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Spatial Analysis of Disaster Vulnerability in Wonolelo, Magelang Regency, Central Java, Indonesia

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ABSTRACT

The research aimed to assess the level of disaster vulnerability in the Wonolelo tourist village area using spatial analysis with an overlay method of several factors causing disaster vulnerability. The research used two physical disaster vulnerability variables: volcanic eruptions and landslides. Determining vulnerability to volcanic disasters involved three variables: distance from the volcano, rivers, and roads. Using GIS, the distribution of urban spatial vulnerability could be overlaid on each indicator. The location of Wonolelo Village was on the slopes of Mount Merapi, with a relatively steep topography, made Wonolelo Village very vulnerable to landslides and the eruption hazards of Mount Merapi. The results showed that Wonolelo Village was highly vulnerable to volcanic disasters (63.71%) and medium vulnerability to landslides (99.12%). The findings of this research can be used to design disaster mitigation policies and strategies in Wonolelo Village and other vulnerable areas.

Keywords: Disaster, geographic information system, tourism village, vulnerability

INTRODUCTION

A disaster, especially a natural disaster, is an event humans cannot avoid. Humans can only try to reduce the risk of disasters through awareness and increasing capabilities in dealing with disasters or disaster mitigation. Disaster mitigation studies are part of efforts to avoid, reduce, or transfer the adverse impacts of hazards through activities and actions for prevention, mitigation, and management (Dewald, 2011). Disaster mitigation is an effort to reduce the loss of life and property by reducing the impact of a disaster (Gougelet, 2016). Disaster mitigation generally functions as reducing and overcoming the consequences of natural disasters in the form of victims or property that can impact human life (Wekke, 2021).

Disaster mitigation efforts must be carried out sustainably and well before a disaster occurs faster and more extensively than expected. The efforts made by the government in dealing with natural disasters are contained in Law No. 24 of 2007 concerning disaster management, which is a guideline for the central and regional governments in planning, managing, implementing, and supervising disaster mitigation. Several studies state that disaster risk mitigation and management must enable each region to develop its approach to disaster management, including tourist villages (Arifin et al., 2021; Surianto et al., 2019). Tourist villages are particularly vulnerable to disasters due to their location, infrastructure, and dependence on tourism (Aznar-Crespo et al., 2020; UNEP, 2007; Zhang et al., 2023).

Natural disasters can prevent visitors from traveling to affected destinations, causing a decline in tourism activity (Rosselló, Becken, and Santana-Gallego, 2020). Disaster mapping in tourist villages is critical to identify at-risk areas and improve disaster management in international tourism by providing accurate information about tourist locations (Ha, 2023). It also can help increase awareness about the risks associated with natural disasters in

tourist villages, encouraging the development of disaster preparedness and risk reduction strategies in the tourism sector (Neef, 2021).

Tourism with a rural theme has recently become a trend in Indonesia's tourism industry. Disaster mitigation is important, especially in areas prone to disasters, one of which is in villages with tourism potential. Disaster mitigation-based infrastructure development is essential in disaster mitigation (Minanto & Ningsih, 2018). Managers of tourist attractions in rural areas are still focused on developing and promoting tourist attraction infrastructure. Disaster mitigation has yet to become a priority among managers and stakeholders. Disaster mitigation can be better and more efficient if there is good coordination between the main stakeholders (BNPD/BNPB) and tourism managers (Mannakkara et al., 2018). Also, differences in understanding disaster risk between managers and tourists are essential. Priatmoko et al. (2019) explained that the differences in understanding occur due to understanding that physically having a disaster risk according to tourists may be safe according to residents in the village, and vice versa.

This study was conducted in Wonolelo village, Magelang district, which is vulnerable to disasters, especially volcanic eruptions, and landslides, which dominate the threats to tourism areas in the region compared to other natural disasters (Widodo & Hastuti, 2019). Volcanic eruptions can result in various threats to health and safety, including floods, landslides, power outages, drinking water contamination, forest fires, and the release of toxic gases such as sulfur dioxide and carbon monoxide (Malawani et al., 2021).

The issue of disasters in Wonolelo village is not only a matter for the local government but requires cooperation with all parties related to disaster management. This research, which plays a crucial role in disaster management for sustainable development, can significantly impact making policies and disaster mitigation programs in disaster-prone areas, especially in Wonolelo village. The importance of this research cannot be overstated, as it has the potential to contribute to eradicating poverty due to disasters.

MATERIALS AND METHODS

Study Area

The research mapped the area's physical vulnerability to disasters in Wonolelo Village, Sawangan District, Magelang Regency, Central Java Province. Astronomically, the Wonolelo Village area is between 7º28'30" South Latitude—7º31'30" South

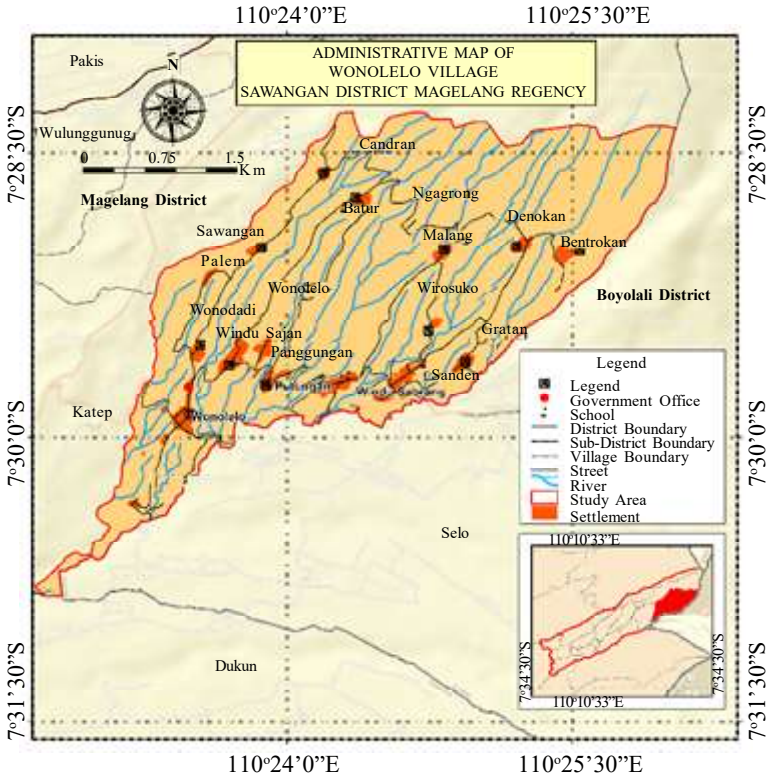

Figure 1. Map of study area.

Table 1. Variables of landslide vulnerability.

Variable	Class	Score
Rainfall (mm day^{-1})		
<13.6	Very low	1
13.6 - <20.7	Low	2
20.7 - <27.7	Moderate	3
27.7 - < 34.8	High	4
>34.8	Very high	5
Slope (%)		
0 – 8	Flat	1
8 – 15	Sloping	2
15-25	Rather steep	3
25-45	Steep	4
>45	Very steep	5
Soil type		
Alluvial, Humus, Planosol, Hydromorph Laterite	Insensitive	1
Latosol	Moderately sensitive	2
Brown forest, Andosol, Latent	Slightly sensitive	3
Grumusol, Podso, Podsolik	Sensitive	4
Regosol, Litosol, Organosol, Renzina	Very sensitive	5
Landuse		
Forest		1
Agriculture, rice field		2
Settlement		3
Bareland		4

Source: (Kementerian Pertanian, 1980)

Latitude and 110º23’30" East Latitude—110º25’30" East Latitude (Figure 1).

Spatial Analysis

The research used a particular analysis assisted by the ArcGIS 10.8.2 with the overlay method. Overlay is a spatial analysis that combines two or more thematic inputs. This research used two physical disaster vulnerability variables, namely eruption disasters and landslides, which would be overlaid to produce a physical disaster vulnerability map in Wonolelo Village. Determining landslide vulnerability involved four variables: rainfall, slope slope, soil type, and land use (Table 1). The steeper the slope, the higher the rainfall, the type of soil with low permeability, coupled with the use of land with

Table 2. Variables of volcanic eruption vulnerability.

Variable	Score
Distance from the volcano (km)	
10	2
20	1
Distance from river (m)	
200	2
>200	1
Distance from road (m)	
<50	4
50 - 150	3
150 - 500	2

Source: (Kementerian Pertanian, 1980)

minimal vegetation, the greater the level of vulnerability to landslides that may occur (Sani, Muryani and Rindarjono, 2018; Noviyanto, Sartohadi and Purwanto, 2020).

Determining vulnerability to volcanic disasters involved three variables: distance from the volcano, the river, and the road (Table 2). Locations that are safe from the dangers of Mount Merapi eruptions are far from volcanoes and rivers that allow lava to flow, have easy access, and are close to evacuation routes.

RESULTS AND DISCUSSION

Volcanic Disaster Vulnerability

Wonolelo Village is moderately vulnerable to volcanic disasters (Figure 2). Most of the Wonolelo Village area is physically vulnerable to high levels of volcanic disaster, covering an area of 680.04 ha (63.71%) (Table 3). Meanwhile, moderate-level volcanic disaster vulnerability covers 421.45 ha of land or 37.29% of the entire area of Wonolelo Village. Wonolelo Village is dominated by high vulnerability in the north because the area is close to Mount Merapi, close to rivers, and far from road access (Figure 2).

Figure 2 shows that the high level of danger to Mount Merapi is spread across several areas in Bentrokan, Denokan dan Wirosuko, Malang, and Klampahan, a protected forest area at the top of Mount Merbabu. Meanwhile, areas with moderate danger include Batur, Candran, Surodadi, Windu Sabrang, Wonolelo, and Gratan. A high level of danger dominates more than part of the Wonolelo Village area. The influencing factor is that some areas are disaster-prone, level III (KRB III), with the highest threat of danger in the event of an

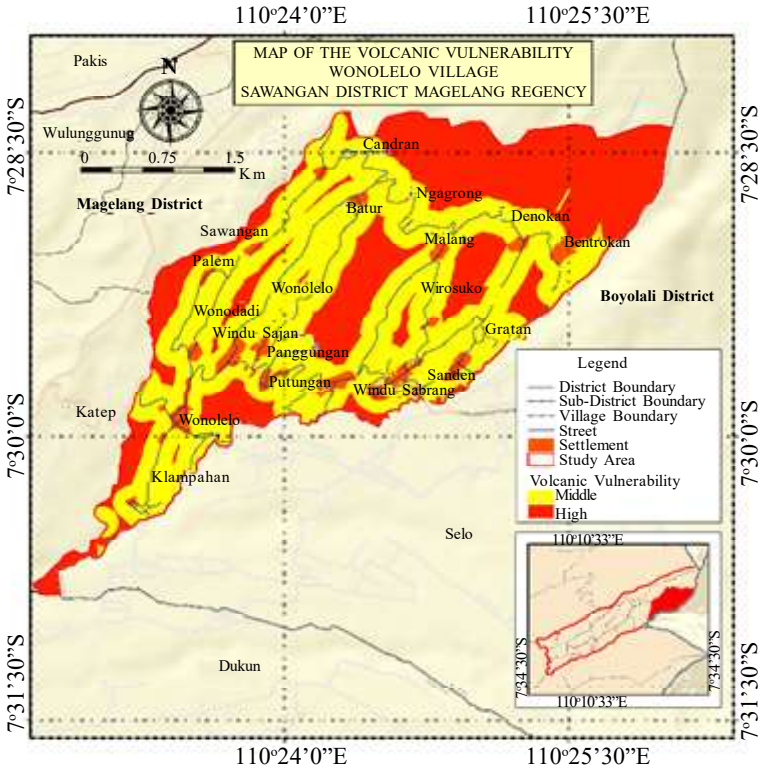

Figure 2. Volcano Disaster Vulnerability Map in Wonolel.

Table 3. Volcanic Disaster Vulnerability in Wonolelo

Level of Vulnerability	Area	
	Ha	%
High	680.04	63.71
Moderate	421.45	36.29
Total	1.101,49	100

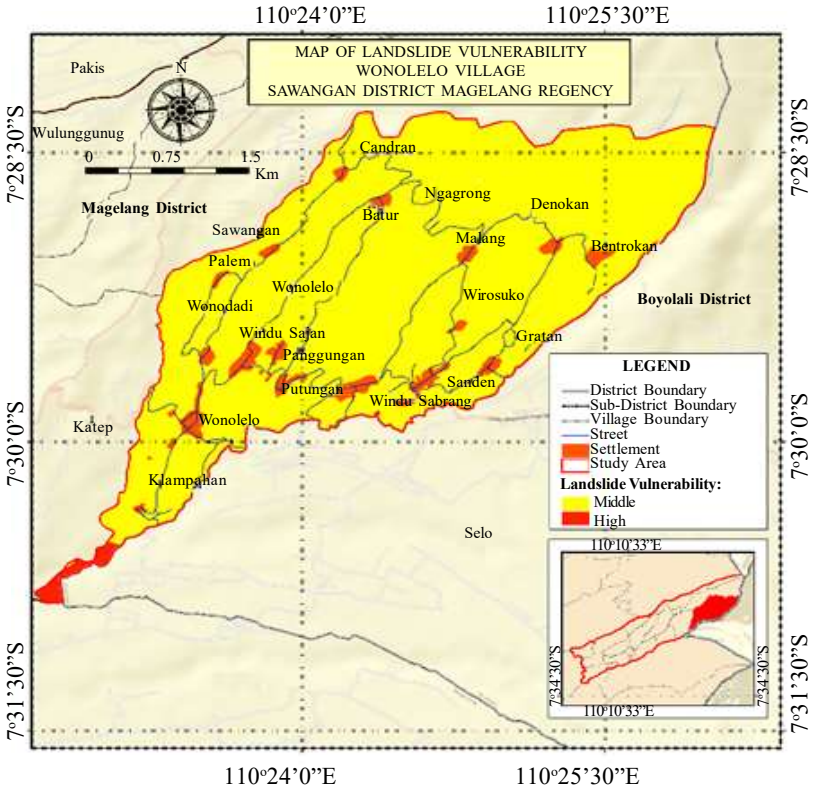

Figure 3. Landslide Disaster Vulnerability Map in Wonolelo.

eruption of Mount Merapi. Most areas with a moderate level of danger are spread across Wonolelo Village. These areas are in the disaster-prone areas level II (KRB II). However, land near volcanoes is often rich in mineral deposits and provides excellent agricultural opportunities, making it a consideration for people to live with the risks of volcanology (Kelman & Mather, 2008).

Landslide Disaster Vulnerability

Wonolelo village has a moderate and high landslide vulnerability (Figure 3). Table 4 shows that Wonolelo village has a moderate level of landslide vulnerability, covering an area of 1091.84 ha (99.12%). High levels of landslide vulnerability were found only in the southern part of Wonolelo Village, which only covers an area of 9.65 ha (0.88%). Figure 3 shows that the Wonolelo village area, which has a high level of landslide vulnerability, is in the north, specifically in Klampahan.

Based on the field measurements, Wonolelo Village is between 1000 meters and 2000 meters above sea level, between the foot of Mount Merapi and Mount Merbabu. As a mountainous area located at an altitude with a slope between 8°-45° and relatively high rainfall, Wonolelo Village has a moderate and high vulnerability to landslides (Figure 3, 4). Steep slopes have a higher frequency of landslides (Nakileza & Nedala, 2020). Likewise, rainfall is a key factor in the occurrence of landslides (Smith et al., 2023). Rainfall infiltration reduces matrix suction, increases pore water pressure, and causes groundwater levels to rise, triggering landslides (Alsubal et al., 2019).

Most landslides in Wonolelo occur in residents' fields and cliffs beside village roads (Figure 6), so

Table 4. Landslide Disaster Vulnerability in Wonolelo.

Level of Vulnerability	Area	
	Ha	%
High	9.65	0.88
Moderate	1091.84	99.12
Total	1.101,49	100

Figure 4. Several landslide locations in Wonolelo: (a) Plantation area near the main road (0434639 mT; 9171556 mU); (b) Plantation area (434694 mT; 9171552 mU).

residents usually work together to clean up the landslide debris that covers the roads. Landslides can cause transport network blockages, delays, detours, damage, and closures, resulting in economic and societal impacts (Ali et al., 2019; Schlögl et al., 2019). Based on the results of interviews with residents of Wonolelo Village, landslides rarely occur in the form of large landslides that hit residents' houses or cause casualties.

CONCLUSIONS

This research has mapped the spatial distribution of areas prone to landslides and vulnerable to Mount Merapi eruptions. This research uses an overlay method with several physical parameters, such as soil type, land cover, and slope, to determine the level of danger of natural landslides at 26 points spread across 18 hamlets in Wonolelo Village. Wonolelo Village has a moderate to high level of danger from the volcanic eruption of Mount Merapi. This location is in the valley between Mount Merbabu and Merapi, with a percentage of 63.71%, an area with a high level of danger.

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REFERENCES

Ali, S., Biermanns, P., Haider, R., & Reicherter, K. (2019). Landslide susceptibility mapping by using a geographic information system (GIS) along the China—Pakistan Economic Corridor (Karakoram Highway), Pakistan, *Natural Hazards and Earth System Sciences*, *19*(5), pp. 999-1022. doi: https://doi.org/10.5194/nhess-19-999-2019.

Alsubal, S., Indra, H., Mohammed, A . M. Al-Bared., & . et al. 2019. A review on the mechanism of rainwater in triggering landslide, *IOP Conference Series: Materials Science and Engineering*, 513(1). Available at: https://doi.org/10.1088/1757-899X/513/1/012009.

Ha, K.M. 2023. Improving disaster management in international tourism, *Management Review Quarterly* [Preprint], (November 2022). Available at: https://doi.org/10.1007/s11301-023-00338-4.

Kelman I & Mather TA. 2008. Living with volcanoes: The sustainable livelihoods approach for volcano-related opportunities, *Journal of Volcanology and Geothermal Research*, *172*(3), pp. 189–198. Available at: https://doi.org/https://doi.org/10.1016/j.jvolgeores.2007.12.007.

Kementerian Pertanian. (1980). Surat Keputusan Menteri Pertanian Nomor:837/Kpts/Um/11/1980 Tentang Kriteria dan Tata Cara Penetapan Hutan Lindung, *SK Menteri Pertanian No 683/Kpts/Um/8/1981*, 837, pp. 1–15.

Malawani, M.N., Franck, L., Christopher, G., Bachtiar, W. M., & Bachtiar, W. M. (2021). Review of local and global impacts of volcanic eruptions and disaster management practices: The Indonesian example, *Geosciences (Switzerland)*, *11*(3), pp. 1–18. Available at: https://doi.org/10.3390/geosciences11030109.

Nakileza, B.R. & Nedala, S. (2020). Topographic influence on landslides characteristics and implication for risk management in upper Manafwa catchment, Mt Elgon Uganda, *Geoenvironmental Disasters*, *7*(1). Available at: https://doi.org/10.1186/s40677-020-00160-0.

Neef, A. (2021). The Contentious Role of Tourism in Disaster Response and Recovery in Vanuatu, *Frontiers in Earth Science*, 9(December), pp. 1–15. Available at: https://doi.org/10.3389/feart.2021.771345.

Noviyanto, A., Sartohadi, J., & Purwanto, B.H. (2020). The distribution of soil morphological characteristics for landslide-impacted Sumbing Volcano, Central Java - Indonesia,*Geoenvironmental Disasters*, *7*(1). Available at: https://doi.org/10.1186/s40677-020-00158-8.

Rosselló, J, Becken, S & Santana, G.M. (2020). The effects of natural disasters on international tourism: A global analysis, *Tourism Management*, *79*, p. 104080. Available at: https://doi.org/https://doi.org/10.1016/j.tourman.2020.104080.

Sani, A.H.M., Muryani, C., & Rindarjono, M.G. (2018). The Analysis of Landslide Vulnerability Map and the Level of School Preparedness in Encountering Landslide in Gumelar Sub-District, Banyumas Regency, *IOP Conference Series: Earth and Environmental Science*, *145*(1). Available at: https://doi.org/10.1088/1755-1315/145/1/012083.

Schlögl, M., Gerald, R., Michael, A., Thomas, T., Gerhard, H., Gernot, L., & Sven, F. (2019). On the nexus between landslide susceptibility and transport infrastructure — an agent-based approach, *Natural Hazards and Earth System Sciences*, *19*(1), pp. 201–219. Available at: https://doi.org/10.5194/nhess-19-201-2019.

Smith, H.G., Andrew, J.N., Harley, B., & Raphael, S. (2023). The influence of spatial patterns in rainfall on shallow landslides, *Geomorphology*, *437,* p. 108795. Available at: https://doi.org/https://doi.org/10.1016/j.geomorph.2023.108795.

Widodo, E., & Hastuti, H. (2019). Disaster and Tourism: How Tourism Responds to Disasters in Magelang District, *IOP Conference Series: Earth and Environmental Science*, *271*(1). Available at: https://doi.org/10.1088/1755-1315/271/1/012009.