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Risk Mapping of Tsunami Ambulu Sub-District, Jember Regency

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Abstract

Tsunami risk level mapping was carried out in Ambulu Sub-District, Jember Regency, to determine the tsunami risk level in the area. Tsunami risk mapping was carried out by including several components such as vulnerability, which consists of several assessment aspects by the Chief of the National Disaster Management Agency Regulation of the Year 2012, and capacity, which is weighted according to the Chief of the National Disaster Management Agency Regulation of the Year 2012. The hazard component was generated from the bathtub method. The tsunami risk level was obtained after overlaying using a GIS application (Geographic Information System). A very high level of risk is found to apply for Sumberejo Village, with an area of 286 Ha, and Sabrang Village, with an area of 288 Ha. Villages at very high risk are directly adjacent to the coast and have high vulnerability and low disaster management capacity. The other villages, such as Karanganyar Village, Ambulu Village, Tegalsari Village, Andongsari Village, and Pontang Village, do not have a very high tsunami risk because they are far from the coastline and have low vulnerability and high disaster response capacity.

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1. Introduction

Earthquakes often occur in Indonesia at small scales and large scales, both on land and in the sea. This situation cannot be removed from many active and moving tectonic plates. Approximately 80% of the region of Indonesia belongs to a region that is prone to the movements of tectonic plates. Research regarding tsunami risk mapping must be conducted to determine tsunami mitigation. Before this research, tsunami risk mapping had been conducted by other researchers. In China, risk assessment of tsunamis has been conducted along the Chinese Coast [1]. In Indonesia, there are also some studies on tsunami risk. Outside Java Island, there are several researches on tsunami risk mapping, for example in Sikka Regency, East Nusa Tenggara Province [2], the City of Palu, Central Sulawesi Province [3], and Weda Tengah Sub-District, North Maluku Province [4]. In the City of Pariaman, West Sumatra Province, the exposure zone of settlements toward tsunamis has also been studied [5].

According to [6], on 3 June 1994 at 01:17:34, an earthquake of 7.2 Ms occurred in the Indian Ocean (10477 South, 112835 East) at a depth of 18 Km, approximately 200 Km south of the coast of Java. This earthquake resulted in a tsunami that affected many areas, one of which was a portion of the coastline of Jember Regency and, in particular Ambulu Sub-District, specifically Watu Ulo Beach. At Watu Ulo Beach, 16 homes were destroyed, three fishers died, and more than 30 boats were severely damaged. The most relevant tsunami effect was found in a small gulf at one end of the village, and field measurements were focused on the area. On one of the walls, marks were found of three waves whose heights could be measured. The third wave was the highest, with a maximum water level height of 7.60 m.

There were also several studies on tsunami risk spatial analysis in Java Island, such as in Pelabuhan Ratu, East Jave Province [7], and the coastal area of East Java [8]. However, although tsunami risk mapping had been conducted for Puger Sub-District [9], no research has focused on tsunami risk mapping for Ambulu Sub-District, located next to Puger Sub-District, Jember Regency. With this background, this research intends to map tsunami risk for Ambulu Sub-District, Jember Regency.

To minimize the number of victims that result from a tsunami, disaster mitigation must be conducted. Efforts that may be conducted to minimize the occurrence of victims due to a tsunami are to create a tsunami risk map, to conduct intervention toward regional vulnerability, and to increase the capacity or condition of spatial resilience toward the extant possibility of occurring disasters [10]. In Chief of the National Agency for Disaster Management Regulation Number 2 of the Year 2012 on the general guidelines for disaster risk analysis, tsunami risk mapping is conducted with the inclusion of several components, such as vulnerability and capacity, which are weighted according to Chief of the National Agency for Disaster Management Regulation of the Year 2012, as well as the hazard component that results from the bathtub method. Next, overlaying was performed using a GIS (Geographic Information System) application to obtain the tsunami risk level. The bathtub method assumes oncoming waves as a still water surface above a fixed topographical area. The wave height is assumed to be the same for each inundated point. Thus the determination of inundated areas is based on the elevations of the locations toward certain water level heights [11]. The advantage of the bathtub method is that the method utilizes simple but quite effective calculations depending on the run-up and DEM elevation data.

In contrast, this method has the downside of a lack of documentation. A GIS is a PC-based system or framework to capture, store, examine, integrate, manipulate, and display data with a digital map, which could then be used in mapping out the tsunami risk level through analytical approaches for hazard level, tsunami vulnerability, and tsunami capacity [12]. This research aims to determine the tsunami risk level for the Ambulu Sub-District, which may become one of the considerations for policymaking for the local government.

2. Research Method

This research takes the location of Ambulu Sub-District, Jember Regency, East Java. Ambulu Sub-District is located at a distance of 40 km from the center of the City of Jember. Geographically, Jember Regency is located within 7° 59' 6" and 8° 33' 56" South Latitude and 113° 16' 28" to 114° 03' 42" East Longitude. Figure 1 shows the map of the research location, Watu Ulo Beach.

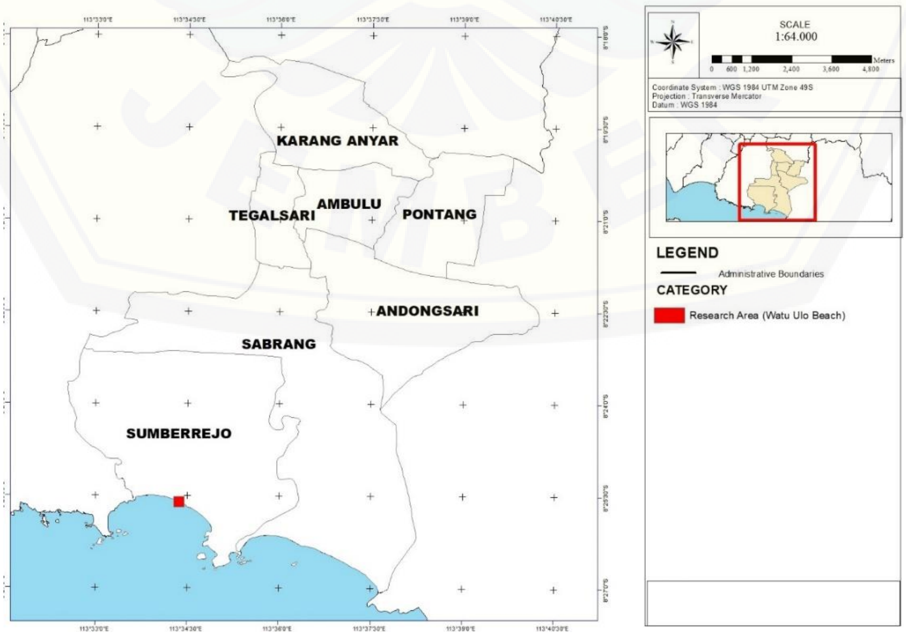

Figure 1. Research Location

The tsunami risk level requires the determination of magnitudes for hazard level, vulnerability, and capacity beforehand. The following methods determine the tsunami hazard level, vulnerability, capacity, and risk.

2.1 Determination of tsunami hazard level

Hazard level was obtained using the bathtub method, which was taken from run-up data based on historical tsunami data in Banyuwangi, East Java, and elevation data from DEMNAS. Hazard level was determined based on the elevation as divided into five categories, which are very high (elevation < 2.5 m), high (elevation 2.5 m-5 m), moderate (elevation five m-7.26 m), low (elevation 7.26 m-100 m), and very low (elevation > 100 m) [13]. Then, the hazard score was obtained by dividing the value in each parameter class by the maximum class. These are the possible scores of each parameter class: 1 is very low, two is low, three is moderate, four is high, and five is very high, with 5 being the maximum [14].

2.2 Determination of tsunami vulnerability

The vulnerability parameter was obtained by overlaying the elements of social, economic, physical, and environmental vulnerability [14]. Each element contains several ratios required to determine the element's score. For each resulting element score, weighting was carried out for each element based on Chief of BNPB Regulation No. 02 of the Year 2012 to result in the overall tsunami vulnerability as the product. The following is the formula that was used to determine tsunami vulnerability [14]:

$$V = (0{,}4 * VS) + (0{,}25 * VE) + (0{,}25 * VF) + (0{,}1 * VL) \quad (1)$$

Remarks:
V = tsunami vulnerability
VS = score of social vulnerability
VE = score of economic vulnerability
VF = score of physical vulnerability
VL = score of environmental vulnerability

After determining the vulnerability score, the category for that score was determined. The categories of vulnerability levels used in this research are very low vulnerability (score of 0-0.01), low vulnerability (score of 0.011-0.25), moderate vulnerability (score of 0.251-0.50), high vulnerability (score of 0.051-0.75), and very high vulnerability (score of 0.751-1) [10]. The parameter became a reference in creating a GIS application vulnerability map.

2.3 Determination of tsunami capacity

The Hyogo Framework for Actions (HFA) represents a basis for determining the levels of capacity, and resilience indicated for a region. The capacity index was calculated based on the indicators of HFA. Therefore, the questions that are posed in conducting interviews must contain the achievement indicators that have been outlined in the HFA.

Determination of capacity was performed based on the resilience level of a region toward a tsunami disaster. Data for capacity were obtained from interviews with village chiefs or actors of management for tsunami disasters in the Ambulu Sub-District. The indicators of determining capacity level in HFA are composed of five indicators: a) regulation and institution of disaster management; b) early warning and risk analysis of disasters; c) disaster education; d) reduction of basic risk factors; and e) preparedness development for all lines. Each indicator was divided into 11 core questions to make it easier to conduct interviews, which makes it possible to clarify the direction of the conversation while conducting the interviews. For each question, the maximum possible value is 5. Therefore, the maximum class score value is 55 because each question has a maximum value of 5; this depends on the actual conditions of the research area, and thus with 11 questions, this resulted in a maximum value of 55. After obtaining the actual value, this was divided by the maximum value to result in the capacity score.

The class score was divided by the maximum class score to obtain the capacity score. For the score that was obtained, the score was classified according to the five categories that have been established, very low capacity (score of 0-0.01), low capacity (score of 0.011-0.25), moderate capacity (score of 0.251-0.50), high capacity (score of 0.051-0.75), and very high capacity (score of 0.751-1).

2.4 Determination of tsunami risk

In determining tsunami risk, overlaying was performed on the three scores of hazard, vulnerability, and capacity using the following formula [14]:

$$Risk = Hazard * \frac{Vulnerability}{Capacity} \quad (2)$$

The values for hazard and vulnerability were taken from the values of each village present in the Ambulu Sub-District. The capacity value was taken from the capacity score that had been previously analyzed. Some regions had hazard levels in the low and very low categories, and several villages had a capacity value of 0. The calculation of tsunami risk used the following formula [14]:

$$Risk = Hazard * \frac{Vulnerability}{(1-Capacity)} \quad (3)$$

The obtained score was then classified according to the five categories that have been established, very low risk (score of 0-0.01), low risk (score of 0.011-0.25), moderate risk (score of 0.251-0.50), high risk (score of 0.051-0.75), and very high risk (score of 0.751-1). After the scores for regions according to the established categories were determined, each region's area was measured using a GIS application.

3. Results and Discussion

3.1 Analysis of tsunami disaster hazard areas

In determining the hazard areas, it is necessary to establish the run-up data beforehand. The run-up is the water level height achieved due to the motion of waves that strike the coast or coastal structures calculated from the elevation of the still water level (SWL). For this research, run-up data were obtained from prior research entitled Analysis of Wave Height, Run-up, and Tsunami Inundation along the Southern Shoreline of East Java [15]. In calculating the run-up value, the researchers used modeling from Delft3D for a case study of an earthquake that occurred in 1994 south of the Province of East Java with a magnitude of 7.8 and resulted in a tsunami. The modeling obtained a run-up value of 7.26 m with a tsunami arrival time of 38 minutes from the earthquake center to the coast [15].

The next step that was conducted was determining the elevations of the research location from DEMNAS. The two data sets found that the areas that will be inundated have elevations less than 7.26 m. In contrast, areas with elevations greater than 7.26 m are included in the safe category. The resulting hazard map is displayed in Figure 2. Figure 2 shows that a very high tsunami hazard level was discovered for the shoreline areas in the villages of Sumberejo and Sabrang. Meanwhile, areas far from the shoreline had low and even very low tsunami hazard levels. It occurs because those areas possess lower elevations than the run-up, and thus inundation occurs in those areas.

3.2 Analysis of tsunami disaster vulnerability

Tsunami vulnerability is divided into several aspects, such as social vulnerability, economic vulnerability, physical vulnerability, and environmental vulnerability.

3.2.1 Social vulnerability

The parameter for determining social vulnerability covers several components, such as population density and vulnerable residents. The component of population density covers the number of people in the research location divided by the land area of the research location. The component of vulnerable residents covers the ratio of gender, the ratio of vulnerable age (ages < 4 years and > 50 years), the ratio of poor residents, and the ratio of disabled residents. To obtain the vulnerability score for each component above, each component was analyzed using the scoring method by dividing the class score by the maximum class score. After obtaining the scores, weighting was conducted according to the Chief of BNPB Regulation No. 02 of 2012 [14].

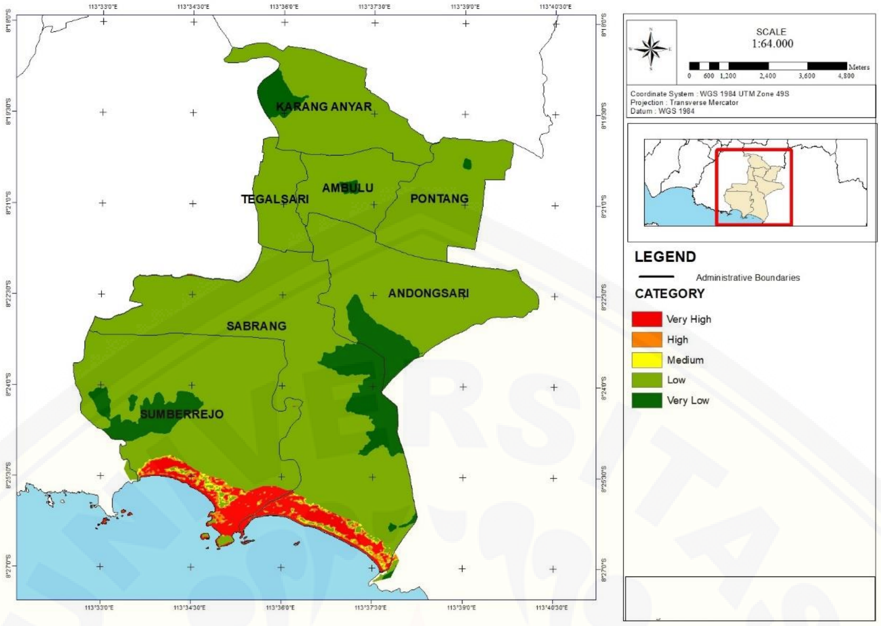

Figure 2. Tsunami hazard map

Table 1. The weighting of social vulnerability

No	Village	Population density	Vulnerable age ratio	Poverty ratio	Gender ratio	Disability ratio	Score	Category
	Weight (%)	0.6	0.1	0.1	0.1	0.1		
1	Sumberejo	0.60	0.10	0.04	0.10	0.10	0.93	Very High
2	Andongsari	0.28	0.10	0.05	0.10	0.05	0.57	High
3	Sabrang	0.07	0.10	0.04	0.10	0.06	0.36	Moderate
4	Ambulu	0.60	0.10	0.07	0.09	0.08	0.94	Very High
5	Potang	0.24	0.10	0.05	0.10	0.07	0.56	High
6	Karanganyar	0.34	0.09	0.10	0.10	0.02	0.65	High
7	Tegalsari	0.53	0.10	0.03	0.10	0.06	0.81	Very High

From Table 1, it can be seen that from the results of the conducted weighting of several parameters of social vulnerability, the category of Very High was obtained for the villages of Sumberejo, Ambulu, and Tegalsari. The resulting map from the table above can be seen in Figure 3. Figure 3 shows the social vulnerability map. In Ambulu Sub-District, the villages with the greatest social vulnerability were the villages of Sumberejo, Ambulu, and Tegalsari. It is because the population density, ratio of vulnerable age, the ratio of disabled residents, the ratio of gender, and the ratio of poverty for the region have high values.

3.2.2 Economic vulnerability

The parameter for evaluating economic vulnerability is the economic condition of the region. The determination of economic condition used the region's resident revenue variable. The residents' revenues of the region may also affect the survival process after a tsunami disaster. In determining the region's financial condition, the utilized data was the Land and Building Tax revenue data for Ambulu Sub-District. The economic vulnerability table is shown in Table 2. In Table 2, the percentage is the division of the target by the realization, multiplied by 100%. The score was obtained by dividing the realization value by the greatest realization value.

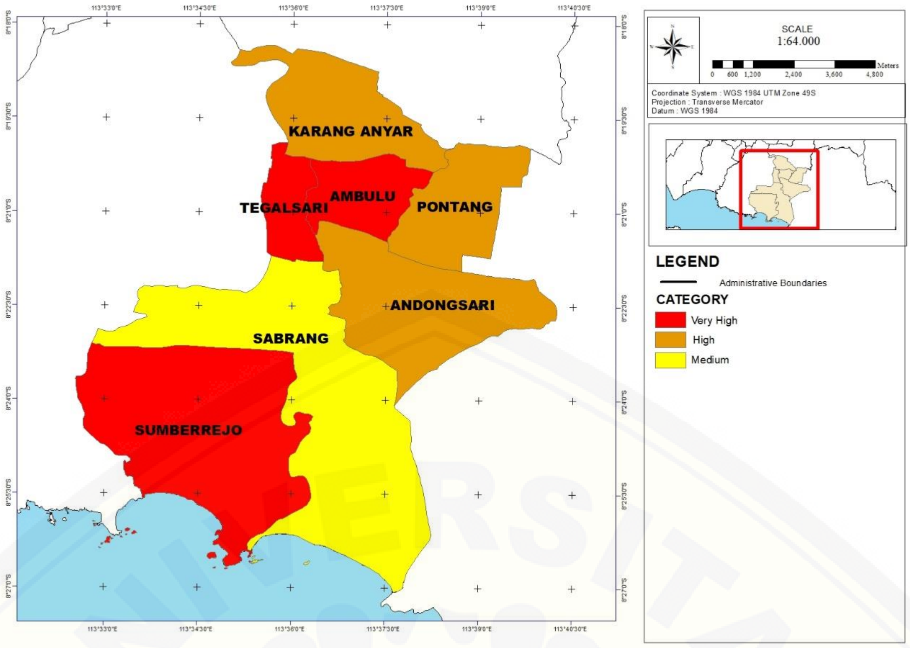

Figure 3. Map of social vulnerability

Table 2. Economic vulnerability based on land and building tax revenue

No	Village	Target	Realization	Percentage	Class	Score	Parameter
1	Sumberejo	530,133,020	528,081,378	99.61%	High	1.00	Very High
2	Andongsari	514,514,268	197,857,637	38.46%	Moderate	0.37	Moderate
3	Sabrang	386,962,498	289,843,025	74.90%	High	0.55	High
4	Ambulu	381,373,455	407,046,538	106.73%	High	0.77	Very High
5	Potang	268,839,175	165,838,651	61.69%	Moderate	0.31	Moderate
6	Karanganyar	346,391,964	182,417,096	52.66%	Moderate	0.35	Moderate
7	Tegalsari	261,556,951	158,027,763	60.42%	Moderate	0.30	Moderate

Table 2 shows that for the results of the weighting from the economic vulnerability parameter based on land and building tax revenue, the Very High category was obtained for the villages of Sumberejo and Ambulu. Figure 4 is the resulting map from Table 2. Figure 4 shows the economic vulnerability map. In Ambulu Sub-District, the villages with the greatest economic vulnerability were the villages of Sumberejo and Ambulu. It is because of the high amount of tax revenue for the region. It indicates that the region has a relatively high economic level.

3.2.3 Physical vulnerability

There are several parameters in determining the physical vulnerability score of a region. The physical vulnerability has several variables: housing, public, and critical facilities. The physical vulnerability was evaluated based on the rupiah or monetary value for each variable of physical vulnerability, and the score was obtained by dividing the class score by the maximum class score. After the score was obtained, weighting was conducted according to the Chief of BNPB Regulation No. 02 of 2012. The rupiah or monetary value was obtained by multiplying the number of an aspect determined by a variable by the unit price of the variable. Table 3 is the table for the weighting of physical vulnerability.

Table 3 shows that by the weighting results from the physical vulnerability parameter, the Very High category was obtained for Ambulu Village. Meanwhile, Figure 5 is the resulting map from Table 3. Figure 5 shows the physical vulnerability map. In Ambulu Sub-District, the village with the greatest physical vulnerability was Ambulu Village. This is because Ambulu Village has a high house density and public and critical facilities.

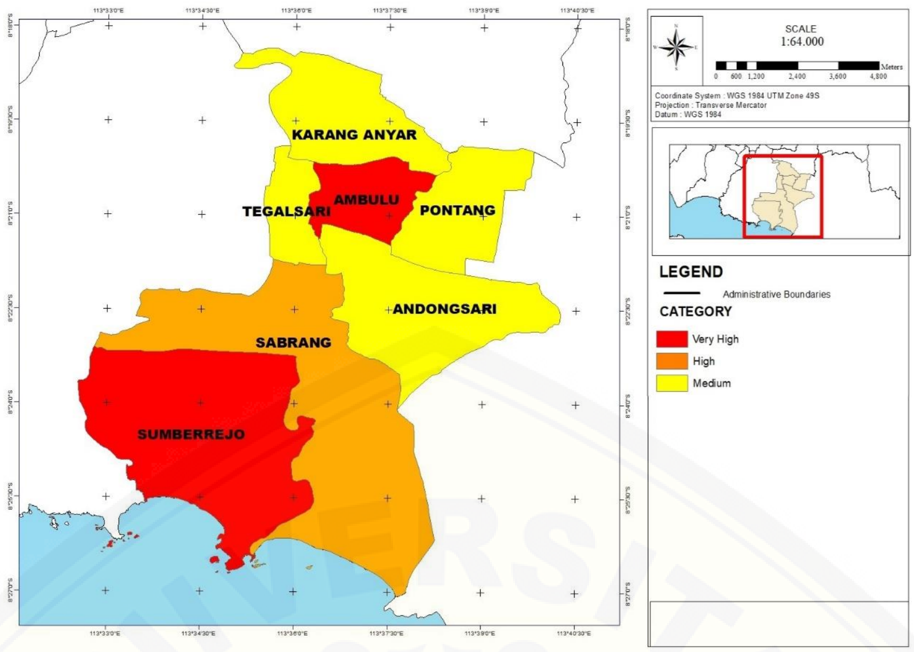

Figure 4. Map of economic vulnerability

Table 3. The weighting of physical vulnerability

No	Village	Housing Density	Critical Facilities	Public Facilities	Score	Category
	Weight (%)	0.4	0.3	0.3		
1	Sumberejo	0.19	0.13	0.30	0.62	High
2	Andongsari	0.19	0.13	0.24	0.56	High
3	Sabrang	0.05	0.07	0.16	0.28	Moderate
4	Ambulu	0.40	0.30	0.21	0.91	Very High
5	Potang	0.16	0.04	0.19	0.39	Moderate
6	Karanganyar	0.23	0.04	0.26	0.54	High
7	Tegalsari	0.37	0.10	0.19	0.66	High

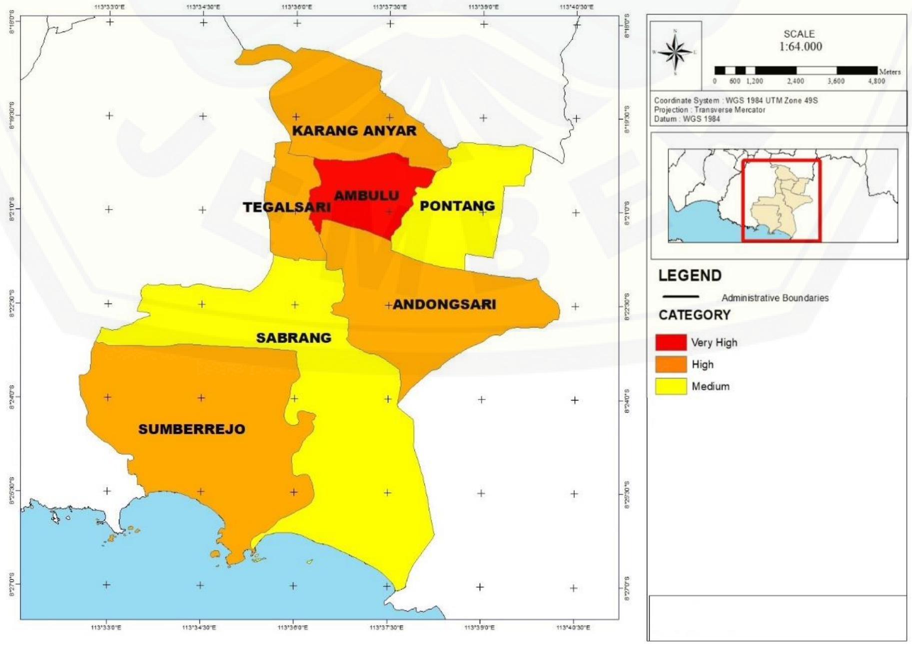

Figure 5. Map of physical vulnerability

3.2.4 *Environmental vulnerability*

Environmental vulnerability comprises the variables of protected forests, natural forests, and mangrove forests. For environmental vulnerability, the required data were the data on the area of each variable. The data were then analyzed using the class parameter, and the score was obtained by dividing the class score by the maximum class score. After a score was obtained for each variable, weighting was conducted according to the Chief of BNPB Regulation No. 02 of the Year 2012. Table 4 shows the results for the weighting of environmental vulnerability. Table 4 shows the resulting environmental vulnerability.

Table 4. The weighting of environmental vulnerability

No	Village	Protected Forest	Natural Forest	Mangrove Forest	Score	Category
	Weight (%)	0.30	0.30	0.40		
1	Sumberejo	0.00	0.01	0.00	0.01	Very Low
2	Andongsari	0.00	0.08	0.00	0.08	Low
3	Sabrang	0.30	0.30	0.00	0.60	High
4	Ambulu	0.00	0.00	0.00	0.00	Very Low
5	Potang	0.17	0.03	0.00	0.20	Low
6	Karanganyar	0.30	0.13	0.00	0.38	Moderate
7	Tegalsari	0.00	0.00	0.00	0.00	Very Low

Table 4 shows the resulting environmental vulnerability map in Figure 6. Figure 6 shows the environmental vulnerability map. In Ambulu Sub-District, the village with the greatest environmental vulnerability was Sabrang Village. It is because Sabrang Village has a great land area of forests. A great area of forests leads to a high vulnerability score because widespread damage to forests can affect the environment.

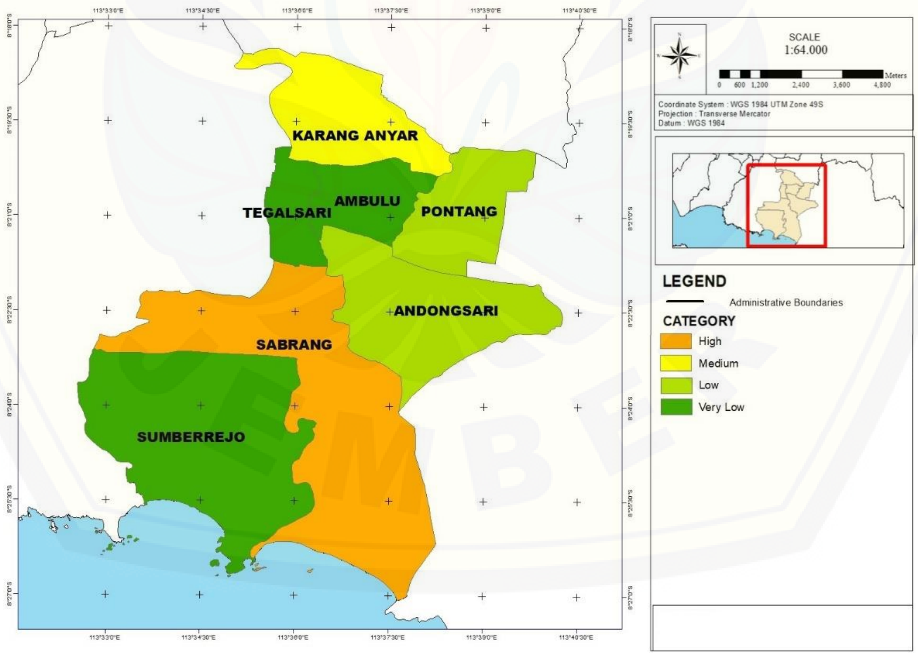

Figure 6. Map of environmental vulnerability

3.2.5 *Overall vulnerability*

An overall vulnerability was obtained from the analysis of the vulnerability parameters of social vulnerability, economic vulnerability, physical vulnerability, and environmental vulnerability. The scores of the four kinds of vulnerabilities were weighted according to the Chief of BNPB Regulation No. 02 of the Year 2012. The vulnerability scores became evident after weighting, and according to the vulnerability scores, the villages were classified into five categories: low, low, moderate, high, and very high. It is shown in more detail in Table 5.

Table 5. Weighting of vulnerabilities

No	Village	Social	Economic	Physical	Environmental	Score	Category
	Weight (%)	0.4	0.25	0.25	0.10		
1	Sumberejo	0.37	0.25	0.15	0.00	0.78	Very High
2	Andongsari	0.23	0.09	0.14	0.01	0.47	Moderate
3	Sabrang	0.15	0.14	0.07	0.06	0.41	Moderate
4	Ambulu	0.38	0.19	0.23	0.00	0.80	Very High
5	Potang	0.22	0.08	0.10	0.02	0.42	Moderate
6	Karanganyar	0.26	0.09	0.13	0.04	0.52	High
7	Tegalsari	0.33	0.07	0.17	0.00	0.57	High

Table 5 created the overall vulnerability map (Figure 7). Figure 7 shows the vulnerability map. For example, in Ambulu Sub-District, the villages with very high vulnerability were the villages of Sumberejo and Ambulu. It is because of the high vulnerability score for the evaluated aspects of social, economic, physical, and environmental vulnerability.

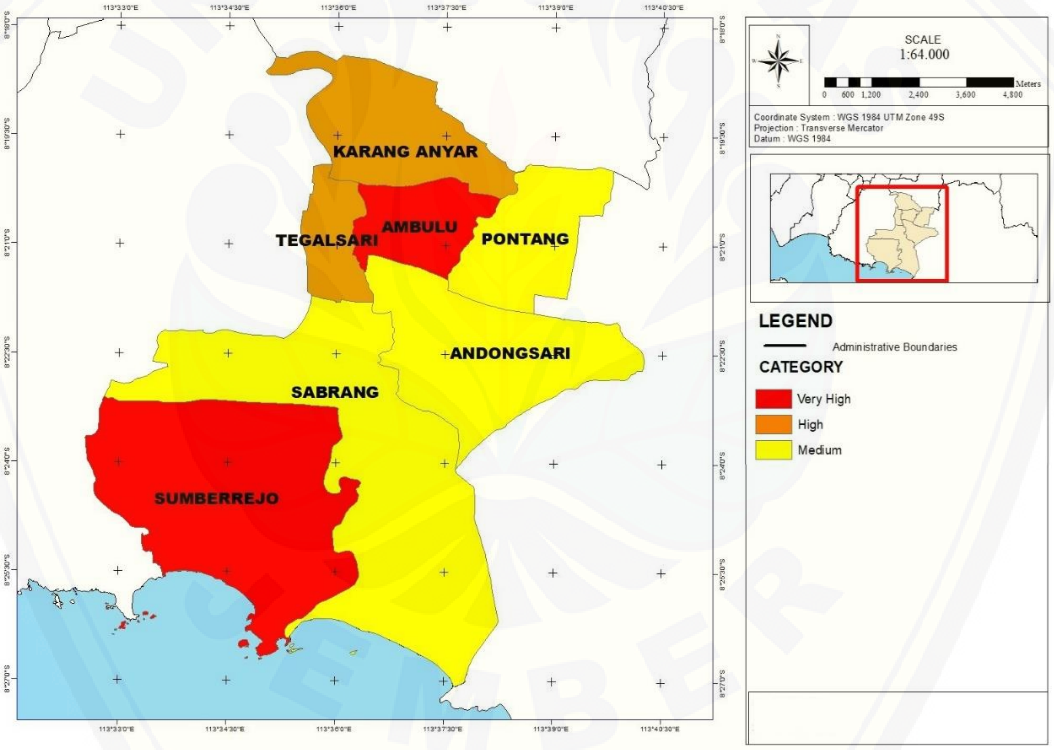

Figure 7. Vulnerability map

3.3 *Analysis of tsunami disaster capacity*

The Hyogo Framework for Actions (HFA) becomes the basis for determining the capacity and resilience possessed by a region. The capacity level-determining indicators in the HFA are composed of five indicators, each divided into 11 variable questions with scores for each variable. After determining each village's score, it was possible to determine their classes and categories. The BNPB has regulated this as Class 1 and very low category (0-0.20), Class 2 and low category (0.21-0.40), Class 3 and moderate category (0.41-0.60), Class 4 and high category (0.61-0.80), and Class 5 and very high category (0.81-1.00) [10]. The following are the results of analyzing the capacity level for the Ambulu Sub-District. From Table 6, the capacity map was then created.

Table 6. Capacity weighting

No	Village	Score	Class	Category
1	Sumberejo	0.73	Class 4	High
2	Andongsari	0.00	Class 1	Low
3	Sabrang	0.20	Class 1	Low
4	Ambulu	0.15	Class 1	Low
5	Potang	0.15	Class 1	Low
6	Karanganyar	0.00	Class 1	Low
7	Tegalsari	0.15	Class 1	Low

Figure 8 shows the capacity map. In Ambulu Sub-District, the village with the greatest capacity was Sumberejo Village. It is because the area's resilience level toward tsunami disasters is high.

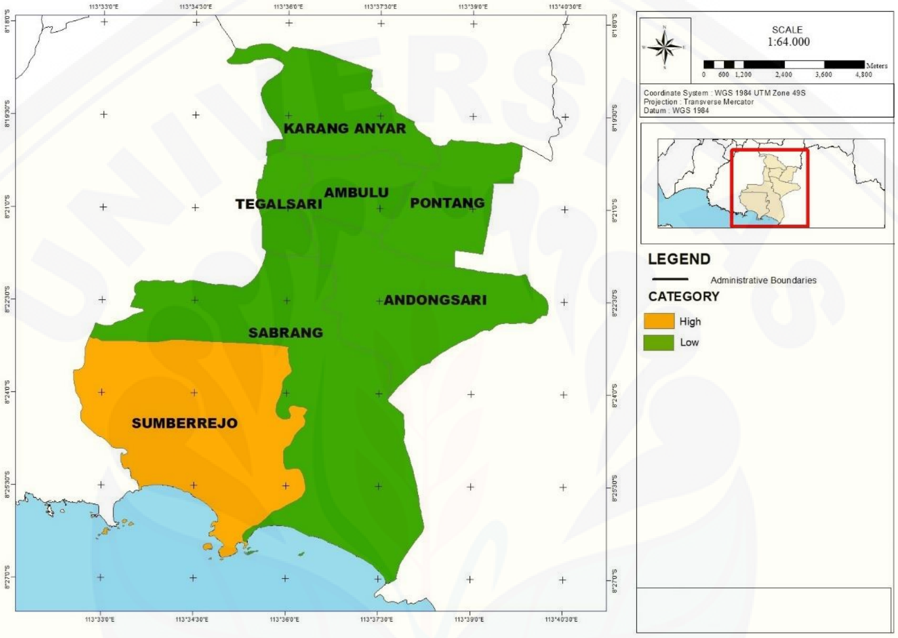

Figure 7. Capacity map

3.4 Analysis of tsunami disaster risk

Determining tsunami disaster risk requires the indicators of tsunami hazard, vulnerability, and capacity. The three indicators were analyzed according to the basis of determination for the tsunami disaster risk level, as the product of hazard and vulnerability divided by capacity. Determining zones with high or low-risk levels was performed in a GIS application using a raster calculator with the formulas explained in the method discussion, as formulas (2) and (3), resulting in Table 7. In Table 7, Sumberejo Village and Sabrang Village are displayed according to differences in hazard category because those villages possess different elevations. Thus the resulting hazard categories for them are also different.

Table 7. The weighting of disaster risk

Village	Hazard		Capacity			Vulnerability		Risk	
	Score	Category	Score	1-C	Category	Score	Category	Score	Category
Tegalsari	0.20	Very Low	0.15	0.85	Low	0.57	High	0.13	Low
Sumberejo	0.20	Very Low	0.73	0.27	High	0.78	Very High	0.21	Low
Andongsari	0.20	Very Low	0.00	1.00	Low	0.47	Moderate	0.09	Low

Village	Hazard		Capacity			Vulnerability		Risk	
	Score	Category	Score	1-C	Category	Score	Category	Score	Category
Sabrang	0.20	Very Low	0.20	0.80	Low	0.41	Moderate	0.10	Low
Ambulu	0.20	Very Low	0.15	0.85	Low	0.80	Very High	0.19	Low
Potang	0.20	Very Low	0.15	0.85	Low	0.42	Moderate	0.10	Low
Karanganyar	0.20	Very Low	0.00	1.00	Low	0.52	High	0.10	Low
Sumberejo	1.00	Very High	0.73	0.27	High	0.78	Very High	1.07	Very High
Sabrang	1.00	Very High	0.20	0.80	Low	0.41	Moderate	2.06	Very High
Sumberejo	0.80	High	0.73	0.27	High	0.78	Very High	0.86	Very High
Sabrang	0.80	High	0.20	0.80	Low	0.41	Moderate	1.65	Very High
Sumberejo	0.60	Moderate	0.73	0.27	High	0.78	Very High	0.64	High
Sabrang	0.60	Moderate	0.20	0.80	Low	0.41	Moderate	1.24	Very High
Sumberejo	0.40	Low	0.73	0.27	High	0.78	Very High	0.43	Moderate
Sabrang	0.40	Low	0.20	0.80	Low	0.41	Moderate	0.82	Very High

Table 7 may be displayed as a risk matrix that is a function of hazard and exposure, as shown in Figure 9. Exposure in Figure 9 is the combination of the parameters of vulnerability and capacity. The results of the calculations are the risk levels as in Table 7.

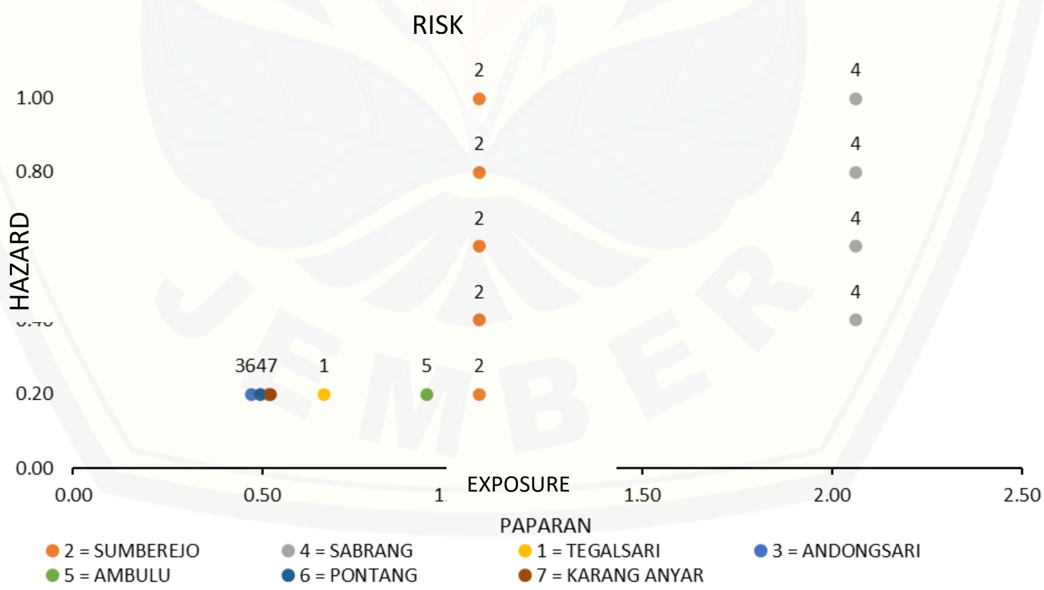

Figure 8. Exposure-hazard matrix

From the polygons found in the GIS application, the areas of each existing parameter for the Ambulu Sub-District may be determined, as indicated in Table 8.

Table 8. Areas of Tsunami Risk in Ambulu Sub-District

No	Village	Total Area per Category (Ha)				
		Very High	High	Moderate	Low	Very Low
1	Tegalsari	0	0	0	434	0
2	Sumberejo	286	63	48	2158	0
3	Andongsari	0	0	0	1712	0
4	Sabrang	288	0	0	2965	0
5	Ambulu	0	0	0	631	0
6	Potang	0	0	0	944	0
7	Karanganyar	0	0	0	1194	0

From Table 8, the vulnerability-capacity matrix may be created, as in Figure 10.

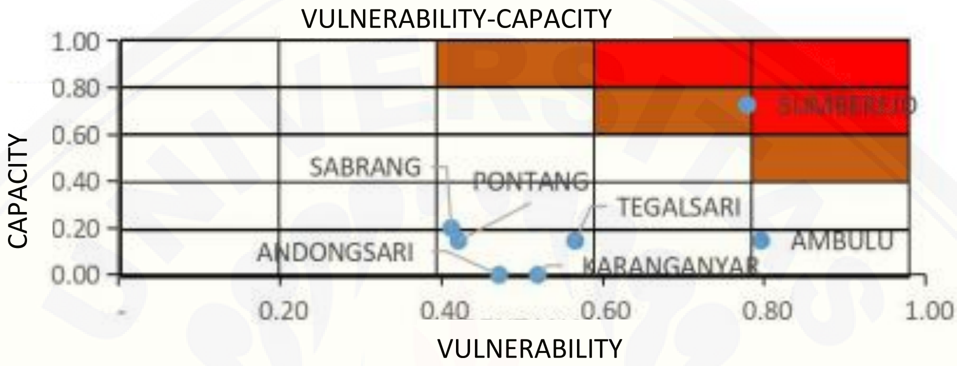

Figure 9. Vulnerability-capacity matrix

From Table 7, the map in Figure 11 became the result.

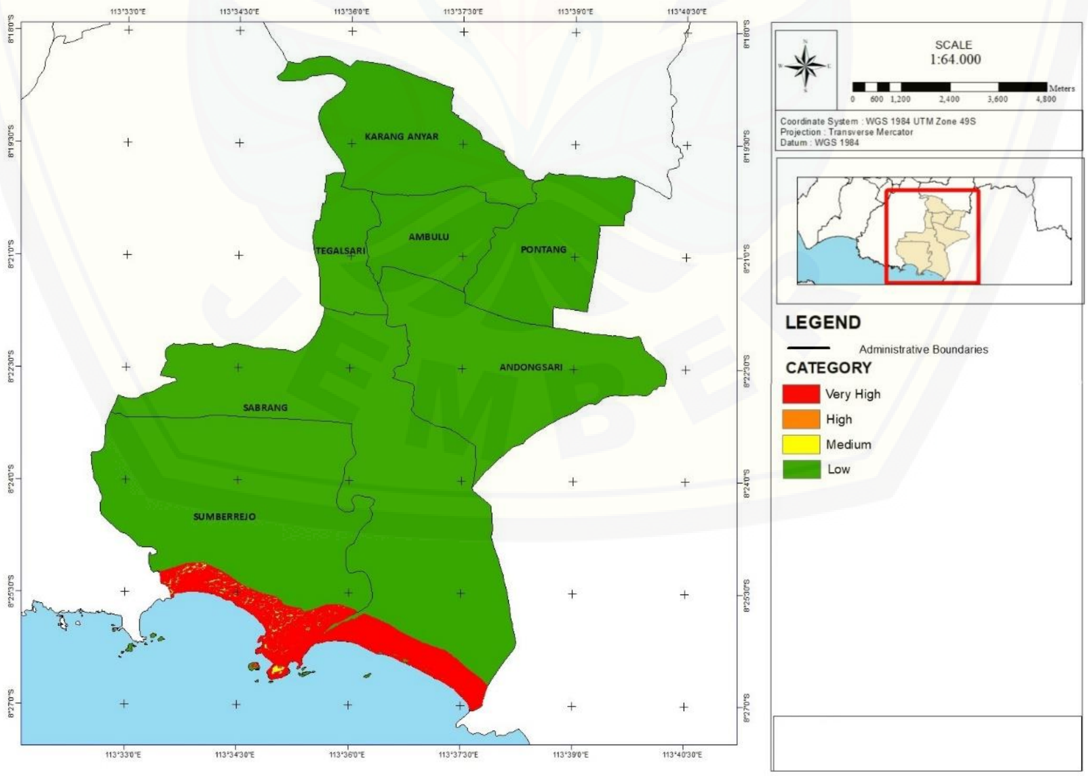

Figure 10. Disaster risk map

Figure 11 shows the risk map for tsunami disasters. For example, in Ambulu Sub-District, the villages with a hazard level of very high were the villages of Sumberejo and Sabrang. However, not all parts of the villages have a very high tsunami hazard level; only the areas near the coastline possess a very high tsunami hazard level. It is because the hazard level in those areas is very high, and a very high capacity level does not support them.

4. Conclusion

Based on analyses of tsunami hazard, vulnerability, and capacity, the tsunami risk for Sumberejo Village (286 Ha) and Sabrang Village (288 ha) in Ambulu Sub-District are of the very high category because those regions have areas close to the shore and thus possess high hazard levels. In addition, the population densities are high, and thus the vulnerability is also relatively high; the preparedness for managing tsunami disasters is relatively low, and thus the capacity level is also low. The other villages of Karanganyar, Ambulu, Tegalsari, Andongsari, and Pontang possess a very low category of tsunami risk because those villages possess relatively low tsunami hazard levels and sufficiently large distances from the coast. The method for reducing tsunami risk is increasing the capacity value through activities such as periodic investigations and training for tsunami disasters.

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