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Tsunami Disaster Mitigation For Population at South Coatal –Munjungan Distric-Trenggalek-East Java

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Abstract—**The coast of Munjungan Subdistrict in the form of a bay and directly facing a subduction zone makes the area prone to earthquake and tsunami disasters. Until now the earthquake and tsunami cannot be predicted when it will occur. Therefore disaster mitigation for the community is very necessary, not least in the community in Munjungan District, Trenggalek Regency, East Java Province.**

The aim to be achieved in this study is to mitigate the tsunami disaster in the South East Java-Coast region in the District of Munjungan-Trenggalek Regency. In detail the mitigation activities in question produce a zoning map prone to tsunami disasters, and explore people's knowledge about tsunamis.

To achieve the objectives of this study consists of two stages, namely the initial stage of making zoning maps of disaster-prone areas, then the next stage based on zoning maps produced at the initial stage is used as the basis for selecting residents to be interviewed about their tsunami knowledge. The sampling technique in this study was used to select respondents who were interviewed. The sampling technique chosen is puporsive random sampling.

The results of the study obtained zoning maps of tsunami prone areas and alternative routes to safeguarding tsunamis. Then based on the results of the interpretation of the map it is known that there are four villages prone to the tsunami disaster. In addition, the results of the study also revealed that the level of knowledge of the population in tsunami prone areas was still low, but most of the people in the tsunami-prone areas and their low knowledge still felt safe from the threat of the tsunami disaster. The reason stated by most of the community was that there had never been a tsunami since the past in their area.

***Keyword*—Mitigasi-Tsunami-Pantai Munjungan -Jawa-Timur Selatan**

I. INTRODUCTION.

Some regions in Indonesia have a high level of vulnerability to earthquake disasters. This is because Indonesia is located at the confluence of three large plates in the world, namely the Indo-Australian plate, the Pacific plate, and the Eurasian plate. The meeting between the plates forms a subduction zone and this zone is a tectonic earthquake source that has been occurring so far.

The basis of the Indian Ocean to the west of Sumatra, south of Java, Bali and Nusa Tenggara is one of the tectonic plate subduction zones in Indonesia, namely between the Indo-Australian plate and the Eurasian plate. As a result of these conditions, the regions are vulnerable to the threat of earthquakes and tsunamis [1].

In coastal areas, in addition to the threat of disasters that are directly caused by tremors of earthquakes, there is another disaster threat as a result of the earthquake, the tsunami. Tsunamis are not solely generated by seismic activity, but tsunamis caused by tectonic earthquakes occupy the largest number, namely 95% [1]. Tsunamis caused by tectonic activity are a secondary symptom of an earthquake in the sea, which originates from along the collision zone of tectonic plates (subduction zones).

A tsunami is a wave consisting of wavelengths, periods and wave heights. Tsunamis have a period of 100 - 2,000 seconds (1.6 - 33 minutes), which is called a tsunami window (Bryant: 27). Waves with this period run at speeds of 600–900 km / h (166-250 m / sec) in the deep sea, 100–300 km / h (28-35 m / sec) above continental exposure, and 36 km / h (10 m / sec) on the beach. Because of the limited depth of the sea and the mechanics of wave formation by earthquakes, the length of a tsunami wave, the distance between successive wave peaks ranges from 1 - 500 km. Such a long wavelength makes the tsunami completely different from storm waves.

Tsunamis are known because of the dramatic wave height above the run up height, which is generally greater than the tsunami height that approaches the beach twice or more. The tsunami run-up height varies greatly. The earthquake that took place off the coast of Gisborne, New Zaeland in 1947 resulted in a wave run up as high as 10 meters. The tsunami in Alaska on April 1, 1946 could wash away radio poles that stood 35 meters above sea level, and the earthquake in Japan in 1896 produced run up as high as 38.2 meters [2]. Based on the tsunami that occurred in Aceh, the tsunami waves towards the land reached the hills and caused rock outcrops at an altitude of 30 meters [3]..

Hills and Mader in [2], stated that the maximum distance of run-up waves entering land on gentle slopes is influenced by several factors, including the magnitude of waves, coastal morphology and land cover. For land that has been covered by

buildings in flat coastal areas, a run up wave as high as 10 m can enter on land as far as 1.4 km. But the tsunami with a run up as high as 40-50 meters can enter land as far as 9 - 12 km. For food crops and grasslands, the same waves can theoretically enter land four times farther, which is as far as 5.8 km for run ups 10 m and 36 - 49 km for run ups as high as 40-50 m. The impact of a tsunami can be minimized on the coastal plain by planting many trees. For example, a 10 meter high tsunami can only go ashore as far as 260 m over a forested coastal plain and run up as high as 40-50 m cannot move over land more than 2.3 km through the area.

Tsunamis experienced by coastal areas in Indonesia generally take place with a lag time of less than 30 minutes after an earthquake. This happens because the distance between the subduction zone and the coastal area facing it is relatively not far while the propagation speed of the tsunami wave can reach 600–900 km / hr.

There are several factors that can be used as the basis for making a tsunami disaster zoning, which consists of (1) the height of the tsunami wave associated with the elevation of the coastline, (2) the shape of the beach or coastal geometry, (3) coastal slope, and (4) roughness beach [1]. Each of the factors can be described as follows. The relationship between earthquake magnitude and creep wave height can be seen in the following table.

TABLE 1. THE RELATIONSHIP BETWEEN MAGNETUDO AND HIGH-STREAM WAVE

Earthquek Magnetudo (M)	High-Stream Wave (meter)
5,5 – 7,0	0 - 4 meter
7,0 – 7,5	4 – 8 meter
7,5 – 8,0	8 – 18 meter

The shape of the coast greatly affects the level of vulnerability of a tsunami disaster in an area. The beach which is straight in length and in the form of a promontory, has a low to moderate vulnerability and a beach in the form of a letter V or U has a high level of vulnerability. The level of vulnerability to the tsunami disaster is also influenced by the level of slope of the coast. On gentle slopes the level of vulnerability is moderate to high and on steep beaches the level of vulnerability is low.

The roughness of the beach can be divided into two types, namely smooth beaches and rough beaches. Smooth beaches are the beaches between the sea and the land there are no obstacles whatsoever, while the definition of rough beaches is a beach that is undulating, vegetated, or a rocky beach. On fine beaches the level of vulnerability is high to very high

Related to the zoning of tsunami-prone areas, Bakosurtanal [4] made a classification of tsunami-prone areas based on place height, as follows.

TABLE 2. RELATIONSHIP BETWEEN PLACE HEIGHT AND TSUNAMI HAZARD LEVEL

Place Height	Tsunami Hazard Level
< 5 m	Hight
5 – 10 m	Medium
10 – 15 m	Lower
15 – 20 m	Very lower

The facts show that every tsunami in Indonesia always takes a heavy toll. The tsunami in Banyuwangi in 1994 killed as many as 377 people died, the tsunami in Aceh in 2004 which claimed the lives of around 200,000 people, and finally, in November 2010, the tsunami in Mentawai claimed as many as 456 person.

The earthquake and tsunami have yet to be predicted when it will occur (unpredictable). For certain regions, earthquakes will potentially cause a tsunami disaster. If the threat of a tsunami is not realized by the people who live in the disaster-prone area, then the risk that can be caused will be very serious.

In connection with the above, to reduce the risk of natural disasters, especially tsunamis, disaster mitigation needs to be done. Tsunami is one of the potential disasters that exist in Indonesia, by that arena, tsunami disaster mitigation for areas with potential disasters is very urgent. According to Hendrajaya [5], mitigation of natural disasters is a human effort so that in the event of a natural disaster the resulting losses are not significant.

Mitigation efforts are to increase the resilience and preparedness of the community in the face of natural disasters so that the risk of natural disasters can be reduced. Disaster mitigation can be done through physical or non-physical efforts. Physical businesses can be in various forms, depending on the type of natural disaster in question. Mitigation efforts for the tsunami disaster can be carried out by mapping disaster prone areas (zoning), identifying safe places for refugees, determining the most appropriate evacuation routes, and education to improve community understanding of tsunamis. In addition, the management / coordination of natural disasters needs to be done well and directed. Therefore, if a tsunami actually occurs in an area, the consequences of the disaster can be minimized.

The southern coast region of Munjungan District, Trenggalek Regency is one of the areas prone to the tsunami. This is caused by its position which is not too far from the tectonic plate subduction path that is at the bottom of the Indian Ocean. Therefore, the area has considerable potential for the tsunami disaster. In addition, the beach in the Munjungan sub-district is in the form of a U, which is theoretically very vulnerable to tsunamis.

This study seeks to conduct tsunami disaster mitigation for residents living in tsunami-prone areas in the south coast region of Munjungan District, Trenggalek Regency. The tsunami disaster mitigation carried out in this study included the mapping of tsunami-prone zones, exploration of people's knowledge of tsunamis, and socialization of the tsunami disaster. With this research activity, it is expected that residents living in tsunami-prone areas have alertness, are always prepared and can take appropriate actions in anticipating the possibility of a tsunami disaster.

More specifically, the purpose of this study is described as follows.

1. Map the tsunami-prone zone in the Munjungan sub-district of Trenggalek Regency.
2. Mapping the appropriate alternative evacuation routes from tsunami-prone residents to safe locations for refugee camps.
3. Identifying people's knowledge about the tsunami disaster.
4. Increase community knowledge about tsunamis and ways to save themselves from tsunami hazards.

II RESEARCH METHODS

A. Population and Samples

Data related to the physical condition of the research area as a whole is the object of research while to obtain data related to population perceptions of tsunamis, the acquisition of data is based on samples. The study population is family heads (KK) who live in tsunami-prone areas. Based on the mapping that has been carried out, there are 4 tsunami-prone villages, namely Craken, Masaran, Munjungan and Tawing Villages. The number of households living in the 4 villages is 6260 households[6]. Referring to the determination of the number of samples from Isaac and Michael with a significance level of 90%, from the popoulation of 6260 families, the minimum sample in the study was 163 families. In this study, a sample of 254 families was taken. Sampling was carried out proportionally in the random sampling area, according to the number of households in each village.

B. Collection Techniques, and Data Sources

Data related to the physical condition of the area (altitude, beach shape, beach slope, beach roughness, and land use) were collected through observation and documentation. Place altitude data refers to a 1: 50,000 scale Earth map with an altitude interval of 12.5 meters, while data related to community perceptions of tsunamis is carried out through interviews and Focus Group Discussions (FGD).

C. Data Analysis Technique

Data related to population knowledge about tsunamis was analyzed descriptively quantitatively, namely with percentages supplemented with qualitative explanations, while data related to the level of vulnerability to tsunami disasters will be analyzed using Geographic Information Systems (GIS), namely by map overlay techniques with using Arc View 3.3 program software.

To compile a zonation map of the vulnerability level for a tsunami disaster, an overlay technique was carried out with a query [7]. Overlayed maps are land use maps, beach shape maps, beach slope maps, coastal roughness maps, and altitude maps. With the query process the level of vulnerability to a tsunami disaster can be described. The next step is tsunami prone zoning maps overlayed with administrative maps and land use maps. From the results of this overlay the vulnerability of each village in Munjungan District to the tsunami disaster can be mapped.

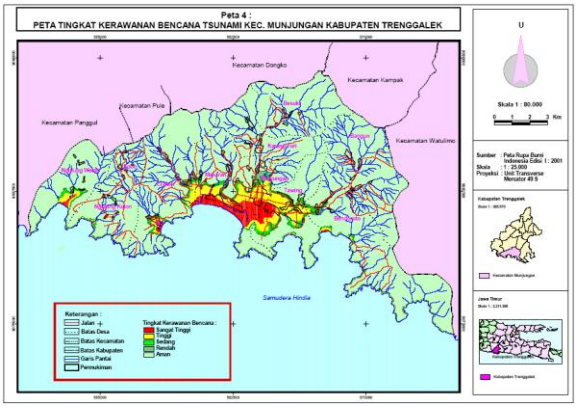
III. RESULT OF THE RESEARCHED

A. Mapping Regionalizm of Tsunami Hazard at Munjugan District

Based on observations it is known that several variables are estimated to influence the vulnerability of the tsunami, beach slope is associated with population dwellings (villages) relatively the same. The beaches are U-shaped, sloping, and the beaches are fine (sand), and between the coastline and the separating settlements are mainly sand, rice fields and gardens, this shows that the coastal area of Munjungan District has a high level of vulnerability to the tsunami disaster. Therefore, variable variability between one place and another place is the height and distance between the coast and the land [8].

Referring to the zoning of tsunami-prone areas from Bakosurtanal, namely that up to a height of 20 meters above sea level is still included in tsunami prone areas and observes the distance between coastlines to land, a map of vulnerability to tsunami disasters can be made. Through measurement, it is known that the farthest distance from the coastline towards the land with an altitude below 20 meters is less than 4 km. Theoretically with conditions such as those found in Munjungan, then with a run up level as high as 10 meters tsunami waves can reach land with a distance of more than 4 km. Therefore, based on this distance variable, all areas that are less than 20 meters high are still affordable if a tsunami occurs. Thus making a hazard level map of a tsunami disaster can be made, which is based on the height of the place with the criteria as mentioned above

Fig 1. Map



B. *Alternative Evacuation Routes Towards Tsunami Safe Locations*

The experience of a tsunami that has occurred in several places in Indonesia has been very rapid. The time lag between an earthquake and the arrival of a tsunami is only about 30 minutes. Therefore, residents living in tsunami-prone areas must recognize well the safe place of the tsunami and the right route that can be reached with the fastest time and safely to the place of refuge. The chosen route to evacuate is to get to the closest distance to a safe place with a direction away from the beach, through existing roads and not crossing the river[9].

C. *Knowledge,Perception, and Attitudes of Residents Against Earthquakes and Tsunamis*

All respondents (100%) stated that earthquakes were frequent in their area of residence, but had never been accompanied by a tsunami. Earthquakes that have been occurring in their area so far are not strong enough to cause significant damage. According to the knowledge of the majority of respondents (78.35%) the result of the earthquake was the occurrence of collapsing houses, while the respondents who stated that the earthquake caused the tsunami to occupy the second largest number, namely as much as 14.57%.

When an earthquake occurs, most of the respondents (87.40%) stated that they would hurry out of the house. In detail the respondent's actions during an earthquake can be seen in the following table.

TABLE 3. ACTIONS CONDUCTEDBY RESPONDENTS AT THE TIME OFAN EARTHQUAKE

Actions Performed When An Earthquake Occurs	Total	Persen (%)
Stay at home	20	8,87
Go out	222	87,40
Go –out at hight location	7	2,76
Sign for the other person	2	0,79
Reached at home	3	1,18
Total	254	100

SOURCE: PREMAIR DATA

The actions taken by most respondents in the form of hurrying out of the house during an earthquake were influenced by their knowledge, most of which stated that the result of the earthquake was the collapse of the house. The number of respondents who anticipated the arrival of the tsunami was only a small number, namely as many as 2.76% of respondents who said that if an earthquake happened they would go out of their homes and look for a high place[10].

Regarding knowledge about tsunamis, most of the respondents (93.39%) had heard the term. Respondents who stated that they had never heard the term tsunami were only a small part, which was as much as 6.61%. As a source of knowledge of respondents regarding the tsunami, most of them came from TV media (71.79%). The source of information about the tsunami for a respondent can be obtained from various media. Referring to this, in more detail the source of information about tsunamis can be seen in the following table

TABLE 4 SOURCE OF INFORMATION ABOUT TSUNAMIS

Sources of Information About Tsunamis	Total	Percent (%)
Pamong / Village / District Officials	18	6,43
Televition	101	71,79
Nwes paper	6	2,14
People	37	13,12
Radio	8	2,85
Shcoll	6	2,14
Police	2	0,71
Internet	1	0,36
Book	1	0,36
Total	280	100

SOURCE: PREMAIR DATA

The second largest source of information after TV is information obtained from fellow villagers. TV is the main source of information about tsunamis, this is normal, because at this time most families have TVs. Since the tsunami in Aceh in 2004, all TV stations broadcast the disaster, and all subsequent tsunami disasters, such as in Nias and Pangandaran were broadcast widely by all TV channels in the country. Furthermore, information from fellow citizens ranks second, this is also reasonable because relations between fellow citizens are very familiar and in various activities and daily life, they often hold communication.

The large number of respondents who were unable to explain the understanding of tsunamis was reasonable, because most of the respondents had never attended counseling about tsunamis while respondents who said they knew the meaning of the tsunami had attended 36.22% of counseling.

Based on the results of the FGD with village officials it was revealed that in the study area counseling had been held on tsunamis, even followed by simulations. But as many as 63.78% of respondents stated that in their area there had never been counseling about the tsunami disaster. This shows that the extension activities that have been carried out by the local government have not touched all levels of society.

All respondents in this study lived in tsunami-prone areas, but the majority of respondents (79.92%) stated that their homes were safe from the threat of a tsunami. Respondents who stated that their area included tsunami-prone areas was 18.51%, while those who said they did not know were 1.57%.

As many as 82.76% of respondents stated that their area was safe, the reason being that there had never been a tsunami in their area in the past. In detail, the reasons for respondents who stated their safe place to tsunami can be seen in the following table.

TABLE: 5. REASONS THAT RESPONDENT VILLAGES ARE SAFE AGAINST TSUNAMI DISASTERS

Reason	Total	%
There has never been a tsunami since the first time	168	82,76
Village sheltered hill	4	1,97
The village is located in a fairly high place	13	6,40
Religious	15	7,39
Save by “Nyi Roro Kidul”	2	0,99
Indiguenos local at save tsunami	1	0,49

Total	203	100

Respondents who felt their place of residence was safe from the threat of a tsunami disaster, they did not / did not yet have an idea of what actions would be taken in the event of a tsunami disaster. This is reasonable because they believe that the tsunami disaster will not occur in their area.

For respondents who felt that their area was prone to tsunami disasters (15.51%) most had plans to anticipate the possibility of a tsunami in their area. Most of the respondents (44.68%) stated that if there was a relatively strong earthquake, they would immediately run to find a high place.

In this study it has been successfully mapped, that is, there are four villages which are included in the tsunami-prone area, but until now in the area there has been no early warning tool for the tsunami disaster. The community's lack of understanding of the tsunami has made it easy for people to be fooled by information that is unclear in its source. After the Jogya earthquake in 2006, there were rumors of two tsunamis circulating in this area, even the police participated in giving warnings to the community of tsunamis, even though there were no earthquakes or the appearance of a tsunami.

This series of research activities is to hold a socialization about tsunamis in the community so that they have sufficient knowledge so that they have a high level of alertness in anticipating a tsunami that can happen someday. The socialization was attended by all village officials whose areas included tsunami-prone areas, with the hope that the socialization material obtained in turn could be passed on to the communities where they carry out their duties as village officials.

The socialization materials included (1) the basics of knowledge about earthquakes and tsunamis, (2) Maps of vulnerability levels in the Munjungan District area against the tsunami disaster, (3) Alternative maps of the evacuation route if at any time a tsunami occurs, (4) and form of preparedness that must be done by people who live in tsunami-prone areas to anticipate that at any time a tsunami disaster will actually occur. In addition to the socialization held directly with the village officials, other forms of socialization were also carried out, namely by placing a banner on the map of the tsunami hazard level in each village including the tsunami-prone area.

IV. DISCUSSION

Theoretically, the coastal area in the Munjungan District is an area prone to the tsunami disaster. There are two things that cause this, namely because the beach in Munjungan Subdistrict is faced with a subduction zone of the Indo-Australian plate against the Eurasian plate and the beach is a bay that resembles the letter "U".

Based on the mapping of the vulnerability of tsunami-prone areas, it is known that there are four villages that are prone to tsunami disasters, namely Tawing, Munjungan, Masaran, and Craken Villages. The vulnerability to the tsunami disaster in the four villages was not realized by most of the people, they felt safe from the tsunami disaster.

There are several reasons raised by the community that their place of residence is safe from the tsunami disaster. Most stated that since ancient times in their region there had never been a tsunami. This reason is unacceptable, because with its geological position and the shape of its beaches, this area has potential for a tsunami disaster. Theoretically, at any time the area could experience a tsunami disaster. If it had never happened before, then it was not a guarantee that the area would not experience a tsunami forever. The absence of a tsunami in this area should not have been used as an excuse that this area was safe from the disaster. Previously, Banda Aceh, Pancer-Banyuwangi and Pangandaran had never experienced a tsunami, but suddenly a tsunami struck these areas. It is precisely the regions that have the potential for earthquakes / tsunamis that have never had a devastating earthquake / tsunami to be more vigilant. Because the potential of earth crust tension as a result of the pressure between the plates that continues to occur, at any time can cause deformation / fault that can lead to earthquakes / tsunamis.

The second most common reason is that the community feels safe from the tsunami because the Munjungan community is religious. With such conditions, some people believe that their area will be protected by God Almighty and freed from the tsunami disaster. Related to this there are several efforts so that God protects them from disasters, namely by holding coastal areas and cleaning up the coastal areas from immorality, for example by dismantling the cafes that were previously on the beach of Munjungan. Efforts to overcome disasters through agana / trust methods are indeed needed, but the effort must also be accompanied by rational thoughts and efforts.

The next reason stated is the distance between their residence and the coastline is too far. This reason is ratio. Based on measurements, the distance between the coastline and the furthest settlements less than 20 meters is not more than 4 km. Between the coastline and the four villages that are prone to tsunami disasters are mainly separated by land use in the form of rice fields and gardens. With these conditions, according to Hills and Mader in [2], a run-up wave as high as 10 meters can enter land on a sloping beach of 5.8 km. If there is a higher run up, the range of the tsunami will be even further. In fact, some of the tsunami run ups can go far beyond 10 meters. The tsunami in Alaska on April 1, 1946 could wash away radio poles that stood 35 meters above sea level, and the earthquake in Japan in 1896 produced run up as high as 38.2 meters (Bryant, 2007: 49). Based on the tsunami that occurred in Aceh, the tsunami waves inland reached the hills and caused rock outcrops at an altitude of 30 meters (Sutikno and Winaryo, 2005

In addition to the reasons mentioned above, it turns out that there are still a small proportion of people who believe in superstition, namely that they feel safe because they are

protected by Nyai Roro Kidul or there are caretakers who can counteract the arrival of the tsunami.

Community perceptions and the reasons given for the absence of threats to the tsunami disaster indicate that people's knowledge of the tsunami is still low. The belief of most people that their homes are safe from tsunamis influences their attitude in anticipating the possibility of a tsunami. Residents who feel safe do not have readiness to anticipate the possibility of a tsunami disaster. This will be fatal if one day a tsunami actually occurs in this area. The number of fatalities caused by the tsunami in Banda Aceh, one of the contributing factors was due to a lack of public awareness of the possibility of a tsunami.

One result of the community's low knowledge about tsunamis is that it is easy for people to be fooled by issues or news sources that are unclear and the truth. In this area the people were shocked by the news of the tsunami disaster, and this news made people panic, even one of the residents died in this incident. This incident repeated up to two times and the police participated in giving warnings to the public. When the issue of a tsunami is circulating in the community, previously there was no earthquake in the area, and after many people were displaced it turned out nothing happened. Reflecting on this incident, the government apparatus must understand the characteristics of natural disasters that have the potential to occur in an area so that they are not easily affected by issues / news which is not necessarily the truth. Because if there are warnings many times and it turns out that the tsunami did not occur, then one day if a tsunami actually occurs a warning from the government apparatus is no longer trusted by the community.

Considering that most people do not realize that they live in disaster-prone areas, mitigation must be done so that people have an awareness of the possibility of a tsunami disaster. The mitigation includes counseling and rescue simulations from the tsunami that were followed by all levels of society, installation of maps of tsunami-prone areas, and making signs for directions to safe places from tsunamis.

Most of the settlements and centers of economic and government activities in the District of Munjungan are in areas prone to the tsunami disaster. In order for a tsunami to occur at any time the risk can be reduced, the existence of a Tsunami Early Warning System needs to be built in this area.

V. CONCLUSION

Based on the results of research and discussion can be concluded several things, namely as follows.

A. Based on coastal geometry, beach slope, beach roughness, altitude, and distance between the coastline and the mainland can be mapped tsunami-prone areas, which include Munjungan Village, Masaran, Tawing, and Craken.
B. Areas safe from tsunami disasters can be accessed from all settlements in disaster-prone areas because the four villages that are prone to tsunami disasters are surrounded by mountains that are more than 20 meters high with a distance of less than 4 km. An alternative map of the evacuation route was made based on the altitude of the place, tsunami-prone settlements, river and road lanes.
C. Most community members (79.92%) who live in tsunami-prone villages feel safe from the disaster. The reasons are: (a) since the past there has never been a tsunami (82.76%), the population is religious (7.39%), the village is located in a high place (6.4%), the village is sheltered by a hill (1.97%), guarded by Nyai Roro Kidul (0.99%), and there is a caretaker who can counteract the tsunami (0.49%). The reasons stated above show that there is still a low level of public knowledge about tsunamis.
D. Community members who feel that their area is safe from the tsunami does not have readiness if there is a tsunami disaster.
E. The attitude of community members who feel their territory is prone to tsunami (18.51%) in anticipating the possibility of a tsunami when a relatively strong earthquake is divided into three groups, namely (a) staying in the village surrendering to God (19.15%), immediately ran to a high place (44.68%), and the rest (56.17%) would save themselves after certain warnings.
F. The socialization of the tsunami disaster was carried out through lectures and discussions followed by all village officials who were included in the tsunami-prone areas who were able to increase the knowledge and awareness of the participants regarding the possibility of a tsunami in their area and the ability of the village officials to take part in the knowledge received. to the community where they are assigned.

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