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MORALITY BEFORE KNOWLEDGE

Landslide vulnerability analysis Sarwodadi Village, Pejawaran District Banjarnegara Regency with scoring methods

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ABSTRACT

Background: Sarwodadi Village is one of the villages in Pejawaran District which is an area that has a high vulnerability to landslides. This study aims to determine the level of landslide vulnerability in Sarwodadi Village, Pejawaran District, Banjarnegara Regency. **Methods:** The data obtained is in the form of secondary data from related agencies. Data analysis was carried out aiming to determine the classification of the level of vulnerability to landslides. **Findings:** From the results of data analysis carried out using the scoring method which refers to the classification from Soil and Agro-climate Research/*Pusat Penelitian Tanah dan Agroklimat* (*Puslittanak*) it can be obtained the level of landslide vulnerability, point 1 enters the low class, point 2 enters the medium class, and point 3 enters the high class against disasters landslide. **Conclusion:** This research reveals that Sarwodadi Village has varying levels of vulnerability to landslides based on the scoring method. Point 1 is in the low vulnerability category, point 2 is in the medium vulnerability category, and point 3 is classified as having high vulnerability. These results provide a deeper understanding of the distribution of landslide vulnerability levels in the region, which can be the basis for more effective disaster mitigation planning. **Novelty/Originality:** This research offers a new contribution by integrating a scoring method based on classification from Soil and Agroclimate Research to evaluate the level of landslide vulnerability at a local scale. This approach allows detailed identification of vulnerabilities at specific points, providing important empirical data for risk mitigation planning in Sarwodadi Village. This area has not been studied much before in this context.

KEYWORDS: risk mitigation; scoring; vulnerability landslide.

1. Introduction

One natural phenomenon that can occur at any time and in any place is a natural disaster, which can result in the loss of both material and immaterial assets. Such disasters can cause damage to property and human lives as well as destruction to infrastructure, potentially impacting economic and social conditions. Unsustainable land-use patterns, such as converting forests into agricultural land, building settlements on steep slopes, and deforestation, can lead to natural disasters such as landslides.

The movement of soil and rocks from higher to lower elevations constitutes a landslide, which results from a process of imbalance. Ecosystems face pressure due to mountainous and hilly topography, high population density in hilly areas, and poor land and space utilization. The hazards posed by landslides require actions to minimize their consequences

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and prevent an increase in casualties. To analyze and address the unique characteristics of landslides in a specific area, it is crucial to identify and plan for landslide-prone areas. This provides an understanding of the current conditions of the region while considering the factors that trigger landslides.

One of the regencies in Central Java Province, Indonesia, is Banjarnegara. Banjarnegara Regency is located between 109° 29'–109° 45'50" East Longitude and 7° 12'–7° 31' South Latitude. The total area of Banjarnegara covers 106,970.997 hectares or 3.10% of the regency's absolute area. The Northern Zone of Banjarnegara, characterized by mountainous regions, is part of the Dieng Plateau and the North Serayu Mountains, forming a significant portion of Central Java's geographical distribution. This area features steep and sloping terrain. The northern border is shared with Pekalongan Regency and the North Serayu Mountains, with Mount Rogojembangan and Mount Prahu being two of the notable peaks in Batang. Some regions are developed as vacation destinations, while others host geothermal power plants.

Subdistricts in the Northern Zone include Kalibening, Pandanarum, Wanayasa, Pagentan, Pejawaran, Batur, Karangkobar, and Madukara. The Serayu Depression Zone, located in the central region, is relatively fertile. Subdistricts in this area include Banjarnegara, Ampelsari, Bawang, Purwanegara, Mandiraja, Purworejo Klampok, Susukan, Wanadadi, Banjarmangu, and Rakit. The Southern Zone, which plays a significant role in the South Serayu Mountains, consists of rugged areas with steep slopes, covering sub localities such as Pagedongan, Banjarnegara, Sigaluh, Mandiraja, Bawang, and Susukan.

Banjarnegara is one of the regions frequently affected by landslides, particularly in Pejawaran District, which is part of Banjarnegara. Located at an altitude of 1,150 meters above sea level, Pejawaran District boasts numerous attractive tourism potentials but is highly prone to landslides. Notable incidents include a landslide on April 20, 2022, and the most recent one on February 20, 2023. This vulnerability is largely due to the region's hilly and mountainous terrain, coupled with frequent rainfall. Therefore, it is crucial to investigate the landslide susceptibility in Pejawaran District, Banjarnegara Regency.

Risk management involves identifying the level of risk and introducing appropriate prevention methods to mitigate it. Additionally, risk mitigation can be achieved by reducing the likelihood of hazardous events, minimizing vulnerability and/or exposure to risk factors, or even eliminating all hazards and their impacts (Sultana & Tan, 2021). The success of mitigation and adaptation strategies for disaster risk reduction at the city level depends on early recognition of the driving factors of landslide risk and must be supported by the active participation of local stakeholders in risk management decision-making and local practices (Measham et al., 2011). Furthermore, adaptation strategies for disaster risk reduction should not solely focus on hazardous processes and structural protection efforts but also on reducing community and asset exposure and vulnerability in the long term (Pereira et al., 2020).

Based on the background of the problem outlined, this study aims to identify the level of landslide susceptibility in Sarwodadi Village, Pejawaran District, Banjarnegara Regency, to assess the extent to which landslides pose a threat to the area based on the influencing environmental factors. Additionally, this research focuses on creating a landslide hazard map for the village, which is expected to provide a visual representation of areas with varying levels of susceptibility, serving as a reference for disaster mitigation efforts. The scope of this research is limited to several aspects, namely the study location, which is confined to Sarwodadi Village, Pejawaran District, Banjarnegara Regency. The data analysis in this study employs a scoring method to determine the level of landslide susceptibility in the area. Additionally, this research involves the use of ArcGIS software as a tool to assist in creating a landslide hazard map for the region.

1.1 Landslide

Landslides refer to the movement of slope-forming rocks, debris, soil, or other mixed materials down or outward along a slope. The following explains how landslides occur. The weight of the soil increases as water seeps into it. Impermeable soil, which acts as a sliding surface, becomes slippery when water penetrates it, causing the weathered soil above to move along the slope (Kementerian ESDM, 2005).

1.2 Landslide occurrence process

The principle of landslides is that they occur when the driving forces on a slope exceed the resisting forces. Resisting forces are influenced by the strength of the rock and the density of the soil while driving forces are affected by the slope angle, water, load, and the specific weight of the soil and rock. Erfandi (2014) explains that the process of landslide formation can be described as follows: water infiltrating the soil increases its weight. If the water penetrates the impermeable layer that serves as a sliding plane, the soil becomes slippery, causing the weathered soil above it to move along and outward from the slope (Aryanti, 2015).

Landslides can be classified into six main types, namely translational slides, rotational slides, block movements, rockfalls, soil creep, and debris flows. In Indonesia, the most common types of landslides are translational and rotational slides, each with distinct characteristics and impacts.

Translational slides occur when soil material moves along relatively flat or undulating topography. While more common in areas with steep slopes, translational slides can also occur on flat terrains, particularly when early signs of instability, such as cracks or saturated soil, become evident. A combination of unstable soil conditions and external factors such as heavy rainfall or human activities often triggers this type of landslide.

Rotational slides are named for the rotational movement of soil material along a concave failure plane, causing the material to rotate as it displaces. This type of landslide is particularly hazardous in concave areas, especially if settlements are located on or around the affected area. The dangers of rotational slides are exacerbated by a lack of awareness among communities living in these high-risk zones.

Block movements involve the displacement of large blocks of rock or soil along relatively flat or gently sloping surfaces. Also referred to as block slides, these events often involve a significant amount of rock material. As a result, block movements pose severe risks to both humans and the surrounding environment, as the falling material can cause extensive structural damage and pose significant threats to human safety.

Rockfalls are characterized by the free fall of rocks from higher elevations to lower areas, typically occurring in steep hillsides or cliffs. This type of landslide is commonly found along coastal cliffs or in mountainous regions with sharp inclines. Rockfalls can be extremely dangerous, particularly when large boulders are involved, posing significant risks to infrastructure and communities located beneath the slopes.

Soil creep is a slow and almost imperceptible movement of soil over time. This type of landslide can cause gradual displacement of structures such as utility poles or buildings. Soil creep typically occurs in soils with fine particles but coarse structures. Due to its slow progression, it often goes unnoticed until the impacts become apparent. It is essential to use strong foundations to mitigate the risks associated with soil creep.

Debris flows occur when soil and other materials are mobilized by water flow. The velocity of the flow depends on slope steepness, water pressure, and the type of material involved. These flows typically follow valley paths and can extend over hundreds or even thousands of meters, particularly in volcanic areas. Debris flows are a significant threat due to their rapid movement and extensive reach. Each type of landslide has unique characteristics and requires tailored mitigation approaches to minimize its negative impacts on the environment and society.

1.3 Causes of landslides

Theoretically, landslides occur when the driving forces of the slope exceed the resisting forces. The strength of the rocks and soil density generally influence the resisting forces.

Meanwhile, water density, load, and the type of soil material affect the driving forces, which include the slope angle (Kementerian ESDM, 2005).

The causes of landslides are explained through various interacting factors, both external and internal. External factors include the removal of lateral or basal support, which often occurs due to riverbank cutting or road construction. When this support is lost, slopes become more susceptible to soil movement. Additionally, the addition of load at the upper edge of the slope, which can be caused by construction or soil dumping, also contributes to slope instability. Changes in relief or slope gradient due to tectonic activity, such as faulting or uplift, further exacerbate the situation (Alexander, 1992).

On the other hand, internal factors also play a significant role in triggering landslides. Natural soil weathering processes can weaken the soil structure, reducing its resistance to shear forces. Plant roots serve as stabilizers that help maintain soil integrity, and deforestation can significantly reduce this stability. Moreover, increased water infiltration into the soil, often caused by unplanned agricultural practices or poor drainage, can lead to soil saturation. This increases pore water pressure and the weight of the surface layer, which, in turn, can trigger a landslide. Lateral pressure generated by changes in conditions, such as freezing and thawing, can also contribute to soil movement (Alexander, 1992).

This research emphasizes that the causes of landslides are not singular but are the result of the interaction of various factors. There are short-term factors, such as vibrations from vehicles or earthquakes and heavy rainfall, which can directly trigger soil movement. On the other hand, long-term factors, such as weathering and gradual slope subsidence, can weaken the slope over time. By understanding the complexity of landslide causes, we can better plan mitigation measures and reduce the risks associated with this natural disaster (Alexander, 1992).

1.4 Scoring method (weighting)

The scoring method uses predetermined criteria to assign scores or values to each parameter. Each parameter has a different level of importance, and a weighting method is employed to determine the ability or characteristics of the land when the research object has multiple parameters. This classification is then used to calculate the total weighting. The formula for determining the landslide susceptibility class refers to the classification used in the study (Sholikhan et al., 2019).

2. Methods

2.1 Research location

The location of this research is in Pejawaran District, Banjarnegara Regency, specifically in Sarwodadi Village, which covers an area of 56.2 km^2. Pejawaran District is situated at an altitude of 1,150 meters above sea level.

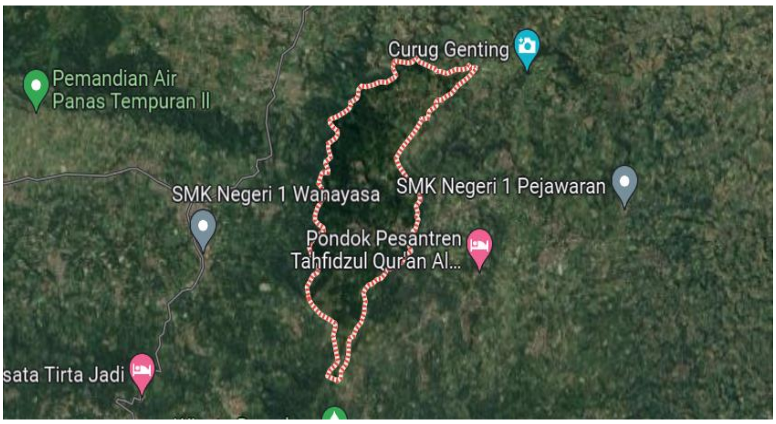

Fig. 1. Research location

2.2 Data and tools

The data required for this final project research includes several types of maps, such as rainfall maps, soil type maps, geological or rock type maps, land cover maps, and slope maps in Sarwodadi Village, Pejawaran District, Banjarnegara Regency, all of which are sourced from the Banjarnegara Regency BPS. In addition, this research requires various supporting tools, both hardware and software. The hardware used in this study includes a laptop or PC, while the necessary software includes a 64-bit Windows operating system, Microsoft Office, ArcGIS software, Clinometer software, and Avenza software, all of which will assist in data analysis and mapping.

2.3 Data analysis

The method used in this study is scoring for the five map parameters required. This method assigns point values to each parameter based on predefined criteria. The method applied is weighting, as each parameter has a different weight. In this case, determining the weight is related to the classification of the study. The following is the formula used to determine the landslide susceptibility class:

$$\text{Total score} = (0.3FCH)+(0.2FJB)+(0.2FKL)+(0.2FPL)+(0.1FJT) \quad \text{(Eq. 1)}$$

The variables used in this study are represented by different factors, each serving a specific purpose. FCH stands for the Rainfall Factor, which accounts for the impact of precipitation on the area being studied. FJB represents the Rock Type Factor, indicating how different rock types affect the environment or land's characteristics. FKL is the Slope Factor, which considers the influence of slope gradients on the land's attributes. FPL stands for the Land Cover Factor, reflecting how the type of land cover (such as vegetation or urban areas) influences the area. Lastly, FJT denotes the Soil Type Factor, which represents the effect of various soil types on the landscape. These factors collectively help in understanding the overall conditions and dynamics of the region under study.

After each parameter score is obtained, the score is then multiplied by the weight of each parameter. The results of these multiplications are then summed to obtain the final score. The author divides the vulnerability classes into three categories: low, moderate, and high. Below is the calculation used to determine the class intervals.

$$\text{Class interval} : \frac{\text{Highest score} - \text{Lowest score}}{\text{Classification Class}} \quad \text{(Eq. 2)}$$

(Sholikhan et al., 2019)

The landslide disaster scoring classification uses five key parameters: rainfall, rock type, slope, land cover, and soil type, each with different weight contributions. The highest influence comes from rainfall (30%), followed by rock type and slope (20% each), indicating their dominant role in landslide susceptibility.

Table 1. Landslide disaster scoring parameter classification table

Parameter	Size	Score	Total
Rainfall	>3000	5	30%
	2501-3000	4	
	2001-2500	3	
	1500-200	2	
	<15000	1	
Rock type	Volcanic Rock	3	20%
	Sedimentary Rock	2	
	Alluvial Stone	1	
Slope Slope	>45%	5	20%
	30-45%	4	

	15-30%	3	
	8-15%	2	
	<8%	1	
	Rice fields	5	
	Shrubs	4	
Land Cover	Forests and Plantations	3	10%
	City/settlement and airport	2	
	Ponds, Reservoirs and Waterways	1	
	Regosol, Litosol, and Organosol	5	
	Andosol, Laterite, and Grumosol	4	
Soil Type	Brown Forest Soil, Mediterranean	3	10
	Latosol	2	
	Alluvial, Planosol, Hydromorph	1	

(Sholikhan et al., 2019)

3. Results and Discussion

3.1 Map of landslide cause parameters

The object of this research is Sarwodadi Village, Pejawaran Subdistrict, Banjarnegara Regency. This study selected three points as research samples. The first point is situated at coordinates 364803, 9199015 in the UTM zone. The second point is located at coordinates 364617, 9199149, also within the UTM zone. Lastly, the third point is positioned at coordinates 364620, 9199387, again in the UTM zone. These points were chosen for their relevance to the research context and geographical distribution.

The process of creating a landslide susceptibility map requires several data inputs for overlay analysis to determine landslide vulnerability. This involves utilizing five parameters that have been discussed: rainfall, rock type, slope gradient, land cover, and soil type. The rainfall data obtained is in the form of a shapefile (SHP) covering Sarwodadi Village, Pejawaran Subdistrict. From the map data of Sarwodadi Village, one rainfall class level was identified, which is >3000 mm/year, indicating an exceptionally high rainfall level.

Soil types are generally categorized into three main types: volcanic rock, sedimentary rock, and alluvial soil. Volcanic rock is a type of igneous rock that forms when magma cools and solidifies, either as lava or frozen fragments on the Earth's surface. Sedimentary rock, on the other hand, is created through the deposition of materials that result from erosion, where various types of particles are deposited over time. Lastly, alluvial soil consists of fine, clay-like particles that are particularly capable of retaining rainwater, making it an important soil type for agricultural purposes. Therefore, paddy fields are well-suited for planting in floodplain areas. Alluvial soil is commonly found along riverbanks, river mouths, and floodplains. Overflowing floodwaters deposit sediments in these areas, forming alluvial soil.

The slope gradient in Banjarnegara Regency is divided into three classes, based on the region's slope inclination. The first slope class, which has a gradient ranging from 0 to 15%, covers 24.61% of the total area of Banjarnegara Regency. The second slope class, with a gradient between 15% and 40%, spans 45.04% of the total area. Finally, the third slope class, characterized by gradients greater than 40%, covers 30.35% of the total area of the regency.

Banjarnegara Regency covers an area of 106,970.997 hectares, approximately 3.29% of the total area of Central Java Province, which spans 3.25 million hectares. In Sarwodadi Village, Pejawaran Subdistrict, Banjarnegara Regency, there are four types of land use: residential areas, forests, shrubs, and rice fields. In Banjarnegara Regency, soil types are generally categorized into six classes, including Latosol, Alluvial, Andosol, Grumosol, and Regosol. Latosol soil is further classified into several subtypes, such as brown Latosol with brown Regosol, brown Latosol from volcanic sources, red-yellow Latosol, and dark brown Latosol. Alluvial soil, which can be grey, brown, or black, is prone to erosion due to its composition of clay and sand. It is typically found along major rivers, particularly in the central and downstream sections of the Serayu River. Andosol soil consists of volcanic and interbedded rocks and is highly erodible, ranging in color from brown to greyish-black. It is commonly found at the summit of Mount Slamet. Litosol soil, formed from sedimentary and igneous rocks, is highly prone to erosion and unsuitable for agricultural use. Grumosol soil, which is composed of clay and clumps, varies in color from grey to black. Although it is prone to erosion, it can be utilized for fertile land and plantations. The soil type found in the research area is classified as Latosol.

3.2 Scoring method

Referring to the research methodology outlined, the study involves processing data from five parameter maps: rainfall map, slope gradient map, rock type map, soil type map, and land use map, all of which are processed using ArcGIS 10.6 software. The determination of susceptibility levels is carried out by assigning weights to each parameter. The weighting proportions for each parameter vary.

3.2.1 Rainfall

According to the research results presented in Table 2, Sarwodadi Village experiences rainfall exceeding 3000 mm/year, which places it in the highest category for rainfall intensity. As a result, the village is assigned a score of 5, reflecting a significant potential for landslide risks associated with heavy rainfall. This high score underscores the critical role of rainfall in influencing landslide susceptibility in the region, suggesting that areas with similar rainfall patterns may face similar risks. The consistent high rainfall in Sarwodadi Village, as indicated by the score, further emphasizes the importance of considering rainfall as a primary factor in disaster risk assessment and management strategies.

Table 2. Rainfall parameter score

Point	Rainfall	Score
1	>3000 mm/year	5
2	>3000 mm/ year	5
3	>3000 mm/ year	5

3.2.2 Rock type

In the research site, as shown in Table 3, the only type of rock found is volcanic rock, which is assigned a score of 3. This score indicates a moderate level of vulnerability to landslides, as volcanic rock has a relatively higher stability compared to other rock types such as sedimentary or alluvial stone. The consistent presence of volcanic rock across the research site further suggests that the risk associated with rock type is uniform throughout the area, with a score of 3 indicating a moderate impact on the overall landslide risk assessment.

Table 3. Rock type parameter scores

Point	Rock type	Score
1	Volcanic rock	3
2	Volcanic rock	3
3	Volcanic rock	3

3.2.3 Slope slope

The slope gradient (Table 4) at the research site varies from gentle to steep, as the location is situated in a highland area. There are three slope classes as follows: (a) Point 1 (8-15%) receives a score of 2; (b) Point 2 (15-30%) receives a score of 3; (c) Point 3 (30-45%) receives a score of 4.

Table 4. Score *slope slope*

Point	Slope slope	Score
1	8–15%	2
2	15–30%	3
3	30–45%	4

3.2.4 Land cover

Based on the data in Table 5, land use at the research site consists of two main variations: forests and plantations, which are both assigned a score of 3, and shrubs, which receive a higher score of 4. The score of 3 for forests and plantations indicates a moderate level of land cover stability, while the score of 4 for shrubs suggests a slightly higher vulnerability to landslides due to the different types of vegetation cover. This distribution highlights the varying degrees of land cover's influence on landslide risk, with shrubs contributing to a higher susceptibility compared to more stable forested and planted areas.

Table 5. Land cover score

Point	Land cover	Score
1	Forests and Gardens	3
2	Shrubs	4
3	Shrubs	4

3.2.5 Soil type

According to Table 6, Sarwodadi Village has a uniform soil type across all three research locations, which is latosol. Each of these locations is assigned a score of 2, indicating a relatively lower susceptibility to landslides compared to other soil types such as regosol or andosol. The consistent presence of latosol throughout the study area suggests that soil type does not vary as a risk factor, and its moderate score reflects the stability it provides, although it still contributes to the overall landslide risk assessment.

Table 6. Soil type score

Point	Land cover	Score
1	Latosol	2
2	Latosol	2
3	Latosol	2

3.3 Landslide susceptibility map overlay

Table 7. Vulnerability class intervals

Interval score	Vulnerability class
2.9–3.3	Low
3.4–3.8	Middle
3.9–4.3	High

The creation of the landslide hazard map for Sarwodadi Village uses a scoring and weighting method based on five parameters sourced from Puslittanak. The calculation of class intervals is obtained from the final total score by subtracting the lowest total score from the highest total score and then dividing by 3. This is because the author divides the hazard levels into three classes.

Table 8. Landslide susceptibility level score

Point	FCH	FJB	FKL	FTL	FJT	Total score	Vulnerability class
1	1.5	0.6	0.4	0.6	0.2	3.3	Low
2	1.5	0.6	0.6	0.8	0.2	3.7	Middle
3	1.5	0.6	0.8	0.8	0.2	3.9	High

The results of the total score calculation and weighting yield a total score divided into three categories. These categories are high vulnerability at location 3, moderate vulnerability at location 2, and low vulnerability at location 1. The total scores for the landslide vulnerability map are shown Table 8.

3.4 Discussion

Tambunan et al. (2019) conducted a study titled Analysis of Landslide Disaster Vulnerability as Mitigation for Haarjawana Region, Lebak Regency, Banten Province. The objective of this study was to identify areas categorized into zones ranging from stable to unstable levels. The research utilized the SMORPH method, which is applied to determine the inclination tendency between the soil surface and the normal plane, and this method was used for data processing. The slope angle was calculated in degrees during the analysis. The study revealed that the review area consisted of fourteen landslide focus points classified into three categories: stable, alert, and unstable. Villages such as Sangkawangi, Mekarmanik, and Parakanbesi fell under the stable category. Meanwhile, landslides in the alert category occurred in the same villages, with some areas exhibiting unstable characteristics.

Wiranata et al. (2020) conducted a study titled *Analysis of Landslide Vulnerability on Slopes Using Particle Motion Graphs*. The research utilized Particle Motion Graphs generated through Geopsy software to produce visual data in the form of graphs, providing valuable insights for interpreting landslide vulnerability on a slope. The study results were obtained by processing data with Geopsy software, revealing distinct patterns. At higher elevations, the particle motion formed a southeast-to-west pattern. In contrast, at lower elevations, particularly on the lower or eastern side of the slope, the particle motion was predominantly omnidirectional. Omnidirectional particle movement was also observed in the mid-slope area. On the southern side of the slope, particle motion did not exhibit an omnidirectional pattern but instead formed specific directional patterns.

Ni'mah (2017) conducted a study on landslide hazards in Munjungan District, Trenggalek Regency, with the objective of determining the levels and distribution of landslide hazards in the area. The research employed descriptive and quantitative methods, utilizing numerical data to explain the observed issues or phenomena. The findings revealed that landslide hazard levels in Munjungan District were divided into two categories: low hazard, covering 96.40% of the total area, and moderate hazard, accounting for 3.60% of the total area. The distribution of landslide hazard levels was categorized into two classes, namely moderate and low. The low-hazard category, comprising 96.40% of the area, was distributed across nine villages: Ngulungwetan, Ngulungkulon, Sobo, Craken, Masaran, Besuk, Bangun, Tawing, and 21 villages in Bendoroto. Meanwhile, the moderate hazard category, representing 3.60% of the area, was concentrated in two villages: Karangtur and Munjungan.

There are five parameter factors that influence the occurrence of landslides. These factors include rainfall, rock-geological type, slope gradient, land cover, and soil type. BMKG (2016) argues that rainfall refers to the height of water that does not absorb, seep, or flow but rather accumulates in a rain gauge on a flat surface. One millimetre of rain means that one litre or one millimetre of rainwater can be contained in an area of one square meter on a flat surface. The intensity of rainfall is a measure of the amount of rain that falls in a given period. One of the most significant influences on landslide occurrences is rainfall. The soil layer will crack and become unstable due to the increased intensity of rainfall in a given area (Effendi, 2016).

According to the Indonesian Encyclopedia, the soil is a collection of rocks that leave natural materials and remnants of life forms, which appear in the Earth's outer layers due to weathering and occur over a long period. In Indonesia, various types of soil can be found, including: Organosol (Peat Soil/Natural Soil), alluvial, regosol, litosol, latosol, grumosol, red-yellow podzol, podzol, andosol, Mediterranean red-yellow, dark hodmurf (gleisol), and rice paddy soil. Soil characteristics play a crucial role in determining the risk of landslides, with various soil-related factors interacting to influence slope stability. One key aspect is soil texture. Soils consisting of clay, silt, and sand have different capacities to absorb and retain water. For example, clay soil has a high absorption capacity, but when saturated with water, it can become heavy, thereby increasing the risk of landslides. In the study area, the dominant soil texture was sandy clay, which allows water to drain quickly but can still pose a risk when the soil becomes saturated (Arsyad et al., 2018).

The water content in the soil also greatly affects its stability. High rainfall can cause the soil to become saturated, resulting in a decrease in soil shear strength. When the soil becomes saturated, it loses its bearing capacity, and if there is insufficient vegetation to hold the soil in place, the potential for landslides increases. Soil situated above impermeable layers, for example, will retain water, creating ideal conditions for landslides, especially in areas with steep slopes.

In addition, the depth of the soil layer plays an important role in slope stability. Deeper soils tend to have more plant roots that can help stabilize the soil. In contrast, shallow soils may not have enough root support, making them more susceptible to landslides. Soil structure is also a critical factor. Well-structured soil with stable aggregates can enhance soil-bearing capacity. However, if the soil structure is damaged or compacted, its stability will decrease, and the risk of landslides will increase. Water-impermeable rocks, such as andesite and breccia, can act as slip surfaces, triggering landslides when the soil above becomes saturated (Arsyad et al., 2018).

The presence of vegetation above the soil is also highly influential. Vegetation serves as a binding agent, helping to stabilize the soil. Plants with strong roots can reduce erosion and hold the soil in place, thereby decreasing the risk of landslides. Studies have shown that areas with good vegetation cover have a lower potential for landslides. Therefore, understanding soil characteristics and their interactions with other factors is crucial for developing effective mitigation strategies to reduce landslide risks, particularly in steep slope areas (Arsyad et al., 2018).

Slope steepness is the ratio of vertical distance (elevation) to horizontal distance (horizontal length) (Çellek, 2020; Maleki et al., 2023). Effendi (2016), the degree or percentage is used to describe the slope. A 10% slope is formed by a 10-meter elevation difference between two points that are 100 meters apart horizontally. A 100% incline is equivalent to a 45° slope. Surface runoff moves faster with steeper slopes, in addition to the increased volume. Furthermore, the number of soil particles transported down the hill increases as the slope steepness rises (Mappatarai et al., 2024). One of the main factors influencing landslides is the slope gradient. This study recorded that slopes with steep gradients, ranging from 62.4% to 100%, have a greater potential for landslides. This is consistent with the view of Sumiyatinah & Yohanes (2000), who stated that landslides generally occur in sloped areas, where the steeper the slope, the higher the potential for a landslide. Furthermore, the types of soil found in the study area, such as clay and sand, also contribute to the stability of the soil. Soils that are easily permeable to water can become heavier during rainfall, thereby increasing the risk of landslides (Arsyad et al., 2018).

The Earth is defined as a unified physical environment consisting of land, water, climate, vegetation, and all human activities that affect its development. Based on this definition, land areas are classified according to common usage types, such as agricultural land, residential land, industrial land, and others. Land use is related to human activities in specific rural areas. Typically, land cover data can be obtained directly through remote sensing, while land cover itself may not always be easily interpreted from the land cover alone. The factors influencing soil movement include the geological structure at the research location. The types of rocks present can affect the strength of the soil itself, as each type of rock has a different influence on the soil's stability.

According to Nandi (2007), landslides have significant effects on human life, animals, plants, and environmental balance (Aryanti, 2015). The impacts of landslides can be categorized into those affecting human life and the environment. In terms of human life, landslides can lead to the tragic loss of lives, causing casualties. Infrastructure such as roads, bridges, and other essential facilities can suffer severe damage, disrupting the normal functioning of society. Additionally, buildings such as homes, offices, and places of worship may be destroyed, displacing people and causing economic losses. The occurrence of a landslide can also hinder human activities, further affecting the surrounding communities and government operations.

Regarding the environment, landslides contribute to the destruction of land, leading to the loss of fertile soil and vegetation that serves as ground cover. This destruction can disrupt the balance of ecosystems, causing long-term damage to biodiversity. Furthermore, landslides can result in the formation of critical lands, which decreases groundwater reserves, exacerbating water scarcity issues.

4. Conclusions

Based on the results of this research, the author concludes that Sarwodadi Village, Pejawaran District, Banjarnegara Regency, has three levels of landslide vulnerability. Point 1 produces a score of 3.3, which indicates a low level of vulnerability; point 2 produces a score of 3.7, which indicates a moderate level of vulnerability; and point 3 produces a score of 3.9, which indicates a high level of vulnerability. The landslide vulnerability map of Sarwodadi Village also shows that most of the area is marked in red and orange, which indicates high and medium levels of vulnerability. In contrast, a small part of the area is marked in green, which means a low level of vulnerability. To reduce the danger of landslides, what can be done to reduce the level of possibility of landslides is for the community to be more able to protect the surrounding environment; perhaps one can do this by planting trees with strong roots according to the conditions required.

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