

# MAPPING TSUNAMI HAZARD LEVELS IN PACITAN BEACH USING REMOTE SENSING METHODS

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## ABSTRACT

Pacitan Regency is one of the tourist destinations in East Java with its beauty of tourism from the caves to the beaches that stretch along the southern part of Pacitan. Apart from its tourism potential, Pacitan Regency, which borders the Indian Ocean in the south, has the potential to be hit by a tsunami wave that occurs due to the collision of Eurasian and Indo-Australian plates. By using a remote sensing method, the tsunami hazard level of an area can be seen based on the parameters of the slope, the height of the area, and the distance from the coastline. In addition, the level of exposure of the population is also a factor in determining the level of tsunami hazard. In Pacitan Regency, the area affected by the low level tsunami reached 33753 Hectare, the medium level was 13498 Hectare, and the high level was 3828 Hectare. Areas with a high level of danger are located along the coast which extends in the southern part of Pacitan Regency. The area with the highest level of danger with a wider coverage is around Pacitan Bay. Therefore, it is necessary to have an appropriate mitigation system in reducing the risk of tsunamis, especially around the coast which is used as a tourist destination.

**Keyword:** Tsunami disaster, Pacitan regency, mitigation, beach

## Introduction

Pacitan is one of the cities in Indonesia that provides various natural beauties from cave tours to charming beaches. There are rows of karst hills with caves and underground rivers that extend to the Gunung Sewu Karst area which occurs due to the dissolution of carbonate rocks. There are also a lot of beaches with big waves that stretch along the south of Pacitan Regency, making it as one of the favorite tourist destinations in East Java. This huge tourism potential resulted in high population and the growth of existing buildings around the coast such as hotels. The location of the coast close to the plate collision zone will have a large tsunami potential, so it is necessary to map the tsunami hazard level.

Geographically, Pacitan Regency is located between 110.55o -111.25o East Longitude and 7.55o -8.17o South Latitude. Pacitan has an area of 138.987 hectare which administratively borders Ponorogo Regency in the North, Trenggalek Regency in the East, Wonogiri Regency in the West, and the Indian Ocean in the South. Based on the tectonics that occurred in Indonesia, there

are three plates that push each other, namely the Eurasian, Pacific and IndoAustralian plates. Pacitan beach is close to the subduction zone between the plates, namely the Eurasian and Indo-Australian plates, so this subduction will cause an earthquake. An earthquake that occurs on the seabed can trigger a tsunami.

Pacitan Regency has the topography of 85% mountainous and hilly areas, 10% wavy areas, and 5% flat areas. The population is up to 555.30 people, with the highest amount of population in the Pacitan Bay area (BPS, 2020).

Tsunami is one of the disasters that threatens the area around the coast. As a result of the fault that causes an underwater earthquake so that the air will accumulate and be knocked out with high energy. The closer to the land, the higher amplitude of the tsunami waves will be until it reaches several meter, this is because its close location to the plate subduction zone. The tsunami waves that occurred in Pacitan had a height of up to 5.2 m (BMKG, 2019).



**Figure 1.** Google Earth Satellite Image of Pacitan Regency

**Table 1.** Slope Classification

Score	Slope
5	0-2%
4	3-5%
3	6-15%
2	15-40%
1	>40%

**Table 2.** The Height of The Area Classification

Score	Height Area Classification
5	<10 m
4	11-25 m
3	26-50 m
2	51-100 m
1	>100 m

**Table 3.** Distance from Coastline Classification

Score	Distance from Coastline
5	0-500 m
4	501-1000 m
3	1001-1500 m
2	1501-3000 m
1	>3000 m

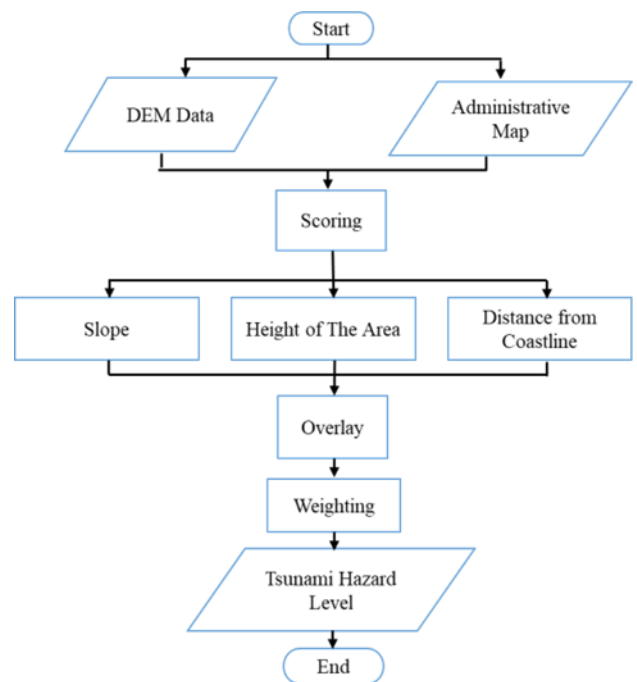
Areas with a tsunami risk are the urban areas close to the coast, since it has a high level of population and infrastructure development. The level of tsunami hazard in an area can be influenced by the slope, height of the area, distance from the coastline, and population.

The classification levels of the slope class, the height of the area, and distance from the coastline are as in Table 1, Table 2, and Table 3. (Iqbal Faiqoh, 2013).

## Methodology

In this study, the tsunami hazard level was determined using remote sensing methods. For the data required for this processing, there are Pacitan Regency administrative data and DEM (Digital Elevation Model) topographic maps which can be obtained from (<http://tides.big.go.id/DEMNAS/>).

The processing method is mapping the slope, the height of the area, and the distance from the coastline based on DEM topographic map data and administrative maps. After that, the scoring of each slope parameter is based on Table 1., the height of the area is based on Table 2., the distance from the coastline is based on Table 3. The scoring results of each parameter are overlaid and weighted to obtain a tsunami hazard level zone. In this processing using ArcGIS software.



**Figure 2.** Flowchart

## Result and Discussion

The tsunami that occurred in Pacitan Regency was caused by tectonic forces, namely the collision between the Eurasian and Indo-Australian plates. This collision can cause a seabed earthquake with great energy and trigger a tsunami wave that propagates from the epicenter towards the land. Through remote sensing methods, the level of danger from a tsunami can be influenced by several parameters such as slope, height of the area, distance from the coastline, and population.

Figure 3 is a map of the slope class in Pacitan Regency. Based on the slope map, the red color shows the level of the flat slope of 0-2% while the green color shows the slope of the slope is very steep > 40%. In the north, it is dominated by moderate- steep slopes, in the middle it is dominated by steep-very steep slopes, while in the south it is dominated by steep-flat slopes. Steep slopes are located in Punung, Donorejo, Kebon Agung, Tulakan and Sidomoro sub-districts, while medium-flat slopes are in Pacitan, Ngadirojo, and parts of Arjosari districts. Areas with low slope levels and close to the coast will have the potential to be affected by tsunami waves in the event of an earthquake and high waves.

Figure 4 is a map of the altitude class of the region in Pacitan Regency. Based on the map, it is shown that most areas of Pacitan Regency have altitudes ranging from low to very high. For the southern part of Pacitan, most of them have a variation in height of 51-100 meters, while for Pacitan the central part has a height that varies from low to very high, this is because the middle part has a more diverse topography.

Figure 5 is a map of the distance from the coastline. Based on the map, the red color shows the land distance from the near coastline, which is 0-500, the greenish yellow meter shows the distance from the coastline reaching 1501-3000 meters.

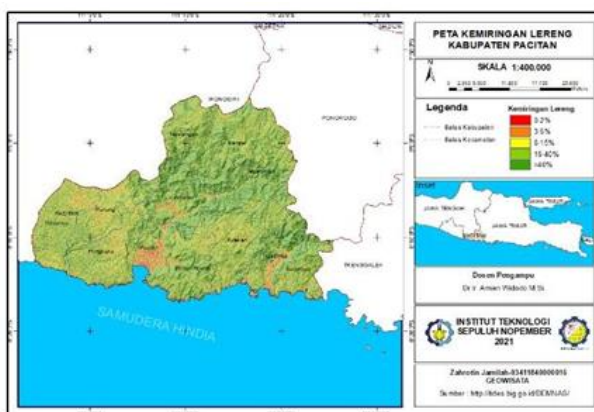


Figure 3. Slope Map in Pacitan Regency

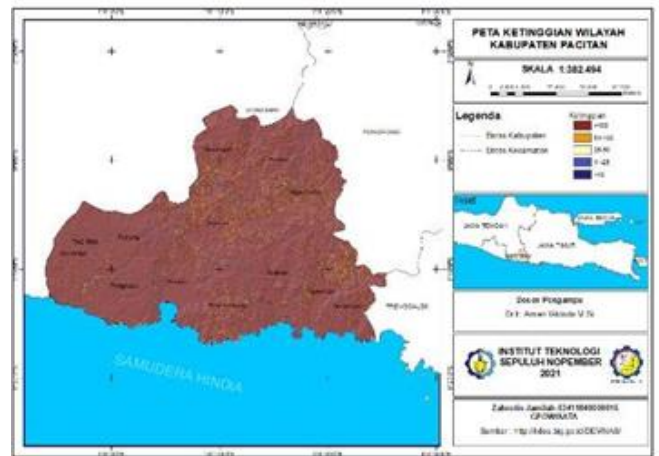


Figure 4. Height Map in Pacitan Regency

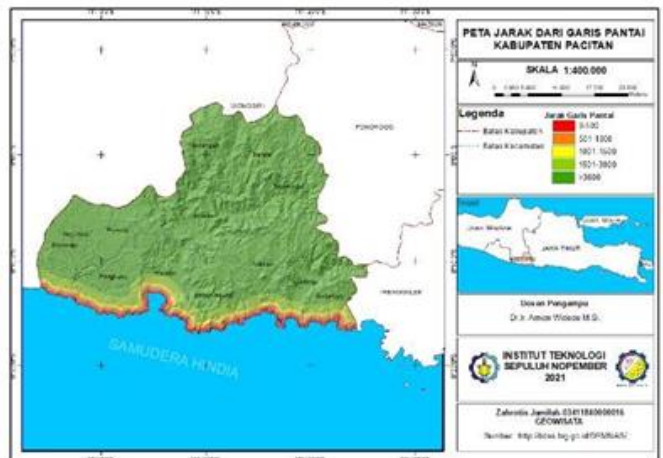


Figure 5. Distance from Coastline in Pacitan

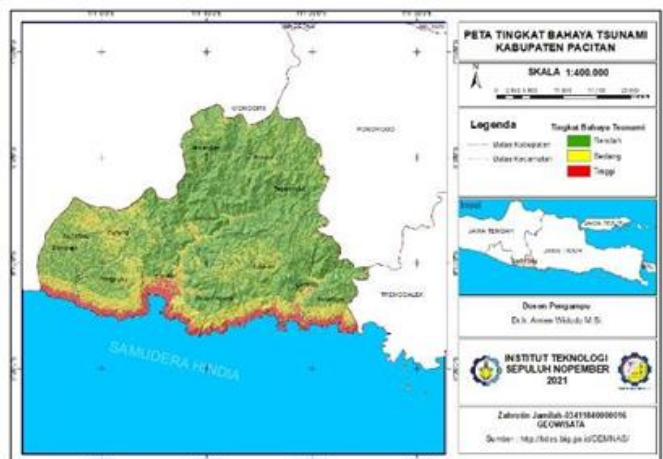


Figure 6. Tsunami Hazard Level Map in Pacitan Regency

Table 4. Tsunami Hazard Level Regency

Tsunami Hazard Level	Area (Hectare)
Low	33753
Medium	13498
High	3828

The distance from the coastline will affect the potential of an area affected by a tsunami wave where the waves propagating to the land will experience a decrease in speed and amplitude as the distance increases so that the farther an area is from the coastline, the potential impact of a tsunami wave will be smaller.

By overlaying and weighting the three parameters, namely the slope, height of the area, and distance from the coastline, the level of tsunami hazard to an area can be seen as in Figure 6. Figure 6 shows the classification of the tsunami hazard level in the Pacitan area starting from low moderate to high. The area affected by the tsunami is shown in Table 4, with a low level reaching 33753 Hectare, a medium level of 13498 Hectare, and a high level of 3828 Hectare. Areas with a high level of danger are areas located on the coast.

As previously explained, the southern part of Pacitan, which is a coastal area, will have a moderate to high tsunami hazard level as indicated by the yellow to red colors. Coastal ranges in southern Pacitan such as Banyu Tibo and Klayar Beaches in Donorejo, Kasap and Srau in Pringkuku, Teleng Ria in Pacitan, and Soge Beach in Ngadirojo will have a moderate-high tsunami hazard because they have a sloping topography with a short distance with the shoreline.

In general, the entire southern Pacitan area close to the coastline will have a moderate-high tsunami hazard level. Areas that have a high tsunami hazard level with a wider area are found in Pacitan District, which is in the Pacitan Bay. Tsunami waves that enter the bay area will result in a greater accumulation of energy so that the danger level will be higher. In addition, the level of tsunami hazard can be affected by the level of exposure of the population. Based on Figure 1., the Google Earth Satellite Image map and population data (BPS, 2019), Pacitan District area has the highest population level due to its community activities, settlements, and infrastructure development. Therefore, this area has a higher tsunami hazard level with a wider coverage than the surrounding area.

Based on the map in Figure 6., the southern part of Pacitan coast is an area with a high level of tsunami

hazard. Where the beach is a tourist destination that is visited by many tourists, so there is a need for proper mitigation to overcome the risk of a tsunami such as an Early Warning System around the coast, directions and pointers for the nearest evacuation route to reach higher places.

## Conclusion

The level of tsunami hazard can be influenced by several parameters, namely the slope, the height of the area, the distance from the coastline, and the level of exposure of the population. The area of impact in Pacitan Regency with a low level reached 33753 Hectare, a medium level 13498 Hectare, and a high level 3828 Hectare. The high level of danger is in the southern part of Pacitan, especially along the coast and Pacitan Bay. This part of Pacitan Bay has a higher and wider tsunami hazard level because the energy from the tsunami waves will accumulate and become larger, accompanied by low topography and a high infrastructure development.

In the coastal area which is the tourist destination, it is necessary to have an appropriate mitigation effort to deal with the possibility of a tsunami such as the Early Warning System, directions, and evacuation routes for all visitors.

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