

# From tweet to tremor: enhancing megathrust disaster monitoring and early warning systems in social media

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**Abstract.** This researches how to explore the potential of social media in improving megathrust disaster monitoring and early warning systems, focusing on two regions in Indonesia: Gunung Kidul and Tanggamus. Using a quantitative approach through a questionnaire-based survey, the research reveals that most respondents (70% in Gunung Kidul and 85% in Tanggamus) consider the internet/social media as an important source of information during disasters. Furthermore, 70% of respondents in Gunung Kidul and 85% in Tanggamus are willing to receive official warnings through these platforms. Nonetheless, challenges related to data verification and reliability of information on social media still exist. Only 12% of respondents in Gunung Kidul and 8% in Tanggamus considered social media to be very reliable as a source of disaster information. This finding underscores the importance of collaboration between the government, disaster management agencies and social media platforms to ensure the accuracy of information disseminated. Overall, this study provides empirical evidence on the potential of utilizing social media to improve early warning systems and response to megathrust disasters. The integration of social media into disaster mitigation strategies can provide significant benefits, especially in terms of early detection, enhancing situational awareness, and facilitating communication and collaboration during disasters.

## 1 Introduction

Natural processes result in a high death toll from disasters, which also affect a sizable section of the population and generate significant social and economic damages; they sometimes may end in political instability [1-3]. In disaster management, quick reaction and evaluation are crucial. As a result, research on creating instruments for quick reaction to and evaluation of natural disasters [4, 5] has expanded in consideration emerging demands over the past few decades [6].

Today, the responsibility of innovation and the application of technology for social good can aid in producing some beneficial results in solving the issues that our cities and urban areas face [7]. Governments can employ social media analytics as sensors, information-sharing platforms, and social intervention tools since it allows for a dynamic engagement with the public. Rising social media apps (like those on Twitter, Inc. and Facebook, Inc.) are growing as countries address these demands. In contrast to other conventional methods, social media platforms record public reactions through both virtual and actual languages, gathering an unparalleled size of data and amount of information. This comes into an important component of sociological studies [8, 9].

In another hand, social media sites can offer a variety of viewpoints on how natural disasters and climate change are affecting people's local communities and cities (e.g., recognizing changes in emotions over time and space in

the context of a natural hazard-related disaster). This phenomenon makes collection of data from various communities and provides additional resources for quantitative research easier to conduct. [10, 11].

For example, some research examined traffic-related event detection detecting severe diseases and symptoms in and across cities [12], and a range of different themes including governance matters connected to COVID-19 [13, 14]. Furthermore, several researchers examined urban logistics [15], public mood assessments of government services, and disaster severity prediction [16] using big data social media analytics.

Therefore, digital technology has significantly improved disaster detection and warning, which has certainly saved lives in the field of natural hazard-related disaster management [17, 18]. Applications of social media in disaster management have garnered a lot of attention from academic and practitioner circles in recent years due to social media's enormous potential. Social media is very helpful in emergency circumstances [19].

The Disaster Prevention and Management Journal features a study by Martin that discusses the significance of emergency communication and warning systems (ECWS). According to that, people may make decisions and act prior to, during, and following an emergency or disaster thanks to emergency communications and warning systems [20].

There are two types of disaster warnings that are in use today. Individuals who convey possible risks according to severity, spread speed, and likelihood of suppression, as

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well as those who notify nearby populations and offer guidance on how to react. [21].

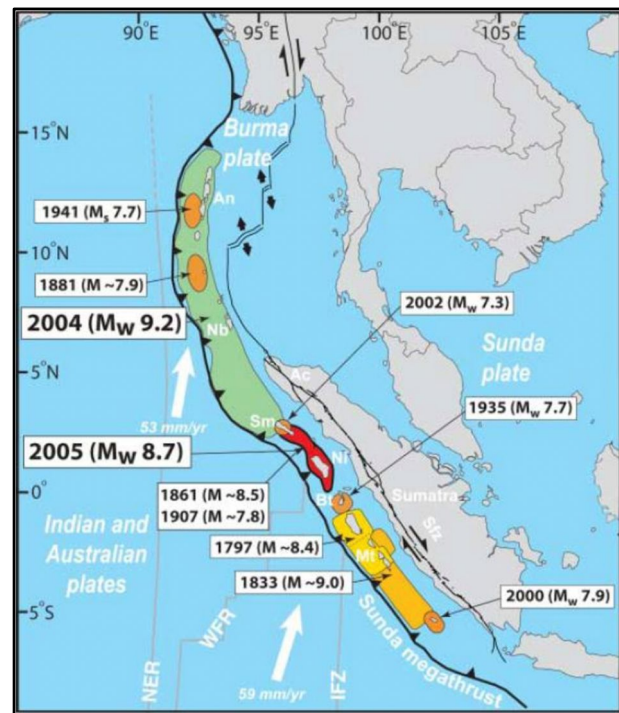
For example, twitter-based warning system would offer prompt, openly available, all-encompassing disaster management to lower the likelihood of fatalities in natural hazard-related disasters [22]. Social media plays a crucial part in resilience. It was revealed that communities with strong social media relationships and networks had stronger adaptive capabilities and were more aware of the severe hazards, which increased their chances of surviving [23]. They [24] proposed a social-psychological theory called nudging in which human behavior is influenced in an easily reversible way without resulting in any particular action.

Megathrust faults in subduction zones are responsible for Earth's largest earthquakes and tsunamis. These faults exhibit diverse slip behaviors, from rapid stick-slip earthquakes to slow creep, influenced by factors such as fault zone complexity and seafloor roughness [25]. Heat flow data suggest smooth megathrusts producing great earthquakes are generally weaker than geometrically rough, creeping megathrusts [26]. The seismic behavior of megathrusts is affected by various parameters, including plate structure, sediments, fluids, and bathymetric roughness [27]. Understanding these factors is crucial for seismic hazard assessment. The Mentawai-Pagai segmentation in Indonesia, which experienced a megathrust earthquake in 2010, has been studied using various methods, including paleo geodesy, teleseismic, and aftershock analysis [28]. Ongoing research combines empirical analysis of global data with analogue modelling to better understand megathrust behavior [29].

The most spectacular event in a subduction zone's life cycle—the conclusion of decades of strain accumulation across a convergent plate boundary—occurs only seldom and manifests itself as a massive megathrust earthquake [30]. Strong seismic signals from all over the world enable calculation of the overall magnitude of the event, but the specifics of the rupture are typically not clear because there aren't any geodetic data immediately overhead or close by.

In contrast to other subduction megathrust events, the massive [moment magnitude ( $M_w$ ) = 9.2] Sumatra-Andaman earthquake of December 2004 (Fig. 1) had geodetic observations of co-seismic motions available from islands directly above the rupture. The origins of the earthquake might be thoroughly investigated thanks to these near-field data. Nevertheless, there were few near-fields geodetic measurements using the Global Positioning System (GPS) [31].

Three months later and directly to the south (Fig. 1), the massive Nias-Simeulue earthquake ( $M_w = 8.7$ ) offers a far greater chance to constrain rupture mechanisms. Recently, several GPS (continuously recording) stations had been set up either directly above or next to the rupture [32]. Furthermore, the measurement of co-seismic uplift and submergence using coral microatolls was made possible by the existence of a tropical archipelago above the breach. We can create one of the most precise and in-depth maps of deformation for a subduction megathrust earthquake thanks to the vast collection of measurements that resulted.



**Fig. 1.** Massive Nias-Simeulue earthquake (source: [ectonics.caltech.edu/sumatra/data.html](http://ectonics.caltech.edu/sumatra/data.html))

A wide range of seismic features have been shown to have depth dependency along megathrusts in recent decades, according to several observations. Focused research on depth-dependent features was spurred by the discovery of tsunami earthquakes [33] that produced significantly greater tsunamis than would be predicted for a conventional earthquake with the same surface wave magnitude ( $M_S$ ). These uncommon shallow ruptures often have unusual characteristics, such as a massive slip that produces a powerful tsunami and a comparatively modest rupture velocity and radiated energy. These are broad, yet rare, have struck along the Aleutians, Japan, the Kuril Islands, Peru, Nicaragua, El Salvador, New Zealand, Java, and Sumatra [34].

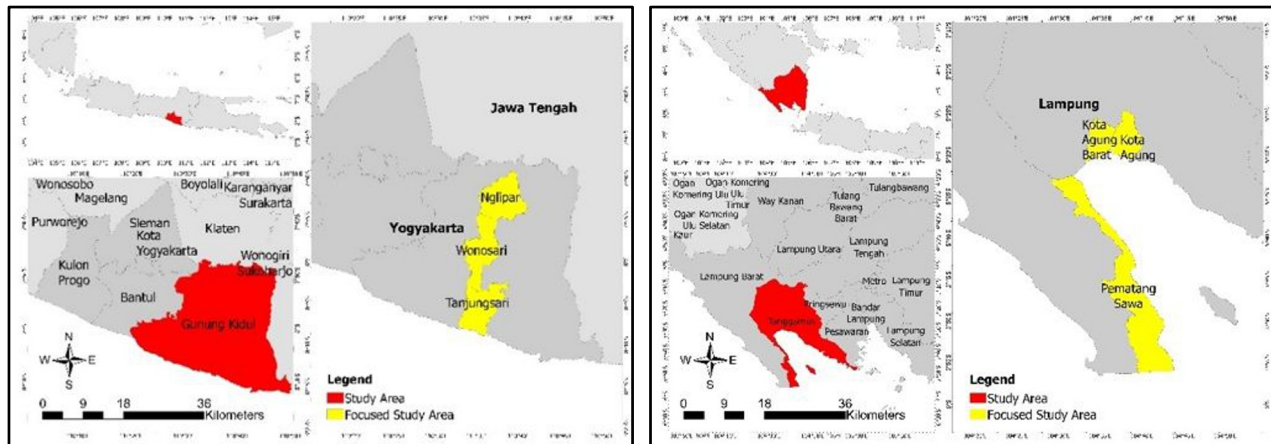
Furthermore, numerous large-magnitude earthquakes ( $M > 8$ ) that have occurred since 2004 have yielded exceptional recordings by an abundance of broadband seismographs, enabling the observation of significant slippage but minimal coherent high-frequency radiation bursts in the shallowest portion of the relevant subduction zone. However, numerous bursts of high-frequency radiation have originated from the deeper regions of the seismogenic zone, where seismic slip is lower [35].

Likely distinguishes itself from other articles on megathrusts in some ways are: a) this research focused on social media integration; such as the usage of social media in megathrust disaster monitoring and early warning systems and this article may delve into how this real-time data can be used to detect early signs of seismic activity or collect data from the ground during a megathrust event, which could enhance situational awareness and reaction times. The article could examine how to engage citizens in data collection and reporting, thereby expanding the reach and coverage of monitoring efforts, particularly in remote or underserved areas.

## 2 Research methods

### 2.1 Study area

The research is located in Yogyakarta Special Province and Lampung Province (see Fig. 2). There are two main perspectives that come into the main argument in choosing these two which is a tourism perspective and



**Fig. 2.** Research location maps (a) Yogyakarta Special Province (b) Lampung Province (source: google maps)

### 2.2 Questionnaire survey design

This study employed a quantitative approach to assess citizen-level tsunami preparedness in coastal tourism areas. Data collection was conducted through face-to-face interviews using questionnaire instruments. The flowchart of the questionnaire survey process is illustrated in figures below.

Then the survey questions was design into several questions delivered to respondents about: their primary sources of information about megathrust earthquakes and tsunami, familiarity with term of megathrust earthquake, the respondents perceived level of information, the respondents knowledge of evacuation routes in case of a disaster, the frequency of use social media platforms, the experience of receiving or sharing information about earthquake in social media, the perception of social medias reliability as a source of information during megathrust, respondents willingness to receive about its information.

### 2.3 Data analysis

Descriptive statistics constituted the focus of the data analysis, because of the limits of the survey methodology in terms of drawing generalizations about the entire population, inferential statistical tests were not performed. To determine the most common answers to each question, the percentage frequencies were computed, and the results were obtained.

disaster perspective. First, tourism perspectives such as: enhanced safety that social media can help tourists make more informed judgments and take preventative measures by giving them access to real-time alerts and information.

Second, disaster perspectives such as: early warning and evacuation; Yogyakarta and Lampung disaster management officials may be able to obtain earlier indications of seismic activity by utilizing the real-time nature of social media data.

## 3 Results and discussion

### 3.1 Characteristics of respondents

From the data in Tables 1 and 2, we can see that a total of 215 responders were retrieved, including 110 respondents from Gunung Kidul Yogyakarta, and 115 from Tanggamus, Lampung. According to their latest educational attainment, sex, age, and place of origin, the respondents' sociodemographic were grouped.

**Table 1.** Socio-demographic characteristics of respondents in Gunung Kidul, Yogyakarta

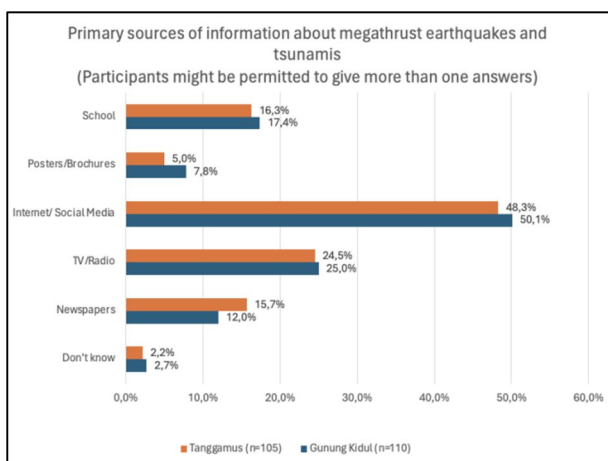
Characteristic	Types	Quantity	%
Origin	Nglipar	40	36%
	Wonosari	22	20%
	Tanjung Sari	48	44%
Sex	Male	58	53%
	Female	52	47%
Age	17-26	30	27%
	27-36	45	41%
	37-46	25	23%
	>= 46 years old	10	9%
Last Education	Elementary School	15	14%
	Junior high school	30	27%
	Senior highschool	40	36%
	Higher education	25	23%

**Table 2.** Socio-demographic characteristics of respondents in Tanggamus, Lampung

Characteristic	Types	Quantity	%
Origin	Pematang Sawa	23	22%
	Kota Agung Barat	37	35%
	Kota Agung	45	43%
Sex	Male	55	52%
	Female	50	48%
Age	17-26	32	30%
	27-36	42	40%
	37-46	21	20%
	>= 46 years old	10	10%
Last Education	Elementary School	12	11%
	Junior high school	33	31%
	Senior highschool	35	33%
	Higher education	25	24%

### 3.2 Questionnaire results

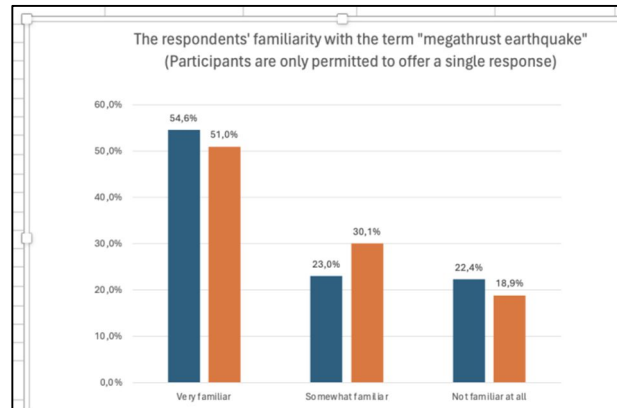
Most respondents in both regions (50.1% in Gunung Kidul and 48.3% in Tanggamus) said they mostly get their information from the internet and social media. Approximately 25% of respondents in both categories (24.5% and 25.0%) mentioned television and radio, indicating their continued importance as sources. This response implies that traditional media is still important for reaching a larger audience, particularly for people who do not have much internet access or who like these kinds of mediums.



**Fig. 3.** Primary sources of information about megathrust earthquakes and tsunami

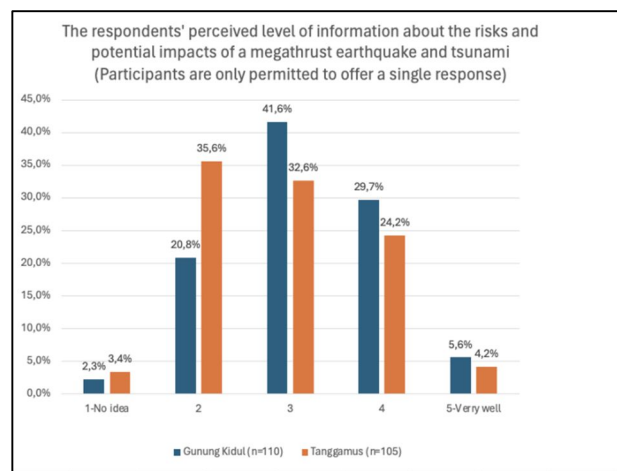
The data shown from Fig. 3 we can see that 54.6% of respondents in Gunung Kidul and 51.0% in Tanggamus fall into the "Somewhat familiar" group, indicating a moderate level of awareness regarding the term "megathrust earthquake." Compared to Tanggamus,

where respondents rated their familiarity with the term at 23.0%, Gunung Kidul respondents rated it at slightly higher (30.1%). In both regions, a worrying percentage of respondents (18.9% in Gunung Kidul and 22.4% in Tanggamus) said they were "Not familiar at all" (with its term) were unclear about their prior experience with earthquakes.



**Fig. 4.** The respondent's familiarity with the term of megathrust earthquake

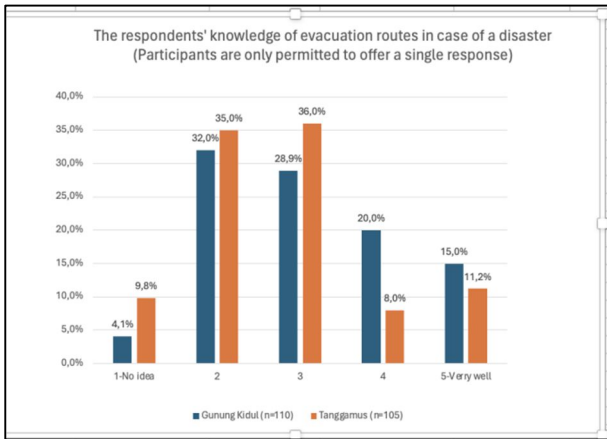
The data shown from Fig. 4 we can see that most responses in Gunung Kidul and Tanggamus are in the middle of the spectrum (levels 2, 3, and 4), indicating a moderate level of perceived information regarding the possible dangers and effects of megathrust earthquakes and tsunamis. In comparison to Tanggamus, a greater proportion of respondents in Gunung Kidul chose levels 4 ("well-informed") and 5 ("very well-informed"). This suggests that people's perceptions of the dangers in Gunung Kidul are marginally improved. A significant portion of respondents in both regions, but especially in Tanggamus (4.2%), chose "1-no idea," indicating that some people are not aware of this.



**Fig. 5.** The respondents perceived the level of information

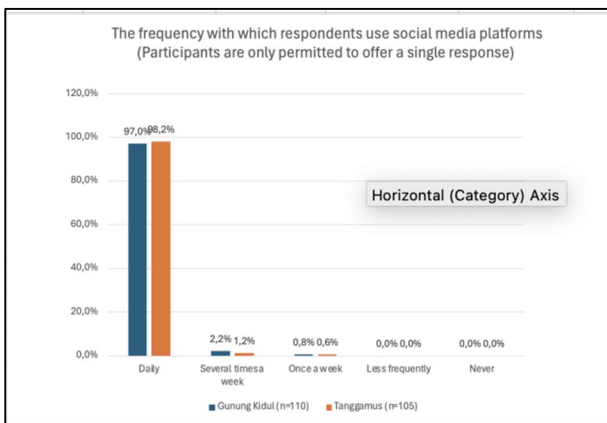
In both Gunung Kidul and Tanggamus, that shown in Fig. 5 that the distribution of responses trends towards the middle categories (levels 2 and 3), showing a moderate level of knowledge regarding evacuation routes. In comparison to Gunung Kidul, a marginally greater proportion of respondents in Tanggamus chose levels 3 ("somewhat well") and 4 ("well"). This implies that

Tanggamus residents believe they know a little bit more about evacuation routes than the typical person. A significant fraction of respondents in both regions, but especially in Gunung Kidul (9.8%), chose "1-No idea," indicating a lack of awareness on the part of the populace.



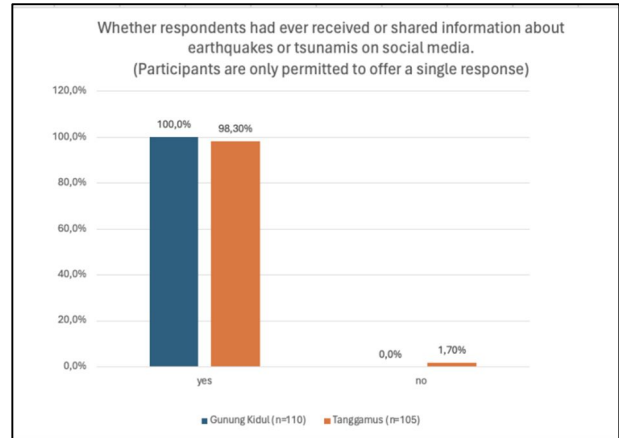
**Fig. 6.** The respondent’s knowledge of evacuation routes in case of a disaster

A large percentage of respondents (97.0% and 98.2%, respectively) drawn in Fig. 6 in Gunung Kidul and Tanggamus reported utilizing social media platforms daily. This suggests that social media usage and penetration are extremely high in both areas. Minimal Other Usage Categories: The percentages of the remaining categories—"Several times a week," "Once a week," "Less frequently," and "Never"—are extremely low, underscoring the prevalence of daily social media use.



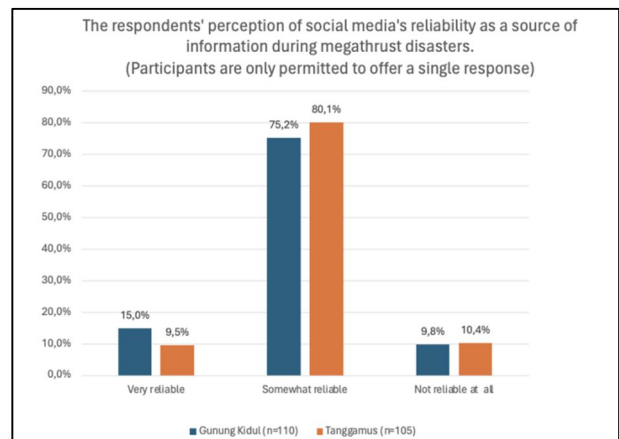
**Fig. 7.** The frequency of use social media platforms

The data shown from Fig. 7 we can see that A staggeringly high proportion of respondents (100% in Gunung Kidul and 98.3% in Tanggamus) said they had either posted or received information about earthquakes or tsunamis on social media. Minimal "No" Responses: Just 1.7% of respondents in Tanggamus and 0% in Gunung Kidul, respectively, reported having never interacted with such content on social media.



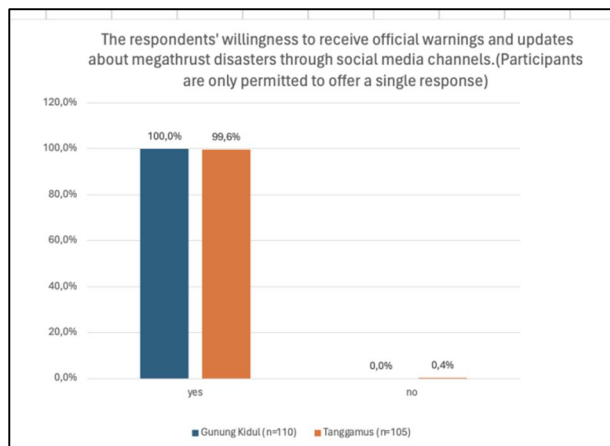
**Fig. 8.** The experience of receiving or sharing information about earthquakes in social media

The data shown in Fig. 8 explained that in Gunung Kidul (75.2%) and Tanggamus (80.1%) people's most common opinion of social media as a report source during megathrust disaster is "Somewhat reliable." This implies some trust, but it also acknowledges certain drawbacks because fewer respondents (15.0% in Gunung Kidul and 9.8% in Tanggamus) choose social media as "Very reliable". This finding suggests a level of mistrust or awareness of the possibility of false information on these platforms in times of emergency. Social media is seen as "Not reliable at all" by a comparatively modest percentage of respondents in both categories (9.5% and 10.4%, respectively). The finding suggests most people see some value in social media as an information source during disasters, even if they do not truly trust it.



**Fig. 9.** The perception of social media’s reliability as a source of information during megathrust

Remarkable 100% of respondents that shown from the data in Fig. 9 in Gunung Kidul and 99.6% of respondents in Tanggamus said that they would be open to receiving official alerts and updates regarding megathrust disasters via social media with 0% in Gunung Kidul and just 0.4% in Tanggamus, the percentage of respondents who are unwilling to accept such information is essentially non-existent.



**Fig. 10.** Respondents' willingness to receive information about

The data in Fig. 10 show 100% of respondents in Gunung Kidul and 99.6% of respondents in Tanggamus said that they would be open to receiving official alerts and updates regarding megathrust disasters via social media with 0% in Gunung Kidul and just 0.4% in Tanggamus, the percentage of respondents who are unwilling to accept such information is essentially non-existent.

### 3.3 Discussion

The findings highlight that earthquakes are perceived as the most significant natural threat in both Tanggamus and Gunung Kidul, likely due to Indonesia's location within the seismically active Pacific Ring of Fire and the coastal vulnerability of Tanggamus to potential tsunamis. The diverse range of natural hazards Indonesia faces is evident in the acknowledgment of extreme weather events and volcanic eruptions as potential risks in both regions.

The primary source of information regarding disaster preparedness for most respondents in both regions is the internet and social media, highlighting the growing reliance on digital platforms for information dissemination. However, traditional media like television and radio remain important, especially for those with limited internet access or preference for these mediums.

The top priority for communities in Gunung Kidul and Tanggamus in dealing with potential megathrust earthquakes and tsunamis is public education about the dangers of these disasters. This shows an awareness of the importance of knowledge and understanding of risks to improve preparedness. In addition, securing large objects in homes and offices is also considered important, especially in Tanggamus, indicating an awareness of the risk of damage from falling objects during an earthquake. Improving early warning systems was also considered crucial, especially in Gunung Kidul. This underscores the need for better infrastructure to provide quick and accurate early warnings, which could potentially save many lives.

However, this level of importance is still below education and securing large objects, indicating a gap in understanding of the importance of having a clear and trained emergency plan in the face of disasters. The low prioritization of building retrofitting may reflect cost

constraints and perceptions about the feasibility of implementing it. This is a challenge, given that building retrofitting is one of the most important steps in reducing the risk of earthquake damage. Levels of confidence in dealing with megathrust earthquakes and tsunamis are moderate, with most respondents feeling "somewhat confident." The high percentage of respondents who feel "not confident at all" indicates the need to improve individual and family preparedness through more intensive training and education. The high use of social media in both regions indicates great potential for utilizing this platform to disseminate disaster-related information and early warnings. The fact that almost all respondents had received or disseminated information about earthquakes and tsunamis through social media further emphasizes this potential.

However, the level of trust in social media as a source of information during disasters is still moderate. This highlights the importance of ensuring the accuracy of information circulated on social media and the need for the government and official institutions to play a role in providing reliable information. The high willingness of respondents to receive official early warnings through social media provides an opportunity for the government and relevant agencies to utilize this platform as an effective risk communication tool. This needs to be balanced with efforts to ensure the information provided is accurate, relevant, and timely.

### 4 Conclusion

This research shows the great potential of social media in improving the megathrust early warning system, especially in vulnerable areas such as Gunung Kidul and Tanggamus. Although communities show good awareness of potential disasters, understanding of megathrust earthquakes and levels of preparedness still need to be improved. Social media has become a major source of information, but the reliability of the information is still a challenge. Therefore, the integration of social media in the early warning system must be balanced with efforts to improve disaster literacy, data verification, and cross-sector collaboration. Thus, the potential of social media can be maximized to reduce the impact of megathrust disasters in Indonesia.

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