Sumatra Journal of Disaster, Geography and Geography Education: June 2025. Vol.9. No.1. pp. 1-11
Disaster, Geography, Geography Education http://sjdgge.ppj.unp.ac.id/index.php/Sjdgge
ISSN: 2580 - 4030 (Print) 2580 - 1775 (Online), Indonesia

MULTICRITERIA SPATIAL DATA ANALYSIS FOR LANDSLIDE PRONE ZONE IN SOUTH BOGOR SUB-DISTRICT

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*Corresponding Author, Received: February 11, 2025. Revised: May 10, 2025. Accepted: June 01, 2025

ABSTRACT: South Bogor District is one of the areas in Bogor City that has a high level of vulnerability to landslide disasters. Factors such as high rainfall, soil types that easily become saturated, steep slope inclinations, and land cover changes due to development are the main causes of the increased landslide risk. This research aims to map the landslide hazard levels in the area using a spatial approach with Geographic Information System (GIS) and a weighted overlay method. The five main parameters used in this analysis are slope gradient, soil type, rock type, land cover, and rainfall. Each parameter is weighted based on its contribution to the landslide potential. Data were obtained from various agencies such as BIG, BNPB, ESDM, and BPBD Kota Bogor. The overlay results show three hazard classes: low, medium, and high. Validation was carried out by comparing the zoning results with the actual landslide occurrence points recorded in the field. The research results show that most of the South Bogor District area falls into the moderate to high hazard class, especially in areas with steep slopes and non-forest land cover. Areas such as Kertamaya, Rancamaya, and Mulyaharja fall into high-risk zones, which aligns with previous landslide occurrence data. The resulting zoning model has proven capable of mapping potential hazards quite well and can serve as a basis for disaster mitigation planning, spatial planning, and landslide risk reduction policies in urban areas.

Keywords: Landslide, GIS, Multicriteria Analysis, Hazard Zone

1. INTRODUCTION

South Bogor District is one of the areas in Bogor City that has a high level of vulnerability to landslides. This is influenced by a combination of geomorphological characteristics, high rainfall, geological conditions, and regional development pressure. Based on the disaster risk assessment from the National Disaster Management Agency [1], most of the South Bogor District area falls into the moderate to high landslide risk zone, especially in areas with steep topography and water-saturated soil.

Morphologically, this area is dominated by the slopes of volcanic cones, riverbanks, and alluvial valleys that are prone to land movements [2]. The presence of weakly structured clay soil and high rainfall intensity exacerbates this disaster potential. According to the Central Bureau of Statistics of Bogor City [3], the average rainfall in this area reaches 4,812 mm per year, making it one of the regions with the highest rainfall intensity in Indonesia. These conditions increase the likelihood of soil mass erosion, especially during prolonged rainy seasons.

According to data from the Central Statistics Agency of Bogor City [4], all sub-districts in Bogor City have experienced landslides, with South Bogor Sub-district recording landslide incidents in all its villages. This fact highlights the importance of accurate spatial identification to support risk-based mitigation policies.

One of the methods that can be used to support such planning is landslide hazard mapping based on multi-criteria spatial data. This approach integrates various parameters such as rainfall, slope gradient, rock type, soil type, land cover, and previous landslide occurrence points. Each parameter is weighted based on its influence on landslide potential and combined using the overlay weighted sum method [5].

The use of Geographic Information Systems (GIS) in this process allows for the creation of more accurate and comprehensive landslide-prone zoning maps [6]. The results of this mapping become an important tool in supporting spatial planning

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decision-making, the development of early warning systems, and educating the community about potential risks in their surroundings [7].

Furthermore, the disaster risk study of Bogor City [1] and data from the Center for Volcanology and Geological Hazard Mitigation [10] indicate that the use of spatial data and a multi-criteria approach can enhance the effectiveness of disaster management in urban areas with high vulnerability, such as South Bogor. In addition, the application of this method has been successfully used in several other areas with similar characteristics, as reported in the research journal by Susetyo and Hermawan [11].

2. RESEARCH METHODS

This research uses the weighted overlay-based multi-criteria spatial analysis method in a Geographic Information System (GIS) to identify landslide-prone zones in the South Bogor District. This approach combines various physical and environmental parameters that influence landslide potential, in accordance with the guidelines and classifications developed by the Soil and Agroclimate Research Center [12].

The spatial data used in this study is sourced from official agencies, including: land slope from the Geospatial Information Agency (BIG), rainfall from the National Disaster Management Agency (BNPB), soil and geology types from the Ministry of Energy and Mineral Resources (ESDM), and land cover from BIG. All data were obtained through surveys and processing by the relevant agencies with intervals adjusted to the needs of spatial analysis. The weighting for each parameter can be seen in the matrix in Table 1.

The classification of landslide hazard zones is divided into three levels: low, moderate, and high, based on the Minister of Public Works Regulation No. 22/PRT/M/2007 on Guidelines for Spatial Planning of Landslide-Prone Areas, which is further validated by landslide incident points sourced from BPBD Kota Bogor data.

Table 1 Matrix of Weighting Physical and Environmental Parameters for Landslide Hazard Analysis

No.	Classification	Parameter	Score	Bobot (%)
1	Slope	>45	5	20
		30-45	4	
		15-30	3	
		8-15	2	
		0-15	1	
2	Soil Type	Regosol	5	10
		Andosol, Podsilik	4	
		Latosol Coklat	3	
		Asosiasi Latosol Coklat Kekuningan	2	
		Aluvial	1	
3	Rock Type	Vulkanik	3	10
		Sedimen	2	
		Latosol	1	
4	Land Cover	Field	5	20
		Thicket	4	
		Forests and Plantations	3	
		Settlement	2	
		Pond, Reservoir, Water	1	
5	Rainfall	>3000 mm/year	5	30
		2500–3000	4	
		2000–2500	3	
		1500–2000	2	
		<1500	1	

3. RESULTS AND DISCUSSION

3.1 Slope

South Bogor District, which is one of the

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administrative regions in Bogor City, West Java Province, has topographical characteristics that are generally dominated by hilly landscapes with relatively steep slopes. Such physiographic conditions make the area highly susceptible to geological vulnerabilities, particularly to landslides that often occur in regions with extreme land slopes. In the context of disaster mitigation and planning, slope analysis becomes a fundamental aspect that needs to be studied in depth to determine the level of vulnerability of an area to mass movement. Based on the analyzed spatial data, the slope in the South Bogor District shows a significant variation, ranging from the gentle slope category with an inclination between 0 to 8 percent, the moderately steep category with a range of 8 to 15 percent, the steep category between 15 to 45 percent, to the very steep category with an inclination of more than 45 percent. The diversity of slope levels directly affects the landslide risk in each regional zone, making it an important component in hazard assessment and disaster risk reduction strategy formulation.

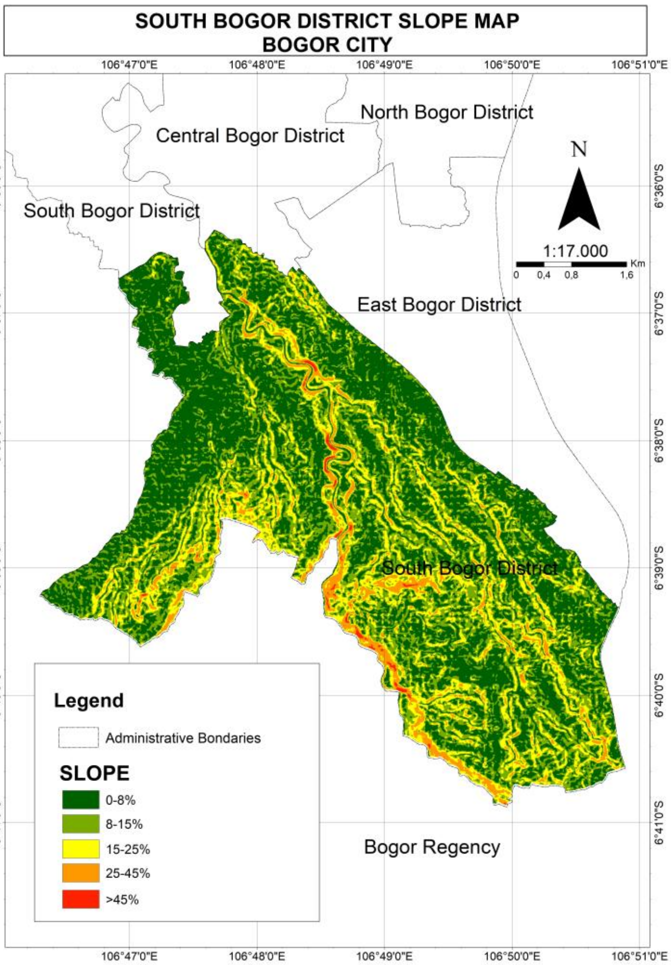

Fig.1 Slope Map

3.2 Soil

The type of soil that dominates the South Bogor District area is Regosol, which is generally one of the young soil types formed from volcanic parent material or fine sediments undergoing initial weathering processes. This soil is generally found in tropical and subtropical regions with high rainfall levels throughout the year, especially in areas with a clear seasonal difference between the rainy and dry seasons. The presence of Regosol soil in this region reflects intensive geological and climatic dynamics, which also influence the overall soil formation processes and characteristics. One of the main characteristics of Regosol soil is its structure and texture, which are still not fully developed, as well as its relatively low fertility due to the limited content of organic matter and nutrients. Another important characteristic is the high level of leaching that occurs due to intense rainfall, making this soil tend to be nutrient-poor and acidic.

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In addition to Regosol, Acrisol soil types are also found in some parts of the region, which have a more advanced level of development but still show vulnerability to land degradation. Acrisol soil is known to be easily eroded, especially if located in areas with steep slopes or in regions experiencing land cover disturbances. In the South Bogor District, the presence of Acrisol soil in areas with steep topography increases the risk of surface erosion and landslides, especially if land use is not managed wisely and conservatively.

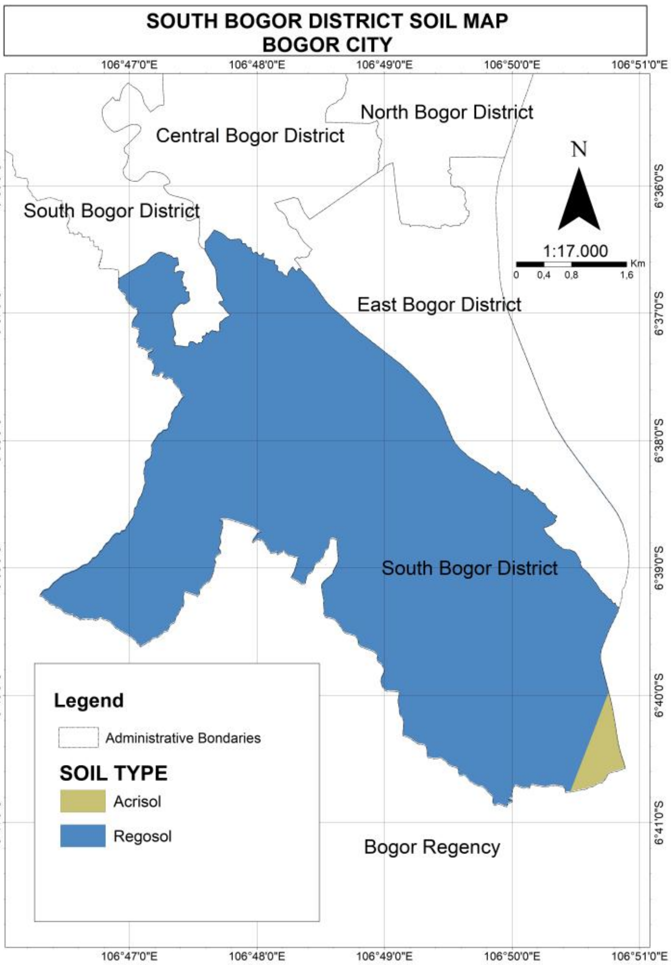

Fig.2 Soil Map

3.3 Rocks and Geology

The types of rocks found in this region are greatly influenced by past geological activities, particularly by the processes of volcanism and sedimentation that have been ongoing for millions of years. The volcanic activity has produced various types of igneous and pyroclastic rocks that are widely spread throughout this area, while the sedimentation process has also formed layers of sedimentary rocks originating from materials resulting from the erosion and weathering of previous rocks. Based on geological observations and interpretations, the type of rock that dominates this area is ancient volcanic sedimentary rock, which formed from the accumulation of volcanic material that has undergone diagenesis over a long period. These sedimentary rocks exhibit distinctive composition and structure, and they serve as indicators of the presence of an ancient volcanic system that was once active in the past.

Besides the sedimentary rocks of ancient mountains, this region also contains rocks resulting from lahar flows (laharic deposits) and lava rocks formed from the solidification of magma on the Earth's surface. Lahar rocks are the result of volcanic material mixed with water that settles after a volcanic eruption, while lava rocks are formed directly from magma that solidifies after reaching the surface. The combination of these three types of rocks reflects the complexity of the area's geological history and also determines the region's physical characteristics, including slope stability, soil permeability, and susceptibility to erosion and

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landslides.

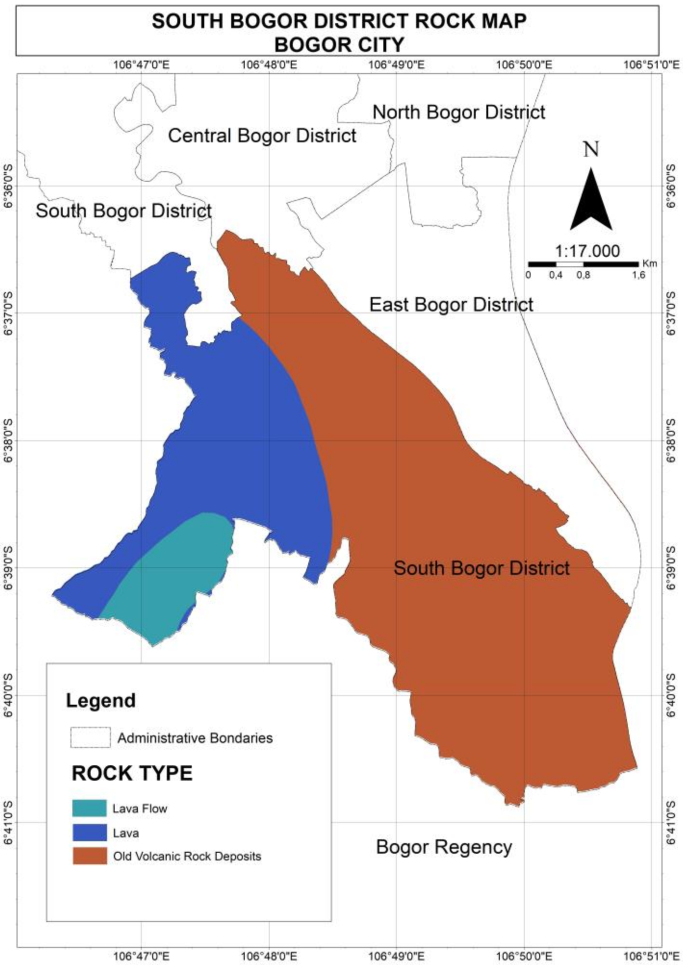

Fig.3 Rocks Map

3.4 Land Cover

The South Bogor District has a highly diverse land cover composition, which indicates the dynamics of space utilization and the interaction between natural elements and human activities. This area is dominated by residential neighborhoods, which are spread both in the plains and on the slopes of the hills, reflecting a pattern of regional development that leads to urbanization and an increasing need for living space in line with population growth. In addition to residential areas, land cover in South Bogor District also includes agricultural areas, such as rice fields and dry fields, as well as natural areas consisting of secondary forests, shrubs, and several remaining vegetation conservation areas. This diversity reflects a blend of ecological and economic functions of the region, where productive spaces and green open areas are still maintained amidst the expansion of settlements and infrastructure.

Land cover in this region is not only determined by biophysical conditions but is also greatly influenced by various factors such as geographical location, land slope and elevation (topography), as well as the intensity and pattern of human activities. Geographical factors such as proximity to the city center and accessibility of main roads also drive the development of settlements and land conversion. Meanwhile, the varied topographic conditions cause the distribution of land cover types to be uneven; areas with steep slopes tend to experience less conversion, while plains and gentle slopes are more extensively utilized for settlement and agriculture. Human activities, such as land clearing for housing development, intensive agriculture, and infrastructure, play a significant role in progressively altering land cover structure.

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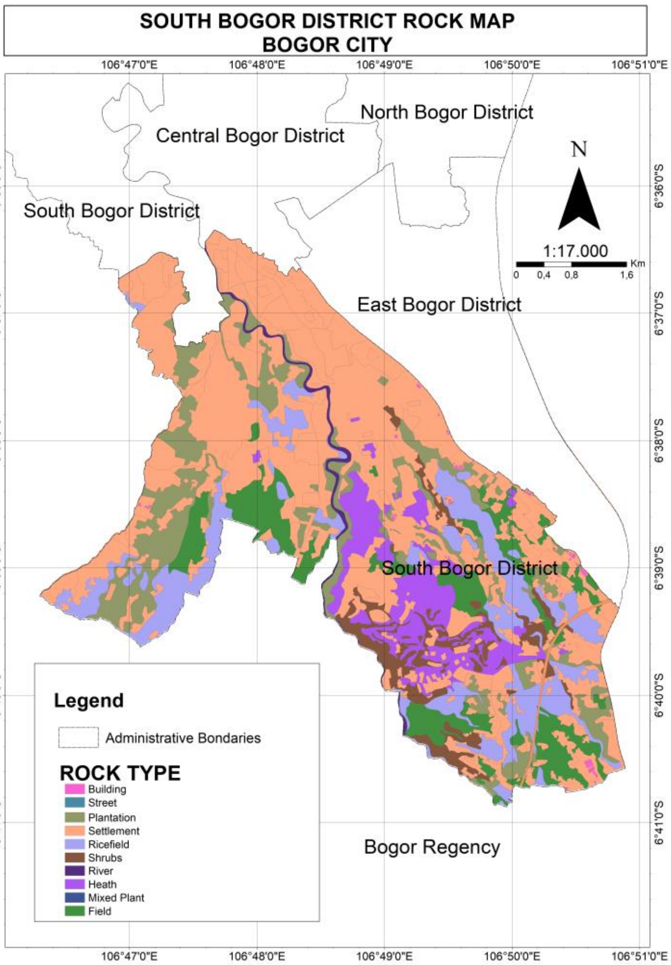

Fig.4 Land Cover Map

3.5 Rainfall

Bogor Selatan District is one of the areas in Bogor City that climatologically falls into the category of regions with very high annual rainfall levels. The high rainfall in this area is influenced by various natural factors, especially its geographical location in the southern part of Bogor City, which is topographically surrounded by mountainous and hilly regions with quite varied elevations. This condition makes South Bogor District one of the main rain catchment areas, where the high humidity from the moist winds originating from the Indian Ocean condenses as it rises to the mountain slopes, resulting in high precipitation throughout the year.

Besides the topographical factors, the tropical climate that dominates this area also plays a significant role in creating intense and even rainfall patterns, especially during the long rainy season, which usually lasts from October to May. Based on the analysis of historical rainfall data from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) for the period from 1981 to 2023, it was found that the average annual rainfall in South Bogor District ranges from 2,900 to 3,500 mm per year. This figure indicates that the area falls into the very wet category according to the humid tropical climate (Af) classification in the Köppen system. The high intensity of this rainfall has a significant impact on environmental dynamics, including a high potential for surface runoff, increased risk of soil erosion, and high vulnerability to hydrometeorological disasters such as local floods and landslides.

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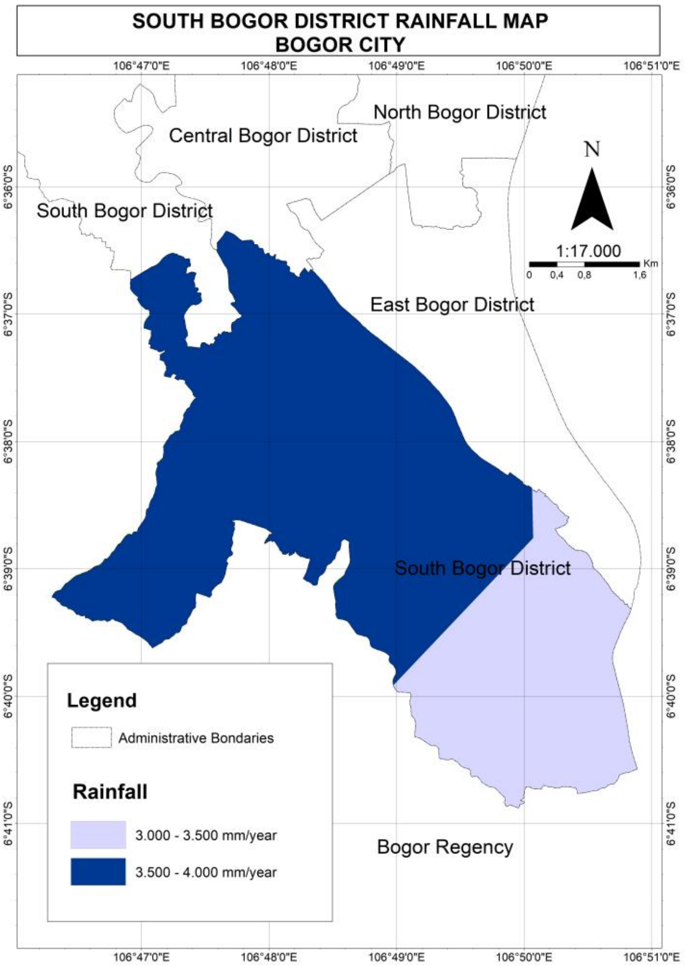

Fig.5 Rainfall Map

3.6 Landslide Hazard

Based on the results of overlaying spatial data with the landslide hazard distribution map, it can be determined that Bogor City has a variety of landslide vulnerability levels in each of its sub-districts. The distribution of this danger level is classified into three categories: low, medium, and high. This analysis aims to identify priority mitigation areas based on the extent of regions classified as high-risk.

Generally, most sub-districts in Bogor City fall into the low and moderate hazard categories, especially those located in the northern and central parts of the city such as Babakan, Panaragan, Cibogor, Gudang, and their surroundings. These areas have relatively flat topography and low levels of geological disturbance, so the potential for landslides is minimal. This is also clearly visible on the map, where the dominance of green color (low danger) covers the city center area.

However, there are several sub-districts in the southern part of Bogor City that show a high potential for landslide danger, both based on the data of the high danger zone area and confirmation from the landslide-prone zone map. Villages such as Kertamaya, Mulyaharja, Bojongkerta, and Rancamaya have significant areas with a high level of danger. For example, Kertamaya Village is recorded to have an area of 1,009,600 m² classified as a high-risk zone, followed by Rancamaya (863,600 m²) and Mulyaharja (988,300 m²). These areas are mostly located in hilly regions with steep slopes, and they directly border Bogor Regency, which is also known as a landslide-prone zone.

The landslide distribution map, particularly in the South Bogor District, reinforces this finding, where the dominance of the red color (high danger level) is clearly visible in those areas. This condition shows that topography, land use, and local geological characteristics play a significant role in determining the level of landslide susceptibility.

In addition, there are other sub-districts such as Pamoyanan, Muarsari, Harjasari, Genteng, and Ranggamekar that also have high-risk areas, although on a smaller scale. Nevertheless, these areas still need to be given attention in disaster management planning.

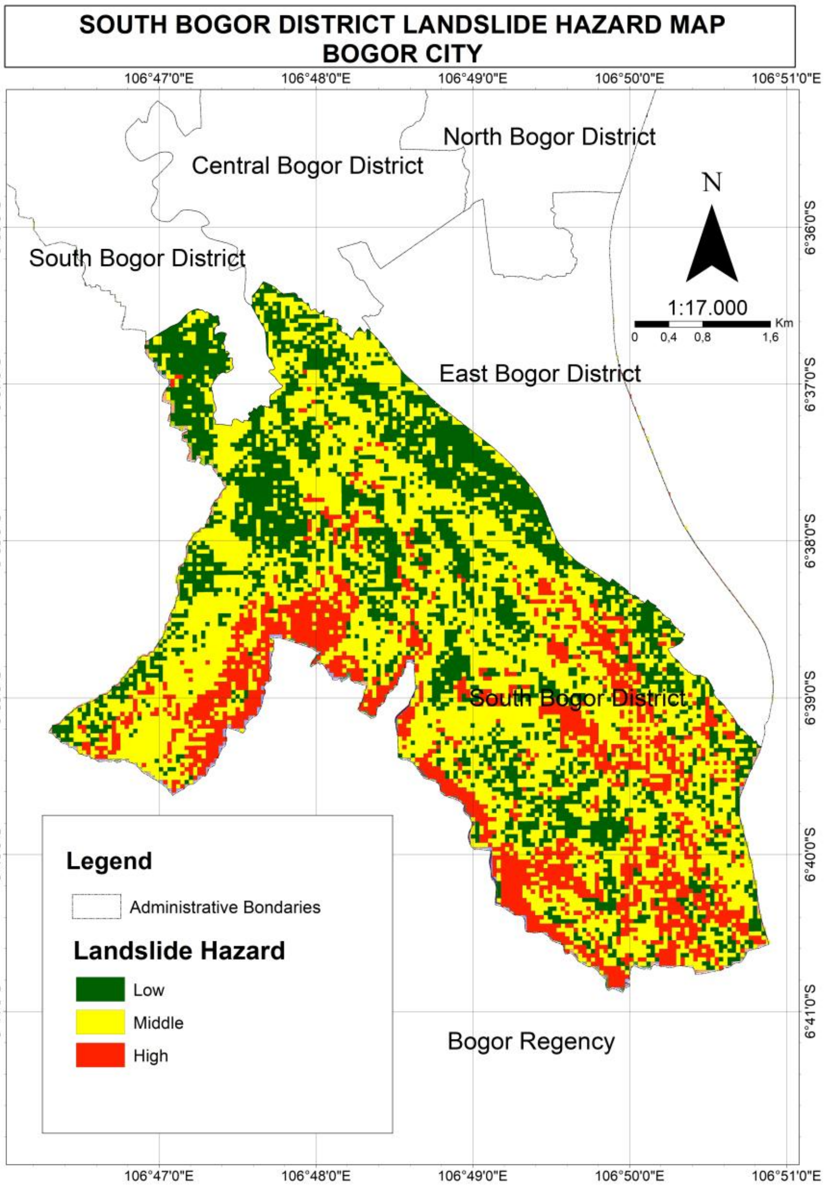

Fig.6 Landslide Hazard

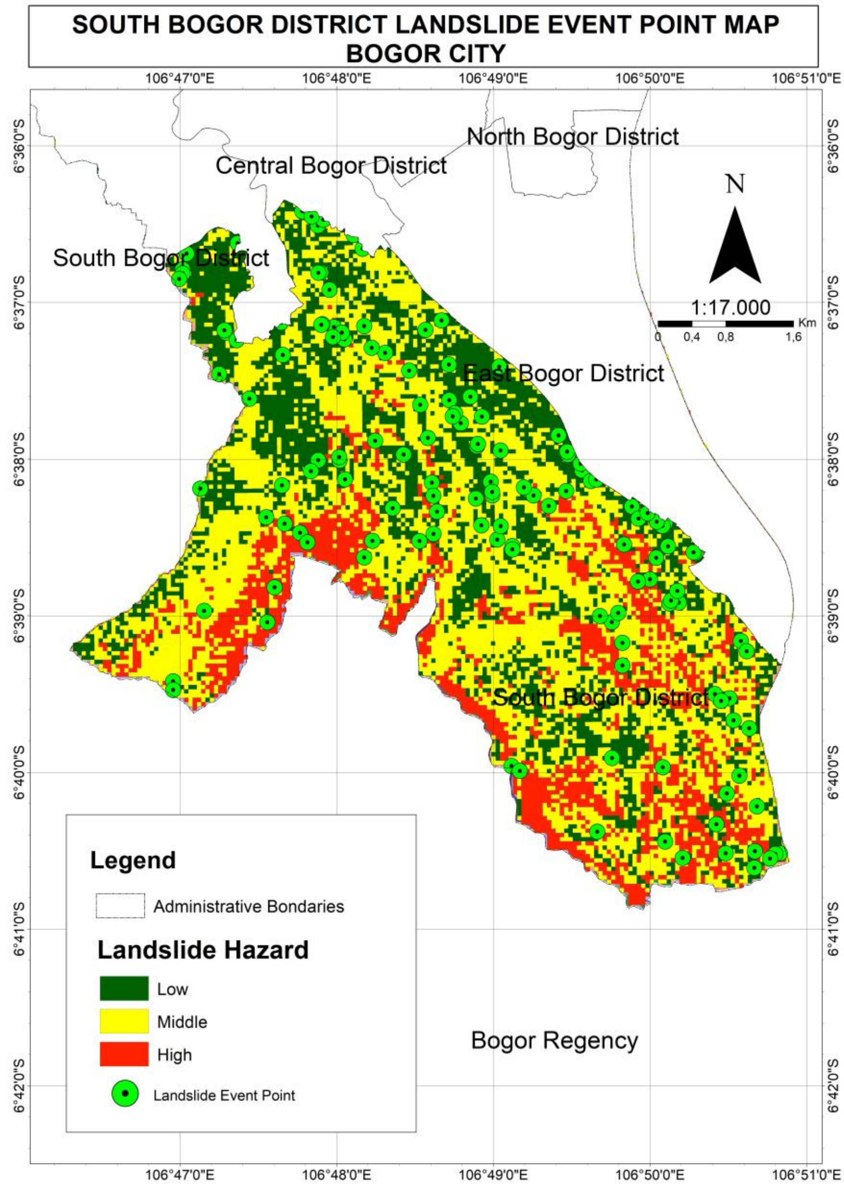

Fig.7 Landslide Incident

To strengthen the landslide hazard mapping results, spatial validation is carried out using historical data in the form of landslide event points. These points were obtained from disaster event records in Bogor City over the past few years and plotted onto a landslide-prone zone map. This validation aims to see the compatibility between the hazard model and the empirical reality on the ground.

Based on the validation map in South Bogor District, it can be seen that the majority of landslide occurrence points (green circle symbols) are concentrated in zones classified as high danger level (red color) and medium (yellow). This distribution shows that the hazard zoning model used is capable of predicting landslide-prone areas quite accurately.

The red zones indicating a high level of danger are quite widespread in the southern and southwestern parts of Bogor Selatan District. In those areas, there is also an accumulation of landslide incidents, especially around sub-districts such as Mulyaharja, Rancamaya, Bojongkerta, and Pamoyanan. This confirms that areas with extreme geophysical characteristics and slope inclinations indeed have a strong correlation with landslide occurrences.

Meanwhile, in the low-risk zone (green color), the number of incident points is very minimal or even non-existent. This reinforces the reliability of the low hazard classification in the map as an area relatively safe from landslide risk.

Thus, these validation results provide empirical support for the landslide hazard mapping that has been conducted. This is very important to ensure that the results of the spatial analysis can be used as a basis for targeted disaster mitigation policy planning. The success of this validation also indicates that the modeling approach used (based on a combination of topographic, land use, and geological factors) has a good level of accuracy in identifying high-risk areas.

4. CONCLUSION

Based on the results of landslide hazard mapping and validation with landslide incident point data in South Bogor District, it can be concluded that the zoning model used has a fairly good level of accuracy. The majority of actual landslide occurrences are recorded in areas classified as having moderate to high danger, particularly in the southern and southwestern parts of the sub-district. This shows that the mapping is capable of representing the spatial conditions of disaster vulnerability with high relevance to empirical events on the ground.

This validation not only strengthens confidence in the results of spatial analysis but also provides a strong scientific basis for use in disaster mitigation planning. The validated hazard maps can serve as an important reference in decision-making related to land use control, spatial planning, infrastructure development, and the formulation of more targeted disaster risk reduction strategies.

Thus, the mapping and validation approach applied in this study is expected to serve as an applicable model for other regions with similar geological and topographical characteristics.

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