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Vulnerability of Farmer Households in the Eruption-Prone Area of Mount Merapi

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Abstract

The eruption causes social crises, hunger, damage to regional spatial planning, degradation of environmental quality, disruption of daily activities, damage to facilities, and agricultural losses. Most of the livelihoods of the population in the Mount Merapi area are farmers. Farmers' vulnerability increases due to eruptions, necessitating identification, anticipation, and mitigation to prevent exacerbation. The purpose of this study is to identify the vulnerability index of farmer households affected by the eruption in the Mount Merapi area. This research was conducted in Selo Sub-district, Boyolali Regency, and Kemalang Sub-district, Klaten Regency, which are prone areas affected by the eruption. The analysis method used was descriptive. Descriptive analysis was used to identify the vulnerability index of farmer households affected by the eruption in the Mount Merapi area using the Livelihood Vulnerability Index. The results indicated that the component value in the Selo sub-district for the socio-demographic profile was 0.127, livelihood 0.66, health 0.035, social network 0.45, food 0.17, water 0.30, and natural disaster 0.027. The component values in the Kemalang sub-district for the socio-demographic profile are 0.125 for livelihood, 0.66 for health, 0.14 for social network, 0.14 for food, 0.93 for water, and 0.017 for natural disaster. Kecamatan Kemalang, Klaten Regency, is more vulnerable than Kecamatan Selo, Boyolali Regency. Kecamatan Kemalang's LVI index is 0.357 greater than Kecamatan Selo's 0.251. The government needs to provide training for farmers on disaster management during eruptions, such as livestock evacuation and post-harvest management for horticultural commodities. Farmers should also participate in government-provided livestock insurance to reduce losses.

Keywords: disaster; eruption; Mt Merapi; vulnerability

Kerentanan Rumah Tangga Petani di Kawasan Rawan Erupsi Gunung Merapi

Abstrak

Erupsi mengakibatkan krisis sosial, kelaparan, kerusakan tata ruang wilayah, penurunan kualitas lingkungan dan terganggunya aktivitas kehidupan, rusaknya fasilitas, dan kerugian pada pertanian. Sebagian besar mata pencaharian penduduk di kawasan Gunung Merapi sebagai petani. Erupsi menyebabkan kerentanan pada petani menjadi masalah yang tidak dapat dihindari, sehingga harus diidentifikasi, diantisipasi dan disiasati agar tidak semakin memburuk. Tujuan penelitian ini adalah mengidentifikasi indeks kerentanan rumah tangga petani terdampak erupsi di Kawasan Gunung Merapi. Penelitian ini dilakukan di Kecamatan Selo Kabupaten Boyolali dan Kecamatan Kemalang Kabupaten

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Klaten yang merupakan daerah rawan terdampak erupsi dengan jumlah responden 120 petani. Metode analisis menggunakan deskriptif. Analisis deskriptif digunakan untuk mengidentifikasi indeks kerentanan rumah tangga petani terdampak erupsi di Kawasan Gunung Merapi menggunakan *Livelihood Vulnerability Index (LVI)*. Hasil penelitian menunjukkan nilai komponen di Kecamatan Selo untuk profil sosial demografi 0,127, livelihood 0,66, kesehatan 0,035, jejaring sosial 0,45, pangan 0,17, air 0,3, bencana alam 0,027. Nilai komponen di Kecamatan Kemalang untuk profil sosial demografi 0,125, livelihood 0,66, kesehatan 0,14, jejaring sosial 0,51, pangan 0,14, air 0,93, bencana alam 0,017. Kecamatan Kemalang Kabupaten Klaten lebih rentan daripada Kecamatan Selo Kabupaten Boyolali. Indeks LVI Kecamatan Kemalang lebih besar 0,357 daripada Kecamatan Selo 0,251. Pemerintah perlu melakukan pelatihan terkait penanggulangan bencana ketika erupsi pada petani antara lain evakuasi ternak dan pengelolaan pasca panen untuk komoditas hortikultura. Petani perlu mengikuti asuransi ternak yang sudah disediakan oleh pemerintah dengan tujuan mengurangi kerugian.

***Kata kunci**: bencana; erupsi; Gunung Merapi; Kerentanan*

INTRODUCTION

Indonesia is one of the countries with a relatively high level of disaster risk. Tectonically, Indonesia is located at the convergence of three major tectonic plates: the Pacific Plate, the Eurasian Plate, and the Indo-Australian Plate. Volcanically, Indonesia also lies along an active volcanic belt known as the Pacific Ring of Fire (Hadi et al., 2019; Hermon, 2014). The country has more than 130 active volcanoes, including several newly formed volcanoes (Malawani et al., 2021).

Mount Merapi is one of Indonesia's active volcanoes and is known for its high volcanic activity (Fahmi & Hizbaron, 2023). Since January 4, 2021, Mount Merapi has entered an effusive eruption phase characterized by the so-called "Merapi-type" eruption. This type of eruption is marked by the formation of a lava dome at the summit. When the dome becomes unstable, it may collapse and generate pyroclastic density currents. At present, Mount Merapi has two active lava domes, namely the central crater lava dome and the southwestern lava dome (Kementerian Energi dan Sumber Daya Mineral, 2024).

Volcanic eruptions can lead to social crises, hunger, and even death (Malawani et al., 2021). Their impacts may include environmental degradation, damage to regional spatial planning, and disruption of daily life activities (Fahmi & Hizbaron, 2023). Eruptions may also damage public facilities, social life, agriculture (Antriyandarti et al., 2013; Wilson et al., 2007), and housing, which is one of the basic needs of the community (Skwarko et al., 2024). Lava flows can damage infrastructure such as bridges and roads. Pyroclastic clouds may also trigger acid rain that endangers both human health and the environment. The toxic substances contained in pyroclastic clouds can reduce soil fertility and cause death among cattle (Ilham & Priyanti, 2011).

The Geological Agency, Center for Volcanology and Geological Hazard Mitigation, Ministry of Energy and Mineral Resources, reported that in early 2024 an eruption occurred in the Mount Merapi area, marked by lava avalanches and pyroclastic clouds. Crops and livestock are also vulnerable to ash particles produced by pyroclastic clouds (Wilson et al., 2007). These ash particles may have glass-like

shapes, making them highly hazardous to health because their sharp edges can damage internal lung tissue and potentially cause severe infections in livestock (Lebon, 2009).

This situation indicates significant economic disruption and the potential for hardship among farmers, most of whom are classified as poor (Khotimah et al. 2019, 2024). Communities facing such conditions require strong resilience to recover from adversity. Resilience refers to the capacity to adapt positively to difficulties, obstacles, stressful conditions, and risks. Resilience among individuals or communities is emphasized as a way to respond to situations that create crises, including barriers, challenges, and conflicts, in a more positive manner without eliminating or avoiding the risks that may arise (Hahn et al., 2009; Izzah & Jazilah, 2022; Luthar et al., 2000; Rutter, 2012). ased on these issues, this study aims to identify the vulnerability index of farmer households affected by volcanic eruptions.

RESEARCH METHOD

The research location was selected using purposive sampling. This method was applied by deliberately selecting areas based on the consideration that farmer households living around Mount Merapi are in eruption-prone areas, particularly within Disaster-Prone Area III (KRB III). KRB III refers to areas located closest to the summit of Mount Merapi. These areas are potentially exposed to pyroclastic density currents, volcanic bomb eru-tions, lava flows, toxic gases, and incandescent rock avalanches. Based on data from the National Disaster Management Agency, Kemalang Sub-district in Klaten Regency and Selo Sub-district in Boyolali Regency were classified as disaster-prone areas in 2024 (Badan Nasional Penanggulangan Bencana, 2024). This study was conducted in Tlogolele Village, Selo Sub-district, Boyolali Regency, and in Sidorejo and Tegalmulyo Villages, Kemalang Sub-district, Klaten Regency, all of which are included in Disaster-Prone Area III, as shown in Figure 1.

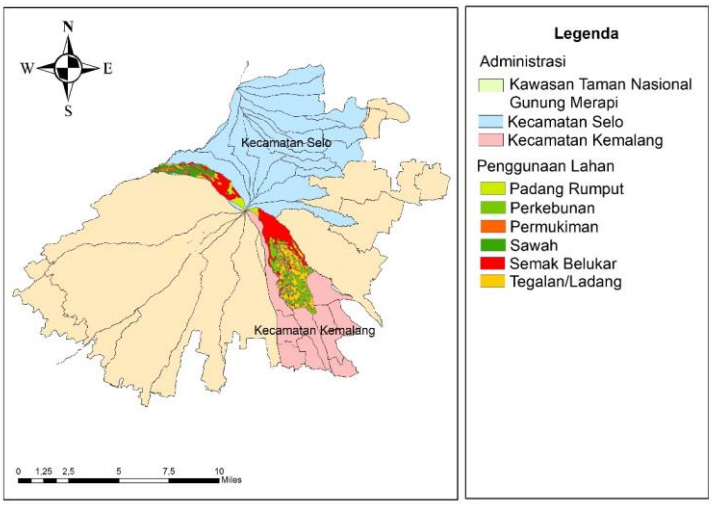

Figure 1. Map of the Study Area

The respondents in this study consisted of farmers and supporting institutions. The supporting institutions included the Disaster Management Agency of Klaten Regency, the Disaster Management Agency of Boyolali Regency, the Agriculture Office of Klaten Regency, the Livestock Office of

Boyolali Regency, the Agricultural Extension Center of Kemalang Sub-district, Klaten Regency, and the Agricultural Extension Center of Selo Sub-district, Boyolali Regency. The sampling technique used in this study was random sampling (Bhattacherjee, 2012), involving farmers who owned livestock. A total of 120 farmer households living in eruption-prone areas were selected as respondents, comprising 60 households in Kemalang Sub-district, Klaten Regency, and 60 in Selo Sub-district, Boyolali Regency.

The vulnerability of livestock-owning farmer households was estimated using the Livelihood Vulnerability Index (LVI) to assess the differential impacts of eruptions on the community. The LVI conmprisesthree cactors: exposure, adaptive capacity, and sensitivity, as presented in Table 1. Exposure consists of the natural disaster component. Adaptive capacity consists of three main components, namely socio-demographic profile, social networks, and livelihood strategies. Sensitivity consists of three main components, namely water, health, and food. The first step in calculating the LVI was to determine the index value of each sub-component using the following formula (Hahn et al., 2009; Sullivan & Meigh, 2005):

$$Index_{Sd} = \frac{S_d - S_{min}}{S_{max} - S_{min}}$$

Index Sd: sub-component index.

Sd : the original value in each area

Smax : the maximum value in Selo and Kemalang.

Smin : the minimum value in Selo and Kemalang.

The main component values for Selo and Kemalang were then calculated as follows:

$$M_d = \frac{\sum_{i=1}^{n} Index_{sdi}}{n}$$

Index sd: sub-component index.

Md : the main component value in each area.

n : the number of sub-components.

After the values of the seven main components were calculated, the LVI for each area was estimated as follows:

$$LVI_d = \frac{\sum_{i=7}^{7} W_M iM_d}{\sum_{i=7}^{7} W_M}$$

LVId : vulnerability index in Selo and Kemalang;

Md : the main component value in Selo and Kemalang;

Wm : the number of sub-components.

The LVI scale ranges from 0, indicating lower vulnerability, to 0.5, indicating very high vulnerability. The component of LVI Index can be seen on Table 1.

Table 1. LVI Index

Main Component	Sub-component	Description
Socio-demographic profile	Dependency ratio	The ratio of people aged below 15 years and above 65 years to the population aged 19 to 64 years.
	Percentage of female-headed households	The percentage of households headed by women.
	Percentage of household heads with no formal education	The percentage of households in which the household head did not receive formal education.
	Percentage of households with orphans	The percentage of households with at least one orphan living in the household. Orphans refer to children under 18 years old who have lost one or both parents.
Livelihood	Percentage of households relying solely on agriculture as a source of income	The percentage of households that depend only on agriculture as their source of income.
	Average agricultural livelihood diversification index	The inverse of the number of agricultural land-based livelihood activities plus one, as reported by the household. For example, a household that farms, raises livestock, and collects natural resources has a livelihood diversification index of $1/(3 + 1) = 0.25$.
Health	Average time required to access health facilities	The average time needed by households to reach the nearest health facility.
	Percentage of households with family members suffering from chronic illness due to disaster	The percentage of households reporting at least one family member with a chronic illness. Chronic illness was defined subjectively by the respondents.
Social networks	Percentage of aid received	The amount of assistance received by households.
	Percentage of post-eruption aid received	The amount of assistance received after the eruption.
	Borrowing ratio	The ratio of households that borrowed money in the past month to households that lent money in the past month.
Food	Percentage of households relying on agriculture for food	The percentage of households that obtain their food mainly from their own farming activities.
	Average crop diversity index	The inverse of the number of crops grown by the household plus one. For example, a household growing cabbage, tobacco, mustard greens, and chili has a crop diversity index of $1/(4 + 1) = 0.20$.
Water	Percentage of households reporting water-related problems	The percentage of households reporting that they had heard of or experienced water-related problems.
	Percentage of households using natural water sources	The percentage of households reporting the use of natural water sources, such as rivers, lakes, or springs, as their main source of water.
	Percentage of households with irregular water supply	The percentage of households experiencing irregular water supply.

Main Component	Sub-component	Description
Natural disasters	Average number of eruptions, earthquakes, floods, and droughts in one year	The number of eruptions, floods, droughts, and typhoons reported by households.
	Percentage of households that did not receive early warnings about upcoming natural disasters	The percentage of households that did not receive warnings about disaster events.
	Percentage of households experiencing injury or death due to natural disasters	The percentage of households reporting injury or death of a family member due to disasters.

Source: Hahn et al., (2009)

RESULTS AND DISCUSSION

Disaster-Prone Area III (KRB III) is located closest to the summit of Mount Merapi, at less than 5 km from the peak. This area is frequently affected by pyroclastic density currents, lava flows, volcanic material ejections, toxic gases, and incandescent rock avalanches. KRB III is considered unsuitable for settlement because to its very close proximity to the summit of Mount Merapi and the high risk of eruption impacts. Local authorities have the authority to follow up on recommendations issued by the Center for Volcanology and Geological Hazard Mitigation (PVMBG) (Badan Nasional Penanggulangan Bencana, 2024).

The Livelihood Vulnerability Index (LVI) was used to estimate the differential impacts of eruptions on communities in the Mount Merapi area, particularly in Boyolali and Klaten Regency. The LVI applies various indicators to assess exposure to natural disasters and climate variability, household social and economic characteristics that influence adaptive capacity, and current health, food, and water resource conditions that determine their sensitivity to the impacts of natural disasters. The LVI is a composite index consisting of seven main components. The second approach combines these seven components into three contributing factors of vulnerability, namely exposure, sensitivity, and adaptive capacity (Hahn et al., 2009).

This study used primary data collected from household surveys of livestock-owning farmers to construct the index. This approach also provides a framework for grouping and combining indicators at the district level, which is highly relevant for development and adaptation planning. The use of primary household data also helps avoid errors that may occur when relying on secondary data (Sullivan & Meigh, 2005).

Table 2 presents the LVI sub-component values for Selo and Kemalang Sub-district. The dependency ratio index was higher in Selo than in Kemalang Sub-district. Overall, the Selo showed greater vulnerability in the socio-demographic profile component compared with the Kemalang Sub-district. The livelihood component had the same value in both Kemalang and Selo Sub-districts. The overall health vulnerability score in Selo was lower than that in Kemalang Sub-district. The average

crop diversity index in Selo was higher than that in Kemalang Sub-district. Kemalang was more vulnerable than Selo Sub-district in the social network component. Water vulnerability was also higher in Kemalang than in Selo Sub-district. In contrast, the Selo was more vulnerable than the Kemalang Sub-district in the natural disaster component.

Table 2. Results of the Livelihood Vulnerability Index

Main Component	Sub-component	Selo Sub-district	Kemalang Sub-district	Main Component Value: Selo	Main Component Value: Kemalang
Socio-demographic profile	Dependency ratio	0.42	0.36	0.127	0.125
	Percentage of female-headed households	0.03	0.06		
	Percentage of household heads with no formal education	0.06	0.05		
	Percentage of households with orphans	0	0.03		
Livelihood	Percentage of households relying solely on agriculture as a source of income	1	1	0.66	0.66
	Average agricultural livelihood diversification index	0.33	0.33		
Health	Average time required to access health facilities	0.10	0.05	0.035	0.14
	Percentage of households with family members suffering from chronic illness	0.06	0.23		
Social networks	Percentage of aid received	0.16	0.50	0.45	0.51
	Percentage of post-eruption aid received	1	0.55		
	Borrowing ratio	0.20	0.50		
Food	Percentage of households obtaining staple food from their	0	0	0.17	0.14

	own farming activities				
Main Component	Sub-component	Selo Sub-district	Kemalang Sub-district	Main Component Value: Selo	Main Component Value: Kemalang
	Average crop diversity index	0.34	0.29		
Water	Percentage of households reporting water-related problems	0	1	0.30	0.93
	Percentage of households using natural water sources	1	0.80		
	Percentage of households with irregular water supply	0	1		
Natural disasters	Occurrence of eruptions, earthquakes, floods, and droughts in the past year	0.30	0.19	0.027	0.017
	Percentage of households that did not receive early warnings about upcoming natural disasters	0	0		
	Percentage of households experiencing injury or death due to natural disasters	0.03	0.017		
LVI Index of Selo Sub-district: 0.25 LVI Index of Kemalang Sub-district: 0.35					

Source: Primary data analysis (2025)

Respondents in Kemalang reported a higher proportion of female-headed households and a lower proportion of household heads who had attended school compared with respondents in Selo Sub-district. No households in Selo reported caring for orphans. Meanwhile, in Kemalang Sub-district, 3% of households, or two respondents, reported having orphans in their household.

The livelihood component had the same value in both Kemalang and Selo Sub-districts. Most residents in the Mount Merapi area work as farmers. In Selo Sub-district, most farming activities are in the horticultural subsector, including chili, broccoli, cabbage, tomato, cabbage greens, and scallions. In addition to crop farming, many residents in Selo Sub-district also raise beef cattle. In Kemalang Sub-district, farmers mostly cultivate horticultural commodities such as chili, tomato, cabbage, scallions,

and rose petals. In addition to crop farming, many residents in Kemalang Sub-district also raise beef cattle. This finding is consistent with Masrukin et al. (2013) who found that communities living on the slopes of Mount Merapi commonly depend on vegetable farming and dairy cattle raising.

Households in Selo Sub-district travel an average of 19.55 minutes to reach health facilities. The nearest health facility to Tlogolele Village is the Selo Community Health Center. Meanwhile, households in Kemalang Sub-district travel an average of 17.95 minutes to reach health facilities. The nearest health facility for Tegalmulyo and Sidorejo Villages is the Kemalang Sub-district Community Health Center. Chronic illness was reported by 6% of households in Selo and 23% of households in Kemalang Sub-district, indicating that households in Kemalang were more vulnerable than those in Selo Sub-district. When the sub-components were combined, the overall health vulnerability score for Kemalang was higher than that for Selo Sub-district. This health vulnerability may be associated with poor sanitation, low health awareness, and limited access to health facilities (Afandi et al., 2024).

The social network indicators consisted of assistance received and borrowing. Around 16% of households in Tlogolele Village, Selo Sub-district, and 50% of households in Kemalang Sub-district received assistance. The assistance included Non-Cash Food Assistance, the Family Hope Program (PKH), and Cash Social Assistance. Non-Cash Food Assistance was provided in the form of 6–10 kg of rice per month. PKH assistance was targeted at poor households and provided in cash, with the amount depending on the category of recipients. Recipient categories included school-age children, persons with disabilities, pregnant or postpartum women, elderly people, and toddlers. The amount ranged from IDR 225,000 to IDR 500,000 every three months for school-age children, IDR 600,000 every three months for persons with disabilities and elderly people, and IDR 750,000 every three months for pregnant women and toddlers. A total of 5% of respondents in Tlogolele Village received PKH assistance. Assistance and loans in disaster-prone areas aim to improve the independence of communities that are vulnerable to disasters (Hutahaean et al., 2026).

A total of 55% of households in Kemalang received post-eruption assistance from Mount Merapi, while all respondents in Selo Sub-district received post-eruption assistance. The assistance included basic food packages, toiletries, and clothing. This assistance was provided by disaster management agencies, the government through village authorities, and volunteers. The borrowing ratio in Kemalang was higher than that in Selo Sub-district. Most loans were used to start farming and livestock businesses. These loans served as a safety net to overcome capital constraints after eruption disasters (Ayuni, 2024). In farming activities, loans were used as initial capital for planting and for purchasing fertilizer and mulch. In livestock activities, loans were used to purchase feeder cattle. Overall, respondents in Kemalang were more vulnerable than those in Selo Sub-district in the social network component.

The average crop diversity index in Selo was higher than that in Kemalang Sub-district. The commodities were cultivated using an intercropping system, with each farmer growing two to seven crops. Crops cultivated in Selo Sub-district included broccoli, cabbage, tomato, chili, scallions, and tobacco. Meanwhile, crops cultivated in Kemalang Sub-district included chinese cabbage, pak choy,

cabbage, chili, tomato, and tobacco. Greater crop diversity reflects farmers' efforts to obtain higher income and to secure their income when vegetable prices decline (Tambunan et al., 2025).

Water vulnerability was higher in Kemalang than in Selo Sub-district. All respondents in Kemalang reported water-related problems, while respondents in Selo Sub-district reported no water constraints. Kemalang Sub-district experiences drought during the dry season, with limited access to clean water for drinking and cooking. This condition occurs because the Sapu Angin water source dries up during the dry season. Sidorejo Village was the most severely affected by drought, with 1,886 households or 6,203 people affected. Efforts to address the drought included the distribution of clean water by the Disaster Management Agency of Klaten Regency. Communities in Kemalang Sub-district also collected rainwater in storage facilities with a capacity of approximately 70 m^3 (70,000 liters).

Natural disaster vulnerability was higher in Selo than in Kemalang Sub-district. Eruptions are the most frequent natural disasters affecting both areas. Both areas are located around Mount Merapi, which remains under alert status. Until now, eruptions have continued to occur frequently, depending on wind direction. In this study, the eruptions counted were those with direct impacts, particularly ashfall that disrupted community activities. Farmers had to harvest earlier, while the evacuation of elderly people and livestock became a strategy respondents used to protect themselves and their assets. All communities in both areas had received early warnings about the eruptions of Mount Merapi. These warnings came from neighborhood units, community units, village governments, local disaster management agencies, and the Center for Research and Development of Geological Disaster Technology. Early warnings were delivered through sirens. In addition, information on eruption early warnings was shared through neighborhood-level WhatsApp groups. Some respondents stated that they obtained early warning information from the Center for Research and Development of Geological Disaster Technology (BPPTKG) through Instagram. Village preparedness teams or volunteers, district government outreach, social media, local wisdom, and training and simulation activities have a strong influence on disaster preparedness among communities in KRB III (Suharto et al., 2021). During eruptions, community members tend to follow government instructions issued by relevant agencies, including BPPTKG, BNPB, and BPBD, to evacuate to safer places (Prasojo, 2015).

CONCLUSION

The results showed that the component values in Selo Sub-district were 0.127 for socio-demographic profile, 0.66 for livelihood, 0.035 for health, 0.45 for social networks, 0.17 for food, 0.30 for water, and 0.027 for natural disasters. Meanwhile, the component values in Kemalang Sub-district were 0.125 for socio-demographic profile, 0.66 for livelihood, 0.14 for health, 0.51 for social networks, 0.14 for food, 0.93 for water, and 0.017 for natural disasters. Overall, Kemalang Sub-district in Klaten Regency was more vulnerable than Selo Sub-district in Boyolali Regency. This is indicated by the higher LVI value in Kemalang Sub-district, which reached 0.357, compared with 0.251 in Selo Sub-district. The government needs to provide disaster management training for farmers during eruptions,

particularly on livestock evacuation and post-harvest management of horticultural commodities. Farmers are also encouraged to participate in the government-run livestock insurance program to reduce potential losses.

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