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Increasing Preparedness Against Earthquake and Tsunami Hazards by Educating and Training a Community in Sipora Island, Indonesia

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Abstract – This research introduces ways of preparing the community to play a direct role in reducing the risk of earthquake and tsunami disasters. Nagari Matobe is a village located in South Sipora. This location is in an earthquake tsunami-prone area. The regional government has prepared Matobe village to be a disaster-resilient village. A previous survey from 2019-2020 showed that the community of Matobe village lacked knowledge of earthquakes, tsunamis, and disaster mitigation systems. This research aimed to improve preparation for earthquake and tsunami disasters by making the people of Matobe village resilient to disasters. The steps taken to improve community preparedness were: 1. An initial survey on community conditions, buildings, soil characteristics, and the community's preparedness to face earthquakes and tsunamis; 2. The creation of a topographic map; 3. Education and training for elementary school students, with simulations, on the mechanism of earthquakes and tsunamis, on how to evacuate and prepare for evacuation, through stories using Doraemon, Nobita, and Dorami, comic characters from Japan; 4.Providing education and training on building materials under the 2002 Indonesian building planning standards and plans for earthquake-safe buildings following the 2016 earthquake-safe building structure standards; 5. Education and training to strengthen existing buildings; and 6. A proposal for a tsunami evacuation map and the location of evacuation signs. The community in Nagari Matobe was very cooperative and took an active role during the implementation of this research. The evaluation questionnaire distributed to elementary school students showed that the students were delighted and, on average, thought that the education and training in preparedness were beneficial. This education and training became an important reference for the community and government in developing Matobe village to become a disaster-resilient village.

Keywords: Evacuation Route, Risk Reduction, Simulation Evacuation, Tsunami Evacuation, Seismic microzonation.

Introduction

Indonesia is one of the world's 'ring of fire' volcanic belts. It means that Indonesia is an area with the potential for earthquakes and tsunamis. The Indo-Australian plate in the western part of Indonesia is moving by 7mm/year, and the Pacific plate in eastern Indonesia is moving by 12mm/year (Natawidjaja, 2018). The magnitude of this movement indicates that each plate is actively moving, and this causes earthquakes. The number of earthquakes per year with an intensity of more than four on the Richter scale is 1200 (Putra, 2012).

West Sumatra is a province located in the western part of Indonesia. Geographically, the West Sumatra province has three potential sources of large-scale earthquakes and tsunamis. The mainland of West Sumatra has a 500 km fault line that crosses through Singkarak, Padang Panjang, Padang, and Painan (Lange *et al.*, 2018; Natawidjaja, 2018). In Figure 1, we can see the Earthquake data from 1779-2020. It shows that the earthquakes that have occurred had a large magnitude because they were shallow earthquakes; this applies to those of 1928

(Mw8.4), 1933 (Mw9.3), 1981 (Mw8.1), and 2007 (Mw8.4). One of the largest earthquakes in the last ten years was the 2009 earthquake, which had a magnitude of 7.9 on the Richter scale and was at a depth of 71 km southwest of Padang City. This earthquake led to the deaths of 1117 people, two people were missing, and 1214 people were seriously injured (Putra *et al.*, 2014).

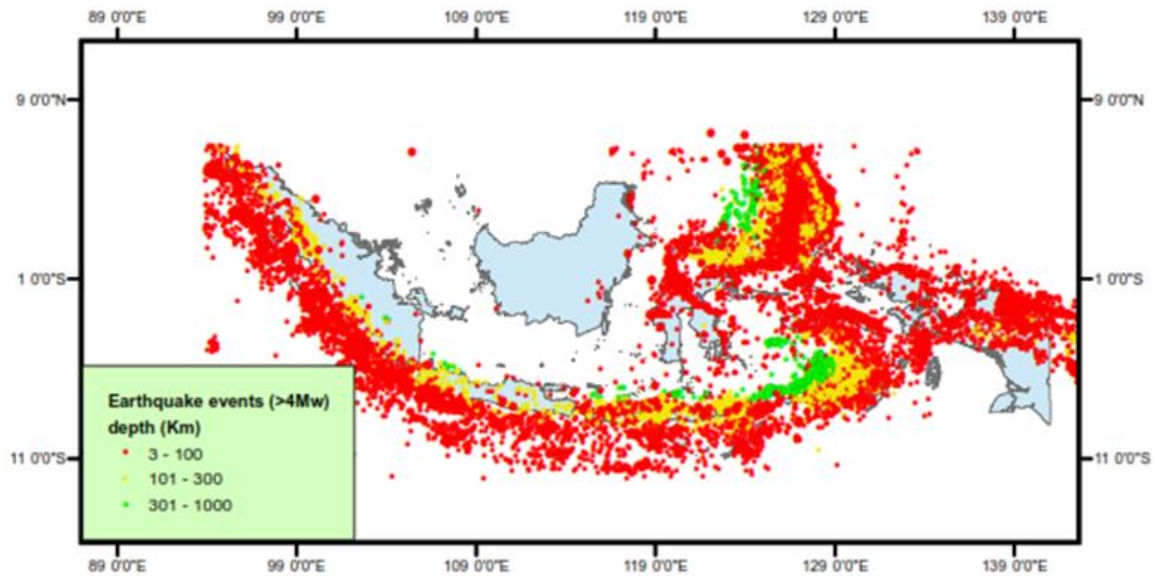

Figure 1. Seismicity map of Indonesia for earthquakes of Mw>4 from 1779 to 2020 (BMKG- Indonesian Agency for Meteorological, Climatological, and Geophysics)

Tsunamis in Indonesia

Indonesia has one of the highest population exposures to a tsunami in the world. Five and a half million people are estimated to be at risk of a tsunami at least once every 500 years (Harig *et al.*, 2020). The number of tsunamis recorded in Indonesia from 1674 to 2018 is 109 (Figure 2). Ninety-eight of those tsunamis happened because of earthquakes, and ten others resulted from volcanic eruptions (Hamzah et al., 2000). Tsunamis in the last ten years include the Mentawai tsunami in 2010, the Central Sulawesi tsunami in 2018, and, most recently, the Sunda Strait tsunami in 2018, which created landslides and liquefaction. Tsunamis have caused fatalities and have damaged buildings (Aránguiz *et al.*, 2020, Omira *et al.*, 2019). On average, the hazard curves for western Indonesia show that Sumatra and Java have similar magnitudes (Fig 3). However, the range of the hazards curves is larger for Sumatra, reflecting the location of Sumatra sites (Horspool *et al.*, 2015). Some are located on the eastern coast of Mentawai and Nias Island. The maximum expected tsunami height on the coast of Mentawai Island is at least 9 m (Brune *et al.*, 2010; Hill *et al.*, 2012). In eastern Indonesia, the tsunami curves for the Banda, Papua, and Sulawesi zones are similar. The potential tsunami hazard is similar for the western and the eastern parts of Indonesia (Aydan, 2008; Putra, 2017). West Sumatra has the potential to experience a tsunami because it has a source for an earthquake in the submarine (subduction) zone (Damayanti *et al.*, 2020; Philibosian *et al.*, 2017, Thein *et al.*, 2015)). This is where the Indo-Australian plate pushes against the stable Indonesian plate. A push beyond the elasticity of the stable plate will generate a great tsunami, such as occurred in 1833 (Mw9.2), 2005 (Mw9.3), and most recently in 2010 in Mentawai. In 2020, more than 61 earthquakes in areas were predicted to be in the megathrust segment with a magnitude of at least 4 Mw.

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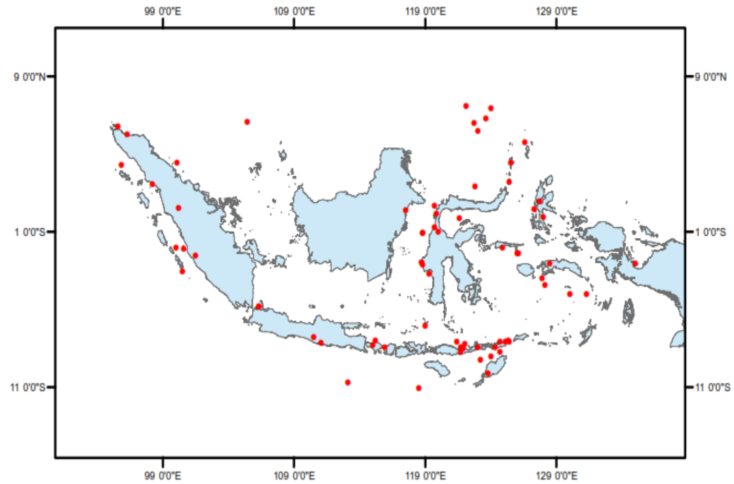

Figure 2. Historical tsunamis from 1600 to 2020 (red circles represent tsunami locations) (BMKG- Indonesian Agency for Meteorological, Climatological, and Geophysics)

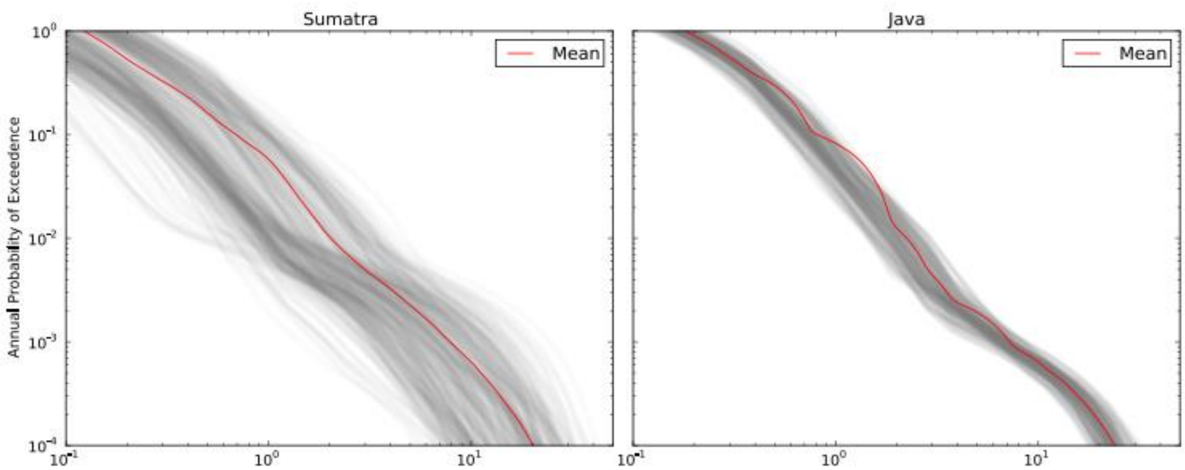

Figure 3. The hazard curves are grouped to gather according to the tsunami zone in Indonesia (Horspool *et al.*, 2015)

The Mentawai Islands and Matobe Village

The Mentawai Islands are one of the regencies of West Sumatra Province. Geographically, this area lies between 98° 35' - 100° 45' E and 0° 55' - 03° 33' N. The economic development of the Mentawai Regency in the period 2009-2017 shows an increase of 5.5% per year (Suwartana & Anggarawati, 2018). The Mentawai Islands are potential areas for encountering earthquakes that generate large tsunami waves (Purnawan *et al.*, 2018; Putera *et al.*, 2019. Geographically, the Mentawai Islands are located between two earthquake sources, and either of these could trigger a tsunami (Aydan, 2008; Jihad *et al.*, 2021). In the eastern part of the Mentawai Islands, one earthquake source is the fault line along Sumatra (Natawidjaja & Triyoso, 2007). Some earthquakes that have occurred and triggered a tsunami in this area are the 2004 earthquake in the northern part of Sumatra Island (with a strength of 8.9 Mw) and the earthquake of 2009 with a strength of 7.3 Mw. The number of victims of these two earthquakes that triggered tsunamis was more than 200,000 (Gaillard *et al.*, 2008).

Matobe village is in the subdistrict of Sipora Selatan (Figure 4). Matobe village is one of the disaster-resilient villages and has become a priority of the Mentawai Islands regional government. The village is located in the eastern part of the island of Sipora. This place has a low topography and is 2 m below sea level along the coastline.

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The people in Matobe village are of Mentawai, Minang, Batak, and Javanese ethnicity. The native Mentawai tribe, specifically in Matobe village, are Polynesians or Early Malay/Proto Malay people. This race is different from the population on the island of Sumatra and those of Malay descent. The residents of Matobe are mostly Christians (Protestants and Catholics), and the rest are Muslims. The total population is 2000 people over an area of 10 km².

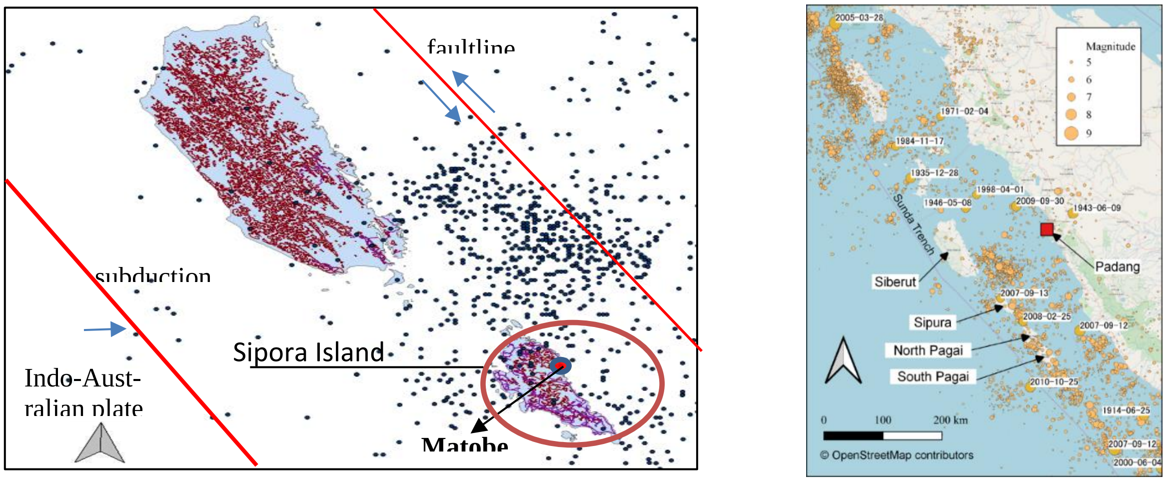

Figure 4. a. Tectonic and plate boundaries of Mentawai, (b) Location of Sipora Island, and the seismic activity around the Sunda Trench from 1900 to the present. The locations and magnitudes have been downloaded from the United States Geological Survey). The large blue arrows in figure 4 (a) indicate the direction of plate motion. The dark red and red circles are Sipora island and Matobe village, respectively, and the map shows the seismicity of Mentawai of earthquakes of Mw>4 from 1779 to 2020.

Geographically, Matobe village is reluctant to feel strong vibrations from earthquakes originating in the Sunda Trench. Figure 5 is a map of the island of Sipora and the earthquake source points in the Sunda Trench. The map in Figure 5 shows the seismic activity on Sipora Island and the magnitude of these activities. There have been many seismic events with an above 4 Mw from 1900 onwards. In the last 20 years, eight earthquakes have been of magnitude above 7 Mw. In 2007 and 2008, Sipora Island was the epicenter of earthquakes with more than 7 Mw on the Richter scale. This certainly affected the condition of the buildings and land of Sipora, especially in Matobe.

The soil type in Matobe is mostly alluvial (Yudhicara & Ibrahim, 2016). The alluvium is a soil type that amplifies earthquake vibrations. This means that earthquake vibrations in this location are stronger than in an area with hard soil.

Most of the buildings in Matobe are semi-permanent and wooden. A building feasibility survey conducted from 19 October to 26 October 2018 concluded that the existing buildings have around 92% vulnerability to earthquakes (Putra, 2020; Sutrisno *et al.*, 2017). This high vulnerability percentage indicates that the existing buildings are not following the correct earthquake-safe standards (Indonesian National Standard for Earthquake-safe Buildings, 2019).

Urgent Issues

The potential for massive earthquakes and tsunamis from existing earthquake sources is indicated by the intensity of events and the strength of the recent tremors. This condition is not compatible with the level of community preparedness to face earthquake and tsunami disasters. The village does not have evacuation routes, and the people have little knowledge about earthquakes and tsunamis. Besides, they do not know how to build earthquake-friendly residential buildings and carry out structural retrofitting.

Methods

From surveys and discussions with the community and the local government, information about the problems faced is set out in Figure 5. The flowchart below shows some of the priorities and the solutions offered to these problems. We adopted the map research to make the tsunami evacuation map (Maeda, 2021).

The creation of the proposed tsunami evacuation map for Matobe followed the procedures (Maeda, 2021), as follow:

- The tsunami inundation height is specified.
- The walking speed during evacuation is specified.
- The evaluation points are generated, along with the road network, with the same resolution as the elevation
- raster data.
- The generated evaluation points are classified into those that are higher than the specified tsunami inundation
- height and those that are lower.
- The tsunami evacuation time is set to zero for points higher than the specified tsunami inundation height.
- For every point lower in altitude than the specified tsunami inundation height, a point higher than the specified tsunami inundation height is sought with the shortest distance from the original point. The required tsunami evacuation time is found.

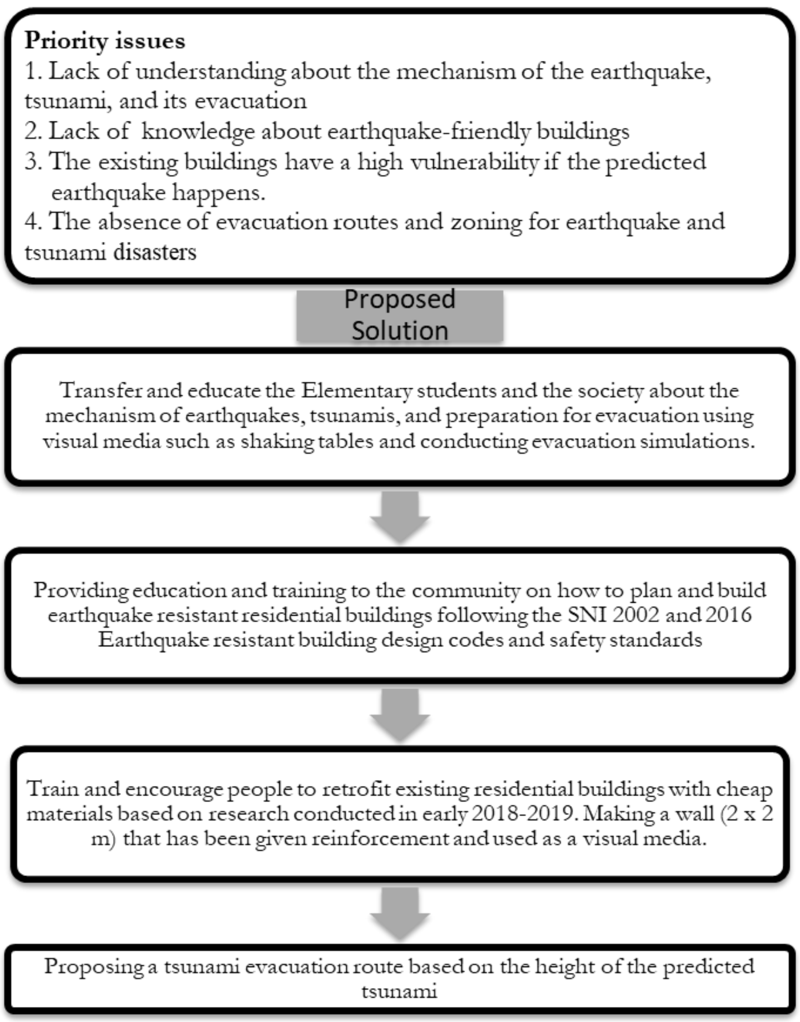

Figure 5. Research Flowchart

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Results

Education and training on the mechanisms of earthquakes and tsunamis and preparation for evacuation were carried out with the help of students from Tottori University, Japan. This activity was carried out in all elementary schools in Matobe village in the two elementary schools, SD 08 and SD 19, in Matobe, from grade 3 to grade 6. The activities were carried out in September 2019 by presenting the playing of Doraemon drama and supporting media, as shown in Figures 6 (a, b). After playing the drama of Doraemon, there were games and discussions about evacuation following a tsunami, as in Figure 6(c).

(a) (b) (c)

Figure 6. (a) Educating elementary school students; (b) Acting the Doraemon drama; (c) Evacuation training

The evacuation training included what people should prepare and bring with them when they heard information about a tsunami from the government (Figure 7) or the tsunami alert siren. Each of these activities involved active roles for elementary school students.

After the Doraemon drama and games, an evaluation was carried out. The evaluation was in the form of questionnaires given to the students. The questionnaires contained five questions and aimed to assess how the drama and games' educational activities had helped the students understand the material presented.

Figure 7. After a tsunami announced by the government, the thing needed to prepare and bring a red circle is an evacuation emergency bag.

Table 1 describes the answers given by the respondents regarding the training methods on the earthquake and tsunami. Question 1 asked whether they had studied earthquakes and tsunamis before. 60% of the SD 19 Matobe students and 95% of the SD 08 Matobe students had learned about earthquakes and tsunamis before. Question 2 was about knowledge of potential disasters around the school or home; 69% of the SD 19 Matobe students and 78% of the SD 08 Matobe students answered they knew about the potential disasters.

Table 1. Respondents' responses to educational and discussion activities.

Questions/ Responses		School	
		SD 19 Matobe (48 students)	**SD 08 Matobe (37 students)**
Q1	1	60%	95%
	2	40%	5%
Q2	1	69%	78%
	2	31%	22%
Q3	1	85%	95%
	2	15%	5%
Q4	1	69%	92%
	2	21%	3%
	3	10%	5%
Q5	1	35%	46%
	2	15%	35%
	3	50%	19%

Question 3 was about being a member of the discussion group during the presentation of material by the research team. 85% of the SD 19 Matobe students and 95% of the SD 08 Matobe students answered that the discussion was sufficient and comfortable with discussion. Question 4 was about the discussion time, and 69% of the SD 19 Matobe students and 92% of the SD 08 Matobe students answered that the time was sufficient. They could focus on the discussion, while 21% of the SD 19 Matobe students and only 3% of the SD 08 Matobe students answered that the discussion was too long and boring. 10% of the SD 19 Matobe students and 5% of the SD 08 Matobe students responded that the discussion time was too short of completing the discussion. Question 5 asked what the most exciting part of the training and simulation was. 35% of the students in SD 19 Matobe and 46% of the students in SD 08 Matobe answered that the most exciting part was the earthquake and tsunami mechanisms. 15% of the SD 19 Matobe students and 35% of the SD 08 Matobe students answered that the most interesting part was the evacuation simulation section. 50% of the SD 19 Matobe students and 19% of the SD 08 Matobe students agreed that the most interesting part was the game. The students were very enthusiastic about the various activities. From these results, we can conclude that some elementary school students who participated in the activity understood the mechanisms of an earthquake and tsunami. They now know what to do to evacuate if a disaster occurs. Information on building earthquake-safe buildings was given to the community, workers, builders, contractors, consultants for building owners, and local governments. The material presented was: (1) materials that comply with the quality required by Indonesian national regulations (SNI 03-6817-2002) [Figure 8 (a)], and (2) procedures for building earthquake-safe residential buildings (SNI 8140: 2016) [Figure 9 (b) and (c)]. There was also information about retrofitting walls.

This community training was very interesting for the participants since a shaking table display provided knowledge about the characteristics of buildings if earthquakes with varying strengths occurred. The training participants seemed enthusiastic and took an active role during the training/simulation.

Topographic maps and tsunami evacuation maps were prepared based on the height of the predicted tsunami, which is 20m. From Figure 9, we can see that it would take 20 minutes for people living on the coast to evacuate (ET = evacuation time) to assembly point 1 (AP1). The results of this study were given to the local government and approved as a reference for the local government in developing the Matobe area to become a resilient village for earthquake and tsunami disasters. In collaboration with the local government of Mentawai, the researchers will prepare evacuation routes by installing evacuation signs at 30 locations (Figure 10).

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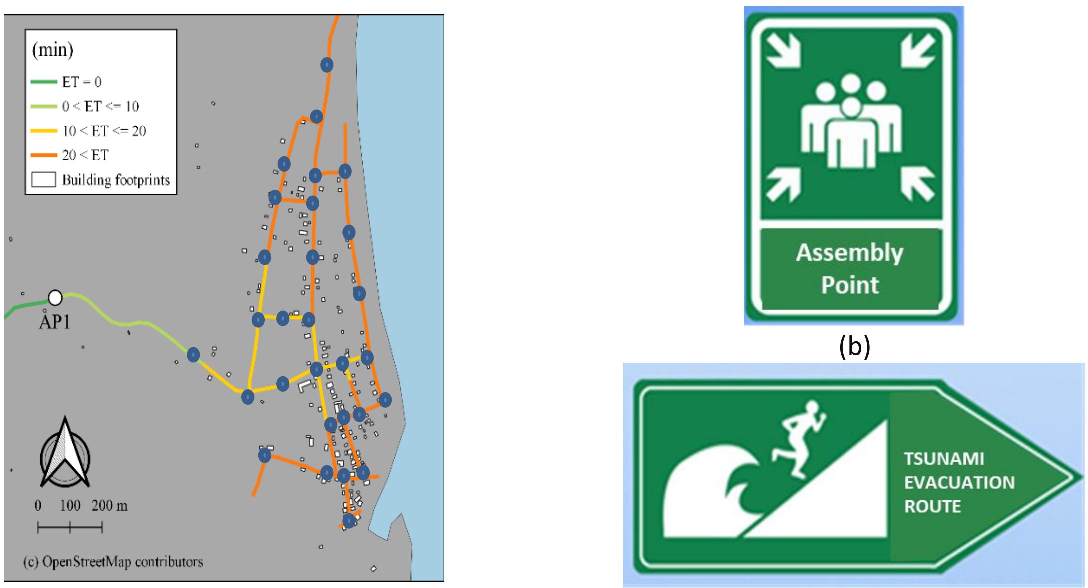
(a) (b) (c)

Figure 8. Community activities (a) Presentation of the material (b) Simulation of retrofitting a 2m x 2m wall using a 2cm x 2cm wire mesh and (c) Direct practice of making wall reinforcement.



(a) (b) (c)

Figure 9. Tsunami evacuation routes (a) Installation of evacuation route signs and the blue circle is tsunami evacuation route sign and (b) API assembly point in Indonesian and (c) Tsunami evacuation signs and their meaning.

Discussion

There has been increasing community preparedness for earthquakes and tsunamis. A memorial monument can become an educational medium and raise awareness about the potential earthquake and tsunami disasters (Thomas *et al.*, 2020). Making a tsunami evacuation map can be a reference for local governments and the community (Syamsidik *et al.*, 2020, Wargadalam *et al.*, 2021). Seismic zoning is also significant to determine the vulnerability of buildings and becomes a reference for the government for making policies for the region's development (Ozcep *et al.*, 2010). Earthquake and tsunami disaster education at an early age is necessary, given that the life span of children is longer than that of the rest of society. These children can use their knowledge if an earthquake or tsunami disaster occurs in the future (Sapriyanti, 2020). Earthquake and tsunami disaster education for early years can use methods that are easy to understand (Umran & Sarim, 2020).

Disaster preparedness educational materials and a simulation have been completed to improve student preparedness in the event of the disaster from the practice to overcome disasters (Herdiansyah *et al.*, 2020). The Indonesian government is developing an earthquake and tsunami early warning system using several areas as pioneers, including the Mentawai Islands area (Harig *et al.*, 2020). Students can maintain long-term memory when they focus, construct meanings when the learning is related to their experience when involved in the learning process, and demonstrate their understanding (Banikowski & Mehring, 2017). Therefore, after doing the activities, the students understood more, and the activities helped them store their knowledge in their long-term memories. Thus, they could carry out the proper procedure for evacuation if a disaster occurs one day in the future (Indriasari *et al.*, 2018).

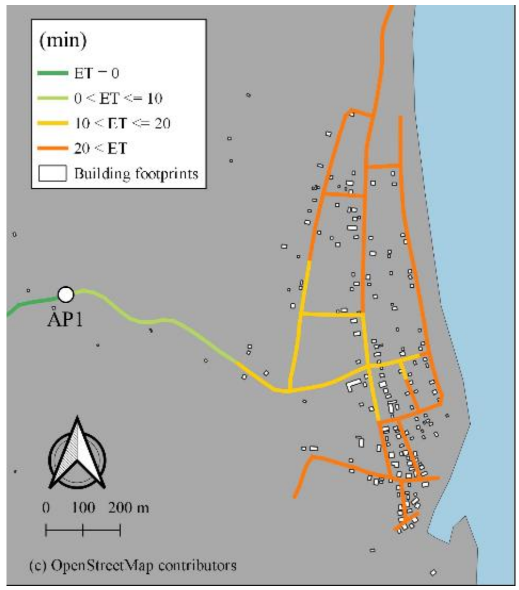


Figure 10. Tsunami evacuation map of Matobe for 20m tsunami inundation height

The workers' lack of knowledge about the earthquake-safe house requirements and retrofitting damaged houses is the main problem in earthquake-prone areas. The construction workers play an essential role in attaining a good construction and safe building (Fauzan *et al.*, 2018). The lack of knowledge of construction material quality significantly impacts the time, cost, and quality of construction (Ahmed et al., 2020). Many coastal regions in Indonesia will be attacked by tsunami (Widiyantoro *et al.*, 2020), educate the society on a tsunami evacuation map, and develop the society evacuation plan based on this map. Through this education program, children and parents got the knowledge about tsunami and got the wisdom about tsunami evacuation (Katada & Kanai, 2008).

This research combines methods from existing research to integrate the knowledge; this was done by providing, as follows: 1. Education to the community, especially elementary school (SD) students, about the mechanisms for earthquakes and tsunamis and how to evacuate, including what to prepare. 2. Education on the danger of earthquakes for buildings 3. Education and training on choosing materials comply with Indonesian national standards (SNI 2002). 4. Training people about earthquake-safe buildings following Indonesian standards for earthquake-safe building structures (SNI 2016) and strengthening the existing buildings with cheap materials that are easy to obtain on the islands of Mentawai. 5. Submitting a tsunami evacuation map to the local government, which results from the research and includes signs. The people were excited and actively contributed to this program. All major aspects, from building to evacuation, were important for them.

Conclusion

Geographically, Nagari Matobe is a village with a high chance of being hit by earthquakes and tsunamis in the future. Several educational and training efforts were carried out in the Matobe village community to address these predictions. The first was to educate the next generation about earthquakes and tsunamis. The education provided included evacuation training for elementary school children. In this study, 85% of the students of elementary school SD 19 Matobe and 95% of the students of elementary SD 08 Matobe stated that the discussion was sufficient and that they were comfortable in discussing these matters. 69% of the SD 19 Matobe students and 92% of the SD 08 Matobe students said that sufficient time had been spent on the discussion and that they had been able to focus on it.

Another part of the training was to provide education to the public regarding earthquake-resistant buildings. The education provided began by explaining the materials and training the people in selecting them. The training was also about planning earthquake-safe buildings and economically reinforcing buildings with easy-to-obtain materials. In this training, the community played an active role in all the actions taken. The results of this training and education can be a reference for local governments in giving building permits. It can also improve their knowledge for monitoring building development in the Mentawai Islands.

Another important activity was building evacuation maps and signs that can help communities deal with a disaster when it comes. This activity can be used as an input and reference for local governments in earthquake and tsunami mitigation planning, including shelter planning (vertical evacuation) that reduces the distance from the danger zone to the assembly point zone. With these efforts, the people of Matobe village will be better prepared for the predicted earthquakes and tsunamis so that the number of victims and the amount of damage can be minimized.

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