.4 while the wet months are 9.8. Based on these data, the study area is classified as a very wet type of precipitation (Siswanto & Sule, 2012). The last ten years have shown a trend of greater fluctuations in rainfall in the upstream compared to the downstream (Suriadikusumah & Herdiansyah, 2014).

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Fig. 7. The location of the landslide in the Pangalengan area is in the form of tuff rock with a slope of 35% (Sulastri, 2021)

IV. CONCLUSION

Based on the results of the landslide susceptibility analysis, three levels of landslide susceptibility zones were obtained in the study area, including low, moderate, and high levels of landslide susceptibility. The results of the analysis show that the Cisangkuy sub-watershed area is dominated by a high level of landslide susceptibility zone with the morphological characteristics of the area having hilly to mountainous landforms with slightly steep slopes, volcanic rock types, and radial drainage patterns with bifurcation ratio indicating deformed river branches (controlled by active faults). Land use is dominated by settlements, forests, rice fields, plantations, agricultural fields, and shrubs. There are several main factors that cause landslides in the study area, including steep slopes, lithology of volcanic rocks that are easily weathered and produce very thick weathered soils, land use for plantations and agricultural fields that require soil loosening and can disrupt slope stability, and high rainfall intensity. The potential for landslides in the study area is quite dangerous because it can close road access and disrupt the activities of local residents. Therefore, there is a need for better regional planning to minimize the impact of landslides in the future.

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