



Analysis of Landslide Susceptibility as a Basis for Community Social Mitigation in Gunungkidul Regency

Novaris Adi Nugroho, Danardono^(✉), and Nirma Lila Anggani

Faculty of Geography, Universitas Muhammadiyah Surakarta, Surakarta 57162, Central Java, Indonesia

danardono@ums.ac.id

Abstract. Gunungkidul Regency has an area dominated by mountains in the northern and southern parts and high rainfall in the northern region. In 2021, landslides in Gunungkidul Regency were relatively frequent with 69 incidents. Therefore, this research aims to 1) analyze the level of susceptibility and landslide-prone areas in Gunungkidul Regency and 2) determine community social mitigation efforts in landslide-prone areas in Gunungkidul Regency. The method employed in this research was quantitative scoring and descriptive. This study's results revealed that the level of susceptibility to landslides in Gunungkidul Regency consists of three levels: low with a percentage of 38.41%, medium with a percentage of 51.35%, and high with a percentage of 10.24%. Sub-districts at a high level of landslide susceptibility with the highest number of landslides are in Patuk Sub-district, Gedangsari Sub-district, Nglipar Sub-district, and Semin Sub-district. Mitigation efforts at low susceptibility are to provide public education about landslide disasters and the dangers that will occur. Then, for areas with a medium level of susceptibility, forming a non-governmental disaster organization can be carried out. Meanwhile, for areas with a high level of susceptibility, mitigation is performed by means that the government is always active in giving warnings about landslides, routinely checking on steep slopes, setting up evacuation posts, and providing logistical assistance, training the community and organizations, and understanding by the government.

Keywords: Landslide susceptibility · mitigation · GIS

1 Introduction

Indonesia has a high level of disaster susceptibility. Indonesia is also an archipelagic country where three plates meet, i.e., the Indo-Australian plate, the Eurasian plate, and the Pacific plate. The interaction of these plates will produce a variety of forms of the earth's surface. Steep mountains are one of the plate interaction results implying landslides, while sloping areas can experience flooding (Sadisun, 2008).

Apart from looking geographically, Indonesia is a country with many islands (archipelago) with a tropical climate. The existence of this climate will impact weather

that changes rapidly, resulting in natural disasters, such as landslides. Additionally, natural disasters can be caused by human activities that do not care about nature. Natural disasters are also natural activity processes that cause losses, both fatalities and property, so it is necessary to do good mitigation of these natural disasters. According to the Law of the Republic of Indonesia Number 24 of 2007 concerning Disaster Management, a disaster is an event that causes disturbance to living things, which causes losses.

Indonesia is dominated by mountainous relief with the potential for landslides. This landslide disaster occurs due to disturbance of soil stability, where this stability is controlled by the condition of the slope and soil conditions. Besides, the occurrence of landslides is caused by two factors, namely the driving factor and the triggering factor. Driving factors are those that affect the condition of the material composition, while triggering factors are those that can cause movement in the material (Faizana et al., 2015).

Landslide, according to (Effendi & Hariyanto, 2016), is a disturbance of the balance between components, which results in the movement of a mass that occurs from a place with high relief to a place with low relief. Fundamentally, this landslide disaster is influenced by topographical conditions and population density conditions. Landslide disaster is also a natural event whose impact can only be avoided and minimized (Haribulan et al., 2019). As (Sejati et al., 2020) stated, landslides are triggered by several factors, including high rainfall and high clay content in soil with little vegetation on steep land.

Consequently, the rainy season, which has a high intensity, will affect the occurrence of landslides on steep relief. Based on data from the National Disaster Management Agency (BNPB), landslides are disasters that often occur in the territory of Indonesia (BNPB, 2021).

From the data on natural disaster events in Indonesia in 2022 (Table 1), it can be denoted that landslides are a disaster that has a relatively large number of events, especially in 2022, with 183 landslides occurring. In this case, Java Island dominates the occurrence of landslides because the morphology of the mountains has steep slopes plus high rainfall. In addition, not only natural influences/climate changes, but influences that come from human intervention, such as massive forest clearing, excavation, and slope cutting, can also trigger landslides (Hadmoko et al., 2017).

Table 1. Data on natural disaster events in Indonesia in 2022 (BNPB Geoportal Indonesian Disaster Data, 2021)

Natural Disaster Events	Number of Events
Earthquake	5
Tidal waves and abrasion	8
Forest and land fires	44
Extreme weather	335
Flood	379
Landslide	183

Moreover, susceptibility is a condition where potential damage occurs in an area that has been predicted. Susceptible areas are those with a level of risk of natural disasters ranging from low, medium, and high levels. Determining landslide-prone areas in a region can be known by looking at physical conditions, such as slope, soil type, and rainfall. In addition, several activities determine areas prone to landslides. These activities include classifying several areas with the potential to be affected by landslides, such as the size of the level caused and activities to identify the source of the landslide disaster.

Therefore, disaster management is an effort to prevent natural disasters. In disaster management, it is necessary to have emergency response activities carried out before the occurrence of natural disasters and after the disasters (Achmad & Aidil, 2017). The disaster management process is divided into three stages: the mitigation stage (prevention, preparedness), evacuation (rescue), and rehabilitation (recovery) (Martini, 2011). According to Mareta (2018), in general, the disaster management cycle is an activity to reduce losses caused by natural disasters.

This research’s location is in Gunungkidul Regency, located in the Special Region of Yogyakarta (DIY) Province. Gunungkidul Regency has 18 sub-districts, of which six sub-districts are located at an altitude of 200–700 m above sea level. The sub-districts include Gedangsari, Patuk, Nglipar, Semin, Ngawen, and northern Ponjong sub-districts.

The number of landslides in Gunungkidul Regency from 2018–2022 can be seen in the following figure (see Fig. 1).

Table 2 describes the data on the occurrence of landslides in the last five years in Gunungkidul Regency. This disaster relatively occurs every year, with the highest number of events with 69 incidents in 2021, influenced by physical conditions in the form of mountains in the north and south. Soil types in Gunungkidul Regency are dominated by litosol, latosol, red Mediterranean, and black grumusol with volcanic parent rock formations, typhoon sediments, and lime as main material, while the topography of this area is divided into three parts, namely the northern zone, the middle zone, and the southern zone. High rainfall intensity predominates in the northern zone, while the central and southern zones have a late onset of rain.

By looking at the data on the occurrence of landslides and the condition of the area in Gunungkidul Regency, dominated by mountains in the north and south, it is necessary to carry out mitigation efforts so as not to cause casualties since the population in

Table 2. Data on landslide disaster events in Gunungkidul Regency (regional disaster management agency (BPBD) of Gunungkidul Regency, 2022)

Years	Number of Events
2022	6
2021	69
2020	57
2019	62
2018	31
Sum	225

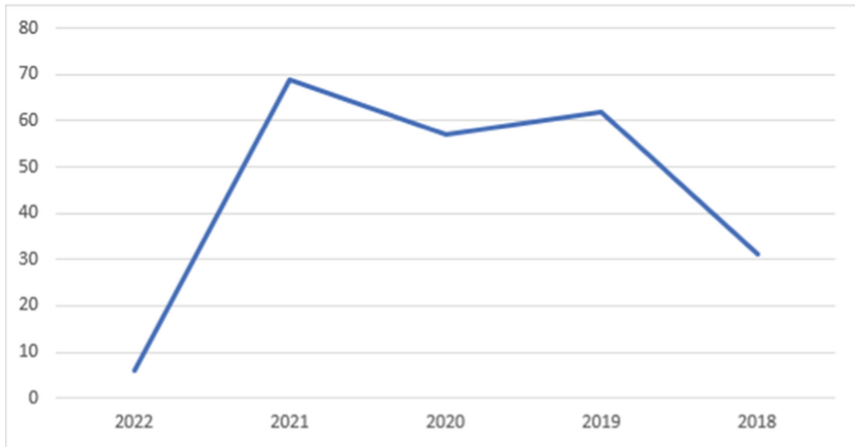


Fig. 1. Number of landslides in Gunungkidul Regency from 2018–2022

Gunungkidul Regency in 2021 reached 774,441 people. Some mitigation activities to reduce disaster risk include providing outreach/training to the community, especially for children, because they are more at risk than adults (Pahleviannur, 2019) about the dangers of landslides and urging the community to regulate spatial planning by paying attention to the environment. From this description, the objectives of this study are (1) to analyze the level of susceptibility and landslide-prone areas in Gunungkidul Regency and (2) to determine community social mitigation efforts in landslide-prone areas in Gunungkidul.

2 Materials and Method

This research used a descriptive method with a quantitative approach, referring to the landslide factor parameters. Overlay was also the method employed, which was previously scored. Materials utilized in this study included: a) Laptops and ArcGIS Software b) Rainfall shapefiles c) Slope shapefile d) Soil type shapefile e) Land use shapefiles f) Administrative boundary shapefile.

This scoring stage was carried out to give a score or value to each parameter to determine the level of ability (Table 7 and Table 8).

1. Rainfall

Rainfall is one of the factors that cause landslides. The greater the level of rainfall, the greater the rate of occurrence of landslides (Table 3).

2. Slope

Areas with a slope level will have the potential for landslides (Table 4).

3. Land Use

The land use factor is also very influential in landslide disasters since land use in areas with steep slopes must be correct (Table 5). If the land is used improperly, it will result in a disaster.

4. Type of Soil

Table 3. Classification of rainfall (Sugianti et al., 2014)

Rainfall	Score	Weight
<2,000 mm/year	1	3
2,000–2.500 mm/year	2	6
2,500–3,000 mm/year	3	9
>3,000 mm/year	4	12

Table 4. Slope classification (Hardianto et al., 2020)

Slope (%)	Information	Score	Weight
<8L	Flat	1	4
8–15	Sloping	2	8
15–30	Oblique	3	12
30–45	Somewhat Steep	4	16
>45	Steep	5	20

Table 5. Classification of land use (Taufik et al., 2012)

Land Use	Score	Weight
Swamp, Water Body	1	2
Shrub Thicket	2	4
Forest	3	6
Rice field, Field, Moor, Plantation	4	8
Settlement	5	10

The type of soil in an area also influences the occurrence of landslides. Several types of soil will break easily and be carried away by water when exposed to water (Table 6).

3 Results and Discussion

3.1 Land Unit

The use of land units aims to simplify the analysis. Making land unit maps used several parameters, including geomorphological maps, slope maps, soil type maps, and land use maps. From this map, an intersect overlay was performed, where each parameter would produce a land unit map. Then, an analysis per unit of land was carried out. The map of land units in Gunungkidul Regency can be seen in Fig. 2.

Table 6. Soil type classification (Effendi, 2002)

Soil Type	Score	Weight
Alluvial, Gleisol, Planosol, Hydromorphic Gray, Lateric Water	1	1
Latosol	2	2
Brown forest soil, Non calcic brown	3	3
Andosol, Lateric, Grumosol, Podsol, Podzolic	4	4
Regosol, Litosol, Renzina, Mediterranean	5	5

Table 7. Classification of landslide weighting for each parameter

Parameters	Weighting
Slope	4
Rainfall	3
Land Use	2
Soil Type	1

Table 8. Classification of landslide susceptibility

Class	Interval	Information
I	4–9	Low
II	9–14	Medium
III	14–19	High

Figure 2 illustrates the number of land units in Gunungkidul Regency, as many as 297 land units, where each land unit has different characteristics. Each land unit is displayed using a code. Each code has a meaning, such as K2 geomorphology, meaning the formation of karst hills; K5 represents karst alluvial plain; S8 and S9 indicate formations of monoclinical mountain and hill structural origin; soil type uses an abbreviation code for the soil type, such as the Lit code, which means latosol soil type; MedRend code signifies Mediterranean rendzina soil type; the slope of the slope employs Roman numerals, where I indicates the degree of slope of a gentle slope, II means the degree of slope of a flat slope, and V denotes the degree of slope of a steep slope. Meanwhile, land use uses abbreviated codes, such as pmk, meaning use of residential land and swf, indicating use of rice fields.

3.2 Landslide Susceptibility Level in Gunungkidul Regency

Susceptibility is a physical condition, in which all aspects of life and the environment are affected by natural disasters due to the low resilience of the community to the effects of

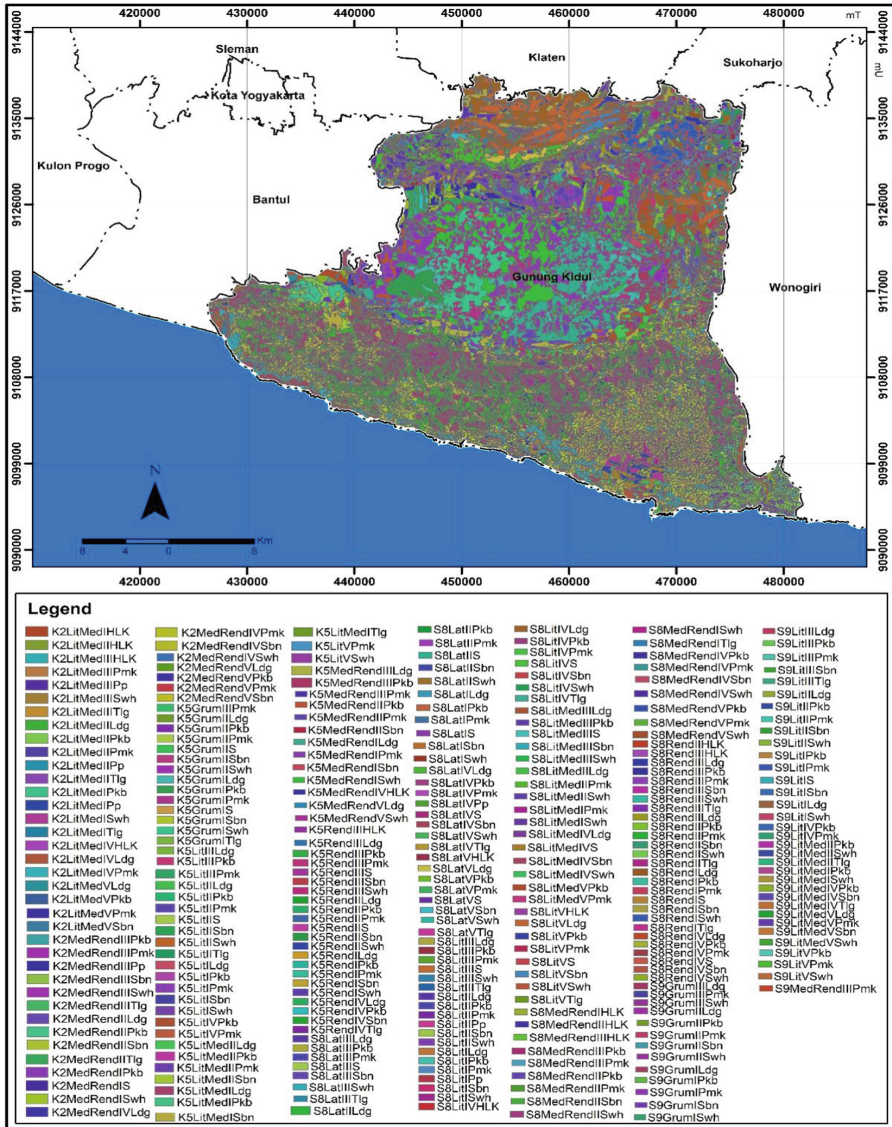


Fig. 2. Land unit map of Gunungkidul Regency

disasters (Husein et al., 2017). Susceptibility can also be interpreted as a characteristic of an area or region that reflects that area, including the category of susceptible or not prone to the possibility of causing a disaster.

The classification of landslide susceptibility was calculated using the formula and then produced an interval of 5. The scoring calculation for each parameter of the land unit was then added together to produce a total of different values. From that total value, it can be seen the level of landslide susceptibility. From the scoring results, the

level of landslide susceptibility of each land unit can also be identified, divided into three classifications: low, medium, and high. Low susceptibility was found in 34 land units, medium susceptibility was discovered in 225 land units, and high susceptibility was uncovered in 38 land units. Land units with high susceptibility are dominated by steep slope conditions, with high rainfall conditions, while land units with medium susceptibility are dominated by sloping slope conditions and moderate rainfall. Figure 3 shows a map of landslide susceptibility in Gunungkidul Regency.

Based on Fig. 3, it can be observed that there are three classifications of susceptibility in the study area. High susceptibility is more dominant in the northern part of Gunungkidul Regency, such as in Patuk Sub-district, Gedangsari Sub-district, Ngli-par Sub-district, Ngawen Sub-district, Semin Sub-district, and Ponjong Sub-district, whereas medium to low susceptibility is spread throughout almost all of Gunungkidul Regency. The area with low susceptibility was 570.73 km², medium susceptibility was 762.35 km², and high susceptibility was 152.28 km² (Table 9).

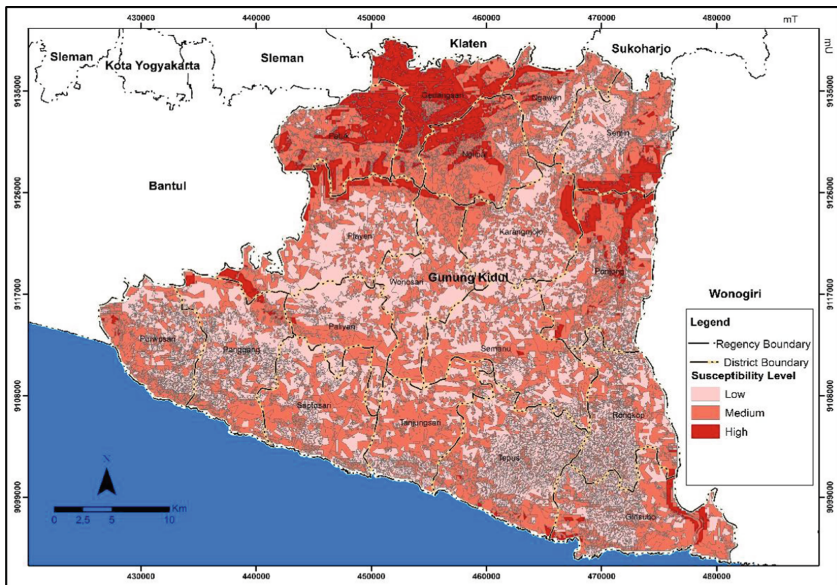


Fig. 3. Landslide susceptible map in Gunungkidul Regency in 2022

Table 9. Landslide susceptible area in Gunungkidul Regency

Number	Landslide Susceptibility Level	Area (km ²)	Percentage
1	Low	570.73	38.41%
2	Medium	762.35	51.35%
3	High	152.28	10.24%

3.3 Community Social Mitigation Efforts Based on Susceptibility Levels

Low Susceptibility Level

Based on the landslide susceptibility map, it can be seen that the low level of landslide susceptibility is spread in the central and southern zones and partly in the northern zone of Gunungkidul Regency. Low landslide susceptibility levels were found in 34 land units with a score of 4–9 and an area of 570.73 km² or 57,073 ha, which are most widely distributed in the original karst formations. It is influenced by the condition of the slopes which are flat and relatively low-moderate rainfall so that no landslides occur in this area. Social mitigation efforts in low susceptibility areas are actually only focused on education or providing understanding/adding insight from government agencies to the surrounding community (Suwaryo & Yuwono, 2017).

Medium Susceptibility Level

In Gunungkidul Regency, the medium landslide susceptibility level dominates 225 land units with an area of 762.35 km² and a score of 9–14. It is influenced by the condition of the steep slope and land use in the form of fields. A suitable social mitigation effort to reduce medium landslide susceptibility is to form a non-governmental disaster organization, whose members are local communities living in medium susceptibility areas to help disseminate information related to landslide disasters, which can occur at any time and be active in protecting the environment by carrying out spatial planning that takes into account the conditions of the surrounding environment. For example, people are not allowed to build houses on sloping areas and are asked to cultivate the land as best they can, such as planting trees or plants on bare land on sloping areas, creating terracing systems on paddy fields, and restoring forest functions on sloping areas (Mubekti & Alhasanah, 2008).

High Susceptibility Level

A high level of landslide susceptibility was found in 38 land units with an area of 152.28 km² and a score of 14–19, distributed dominantly in formations of structural origin; also, areas with a high susceptibility to landslides are caused by parameters that also have a high influence on the occurrence of landslides (Piyono & Mubarok, 2021). The research location was in a mountainous area with steep slopes. In addition, land use was not appropriate, such as settlements were still found on steep slopes with high landslide susceptibility; for soil types, it is dominated by red latosol and latosol soil types, where this soil type has a sandy and fine texture making it difficult to absorb water and unable to pass water quickly so that most landslides occur on latosol and latosol soil types (Baskoro & Tarigan, 2007). High susceptibility to landslides is caused by high rainfall intensity (Susanti et al., 2017), and in conditions of somewhat steep to steep slopes, the slope has a large influence on landslide events because the steeper the slope conditions, the greater the potential for landslides to occur (Meviana & Sari, 2017).

By looking at the data on landslide events in Gunungkidul Regency in 2021, which totaled 69, three sub-districts have a large number of landslides and have a high level of susceptibility, including Gedangsari Sub-district, Nglipar Sub-district, Patuk Sub-district, and Semin Sub-district. For this reason, social mitigation efforts need to be

carried out in areas with a high level of susceptibility, such as when the rainy season arrives, the government issues a warning that landslides can occur at any time so that people need to be reminded always to be on alert. Apart from that, the government is also advised to routinely check steep slopes so that a landslide retaining wall is installed; government/disaster agencies also provide locations for evacuation if landslides occur (Hermon, 2014). Moreover, it is necessary to prioritize the logistical needs of the displaced victims of the landslide disaster; the community and organizations are given training and understanding by the government regarding mitigation carried out before and after a disaster occurs so that public awareness is very much needed in landslide disaster mitigation.

The community is also expected to become aware of protecting nature by carrying out activities that trigger landslides, such as illegal cutting of trees on slopes, negatively impacting because depleted trees on slopes will inhibit water absorption. It includes the factors triggering landslides. Replanting should also be carried out with plants with strong roots and close the soil cracks immediately since it can cause infiltration when it rains; the water will enter the soil causing the soil to change its properties to become saturated, triggering landslides (Priyono et al., 2006).

4 Conclusions

The landslide susceptibility level in Gunungkidul Regency consists of three levels: low, medium, and high. The low-level scoring classification is 4–9 with a percentage of 38.41%, the medium-level scoring classification is 9–14 with a 51.35% percentage, and the high-level scoring classification is 14–19 with a 10.24% percentage. Sub-districts at a high level of landslide susceptibility and the highest number of landslides are in Patuk Sub-district, Gedangsari Sub-district, Nglipar Sub-district, and Semin Sub-district, and these areas are located in mountainous areas.

Mitigation efforts carried out in areas with a low level of susceptibility are providing education to the public about landslide disasters. For areas with a medium level of susceptibility, a non-governmental disaster organization is formed. For areas with a high level of susceptibility, the government always needs to be active in providing landslide disaster warnings, routinely checking on steep slopes, setting up evacuation posts, and providing logistical assistance to refugees and the community, along with organizations being given training and understanding by the government.

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