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LANDSLIDE RISK ANALYSIS IN KELING DISTRICT, JEPARA REGENCY, JAWA TENGAH PROVINCE, INDONESIA

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ABSTRACT

Keling District, Jepara Regency conducted a landslide risk analysis to determine the area's susceptibility and develop workable mitigation solutions. The analytical procedure includes threat identification, vulnerability and capacity evaluation, and methodology-based risk determination. The data used were topography, soil and rock types, joints and faults, rainfall, land use, and the frequency of disasters. Landslide-prone areas were mapped, and contributing factors were evaluated through the application of the VCA (Vulnerability Capacity Analysis) matrix multiplication approach. The findings demonstrate that population growth, deforestation, clearance of additional land, excessive rainfall, erosion-prone soil and rock conditions, and uncontrolled human activities contribute to the likelihood of landslides in Keling District. Building landslide infrastructure, raising public awareness, and closely monitoring changes in land use are all advised mitigating techniques. This strategy's implementation is anticipated to lower the likelihood of landslides and improve readiness for potential natural disasters.

A. INTRODUCTION

Landslides are one of the natural disasters that frequently occur in Indonesia and can cause significant damage and loss to local communities. Natural elements, including seismic activity, heavy rainfall, geological structure, and regional topography, are frequently the cause of landslides (Yogo Utomo & Widiatmaka, 2014); (Hasibuan & Rahayu, 2017). However, according to (Priyono & Priyana, 2006), unmanaged land use can also make landslides more likely. A number of elements, including vegetation, topography, distance from faults, precipitation, and geology, are linked to landslide incidents, according to (Wang et al., 2017).

One Indonesian region that is susceptible to landslides is the Keling District area of Jepara Regency. The primary causes of the high risk of landslides in this area include steep topography, landslide-prone rock types, and significant rainfall (Rohman et al., 2017). In addition, the risk of landslides in Keling District is rising due to unmanaged landuse changes and population increase. Since landslides have historically resulted in fatalities and

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the displacement of inhabitants, the damages incurred include harm to houses, infrastructure, and educational facilities. When disasters strike, there are higher risks and losses since there is less knowledge available about landslide vulnerability and there are fewer early warning systems in place (Noor, 2014).

Effective mitigation measures, which are predicated on precise risk assessment, including assessment of disaster-prone locations, are required to lessen the impact of landslides. Spatial landslide risk analysis can be done with the aid of Geographic Information Systems (Taruna et al., 2021). In order to identify locations that are susceptible to landslides and develop effective mitigation techniques, precise geospatial data can be retrieved and evaluated using GIS (Rahmad & Nurman, 2018).

In order to identify sites in Keling District, that are susceptible to landslides, a landslide risk analysis is required. The information gathered from this study can serve as the foundation for creating mitigation plans (Faizana et al., 2015).

B. METHOD

a. Hazard Assessment of Landslide Disasters

Table 1 displays the weighting of each parameter used to generate landslide threat maps.

Table 1. Hazard Assessment of Landslide Disasters

Hazard Parameters		Class	Score	Weight (%)
Presipitation (mm)	2000-2500	Low	1	30
	2501-3000	Medium	2	
	3001-3500	High	3	
	>3500	Very high	4	
Rock type	Alluvium	Low	1	20
	Sedimentary rock	Medium	2	
	Volkanic rock	High	3	
Slope	0-7%	Flat	1	15
	7-15%	Sloping	2	
	16-40%	Steep	3	
	>40%	Very steep	4	
Soil type	Alluvial	Not sensitive	1	20
	Yellowish Latosol Association	Quite sensitive	2	
	Brown Latosol	Less sensitive	3	
	Andosol, Podsolic	Sensitive	4	
	Regosol, Litosol	Very sensitive	5	
Join	Found		2	5
	None		1	
Land use	Swamp, pond	Low	1	10
	Brush, Shrubs, Grass	A bit low	2	
	Forest	Medium	3	
	Moor, Paddy field, Crop land, Groves	High	4	
	Residential, Build-up land	Very high	5	

Sources: (Faizana et al., 2015); (Yuniarta et al., 2015);(Multi Astuti et al., 2016); (G. Bayuaji et al., 2016); (Krisnandi et al., 2021); (Taufik et al., 2016); (Rahmad & Nurman, 2018); processed

The climatology, rock type, slope slope, soil type, existence of faults/joints, and land use are among the connected parameters taken into account while assessing the hazard level of landslides. Variables that cause landslide disasters are given a weight according to their degree of effect in the landslide threat component. Every parameter has a unique score based on its individual assessment. Next, the data is converted from polygon to raster form and weighted using the weighted overlay method

b. Vulnerability Assessment for Landslide Disasters

Data regarding the degree of exposure serves as a reference for determining the degree of susceptibility.

Table 2. Vulnerability Assessment for Landslide Disasters

	Vulnerability Parameters	Weight (%)	Vulnerability Classes		
			Low	Medium	High
Social	Population density	60	<903 person/km^2	903-1607 person/km^2	>1607 person/km^2
	Sex ratio	20	>100	100-102	<102
	Percentage of population aged 0-9 years	10	<765 person	765-1203 person	>1203 person
	Percentage of population aged +65 years	10	<354 person	354-533 person	>533 person
Physical	Number of educational facilities	25	<10	10-17	>17
	Number of worship facilities	25	<31	33-47	>47
	Percentage of network telecommunication	25	<7,5%	7,5-14,8%	>14,8%
	Percentage of build-up area	25	<15%	15-30%	>30%
Economy	Agricultural land area	25	<138 ha	138-259 ha	>259 ha
	Number of Industriaies	25	<58	58-78	>78
	Number of economic means	25	<178	178-289	>289
	Percentage of work population	25	<8%	8-10%	>10%
Environment	Moor area	33.3	<259 ha	259-514 ha	>514 ha
	Groves area	33.3	<491 ha	491-982 ha	982 ha
	Forest area	33.3	>998 ha	499-998 ha	<499 ha

Source : (G. Bayuaji et al., 2016); (Faizana et al., 2015), processed

This exposure comprises an estimate of losses in terms of the economy, physical environment, and social aspects of human life, as well as the exposed population index (BNPB, 2014). The index class is determined using the parameters utilized in the research (Table 2). The following equation (BNPB, 2014) is used to calculate the vulnerability value to the hazard of landslides.

*Vulnerability = (0.4*social vulnerability score) + (0.25*economic vulnerability score) + (0.25*physical vulnerability score) + (0.1*environmental vulnerability score)* ……(1)

c. Capacity Assessment for Landslide Disasters

Through a review of the literature and conversations with regional disaster management stakeholders, capacity was evaluated (BNPB, 2014). In landslide disasters, capacity is determined by five parameters: Number of health personnel, number of health facilities, disaster socialization, support, and disaster preparedness initiatives. Table 3 displays the weighting of each at the capacity map. The following formula can calculate the capacity value for landslide risk.

*Capacity = (0.2*score of number of health workers) + (0.2*score of number of health facilities) + (0.2*score of disaster outreach) + (0.2*score of obtaining aid) + (0.2*score of anticipatory efforts disaster)* ……(2)

Table 3. Capacity Assessment for Landslide Disasters

Capacity Parameters	Capacity Classes			
	Weight (%)	Low	Medium	High
Number of health workers	20	<5 person	5-10 person	>10 person
Number of health facilities	20	<6	6-9	>9
Disaster socialization	20	none	-	found
Obtaining assistance	20	none	-	found
Disaster anticipation effort	20	none	-	found

Source : (G. Bayuaji et al., 2016); (Faizana et al., 2015); processed

d. An Assessment of the Landslide Risk

The risk of a landslide disaster is determined by combining the Hazard, Vulnerability, and Capacity variables. The VCA (Vulnerability Capability Analysis) matrix multiplication approach, as shown in Table 4, is then used to calculate scores and categorize the outcomes of landslide hazard, vulnerability, and capacity in the context of analyzing the risk of a landslide disaster.

Table 4. VCA Matrix Multiplication

V/C		Capacity (C)		
		High	Medium	Low
Vulnerability (V)	Low	Low	Low	Medium
	Medium	Low	Medium	High
	High	Medium	High	High

H*V/C		V/C		
		Low	Medium	High
Hazard (H)	Low	Low	Low	Medium
	Medium	Low	Medium	High
	High	Medium	High	High

Source : (Faizana et al., 2015)

: Low classes : Medium classes : High classes

For the purpose of disaster mitigation, the developed land map and the outcomes of the disaster risk mapping are then merged. In order to minimize the losses resulting from a disaster, it is necessary to promptly identify the areas that require mitigation efforts before anything else.

C. RESULT AND DISCUSSION

C.1. RESULT

a. Hazard of Landslides

Figure 1a displays the findings of the examination of the landslide hazard in Keling District. The criteria for a high landslide hazard in Keling District are 7,606.81 Ha or 60% of the territory; a medium landslide hazard is 4,403 Ha or 35% of the area; and a low landslide hazard is 653.38 Ha or 5% of the area. According to the survey data, the road's cutting of the slope was the primary cause of the landslide location.

Dry land is safer than mixed plantations because the soil has a high permeability, which allows water to soak fast, loosens the soil structure, and increases the risk of landslides. Soil with high permeability increases groundwater pressure and reduces soil-bearing capacity, increasing the risk of landslides (Priyono & Priyana, 2006).

b.Vulnerability to Landslide Disasters

Exposure information is the indicator used to determine vulnerability level. Exposure data is derived from the exposed (social) population index, which is related to human life, as well as the economic, physical, and environmental loss indexes. Figure 1b presents a summary of landslide catastrophe vulnerability evaluations based on exposure data.

b.1. Social Vulnerability

Because of unsuitable development, land change, and human activity, landslides can become more frequent in areas with high population densities. Women are typically more susceptible, which is why the sex ratio is employed. It is believed that older people and children are more susceptible to the effects of disasters. Kelet Village is classified as having a high social vulnerability index, but the villages of Klepu, Keling, and Bumiharjo have moderate social vulnerability. The villages of Tempur, Damarwulan, Kunir, Watuaji, Tunahan, Kaligarang, Gelang, and Jlegong were deemed to have low social vulnerability.

b.2. Physical Vulnerability

The amount of educational and religious places of worship, as well as the percentage of telecommunications networks, all have an impact on landslide risk. The location of schools and houses of worship in landslide-prone locations raises the risk, whereas selecting a safe location and building quality can give better protection. Effective evacuation

capabilities are also critical in coping with landslides.

In addition, the percentage of land developed influences the danger of landslides. Construction in landslide-prone locations can enhance danger by disrupting slope stability. High residential density on developed terrain can also enhance the likelihood of landslides. Buildings and infrastructure constructed without sufficient engineering considerations might exacerbate situations. Damarwulan, Tunahan, Kelet, and Bumiharjo villages have a high physical vulnerability, Keling Village has a medium vulnerability, while Tempur, Kunir, Watuaji, Klepu, Kaligarang, Gelang, and Jlegong villages have low vulnerability.

b.3. Economic Vulnerability

Although trade and services have no direct impact on landslide risk, their rise can result in changes in land use that enhance landslide risk. Economic vulnerability is also tied to how many individuals lose their jobs as a result of a disaster. Relocating residents to safer locations may also be a possibility if there is a significant loss of livelihood.

Data on the number of working residents and the village's economic vulnerability index are used to assess hazards and design mitigation strategies. Villages with a high economic risk index, such as Damarwulan and Kelet, need special attention in mitigation activities. Meanwhile, settlements with minimal economic vulnerability, such as Tempur, Kunir, Watuaji, Klepu, Kaligarang, Keling, Gelang, and Jlegong, may be less vulnerable to landslides, but they still need to be monitored and mitigated properly.

b.4. Environmental Vulnerability

The presence of moorlands, woodlands, and gardens is a key indicator of environmental risk. Moorland, despite being in the lowlands, can enhance the risk of landslides, particularly in sloping terrain or near rivers, especially during periods of heavy rainfall. Unsustainable agriculture methods can amplify these hazards (Wicaksono & Khafid, 2022).

Villages in Keling District are classed according to their environmental vulnerability index, with Tempur and Bumiharjo Villages in the high category and Damarwulan Village in the medium category. Other settlements are categorized as low vulnerability.

According to Figure 1b, Damarwulan, Tunahan, and Keling Villages are in the medium disaster vulnerability category, while Tempur, Kunir, Watuaji, Klepu, Kaligarang, Gelang and Jlegong Villages are in the low disaster vulnerability category. Kelet Village and Bumiharjo Village are considered highly vulnerable.

c. Landslide Disaster Capacity

Disaster capacity plays a vital role in Keling District's disaster preparedness

measures. Disaster outreach is an important endeavour in disaster prevention to raise public awareness, comprehension, and preparedness for the risk of landslides.

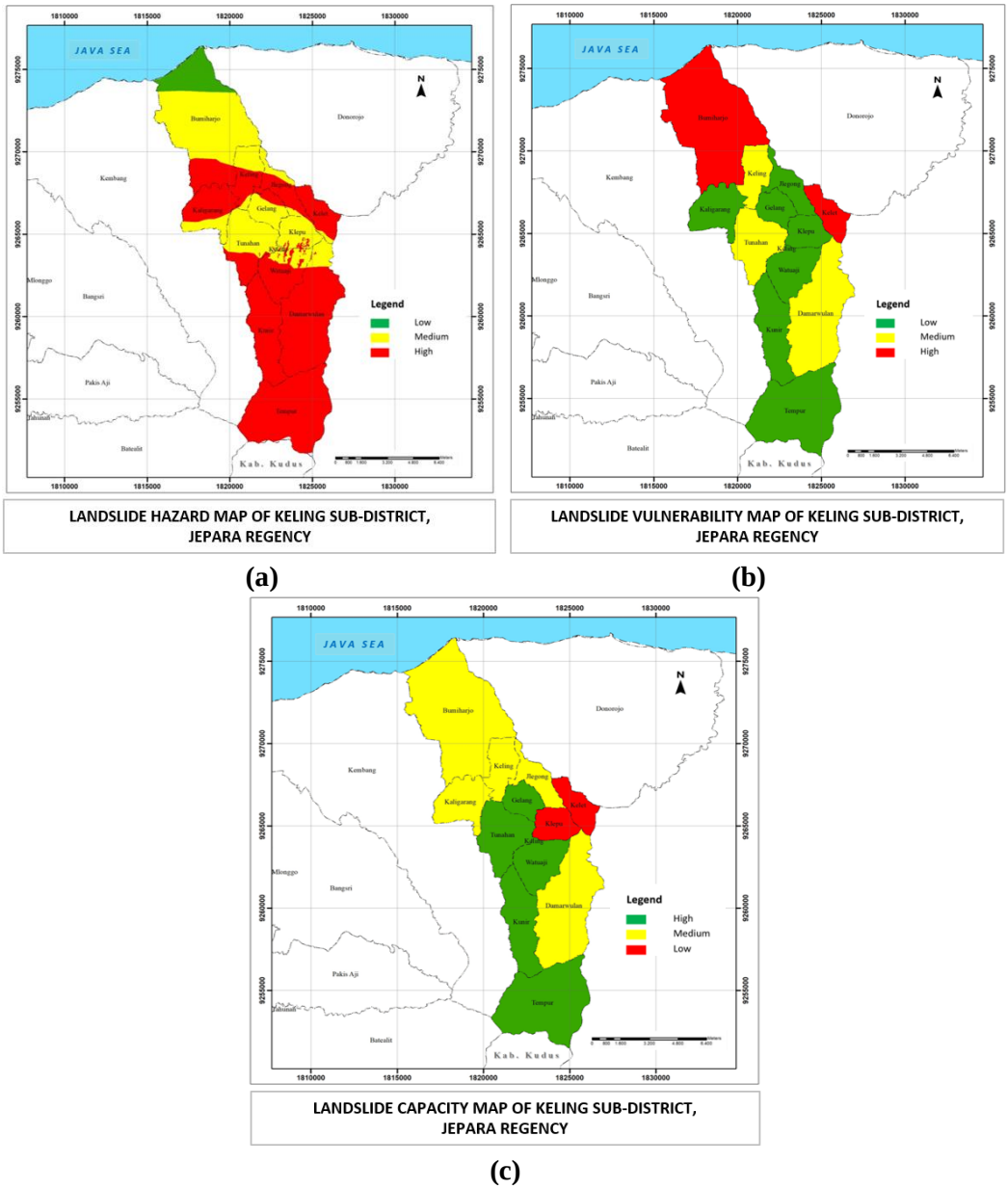

Figure 1. (a) Landslide Hazard Map, (b) Landslide Vulnerability Map, (c) Landslide Capacity Map of Keling Sub-District, Jepara Regency. Source: Analysis results, 2023

Junaidi (2018) emphasized the importance of understanding and knowledge in lowering the risk of landslides. This is because the community can address the repercussions of landslides by recognizing the conditions and features of those that occur, as well as knowing how to deal with and avoid them.

Disaster anticipation measures in Keling District are carried out under the Disaster Resilient Village program, which has classified two villages as disaster resilient: Tempur Village and Kunir Village. This initiative is still being developed in order to reduce disaster risk, but it will require additional resources such as manpower and medical facilities. According to the analysis, the villages that have high disaster capacity are Tempur, Kunir, Watuaji, Tunahan, and Gelang, while the villages with weak capacity are Klepu and Kelet (Figure 1c).

C.2. DISCUSSION

a. Landslide Disaster Risk

The landslide risk map in Kelet District, Jepara Regency, shown in Figure 2, is generated from an analysis of hazard, vulnerability and capacity mapping using the previously mentioned methods.

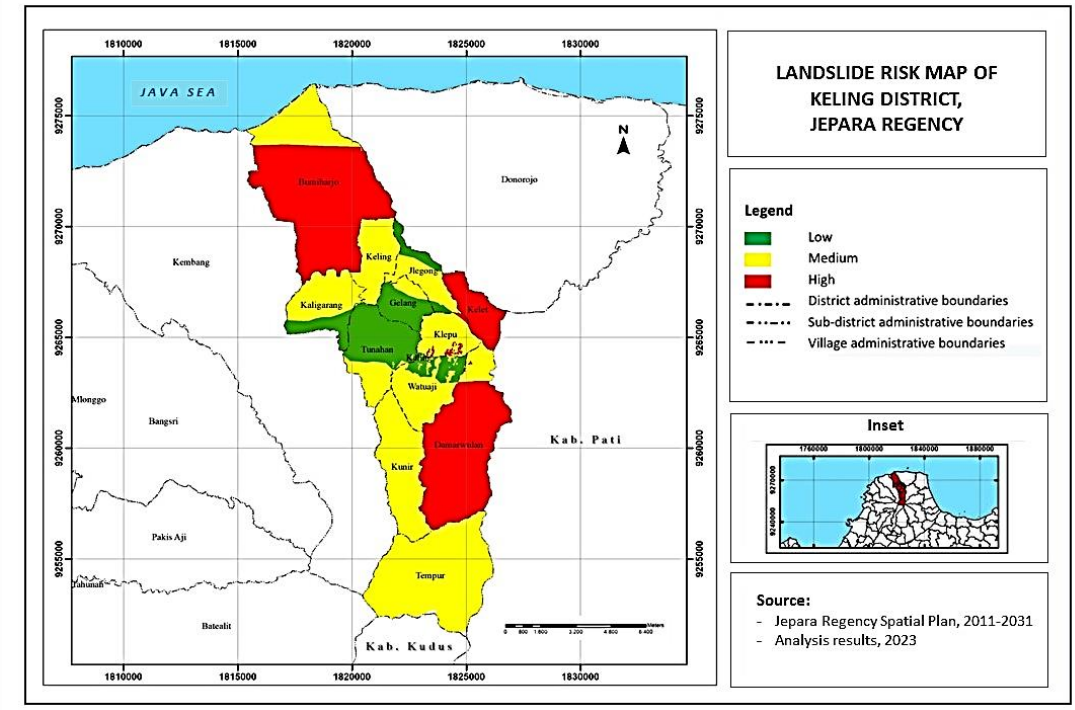

Figure 2. Landslide Risk Map of Keling District, Jepara Regency
Source: Analysis results, 2023

According to the assessment results, Bumiharjo Village has a high risk of landslides, with an area of 2,442.52 hectares. Damarwulan Village covers 1,794.48 hectares; Kelet Village comprises 431.67 hectares; and Klepu Village covers 35.32 hectares.

Several factors raise the risk of landslides in locations with similar features. One is that soil types like andosol and latosol are prone to erosion, whereas volcanic rocks with high weathering rates increase the risk of landslides. This is in line with (Robbi et al., 2022) research, which found that

volcanic soil with a loose texture is prone to surface flow.

The steep slope further heightens the potential of landslides. Large slopes increase the downward force acting on the slope (Sholikhan et al., 2019), which can affect the occurrence of landslides (Krisnandi et al., 2021); (Yusrina Ramadhani & Lukito, 2021). Another cause is heavy rainfall, which can exacerbate slope conditions, and the presence of built-up terrain raises the likelihood of landslidesIn addition to physical considerations, moderate to high levels of catastrophe sensitivity are important to low, reflecting the region's ability to predict and mitigate the consequences of landslides.

Landslide risk assessment is important for risk management and loss–damage reduction (Ahmed & Dua, 2023). Disaster risk assessment also takes into account how well communities or villages are prepared to deal with the possibility of landslides.

b. Efforts to Mitigate Landslide Hazard

The key reason contributing to Keling District's landslide risk is the significant hazard of landslides. Up to 60% of its area is classed as a high landslide threat, signifying a large risk of landslides endangering populations and infrastructure. This landslide hazard has increased casualties and considerable material damage disrupted transit lines and caused significant economic losses.

b.1. Landslide Mitigation Efforts Related to Social Vulnerability

High population density increases the danger of societal susceptibility to landslides, which can result in greater loss of life (Kasiyanchuk & Shtohryn, 2021). To lessen vulnerability to population density-related disasters, pre-disaster actions that can be explored include limiting population density through settlement policies that control population dispersal. To control population growth in densely populated areas, particularly Kelet Village, development restrictions and family planning programs are put in place. New jobs are being created in less densely populated areas to influence population movement, as is the building of infrastructure like as roads, public transit, and health and education facilities in underdeveloped areas.

To reduce vulnerability related to sex ratio, measures that can be considered are: (1) Increase women's awareness and well-being through empowerment programs. (2) Inclusive local economic development to create equitable employment for women and men and reduce economic pressures that encourage male migration, thereby improving the sex ratio. (3) Public education campaigns on gender equality and women's rights. (4) Family planning

programs and access to reproductive health services to help families make informed decisions about the number of children and their age gap.

The high number of children in Bumiharjo, Kelet, Tunahan, and Damarwulan villages, it needs to be recognized that this situation can increase social vulnerability to landslides. Children are often among the most vulnerable groups to the effects of natural disasters due to physical limitations, frailty, and dependence on adults.

To reduce children's vulnerability to disasters, steps that can be taken in advance are: (1) Ensure easy access to reproductive health services to control the birth rate. (2) Conduct awareness campaigns on the benefits of family planning and the impact of high birthfall. (3) Educate children about disaster risk and safety and involve schools in emergency planning exercises. (4) Integrate the needs of children in evacuation and protection plans, including safe evacuation routes.

Meanwhile, regarding the high number of elderly people in Bumiharjo, Tunahan, and Damarwulan villages, this situation can also increase social vulnerability to landslides because the elderly are often a vulnerable group in the context of natural disasters. They are vulnerable because they have physical limitations, mobility, and dependence on others for care and assistance.

Several measures can be taken to reduce vulnerabilities involving the elderly before a disaster strikes. (1) Providing education and counselling to the elderly about landslide risk, preventive measures, and emergency response plans can increase their awareness. (2) Make special emergency plans for the elderly in landslide-prone areas, including safe evacuation routes and evacuation locations close to health facilities. (3) Encourage parents to have emergency supplies and access early warning systems. (4) Establish a health referral system and care accessible to the elderly, including mental health services and psychosocial support.

b.2. Landslide Mitigation Efforts Related to Physical Vulnerability

The existence of a high number of educational facilities in Bumiharjo and Kelet villages actually does not directly cause the level of social vulnerability to landslides to be high. On the contrary, the existence of adequate educational infrastructure should help increase public awareness and preparedness for disasters so as to reduce social vulnerability.

Disaster education should be incorporated into the curriculum of schools in the region to increase public knowledge and awareness of landslide hazards. Each school should also have a detailed emergency plan, including evacuation procedures and safe gathering

points. (Ahmed & Dua, 2023) mentioned that school buildings must be built by considering the safety factor of potential landslides and earthquake-resistant construction. Schools can act as information and preparedness centres by organizing disaster training, disseminating prevention information, and facilitating disaster drills.

Worship facilities are important in the social and cultural infrastructure of communities and are usually not directly related to landslide risk. The existence of worship facilities in Kelet, Tunahan, and Damarwulan villages indirectly increases vulnerability to landslides. This is because the number of worship facilities can reflect the population density in the region. In addition, the risk of landslides can increase if the land is used incorrectly, such as development on steep slopes or excessive soil compaction.

To reduce vulnerability to landslides around worship facilities, infrastructure maintenance, vegetation management, and disaster mitigation strengthening are needed. This includes routine repairs, reforestation to protect soil, installation of early warning systems, and safety training for attendees and officers. Community participation is also important through cooperation in the mitigation process.

The extensive telecommunication networks in Kelet, Keling and Tunahan villages show a high level of connectivity. Such infrastructure development can also increase physical vulnerability to landslides indirectly through several means, such as large land use, excavation, and planting of structures that destabilize slopes and improper construction waste management.

Some steps that can be taken to reduce the negative impact of telecommunications infrastructure development on landslide risk include strengthening telecommunication tower structures, integrating landslide risk considerations in spatial planning, installing monitoring and early warning systems, reducing soil erosion and improving slope stability, and developing recovery and reconstruction plans after disasters.

The large built-up areas in Bumiharjo and Tunahan villages show high development and settlement activities in the area. However, the increase in built-up areas also carries a potential risk of physical vulnerability to landslides, although new infrastructure can be a sign of economic and social progress.

An increase in built-up areas can change land structure and topography, upsetting the natural balance of the environment. These development processes, such as soil compaction and vegetation conversion, can reduce slope stability and increase the risk of

landslides. Dense built-up areas also worsen rainwater flow and soil erosion, increasing vulnerability to landmass movement, especially in areas with a high percentage of built-up areas (Wang et al., 2017).

b.3. Landslide Mitigation Efforts Related to Economic Vulnerability

Agricultural land in Kelet, Tunahan, and Damarwulan villages, although fertile and provides abundant yields, can also pose a risk of landslides. Its presence increases economic vulnerability to landslides by damaging crops and agricultural infrastructure and disrupting access to markets. The impact has the potential to harm the local economy due to damage to crops and agricultural infrastructure, as well as difficulties in the distribution of agricultural produce.

Measures to prevent and mitigate landslides on agricultural land include 1) Strict implementation of regulations related to land use and agricultural practices. 2) Soil conservation practices such as terraserring, strip cropping, and contour ploughing (Multi Astuti et al., 2016). 3) Plant ground cover vegetation to improve slope stability and reduce erosion. 4) Efficient drainage system to reduce groundwater pressure. 5) Training farmers on safe farming practices and diversification of agriculture. 6) Development of monitoring and early warning systems for the identification of potential landslides.

The significant number of industries in Keling, Kaligarang, Tunahan, Kelet and Damarwulan villages signifies strong economic activity in the region, but the increasing number of industries also carries risks to economic vulnerability to landslides. Measures to reduce economic vulnerability related to the number of industries include the implementation of strict regulations on building standards and industrial infrastructure, investment in public infrastructure that supports accessibility, sustainable industrial waste management, identification and monitoring of hazardous materials, installation of early warning systems, and implementation of education and training programs for industry on disaster risk management.

The high amount of trade and services in Kelet Village reflects strong economic activity, but also carries the risk of landslides. Operational disruptions, decreased revenues, and financial losses can occur in landslide disaster situations. Factors such as damage to transport infrastructure, decreased purchasing power, and disruption of the supply of goods and services from outside the region can aggravate the situation. Preventive and mitigation measures are needed to reduce

vulnerability to landslides around trade facilities and services.

Measures to reduce economic vulnerability to landslides in Kelet Village: (1) implementing safety regulations and inspections for trade and service businesses. (2) build emergency response infrastructure and alternative distribution channels (3) Install efficient drainage systems to manage rainwater. (4) Maintain or plant vegetation around trade and service areas. (5) Employee education on safety and disaster preparedness. (6) Build partnerships with governments and recovery organizations for emergency response and post-disaster economic recovery.

The number of working people in Bumiharjo, Klepu, Kelet, and Damarwulan villages shows significant economic activity. However, the increasing number of working people also increases economic vulnerability to landslides. Measures to reduce economic vulnerability to landslides in areas with high employment include: (1) Informing residents about landslide risks and preparedness measures. (2) Conduct preparedness and evacuation training for the community. (3) Improve infrastructure and accessibility in the region. (4) Ensure employees are equipped with safety equipment and evacuation equipment.

b.4. Landslide Mitigation Efforts Related to Environmental Vulnerability

The high area of moorland in Damarwulan Village is characteristic of land use patterns in the region. However, the high area of moorland can also increase the level of environmental vulnerability to landslides. Moor fields are often located on hillsides or sloping areas, which can essentially increase the risk of landslides. As stated by (Susetyo et al., 2023), the use of moor land causes the potential for landslides to be higher because land with moor land use is less able to withstand soil structure when rainfall is high.

To reduce environmental vulnerability to landslides on moorland, the following steps need to be taken: implement soil and water conservation practices such as planting ground cover vegetation, terraserring, and maintaining soil moisture, raising public awareness about landslide risk and the importance of sustainable agricultural practices on moorland, and tightening supervision of human activities on moorland, and implementing monitoring systems and early warning.

The low forest area in Keling, Kaligarang, Jlegong, Gelang, Tunahan, Klepu, Kelet, Watuaji, Kunir and Damarwulan villages shows a pattern of land use that is mainly dominated by land use types other than forests. However, it is important to realize that a low forest

land area can increase the level of environmental vulnerability to landslides.

To reduce environmental vulnerability to landslides in areas with low forest area, the following steps need to be taken: forest rehabilitation, encouraging sustainable land management practices such as agroforestry or planting protective trees around slope areas. Furthermore, public awareness about the importance of forest conservation needs to be increased, supervision of illegal activities such as illegal logging or forest burning is tightened, and cooperation between the government, communities, and environmental organizations is needed.

The large area of garden land in Bumiharjo Village indicates the dominance of agriculture in the region. However, the high area of garden land also increases the risk of landslides because agricultural activities often alter natural land, damage soil structure, and reduce the ability of soil to resist erosion. Plants in the garden have shallow roots, which makes the soil more susceptible to landslides, especially when it rains. The use of pesticides and chemical fertilizers also exacerbates susceptibility to landslides by damaging soil structure.

To reduce environmental vulnerability to landslides in areas with high plantation land area such as Bumiharjo Village, the following steps can be taken: implement sustainable agricultural practices such as soil conservation, crop rotation, and maintenance of ground cover vegetation; planting soil-retaining trees on slopes and areas around gardens prone to landslides; develop proper irrigation systems and good drainage systems; raising public awareness of environmentally friendly agricultural practices; and tighten supervision of agricultural practices that damage the environment. These measures it is expected to reduce the risk of landslides and improve environmental resilience and the safety of local communities.

D. CONCLUSION

Landslide risk analysis in Keling District, Jepara Regency, reveals a high level of risk due to population increase, deforestation, and ineffective new land clearing. The main causes of landslides are excessive rainfall, erosion-prone soil and rocks, and human activity. The identification of risky locations based on geological characteristics and environmental variables reveals that most sub-districts have a significant risk of landslides. The investigation did, however, take into account the vulnerability of communities and infrastructure, revealing variations in vulnerability levels between villages. Although mitigating initiatives have been made, such as the Disaster Resilient Village program, more action is required

to lower the danger of landslides. Hospitals and evacuation routes are critical infrastructure that must be upgraded. Land use monitoring, community capacity building, infrastructure improvement, and key cross-sectoral cooperation are all part of a holistic approach to minimizing the region's landslide risks and impacts.

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