

Indigenous knowledge-based tsunami disaster mitigation strategies in South Lampung coastal areas, Indonesia



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South Lampung Regency, located in southern Sumatra, Indonesia, records a high disaster risk index score of 176.14, with its coastal areas acutely exposed to tsunami hazards. Historical evidence of the 1883 Krakatoa and the 2018 Anak Krakatau tsunamis, which caused 118 deaths and extensive infrastructural losses, underscores the urgency of comprehensive mitigation efforts. This study adopts a qualitative ethnographic design integrated with geographic information system (GIS)-based spatial analysis to examine how coastal communities in Kalianda and Rajabasa transform indigenous knowledge into practical resilience strategies. Data were gathered through in-depth interviews, participant observation and satellite image-based land-use mapping. The spatial analysis classified six vulnerability zones and revealed that 42% of settlements remain within high-risk coastal buffers. The findings indicate that local communities complement structural mitigation, such as breakwaters and evacuation sites with culturally embedded practices, including interpreting natural warning signs, reinforcing communal solidarity and intergenerational transfer of evacuation knowledge.

Contribution: The research contributes an integrated vulnerability map that merges structural, environmental and socio-cultural dimensions, demonstrating that the fusion of indigenous knowledge and scientific spatial assessment substantially enhances tsunami preparedness. These insights provide a replicable model for policymakers and disaster risk-reduction practitioners in similar coastal regions.

Keywords: tsunami; disaster mitigation; indigenous knowledge; GIS; community resilience; South Lampung.

Introduction

Indonesia is one of the countries with the highest disaster vulnerability in the world. Its geographical position at the convergence of four major tectonic plates, namely the Eurasian, Indo-Australian, Pacific and Philippine plates, makes the region highly susceptible to geological disasters such as earthquakes, tsunamis and volcanic eruptions (Adi et al. 2022, 2023; Ammann 2013; UNISDR 2009). In addition to geological factors, Indonesia's location within the tropical zone and its complex topography also expose it to hydrometeorological disasters such as floods, landslides, droughts, extreme weather events and coastal abrasion (Adi et al. 2022). According to the 2022 Indonesian Disaster Risk Index (IRBI), 15 provinces are categorised as having a high disaster risk. Among them is Lampung Province, where South Lampung Regency recorded a disaster risk index of 176.14, placing it in the category of very high disaster risk (Adi et al. 2022). This condition underscores the urgent need for well-structured and systematic disaster mitigation planning and implementation.

South Lampung Regency has a long history of major disasters, particularly tsunamis. The first recorded tsunami occurred on 27 August 1883, following the catastrophic eruption of Mount Krakatoa, which devastated coastal areas along the Sunda Strait. A similar disaster struck again on 22 December 2018, caused by an underwater landslide following the eruption of Mount Anak

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Krakatoa, triggering a tsunami (Machruf, Hermawan & Meutia 2020). Based on data from the Regional Development Planning Agency (Bappeda) of South Lampung Regency, this event resulted in 118 fatalities, 5329 injuries, 7 missing persons and the destruction of at least 710 residential houses (Machruf et al. 2020). The two most severely affected sub-districts were Kalianda and Rajabasa. The tsunami inundation area in Kalianda reached 978.18 ha with water levels exceeding 3 m, while in Rajabasa, 660.8 ha were inundated with water levels ranging between 1 m and 3 m.

Disaster mitigation is a strategic effort to reduce risks and impacts through both structural and non-structural approaches. Structural approaches include physical constructions such as breakwaters, evacuation routes and warning signs. In contrast, non-structural approaches focus more on institutional frameworks, public education and community awareness (Diposaptono 2011; Haryani 2016; Powell et al. 2019). The Indonesian government has also regulated the importance of coastal mitigation through Government Regulation No. 64 of 2010 concerning Disaster Mitigation in Coastal Areas and Small Islands (Pemerintah 2010; Tenri, Santoso & Setiyono 2022).

This study aims to identify existing land use patterns based on tsunami disaster resilience criteria in the coastal areas of South Lampung Regency, particularly in Kalianda and Rajabasa sub-districts. The analysis is conducted through a spatial approach using satellite imagery data and adjusted to the needs of structural mitigation in the region. The findings are expected to provide valuable input for strengthening coastal area resilience through risk-based spatial planning.

Literature review

Disaster mitigation in coastal areas

Disaster mitigation refers to a series of efforts carried out before a disaster occurs to reduce potential losses, including casualties and infrastructure damage. In coastal areas, mitigation is especially crucial, as these zones are the most vulnerable to tsunami hazards (Diposaptono 2011). Mitigation strategies in coastal regions must consider the geophysical and socio-economic characteristics of local communities to ensure that the approaches implemented are both participatory and adaptive (Haryani 2016; Wibowo et al. 2019). Government Regulation of the Republic of Indonesia No. 64 of 2010 states that disaster mitigation must be implemented through both structural and non-structural approaches. Structural approaches include physical infrastructures such as breakwaters, evacuation routes and signs and emergency shelters. Meanwhile, non-structural approaches focus on enhancing community capacity through education, training and the strengthening of early warning systems (Pemerintah 2010).

However, effective mitigation cannot rely solely on modern technology. In the context of coastal communities, indigenous knowledge has long been an integral part of natural early warning systems, self-evacuation practices and post-disaster

social solidarity mechanisms (Hamid et al. 2021; Hiwasaki, Luna & Shaw 2014; Simarmata & Indrawati 2022; Syarif, Hendra & Saputro 2023).

Regional resilience strategies

Regional resilience in facing disasters is shaped by a combination of structural and non-structural factors. Coastal resilience can be strengthened through local adaptations that take into account the social and cultural capacities of the community. These include trust in natural signs, the role of traditional leaders as mobilisers and inherited traditions that reinforce community awareness (Chowdhooree 2019; Sarthi & Michael 2025; Yance et al. 2024).

The Ministry of National Development Planning (Bappenas) and the National Disaster Management Agency (BNPB) have also emphasised the importance of disaster risk reduction (DRR)-based development strategies that are integrated with local socio-cultural systems to ensure greater adaptability and inclusiveness (BNPB 2020). This approach is crucial to ensure that mitigation strategies are not solely dependent on physical infrastructure but also incorporate the values and lived experiences deeply embedded in community life.

Structural infrastructure and the role of indigenous knowledge

The development of infrastructure such as breakwaters and evacuation routes is a crucial component of structural mitigation strategies. However, such infrastructure will not function optimally without a solid understanding of local contexts (Kusumasari & Alam 2012). While breakwaters can reduce the intensity of tsunami waves, the effectiveness of evacuation is largely determined by the community's ability to recognise and respond to warnings both formal and informal (Hirmawan & Anisah 2018). Local wisdom, such as the use of natural evacuation paths (e.g. footpaths leading to higher ground), the designation of places of worship or traditional halls as emergency gathering points and the interpretation of natural sounds as danger signals, serves as a complement to structural mitigation systems (Kusuma, Ramadhan & Suryanda 2020; Mare, Angin & Rahmawati 2021).

Risk mapping, land planning and cultural adaptation

Spatial-based risk mapping is an essential tool for identifying tsunami-prone areas and establishing evacuation zones (Purwanto et al. 2017). However, for such planning to be effective, it must be aligned with the spatial patterns and cultural values of local communities. Evacuation routes that conflict with local customs or beliefs are often ignored or underutilised. In the context of South Lampung, many coastal communities possess a collective historical experience of disasters and have inherited knowledge systems passed down through generations. Therefore, the ideal mitigation strategy integrates modern mapping technologies with local knowledge and existing customary social structures (Hiwasaki et al. 2014).

Related research

Disaster mitigation based on indigenous knowledge is a strategic approach that integrates cultural values, traditional knowledge and social norms in efforts to prevent and reduce disaster risks. The culturally rich Indonesian society has long practiced various forms of indigenous knowledge, both in ecological aspects, such as earthquake-resistant house designs in Minangkabau, Nias and Acehese communities, and in social systems, such as the *tane' olen* [customary forest] concept among the Dayak people or tsunami warnings through the 'smong' tradition in Simeulue. These forms of indigenous knowledge reflect a life philosophy in harmony with nature and have been passed down across generations, proving that simple yet meaningful local practices can offer real protection from natural hazards (Aldiansyah 2021). Therefore, the preservation and strengthening of indigenous knowledge are crucial to developing sustainable, community-based disaster mitigation strategies.

Indigenous knowledge also manifests in adaptive behaviours towards the environment. Such wisdom can be transferred to other communities with similar characteristics and disaster contexts. It serves as a vital safeguard in improving community preparedness for natural hazards like tsunamis (Dewi & Sihombing 2022). Haryani's research underscores the importance of empowering coastal communities to design and implement mitigation strategies aligned with their socio-cultural values (Haryani 2016; Zalmansyah et al. 2023). By positioning communities as subjects rather than objects in disaster planning, this approach fosters long-term risk awareness and enhances community resilience from within.

Studies conducted across several island nations in Asia show that integrating local knowledge with modern warning systems significantly improves community preparedness for hydrometeorological disasters and tsunamis (Hiwasaki et al. 2014). Communities that are given the space to utilise and develop their indigenous knowledge exhibit faster and more accurate responses when disasters occur. In Simeulue, Aceh, the community preserves and transmits the *smong* narrative, a local term for tsunami, through songs, folklore and rituals (Kurniasih, Marin & Setyawan 2020; Rahman, Sakurai & Munadi 2017, 2018). This knowledge proved life saving during the 2004 tsunami, making Simeulue one of the regions with the lowest fatality rate despite its proximity to the epicentre.

Based on the findings above, it is evident that indigenous knowledge is not merely a complement but the core of sustainable disaster mitigation strategies. The integration of modern scientific systems with local practices can create mitigation frameworks that are more adaptive, contextual and resilient, especially in coastal areas like South Lampung. Research in Papua New Guinea and the Solomon Islands shows that traditional knowledge has strategic value in DRR systems. Communities in these regions recognise natural signs such as changes in sea colour, seabird behaviour and ground tremors as early warnings, passed down through oral traditions (Kusuma et al. 2020; Mare et al. 2021;

Mercer et al. 2010). These studies affirm that when traditional knowledge is integrated with scientific systems and modern technologies, mitigation effectiveness increases significantly, particularly in remote areas with limited formal infrastructure.

Meanwhile, research in Japan reveals that locally rooted preparedness cultures, especially through traditional evacuation routes and community-led disaster training, play a key role in reducing casualties during tsunamis (Shaw 2014). Coastal communities in Japan do not solely rely on high technology but consistently maintain routine evacuation drills, narrative-based disaster history markers and spatial planning based on traditional practices. This research demonstrates that the success of mitigation is not solely determined by technological sophistication but also by consistency, community education and the sustainability of local culture.

Research methods and design

This study employed a mixed-method design integrating descriptive–qualitative and spatial–quantitative approaches to comprehensively examine existing land-use patterns and the incorporation of indigenous knowledge in tsunami disaster mitigation. This methodological combination allowed an in-depth understanding of socio-cultural dynamics while simultaneously visualising spatial transformations in coastal areas (Creswell & Creswell 2017; Miles & Huberman 1984). The research was conducted in Kalianda and Rajabasa sub-districts, South Lampung Regency, Lampung Province, regions characterised by high tsunami vulnerability and the persistence of traditional cultural practices. These sites were purposefully selected based on their historical exposure to tsunami events, such as the 2018 Sunda Strait tsunami, and the sustained presence of indigenous knowledge within coastal communities (Hiwasaki et al. 2014).

The data utilised in this research comprised three main types. Firstly, spatial data were derived from Sentinel-2A satellite imagery obtained through the United States Geological Survey (USGS) EarthExplorer platform, which were used to identify, classify and map existing land-use patterns. Secondly, socio-cultural data were gathered through field observations and semi-structured interviews with community leaders, traditional elders and local residents to document indigenous knowledge and community-based disaster mitigation practices (Hiwasaki et al. 2014; Rahman et al. 2017). Thirdly, shapefile data, including administrative boundaries and official land-use zoning maps, were acquired from regional government institutions such as the Regional Development Planning Agency (Bappeda) and the Public Works and Housing Office (PUPR) of South Lampung Regency (Wahyunto, Ritung & Sulaeman 2014).

Data collection was conducted using two complementary methods. Sentinel-2A satellite imagery downloaded from the USGS EarthExplorer portal was processed using geographic information system (GIS) software, including ArcGIS and QGIS. Analytical procedures included land-use classification,

change detection and overlay analysis based on pre-existing shapefile datasets (Purwanto et al. 2017). In addition, qualitative data were obtained through participatory observation and interviews focusing on local narratives, symbolic traditions, evacuation routes and community infrastructures such as *balai adat* (traditional halls) and stilt houses. Triangulation techniques were applied to enhance data validity and reliability (Creswell & Creswell 2017).

Data analysis integrated both spatial and qualitative dimensions. Spatial analysis was performed to assess land-use dynamics and their relationships with coastal resilience parameters, including distance from the shoreline, elevation, slope and accessibility of evacuation routes (Bintarto 1979). Meanwhile, qualitative descriptive analysis followed the Miles and Huberman model, encompassing data reduction, data display and conclusion drawing. This process facilitated thematic mapping of local values relevant to community-based tsunami disaster mitigation (Miles & Huberman 1984).

Ethical considerations

Ethical clearance to conduct this study was obtained from the Institute for Research and Community Service of Sumatra Institute of Technology (No. [2593/IT9.2.1/PT.01.05/2025]).

Results

Tsunami disaster mitigation strategies in coastal areas cannot be separated from risk reduction efforts through complementary structural and non-structural approaches. Government Regulation of the Republic of Indonesia No. 64 of 2010 affirms that mitigation activities must combine physical development with the strengthening of social capacity to face disaster threats in coastal regions (Pemerintah 2010). This approach is reinforced by Diposaptono, who asserts that effective tsunami mitigation is achieved through a combination of physical and infrastructural strategies and non-physical approaches such as community empowerment and the integration of local culture (Diposaptono 2011). In

this context, the indigenous knowledge of coastal communities constitutes a key non-structural element that must not be overlooked (Hiwasaki et al. 2014).

Breakwater construction

Breakwaters are widely implemented as structural measures in tsunami-prone coastal regions. In Kalianda and Rajabasa, breakwaters have been constructed since 2022 through central government funding (APBN). Field observations (Figure 1 and Figure 2) indicate that approximately 65% of high-risk shoreline areas in Kalianda and 52% in Rajabasa are directly protected by breakwaters, reducing wave energy and mitigating potential damage (Firdaus et al. 2023).

Beyond their physical function, local communities perceive breakwaters as symbols of protection, integrating cultural narratives such as ‘coastal guardians’ into their use (Douvinet et al. 2024; Rahman et al. 2018; Triana 2017). This demonstrates the synergy between infrastructure and local cultural values.

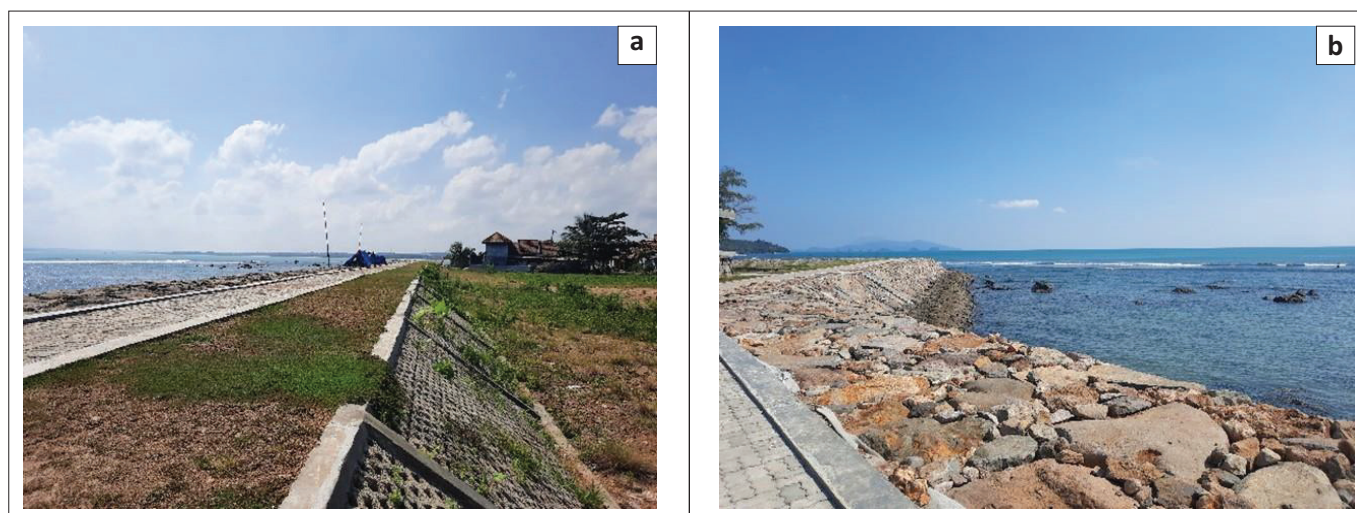
Signs, roads and evacuation sites

Mitigation facilities, including evacuation signs, designated evacuation routes and assembly points, are essential components of effective disaster response strategies. Field observations in Kalianda and Rajabasa districts indicate that most evacuation signs comply with the Indonesian National Standard (SNI 7743:2011) (BSN 2011), ensuring clear guidance during emergencies. Several villages have reinforced key evacuation routes with concrete pavements, enhancing accessibility for vulnerable groups such as the elderly, children and pregnant women (Figure 3). Despite these improvements, disparities remain, as some routes are still unpaved or covered with gravel, which can impede rapid evacuation during a tsunami event. This situation underscores the critical role of community involvement in planning, maintaining and evaluating evacuation infrastructure. Local knowledge from past disasters informs the placement and



Source: Zalmansyah, 2025, Breakwater on Rajabasa coastline, [Photograph] Field observation

FIGURE 1: Breakwater in Rajabasa coast.



Source: Zalmansyah, 2025, Breakwater on Kalianda coastline, [Photograph] Field observation

FIGURE 2: Breakwater in Kalianda coast.



Source: Zalmansyah, 2025, Evacuation signs and routes (Kalianda & Rajabasa), [Photograph] Field observation

FIGURE 3: Evacuation signs and routes in Kalianda and Rajabasa districts.

usability of evacuation routes, while community participation ensures that infrastructural improvements align with cultural practices and local environmental conditions.

Evacuation sites are generally open fields situated on higher terrain, such as the slopes of Mount Rajabasa. In several villages, residents supplement formal assembly points by utilising traditional halls [*balai adat*] or community-owned land as emergency gathering locations (Douvinet et al. 2024). These practices highlight the importance of social capital in disaster mitigation, demonstrating how local communities actively compensate for gaps in formal infrastructure, strengthen preparedness and reinforce collective resilience (Mercer et al. 2010).

Structural integration and indigenous knowledge

Effective tsunami mitigation in Kalianda and Rajabasa sub-districts extends beyond physical infrastructure, requiring the integration of cultural values and local

knowledge into disaster management strategies. Coastal communities continue to rely on traditional knowledge systems, including the interpretation of ocean sounds, wind patterns and animal behaviour, as early indicators of impending hazards. Additionally, orally transmitted narratives about historically recognised 'safe zones' guide residents during evacuations, ensuring timely and contextually informed decision-making (Rahman et al. 2017, 2018; Trogrlić et al. 2022).

Beyond these cognitive tools, social practices such as cooperation [*gotong royong*], adherence to traditional leadership structures and strong communal bonds function as critical social capital that reinforces community-based disaster response. For example, collective decision-making and voluntary mobilisation during emergencies enhance both the reach and effectiveness of mitigation measures.

The integration of local systems with formal disaster management mechanisms exemplifies the principles of

the community-based disaster risk reduction (CBDRR) approach, which emphasises active community participation across the mitigation cycle from planning and preparedness to response and recovery (Firdaus et al. 2023; Hiwasaki et al. 2014; Shaw 2014). This approach ensures that infrastructural interventions, such as breakwaters, evacuation routes and assembly points, are not only technically sound but also socially accepted, culturally relevant and sustainably maintained by the community.

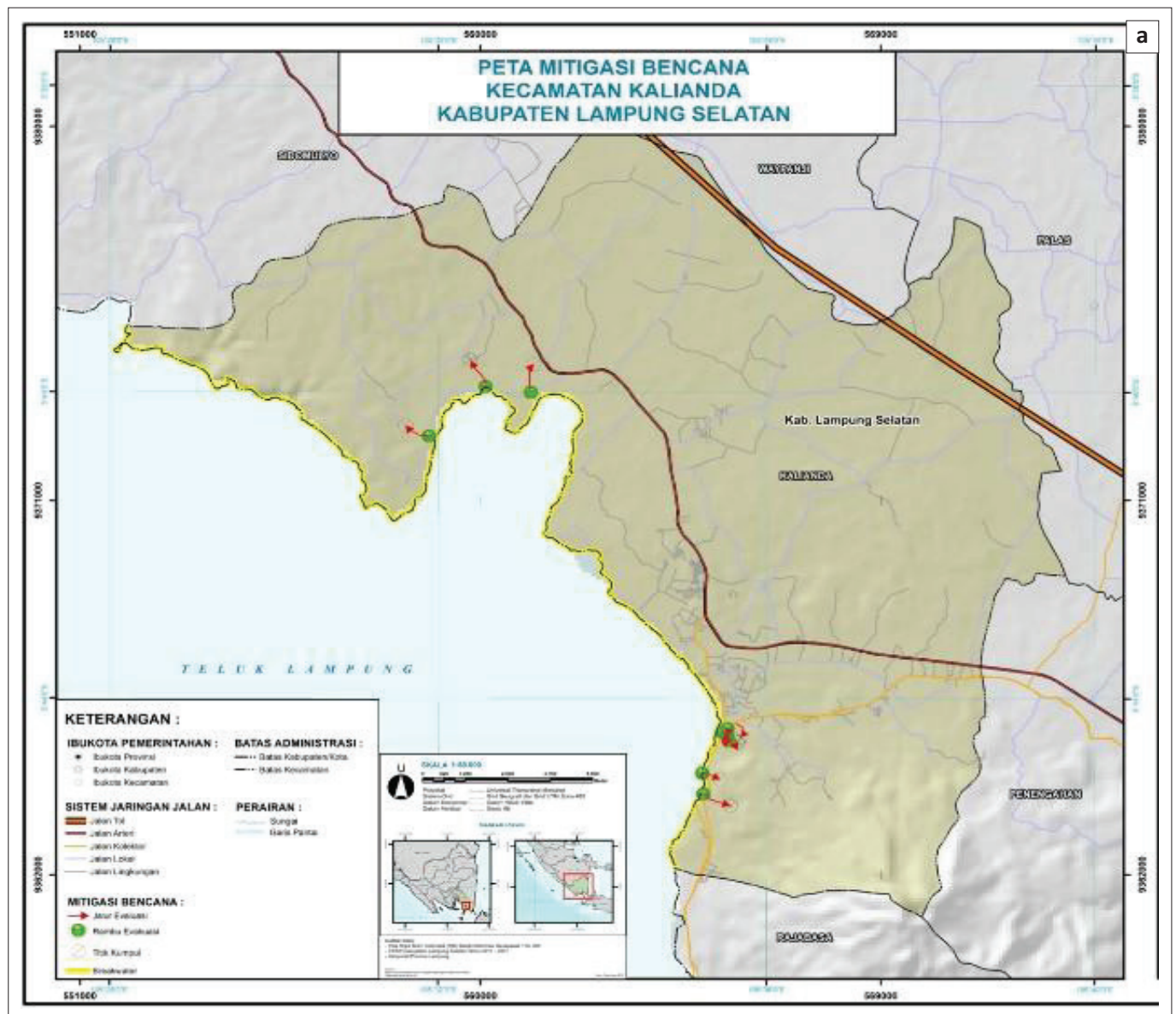
Mitigation and regional vulnerability map

Figure 4 presents a composite vulnerability and mitigation map generated using ArcGIS, which visualises the spatial distribution of breakwaters, evacuation routes, signage and gathering points in Kalianda and Rajabasa districts (Lin & Lee 2025). This map not only depicts the existing disaster mitigation infrastructure but also identifies areas

that still require intervention, serving as both a technical tool and a decision-support resource.

The distribution of mitigation facilities in Kalianda is relatively uniform, reflecting the district's flatter topography and greater accessibility. In contrast, Rajabasa's hilly and less accessible terrain results in a more uneven placement of infrastructure. Notably, many evacuation points were located based on community input regarding traditionally recognised 'safe zones', demonstrating the integration of local knowledge with spatial analysis. This collaboration between scientific mapping and indigenous knowledge strengthens both the relevance and usability of mitigation plans.

The presence of disaster-related infrastructure has enhanced the effectiveness of community response. Socially, residents



Source: Rasyid, F.M., Zalmansyah, A., Arinta, F.K., Slameto, S., Kifli, G.C., Aminah, S. et al., 2026, Disaster Mitigation Map. Created using: ArcGIS. Data source: South Lampung Regency Spatial Plan 2011-2031, RBI 1:50.000, 2023

FIGURE 4: Disaster mitigation map of Kalianda and Rajabasa districts, South Lampung.

Figure 4 continues on the next page →

A key element of this indigenous knowledge is the use of natural signs as early warnings for tsunami hazards. Residents recognise phenomena such as sudden sea retreats, roaring ocean sounds and unusual animal behaviours as critical indicators of impending disasters. While this knowledge is not formally documented, it is transmitted orally by traditional elders, who act as custodians of cultural memory and historical disaster experiences, including the tsunamis of 1883 and 2018 (Douvinet et al. 2024; Fakhriati et al. 2023; Hermans et al. 2022; Jokowinarno 2011; Marhadi et al. 2024; Rahman et al. 2017, 2018).

Traditional and community leaders play an essential role in disseminating this knowledge, particularly through informal channels such as religious gatherings, village meetings and ceremonial events (Benazir et al. 2023; Firdaus et al. 2023). Their authority enables them to mobilise residents during emergencies, with some even organising self-initiated evacuation drills carried out by local youth groups or fishing communities (Fakhrudin & Elmada 2022). In some instances, they even initiate self-organised evacuation simulations conducted by fishing groups or village youth.

Another significant aspect of indigenous knowledge as Indonesian local wisdom is the culture of cooperation [*gotong royong*], which constitutes a core identity of South Lampung communities. During disasters, this principle manifests as spontaneous assistance to vulnerable populations, such as the elderly, children and pregnant women, collective cleanup of debris and the establishment of temporary shelters. *Gotong royong* also plays a preventive role, seen in regular maintenance of evacuation routes and community-installed signage (Purwanto et al. 2017; Wialdi et al. 2021). In disaster mitigation, the presence of traditional leaders and the active practice of *gotong royong* complement formal technical strategies implemented by government agencies. Without these socio-cultural supports, interventions such as evacuation signage, rescue routes and assembly points often face low community acceptance and limited effectiveness (Table 1). Therefore, an integrative and participatory mitigation approach is ideal in South Lampung, combining modern technological and infrastructural measures with local socio-cultural systems to enhance acceptance, sustainability and resilience of disaster mitigation efforts (BNPB 2020; Jokowinarno 2011; Machruf et al. 2020; Rahman et al. 2017).

TABLE 1: Community mutual cooperation in Tsunami disaster mitigation.

| Phase (Disaster) | Form of mutual cooperation | Descriptions |
|------------------|---------------------------------------|---|
| Before | Cleaning evacuation routes | Residents collectively clean and repair access roads to evacuation points, including clearing the paths voluntarily. |
| | Installing self-made evacuation signs | Evacuation signs are created and installed by the community using available materials to enhance preparedness. |
| | Community-based evacuation drills | Evacuation drills are conducted voluntarily and facilitated by local leaders or youth groups. |
| During | Evacuation of vulnerable groups | Residents assist in evacuating the elderly, children and people with disabilities collectively to safe areas without waiting for official instructions. |
| | Use of shared vehicles | Community members lend vehicles to expedite evacuation and reach difficult areas. |
| | Distribution of emergency supplies | Food, water and medicine are fairly distributed to all affected residents through a mutual cooperation system. |
| After | Debris and environmental cleanup | Residents work together to clean homes and public facilities from mud and debris. |
| | Construction of emergency shelters | Temporary shelters are built collectively using simple materials. |
| | Local fundraising | Solidarity is shown through fundraising or collecting basic needs for affected residents who have lost their livelihoods. |

The role of traditional leaders in disaster mitigation based on indigenous knowledge

Traditional leaders hold a highly strategic position within the social structure of coastal communities (Crosweller & Tschakert 2021; Humaedi 2016; Wialdi et al. 2021). Their presence is not only respected as guardians of cultural values but also trusted as moral authorities in collective decision-making, including in disaster management contexts. In the tsunami mitigation practices in Kalianda and Rajabasa sub-districts, traditional leaders fulfil various essential functions that reflect the integration between local knowledge and community-based disaster response (Jokowinarno 2011).

Custodians of collective memory and local knowledge

Traditional leaders serve as keepers of collective memory regarding past disaster events, such as the tsunamis of 1883 and 2018. They convey this knowledge through oral narratives, customary advice and during religious or cultural ceremonies. Stories about the behavioural changes of animals, the sudden retreat of seawater or other natural signs are commonly shared by traditional leaders as part of intergenerational knowledge transmission (Božić Marojević 2014; Liew, Yeates & Lilley 2021; Rahman et al. 2017).

Educators and social advocates

Traditional leaders also act as advocates by raising public awareness of natural warning signs, self-evacuation techniques and safe locations during disasters. In customary gatherings, village religious events or communal celebrations, they often insert preparedness messages that are easily accepted by the community, as they are delivered in familiar language and style (Fakhrudin & Elmada 2022; Kusuma et al. 2020).

Informal leaders during emergencies

In disaster situations, traditional leaders frequently lead evacuation efforts (Fletcher et al. 2013; Humaedi 2016; Saputra 2023). Because of their respected status, their instructions are more readily followed than those from external parties. They organise residents, guide vulnerable groups during evacuations and even oversee fair distribution of logistics in the aftermath. This trust becomes a vital social asset when formal communication channels are not yet functioning optimally.

Mediators between government and communities

Traditional leaders also serve as intermediaries between government programmes and local community practices. They help harmonise structural approaches, such as the construction of breakwaters or evacuation routes with pre-existing local knowledge (Mercer et al. 2016). This role helps prevent community resistance to external programmes that are deemed culturally inappropriate.

Promoters of communal work (Gotong Royong)

In post-disaster activities, traditional leaders are central figures in organising communal work, ranging from debris cleanup and building temporary shelters to facilitating psychosocial recovery programmes (Azad et al. 2019; Fletcher et al. 2013; Nurcahyo, Setyawan & Ansori 2022). Through an approach rooted in togetherness and spirituality, they successfully foster collective spirit during times of crisis.

Utilisation of local adaptive plants as natural barriers against ocean waves and coastal tourism buffers

Local adaptive plant species along coastal areas play a crucial role in disaster mitigation and enhancing food security. These plants naturally grow along shorelines, possess strong woody structures and have robust root systems capable of withstanding high winds and large waves, including tsunamis. Key species include mangroves (*Rhizophora spp.*, *Avicennia spp.*, *Sonneratia spp.*), beach almond (*Terminalia catappa*), she-oak (*Casuarina equisetifolia*), Ambon palaka (*Sterculia foetida* L.), banyan (*Ficus benjamina*), mahogany (*Meliaceae sp.*), sea hibiscus (*Thespesia populnea*), devil tree (*Alstonia scholaris*) and coconut (*Cocos nucifera*). Ecologically, these species function effectively as natural wave breakers, air pollutant absorbers, soil stabilisers and oxygen providers.

Beyond ecological benefits, these plants hold significant economic and social value. For instance, mangroves can be utilised in traditional medicine, mahogany serves as raw material for furniture and botanical pesticides and coconut trees provide products such as VCO, coconut fibre and charcoal. Beach almond and she-oak contribute to aesthetic value and habitat provision for local fauna, while some species also serve as alternative food sources, enhancing local food security. Consequently, the utilisation of coastal vegetation should be integrated with environmental conservation and community education efforts, creating synergy between ecological preservation and economic empowerment. Mangrove ecosystems, in particular, have been proven effective in dissipating tsunami energy while supporting sustainable livelihoods for local communities (Alongi 2008; Lin & Lee 2025; Rasyid 2024; Ruiz-Ballesteros 2011).

In addition to bolstering community resilience, local wisdom-based mitigation strategies in Kalianda and Rajabasa sub-districts contribute directly to the sustainability of coastal

tourism. The southern coast of Lampung, with destinations such as Kedu Warna Beach, Canti Beach and Rajabasa Mountain Tourism Area, benefits from mitigation infrastructure including breakwaters, evacuation routes and safe assembly points, which provide a sense of security for both tourists and businesses. Furthermore, incorporating indigenous knowledge into disaster mitigation enriches culture-based tourism by showcasing disaster history narratives, traditional rituals and coastal vegetation as part of disaster education tourism programmes (Lin & Lee 2025; Rusmiati, Persada & Hardilla 2023; Tatiyanantakul 2021; Zaidan 2019). These integrative strategies demonstrate that effective disaster mitigation not only safeguards residents but also supports the development of a resilient and sustainable tourism economy.

Conclusion

This study demonstrates that strengthening the resilience of coastal communities against tsunami risks in South Lampung Regency, particularly in Kalianda and Rajabasa districts, requires a holistic strategy that integrates structural approaches with local wisdom. Infrastructure development, including breakwaters, evacuation routes and signs and safe assembly points, plays a critical role in reducing physical risks. However, the effectiveness of these measures is strongly dependent on their integration with the living local knowledge embedded within coastal communities.

Indigenous knowledge in these communities encompasses the interpretation of natural signs as a non-formal early warning system, the practice of mutual cooperation [*gotong royong*] before, during and after disasters and the pivotal role of customary leaders as custodians of collective knowledge and informal emergency leaders. These socio-cultural value systems have been proven to enhance community resilience, as evidenced by responses during the 2018 tsunami event.

The novelty of this research lies in the development of an integrated vulnerability map that combines spatial land use data with local socio-cultural dimensions. This approach provides a more comprehensive depiction of community vulnerability and capacity and remains rarely applied in tsunami disaster mitigation studies in Indonesia, especially in regions with strong socio-cultural characteristics such as South Lampung.

Beyond local DRR, the findings hold strategic implications for sustainable coastal tourism development. By implementing a community-based integrated mitigation system, coastal areas in South Lampung can serve as a model for resilient coastal geotourism in Indonesia (Handoko et al. 2023; Park & Kim 2016). The integration of disaster risk management with the preservation of local cultural heritage enables the creation of tourism destinations that are safe, educational, culturally rooted and economically beneficial while simultaneously enhancing community protection against disaster risks.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

CRedit authorship contribution

Fachri M. Rasyid: Conceptualisation, Data curation, Formal analysis, Investigation, Methodology, Visualisation, Writing – original draft; Achril Zalmansyah: Data curation, Formal analysis, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing; Farah K. Arinta: Data curation, Formal analysis, Methodology, Writing – original draft; Slameto Slameto: Formal analysis, Methodology, Supervision, Writing – review & editing; Gontom C. Kifli: Formal analysis, Writing – review & editing; Sitti Aminah: Formal analysis, Writing – review & editing; Eka Suryatin: Formal analysis, Methodology; Mulyadi Mulyadi: Formal analysis, Project administration; Musfeptial: Formal analysis, Writing – review & editing; Sri Haryatmo: Formal analysis, Writing – original draft; Asep Supriadi: Formal analysis, Project administration. All authors reviewed the article, contributed to the discussion of results, approved the final version for submission and publication and take responsibility for the integrity of its findings.

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Data availability

The data that support the findings of this study are available from the corresponding author, Achril Zalmansyah, upon reasonable request.

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