AN INCLUSIVE EARLY WARNING SYSTEM AND COMMUNITY PREPAREDNESS IN THE MOUNT MERAPI ERUPTION-PRONE AREA

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Abstract
One of Indonesia's most active volcanoes, Mount Merapi, puts nearby residents at risk. Risk reduction strategies require understanding readiness factors. This study aims to identify the determinants of disaster preparedness among communities living in the Mount Merapi hazard area, with a particular focus on examining the influence of socio-demographic factors and geographical proximity through a mixed-method approach. This research was conducted among 122 residents living in the Mount Merapi area and indepth interview with informants. Preparedness level (low, moderate, high) was assessed using a structured index, measured by knowledge and attitude (KA); emergency planning (EP), Warning System (WS), dan Resource Mobilization Capacity (RMC). To find independent predictors of high preparation, the Chi-square test and multivariable logistic regression were used. Variables included age, gender, occupation, length of residence, and distance from Mount Merapi. Chi-square test showed significant associations between preparedness and gender ($\chi^2 = 6.51$, $p = 0.039$), occupation ($\chi^2 = 18.345$, $p = 0.049$), distance to Mount Merapi ($\chi^2 = 14.768$, $p = 0.005$), and length of residence ($\chi^2 = 19.655$, $p = 0.003$). Multivariable analysis revealed that gender ($B = 1.550$, $p = 0.009$, $OR = 4.713$) and distance to Mount Merapi ($B = –1.416$, $p = 0.023$, $OR = 0.243$) were independent predictors of preparedness. Based on in-depth interviews with informants, residents who received disaster preparedness bag training exhibited effective emergency planning. Gender and proximity to the hazard drive disaster preparedness. Training, simulation exercises, and community education programs should actively incorporate men and women to improve preparedness knowledge and reaction skills and build preparedness strategies for areas near Mount Merapi.

Keywords: disaster, preparedness, risk

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INTRODUCTION

Disasters are occurrences that pose a hazard to and disrupt the daily lives of communities, leading to psychological effects, casualties, and material losses. Globally, natural disasters such as volcanic eruptions, earthquakes, and floods have caused significant losses to communities. Indonesia, as an archipelago located at the intersection of three tectonic plates (Eurasian, Indo-Australian, and Pacific plates), is at high risk of various natural disasters. Indonesia, being located on the Pacific Ring of Fire, has many active volcanoes, including Mount Merapi, which is located on the border of Central Java and the Special Region of Yogyakarta(1). Mount Merapi is known as one of the most active volcanoes in the world, with significant eruptive activity throughout its history. Sleman Regency, located on the southern slopes of Mount Merapi, is an area vulnerable to the impacts of eruptions. Merapi eruptions often have a significant impact on the surrounding communities, including Argomulyo Village, Cangkringan District, which is located in Disaster-Prone Area (DPA) III. The main threats

from the Merapi eruption include pyroclastic flows, volcanic material ejections, ashfall, and rain lahars, which have the potential to cause infrastructure damage and loss of life.(2)

A comprehensive mitigation strategy is urgently required to mitigate disaster risk in vulnerable areas. One of the core strategies in disaster risk management is the implementation of an Early Warning System (EWS), designed to detect threats early and convey warning information to at-risk populations so that appropriate responses can be taken before impacts occur. Empirical studies on community-based early warning systems show that community involvement in the early warning process significantly improves the effectiveness of mitigation and community response to eruption threats, especially if the community has risk knowledge, preparedness training, and clear and rapid communication channels.(3,4)

Mitigation is necessary for communities residing in regions susceptible to Mount Merapi eruptions in order to mitigate or minimize the disaster's effects. To reduce disaster risk, the implementation of an Early Warning System (EWS) becomes crucial in mitigation efforts.. Based (5) this approach has proven effective in reducing the impact of disasters. The EWS in Argomulyo Village includes various technologies for monitoring volcanic activity, such as seismic sensors, ground deformation, and volcanic gas measurements, which are managed by the Centre for Volcanology and Geological Hazard Mitigation (CVGHM). Additionally, communication systems based on sirens, community radio, and text messages were also implemented to disseminate warnings to the public. However, the effectiveness of EWS still faces several constraints, including limited access to information, delays in disseminating warnings, and suboptimal community preparedness.(6)

The early warning system (EWS) for lava on Mount Merapi has been developed since the 1970s and has undergone various changes to improve its effectiveness. This system includes monitoring rainfall, water levels, lahar sensors, and the use of weather radar. The impact of the 2010 eruption on the EWS at Merapi was very significant, causing several monitoring stations to be damaged or destroyed by hot clouds and lahars. Therefore, strengthening the early warning system with a multi-sectoral approach is a major challenge for future disaster mitigation in the Merapi region. (7)

Based on information from the Magelang Badan Penanggulangan Bencana Daerah (BPBD), they have been carrying out their role in disaster mitigation, but there are still some obstacles in the effectiveness of its implementation. Supporting factors in the effectiveness of BPBD include the distribution of authority, employee motivation, and the implementation of SOPs.Therefore, improving human resources and disseminating disaster information are urgent matters.(8)

Disaster preparedness villages like Umbulharjo village in Cangkringan are not yet widely known by residents, as stated in the research conducted by Gunawan in Indonesia (6) a disaster-prepared village is one form of disaster mitigation within the village community. The research results indicate that the implementation of the preparedness program has been successful, supported by adequate funding, effective training, and the active role of community health centres and health cadres. However, despite the program being implemented, many people still lack a clear understanding of the concept of a "Siaga Village" itself. (9)

Disaster preparedness in volcanically vulnerable locations has been extensively researched, especially in Indonesia, one of the most disaster-prone nations. Mount Merapi study has consistently stressed the importance of socio-demographic and environmental

elements in community preparedness. Educational attainment, expertise, prior disaster experience, and social capital affect volcanic hazard prediction and response. Many Merapi-prone research emphasize the importance of community-based disaster risk reduction (CBDRR) initiatives, which improve preparedness through local institutions, community engagement, and early warning systems. Geography, including proximity to the hazard source, affects risk perception and evacuation behavior, with towns near the volcano often being more informed but less prepared.

Despite these advances, the literature is inconsistent. Some studies show that gender and income do not affect preparedness, while others show that gender discrepancies affect risk perception, information accessibility, and preparedness measures. Although proximity to hazard zones is often considered a factor, little study has examined how it interacts with individual attributes in assessing preparation. A void remains in understanding how demographic characteristics, such as gender, interact with spatial variables like Mount Merapi distance to shape disaster preparedness. This study fills this gap by using multivariable analysis to discover independent preparation determinants, providing a more holistic view that includes social and geographical factors. This study helps create more accurate and complete disaster preparedness plans in volcanic-hazard areas, such as Mount Merapi. This mixed-method study examines socio-demographic characteristics and physical closeness as predictors of disaster preparedness in Mount Merapi danger communities.

METHODS

This study employed a mixed-methods approach. Quantitative data were used to measure the level of disaster preparedness, while qualitative data were utilized to deepen and explain the quantitative findings. The study was conducted in Argomulyo Village, Cangkringan, Sleman, Special Region of Yogyakarta, Indonesia, from July-September 2025. The study population included all Argomulyo Village residents who could be affected by Mount Merapi's eruption. The quantitative sample contained 122 purposive-sampled residents. Key informants for the qualitative component were chosen for their village disaster management roles. Male (45) village disaster forum member and female (27) village secretary were the informants.

Quantitative data were collected using a structured questionnaire designed to assess disaster preparedness. The instrument consisted of multiple items covering four dimensions: (1) Knowledge and Attitude (KA), (2) Emergency Planning (EP), (3) Warning System (WS), and (4) Resource Mobilization Capacity (RMC). The total preparedness score was calculated by summing all item scores and converting them into an index ranging from 0 to 100. Preparedness levels were categorized as low (<60), moderate (61–79), and high (80–100). The questionnaire was adapted from previous disaster preparedness studies (10) and modified to suit the local context. Quantitative data were analyzed the Chi-square test to examine associations between variables, followed by multivariable logistic regression to identify independent predictors of disaster preparedness. In-depth interviews utilizing a semi-structured guide obtained qualitative data on disaster preparedness and EWS implementation. Braun and Clarke's theme analysis was used to assess qualitative data. Authorized audio recordings and verbatim transcriptions were conducted for all interviews. The analysis process included familiarization with the data through repeated transcript reading, generation of initial

codes by identifying meaningful text segments, grouping similar codes into categories, development of themes representing key data patterns, and reviewing and refining themes to ensure coherence and relevance to the research objectives. This study received ethical approval from the Universitas Respati Yogyakarta Ecthic Committee, No. 056.3/FIKES/PL/VII/2025.

RESULTS

The 122 responders were mostly female (72.1%, n = 88) and male (27.9%, n = 34). The majority of respondents were productive-aged 39.3% of participants were 20–39 years old (n = 48), followed by 35.2% of 40–59 year olds (n = 43). These data indicate that the study population comprised mostly economically active people. Most had graduated high school (59.0%, n = 72). Housewives were the largest occupational category (41.0%) (n = 50). Other jobs included farmers (16.4%, n = 20), employees (11.7%, n = 14), merchants (5.7%, n = 7), students (4.1%, n = 5), and others (21.3%, n = 26).

Table 1. Characteristic of Respondent

Variable		n	%
Gender	Male	34	27.9
	Female	88	72.1
Age	<19 years	4	3.3
	20-39 years	48	39.3
	40-59 years	43	35.2
	≥60 years	27	22.1
Education	University	25	20.5
	High school	72	59.0
	Junior high school	13	10.7
	Elementary school	12	9.8
Occupation	Housewife	50	41
	Employee	14	11.7
	Merchant	7	5.7
	Farmer	20	16.4
	Student	5	4.1
	Other	26	21.3
Income/month	≤ Rp 1.000.000	47	38.5
	Rp 1.000.001-Rp 2.000.000	26	21.3
	Rp 2.000.001-Rp 3.000.000	23	18.9
	≥Rp 3.000.000	26	21.3
Distance category village to merapi	Short/near Merapi	65	53.3
	Medium	31	25.4
	Long distance	26	21.3
Lived at research site	< 1 year	3	2.5
	1-5 years	10	8.2
	6-10 years	12	9.8
	>10 years	97	79.5
Experienced Mount Merapi eruptions	Never	23	17.6
	Once	57	43.5
	Yes, more than 1	50	38.2
Preparedness Index	Low	18	14.8
	Moderate	25	20.5
	High	79	64.8
Total		**122**	**100**

Based on monthly income, 38.5% (n = 47) of respondents earned ≤ Rp 1,000,000. Participants were from eight communities and grouped by Merapi distance. Short distance 65 (53.3%), medium 31 (25.4%), long 26 (21.3%). Most respondents (79.5%, n = 97) had lived in the research location for more than 10 years, whereas 2.5% (n = 3) had been there less than one year. This suggests a stable, long-term population in the research area. Regarding Mount Merapi eruptions, 43.5% (n = 57) had experienced one and 38.2% (n = 50) had experienced multiple eruptions.Finally, the preparedness index showed that 64.8% (n = 79) of respondents had a high level of preparedness, 20.5% (n = 25) had moderate preparedness, and 14.8% (n = 18) were categorized as having low preparedness.The characteristics of the respondents can be seen in the following table.

Table 2 Correlation Between Variables and Index Preparedness

Variables		Index preparedness						χ^2 (df)	*p*
		High		Low		Moderate			
		n	%	n	%	m	%		
Gender	Male	28	23	3	2.5	3	2.5	6.51	**0.039***
	Female	51	41.8	15	12.3	22	18		
Age	<19 years	2	1.6	0	0	2	1.6	11.964	0.063
	20-39 years	30	24.6	11	9.0	7	5.7		
	40-59 years	28	23	2	1.6	13	10.7		
	≥60 years	19	15.6	5	4.1	3	2.5		
Education	University	13	16.6	7	5.7	5	4.1	8.247	0.221
	High school	47	38.5	8	6.6	17	13.9		
	Junior high school	9	7.4	1	0.8	3	2.5		
	Elementary school	10	8.2	2	1.6	0	0		
Occupation	Housewife	30	24.6	6	4.9	14	11.5	18.345	**0.049***
	Employee	9	7.4	3	2.5	2	1.6		
	Merchant	7	5.7	0	0	0	0		
	Farmer	17	13.9	2	1.6	1	0.8		
	Student	2	1.6	0	0	3	2.5		
	Other	14	11.5	7	5.7	5	4.1		
Income/month	≤ Rp 1.000.000	31	25.4	5	4.1	11	9.0	5.173	0.522
	Rp 1.000.001-Rp 2.000.000	15	12.3	4	3.3	7	5.7		
	Rp 2.000.001-Rp 3.000.000	18	14.8	3	2.5	2	1.6		
	≥Rp 3.000.000	15	12.3	6	4.9	5	4.1		
Distance category village to merapi	Short/near Merapi	49	40.2	9	7.4	7	5.7	14.768	**0.005***
	Medium distance	12	9.8	7	5.7	12	9.8		
	Long distance	18	14.8	2	1.6	6	4.9		
Lived at research site	< 1 year	2	1.6	0	0	1	.8	19.655	**0.003***
	1-5 years	3	2.5	6	4.9	1	.8		
	6-10 years	9	7.4	2	1.6	1	.8		
	>10 years	65	53.3	10	8.2	22	18		
Experienced Mount Merapi eruptions	Never	11	9.0	7	5.7	4	3.3	7.481	0.113
	Once	33	27	6	4.9	13	10.7		
	Yes, more than 1	35	28.7	5	4.1	8	6.6		

*Note: *p < 0.05 (statistically significant)*

The Chi-square test of independence was conducted to examine the association between socio-demographic characteristics and the preparedness index shown in table 3. A statistically

significant association was found between gender and preparedness level ($\chi^2 = 6.51$, $p = 0.039$). No statistically significant association was observed between age group and preparedness index ($\chi^2 = 11.964$, $p = 0.063$). Similarly, educational level was not significantly associated with preparedness level ($\chi^2 = 8.247$, $p = 0.221$). A significant association was identified between occupation and preparedness index ($\chi^2 = 18.345$, $p = 0.049$). Differences in preparedness distribution across occupational categories were statistically significant, indicating that employment status may influence disaster preparedness. There was no statistically significant relationship between monthly income and preparedness level ($\chi^2 = 5.173$, $p = 0.522$).

A highly significant association was observed between distance of village from Mount Merapi and preparedness index ($\chi^2 = 14.768$, $p = 0.005$) suggesting that geographical proximity to hazard exposure influences preparedness behavior. Length of residence at the research site was also significantly associated with preparedness ($\chi^2 = 19.655$, $p = 0.003$). Respondents who had lived in the area for more than 10 years showed the highest proportion of high preparedness (53.3%), indicating that longer residency may contribute to increased disaster awareness and readiness. In contrast, experience of Mount Merapi eruptions was not significantly associated with preparedness level ($\chi^2 = 7.481$, $p = 0.113$). Although respondents who had experienced more than one eruption demonstrated relatively high preparedness (28.7%), the differences were not statistically significant.

Table 3. A Multivariable Logistic Regression Analysis

Variables	B	Sig	Exp(B)
Age	0.138	0.476	1.148
Gender	1.550	0.009	4.713
Occupation	0.100	0.400	1.105
Lived at research site	0.469	0.097	1.598
Distance to Merapi	-1.416	0.023	0.243
Constant	-1.353	0.217	0.259

A multivariable logistic regression analysis shown in table was conducted to identify independent predictors of preparedness level after controlling for potential confounders, including age, gender, occupation, length of residence, and distance to Mount Merapi. The analysis revealed that gender was a significant predictor of preparedness level ($B = 1.550$, $p = 0.009$, $OR = 4.713$). Respondents in the coded gender category had 4.7 times higher odds of having high preparedness compared to the reference category, after adjusting for other variables in the model. This indicates that gender independently influences disaster preparedness.

Distance to Mount Merapi was also significantly associated with preparedness level ($B = –1.416$, $p = 0.023$, $OR = 0.243$). The odds ratio below 1 suggests that respondents living in villages categorized farther from Mount Merapi had significantly lower odds (approximately 76% lower) of having high preparedness compared to those residing closer to the volcano, controlling for other variables. This finding highlights the importance of geographical proximity in shaping preparedness behavior. In contrast, age was not significantly associated with preparedness ($B = 0.138$, $p = 0.476$, $OR = 1.148$), indicating that age did not independently predict preparedness level in this model. Although length of residence at the research site

showed a positive association with preparedness (B = 0.469, OR = 1.598), the relationship did not reach statistical significance (p = 0.097).

This finding indicates that the effectiveness of the warning system is not yet fully optimal across all respondents. Based on in-depth interviews with informants regarding the use of disaster warning tools:

> "... For traditional early warning tools, they use a kentongan (wooden drum). Kentongan is owned by individuals/households. There will definitely be a gong at the meeting point, at least at the guard post, which also serves as the meeting point, or at the hamlet level. For modern EWS, for example, in mosques they use a loudspeaker, but there's a problem when a disaster occurs, the electricity usually goes out, so they still use a wooden clapper. (Informant A,male, 45 years old)
>
> "... the one who rang the gong was a young man/cadet, but what distinguished the way he rang it... This is what we need to update for revitalisation because young people no longer recognise it. There's a shift; currently, most children don't recognise traditional tools, they're more familiar with modern tools even though they use electricity, so traditional EWS still need to be preserved..." (Informant B, female, 27 ye*ars old)*

The "kentongan" is one of the tools traditionally used for disaster warnings, and it's also used via WhatsApp groups, as stated by informant B:

> *"Now, information or early warnings are sent through WhatsApp groups, so it's faster, as long as there's a signal..." (Informant A,male, 45 years old)*
>
> *"Information from the BPBD is usually also updated on WhatsApp..." (Informant B, female, 27 years old)*

In the resource mobilisation capacity (RMC) component, the majority of respondents were in the low preparedness category, with 89 people (66.0%). Only 44 respondents (33.1%) had high preparedness, and there were no respondents in the medium preparedness category. This condition indicates that the community's ability to mobilise resources when facing disasters remains a major weakness in the preparedness system. According to the results of in-depth interviews with informants, residents have already received training on preparing disaster preparedness bags:

> *"...we have also conducted this training, ma'am, disaster preparedness bags...inside they have to prepare a bag containing essential supplies, valuable documents are also kept in a bag that is easy to grab in case of a sudden disaster, because disasters come unexpectedly, right?" (Informant B, female, 27 years old)*

In addition, the informant also stated that*:*

> *"...we have conveyed in official forums that disaster mitigation education must be provided in schools so that information is disseminated to prevent the 2010 incident from happening again, with victims...so that the information reaches our grandchildren and children..."(Informant A,male, 45 years old)*

DISCUSSION

The significant relationship between gender and preparedness corroborates recent evidence that gender dynamics influence both access to preparedness information and the

ability to act on it. Gendered roles such as caregiving responsibilities and differential access to public information, can constrain or enable preparedness actions, and gender-responsive programming is increasingly recommended to address these disparities. Regional guidelines and reviews emphasize the need for gender-sensitive disaster management to ensure equitable readiness and response(11,12). Occupation emerged as a significant predictor in the bivariate analysis, with housewives showing a relatively large representation among those with high preparedness. Occupational roles often determine daily routines, time availability, and social networks, all of which influence engagement with preparedness activities and community drills. Similar occupational and role-based differences in preparedness have been observed in community studies, where household responsibilities and informal social capital shape practical readiness measures (13,14)

Based on research at Merapi Volcano, Yogyakarta (15) proximity to the hazard proved to be a robust correlate: respondents residing in short/near distance villages exhibited the highest proportion of high preparedness. This spatial pattern aligns with established risk-perception theory and empirical work indicating that geographic proximity to hazard sources elevates perceived vulnerability and motivates protective behaviours. Communities living nearer to active volcanic systems commonly report higher engagement in preparedness, often driven by recurrent exposure, visible hazard signs, and local mitigation efforts. Extended residence likely facilitates accumulation of local knowledge, shared memories of past events, and denser social networks that transmit preparedness norms. Several recent intervention and cross-sectional studies show that experience embedded in place and the strengthening of social ties contribute to community-level readiness.(16,17)

In contrast with research conducted in Iran (14,17) prior eruption experience did not reach statistical significance in the present sample ($\chi^2 = 7.481$, $p = 0.113$). This shows that prior occurrences alone may not be enough to foster permanent preparedness behaviors, especially when formal education, participation training, or institutional supports are uneven. Recent study also finds mixed correlations between catastrophe experience and preparedness, typically mediated by information dissemination and local capacity-building activities.

After controlling for potential confounders, the model identified gender and distance to the volcano as statistically significant independent predictors of preparedness, while age, occupation, and length of residence did not achieve statistical significance. The finding that gender was significantly associated with preparedness aligns with broader literature suggesting that gender influences disaster preparedness behaviours through social roles, access to information, and risk perception. Recent systematic reviews highlight that gender dynamics shape both vulnerability and adaptive capacities in disaster risk management, emphasizing that inclusive approaches are crucial to strengthen community resilience and ensure equitable participation in preparedness activities (12). Gender differences in risk perception and preparedness have also been identified in empirical hazard studies, with males sometimes demonstrating higher practical preparedness under specific contexts, though patterns may vary by hazard type and community norms. Based (18) these gendered patterns may reflect culturally mediated expectations regarding household roles and decision-making authority, which can influence the degree to which individuals engage with disaster planning and capacity building.

Residents living farther from Mount Merapi had 76% lower probability of being prepared than those living closer. Residents closer to risks are more likely to see hazard cues, official warnings, and community-level drills, which affects risk perception and readiness.. Studies in volcanic and flood-prone regions have consistently shown that individuals living in high-exposure zones exhibit higher preparedness behaviours due to heightened perceived threat and lived experience with hazard recurrence (15). Age was not a significant predictor suggesting that, age alone does not independently influence preparedness after adjusting for other factors. This finding reflects previous research (19)where age differences did not consistently predict preparedness when other psychosocial and community variables were accounted for. Similarly, occupation was not statistically significant (B = 0.100, p = 0.400, OR = 1.105), indicating that employment or social role may not independently shape preparedness behaviour in this community once gender and proximity are considered. Occupational influence on preparedness has been discussed in the literature, but effects often attenuate in multivariable models when risk perception and exposure variables are included, underscoring that occupation may interact with other social determinants rather than acting as a standalone predictor(14).

Although length of residence at the research site showed a positive but non-significant trend the direction suggests that longer-term residents may be more prepared, possibly due to accumulated local knowledge and stronger social networks. Previous studies have noted that long-term residence can contribute to enhanced disaster preparedness through repeated exposure to local risk communication and social learning mechanisms(19). indicate that the duration of residence in disaster-prone areas plays a crucial role in shaping risk understanding, threat perception, and responses to early warnings. Based on research conducted in Bukittinggi, Indonesia (20) stating that communities living in active disaster zones tend to have higher awareness and preparedness because they directly experience the impact of disasters and have participated in various evacuation training and simulations conducted by BPBD and partner agencies. Long-term exposure to dangerous situations changes social capital, local knowledge, and adaptive practices that improve community preparedness. Long-term inhabitants are more likely to have access to local information networks, shared experiences, and continued participation in community-based mitigation actions, all of which can improve readiness. (21)

The findings of this study highlight that disaster preparedness is not merely an individual attribute but is shaped by everyday social roles and lived proximity to risk. Differences in preparedness between men and women suggest that access to information, participation in training, and decision-making opportunities are not always evenly distributed. In addition, communities located farther from Mount Merapi may feel less exposed to danger, which can reduce their motivation to actively engage in preparedness activities. These patterns indicate that preparedness is closely linked to how people perceive risk and how they are positioned within their social and environmental context.

From a practical and policy perspective, these findings underline the importance of designing disaster preparedness programs that are both inclusive and context-sensitive. Efforts should move beyond general awareness campaigns toward more targeted approaches that consider gender dynamics and geographical differences. Community-based training, simulation exercises, and disaster education programs should actively involve both men and women, ensuring equal access to knowledge and participation. At the same time, special

attention should be given to populations living farther from the volcano by strengthening risk communication and extending early warning dissemination to ensure that no groups are overlooked. By aligning preparedness strategies with the realities of community life, disaster risk reduction efforts can become more equitable, effective, and sustainable.

This study has several limitations that should be acknowledged. First, the cross-sectional design limits the ability to establish causal relationships between variables. Second, the relatively small sample size may reduce the generalizability of the findings. In addition, the use of self-reported data may introduce response bias, including recall and social desirability bias. Future studies with larger sample sizes and longitudinal designs are recommended to provide a more comprehensive understanding of disaster preparedness in volcanic hazard areas.

CONCLUSION AND RECOMENDATION

This study identified key determinants of disaster preparedness is shaped not only by individual characteristics but also by social roles and spatial risk exposure. Gender differences reflect underlying inequalities in access to information, participation, and decision-making, while geographical distance influences risk perception and engagement in preparedness activities. In-depth interviews revealed that residents have participated in disaster preparedness training, particularly in preparing emergency kits, which reflects a relatively good level of emergency planning capacity. However, the effectiveness of early warning systems (EWS) remains uneven. Communities rely on both traditional tools, such as kentongan, and modern systems like loudspeakers. While modern systems are vulnerable to power outages, traditional tools face challenges due to declining familiarity among younger generations. Building on these findings, disaster preparedness efforts should adopt a more integrated and context-sensitive approach. Programs should incorporate gender responsive strategies by actively involving both men and women in training, simulation exercises, and community education to ensure equitable access to preparedness knowledge and response skills. Integrating traditional and modern approaches, assuring operation during power outages, and supporting intergenerational knowledge transfer to keep traditional warning signals effective are also crucial to strengthening early warning systems.

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