Geographic Information System and Weighting Technique for Tsunami Risk Assessment in Coastal Villages of Jember Regency, Indonesia

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Abstract

Jember is one of the regencies in East Java having tsunami-prone areas. Regional Disaster Management Agency (BPBD) of Jember defined six sub-districts that are vulnerable to tsunami disasters comprised of Kencong, Puger, Gumukmas, Wuluhan, Ambulu, and Tempurejo. Settlements in coastal areas are at risk of being affected by the tsunami. The residential household close to the seashore is centrally located in Kencong, Gumukmas, Puger, and Ambulu sub-district. The high density of buildings can cause economic losses and fatalities in the surrounding area when a tsunami disaster strikes.

This research aims to identify and measure tsunami risk levels in all coastal villages of the Jember Regency. The research method used a quantitative approach through scoring and weighting technique, also a disaster risk matrix. Spatial analysis conduct used a geographic information system app (Arc GIS). The Arc GIS output is of several maps of hazard, vulnerability, capacity, and tsunami disaster risk in the Jember Regency Coastal Area. The research result of the tsunami disaster risk assessment showed that six villages had high risk from twelve coastal villages in Jember Regency.

Keywords: Tsunami, Risk Assessment, Geographic Information System (GIS).

Introduction

Indonesia is an archipelago with various types of disasters in varying levels of risk for each region, one of them is East Java province. The Climatology and Geophysics Meteorology Agency (BMKG) of Malang established eight regencies in the East Java southern region prone to the tsunami disaster. The regencies included Jember located in an earthquake-prone area (Zone I/High). Jember Regency has faced the Indian Ocean, the meeting place of two tectonic plates.

The Eurasian Plate and Indo-Australian Plate are tectonically very active and can be source of tsunami disaster. Jember has a total area of 3,292.34 km^2 with 170 km coastline length[4]. Based on Disaster Hazard Index Map in East Java province, which originated from The National Disaster Management Agency (BNPB) from the geographical aspect, Jember Regency has a high level of disaster vulnerability.

According to the Regional Disaster Management Agency (BPBD) in Jember, almost all multi-hazard disasters potentially occur in Jember Regency. Data from Regional Disaster Management Agency (BPBD) in Jember recorded that 19 out of 31 sub-districts in Jember were disaster-prone areas such as floods, landslides, tornadoes, and tsunamis. The Regional Disaster Management Agency (BPBD) of Jember Regency defined six sub-districts comprised of Kencong, Puger, Gumukmas, Wuluhan, Ambulu and Tempurejo prone to tsunami disasters. Generally, high-risk areas of tsunami disasters are having overexposure by high density near the seashore.

Coastal fishermen settlement is vulnerable because of human activities center. The fisherman settlement location close to the coast causes high vulnerability when a tsunami disaster strikes. It can take property losses and affect the economy of the surrounding society. The research purpose is to calculate tsunami disaster risk levels in Jember Regency coastal villages.

Material and Methods

Research on tsunami disaster risk in the coastal area of Jember Regency used quantitative and spatial analysis techniques. Quantitative analysis techniques used are scoring and weighting technic to determine vulnerability and capacity classification. Spatial analysis techniques[14] were also performed using Arc GIS 10.5 to make tsunami disaster risk mapping. GIS gives advantages on presenting information that will be easily understood either to simulate or to analyze the impact of tsunami attack[16,24].

Research Variable: The variables used from disaster risk assessment by Head of National Disaster Management Agency (BNPB) Regulation Number 2 of 2012 consist of hazards, vulnerabilities, and capacities[12]. The variables and sub-variables in this research are listed in table 1.

Geographic Information System is powerful to analyze tsunami hazard potential. Each parameter relating to the tsunami hazard map is represented layer by layer in GIS. Each layer consists of spatial and attributes data. The existing data such as road, building along the road, and land use are essential in the tsunami mitigation analysis because those data register as attributes related to spatial data[14].

Tsunami hazard mapping in this research originated from German-Indonesia Tsunami Early Warning System (GITEWS)[1]. Vulnerability variables (Table 2) have sub-variables in aspects physical, social, economic, and environment. Each sub-variable consists of several indicators[8,13,20]. Disaster vulnerability data was obtained from secondary data through government documents and primary data through field observation.

The indicator from the capacity variable used the combination between government and community resilience. Disaster capacity data was obtained through in-depth interviews and forum group discussions to acquire information related to tsunami disaster capacity. Disaster capacity in Jember Regency coastal area has several sub variables comprised of institutional regulation on disaster management at the local level, early warning and disaster risk, disaster education, risk factors reduction etc. Each sub variable was measured to get disaster capacity level by specific indicator[10,12,15] provided in table 3.

Research Analysis: Measurement of disaster risk variable for vulnerability and capacity was done using scoring and weighting techniques in each indicator. The formulation for calculating class width is:

$$c = \frac{Xn - Xi}{k} \qquad (1)$$

where C = estimated class size, k = number of classes, Xn = highest observation value and Xi = lowest observation value.

The difference between class upper limit and class lower limit defined the class width to measure each indicator category. Class determination in this research will show the level of disaster risk variables in the study area. The value of k, which represented a class, is classified into three-level categories consisting of low, medium, and high. The concept of disaster risk assessment was adopted based on the Head of BNPB Regulation Number 02 of 2012 concerning General Guidelines for Disaster Risk Assessment12 with the following risk formula:

$$R = \frac{HxV}{C} \qquad (2)$$

where R = Disaster Risk, H = Hazard Threat, V = Vulnerability and C = Capacity.

Table 1
Research Variable

Purpose	Variable	Sub Variable
Identify and measure the level of tsunami risk in coastal villages of Jember Regency.	Hazard	• Tsunami Disaster Hazard Map (elevation accuracy, water depth, and wave height)
	Vulnerability	• Physical Vulnerability • Social Vulnerability • Economic Vulnerability • Environmental Vulnerability
	Capacity	• Institution of disaster management at the local level • Early warning and disaster risk assessment • Disaster education • Basis risk factors reduction • Preparedness development in all lines

Table 2
Indicator of Disaster Vulnerability

Vulnerability	Indicator
Physical Vulnerability	• Percentage of building area
	• Percentage of damaged roads
	• Building density
Social Vulnerability	• Population density
	• Educational level (low percentage of educated population)
	• Percentage of vulnerable population (women)
	• Population growth rate
Economic Vulnerability	• Percentage of labor in the vulnerable sector
	• Percentage of productive land area
	• Percentage of the poor population
Environment Vulnerability	• The Green open space area

Table 3
Indicator of Disaster Capacity

Capacity	Indicator	Weight Value
Institutional regulation on disaster management at the local level	• Villages have adopted a basis for disaster risk reduction in developing disaster management documents at village scale	1
	• Community groups have been formed concerned about disaster risk reduction	2
	• The establishment or being planned to become disaster resilient villages	3
	• Facilitation of government and non-government organizations related to disaster risk reduction	4
Early warning and disaster risk	• Disaster risk on a district scale (minimal) and is known by village officials	1
	• Distribution of disaster mapping	2
	• Installation of early warning system by the government	3
	• Installation of early warning system by communities or group of organization	4
Disaster education	• Public awareness of tsunami disaster vulnerability	1
	• Socialization about disaster risk reduction by the government, especially related to the tsunami disaster	2
	• Simulations have been conducted by the government, especially to face tsunami disaster	3
Basic risk factors reduction	• The village government has collected data about vulnerable population	1
	• Strengthening and diversifying community's economy in the form of training and aid	2
	• Social actions to increase community capacity	3
Preparedness development in all lines	• The existence of an emergency response command system and involving village officials	1
	• The availability of technical capacity in the form of disaster management volunteers who gain access to coordinate with The Regional Disaster Management Agency (BPBD)	2
	• The availability of policies, disaster management plans, or contingency plans is known to all government networks and village officials.	3

Each risk variable (hazard, vulnerability, and capacity) was classified into three categories (low, medium, high). The implementation of formula operation was executed using a disaster risk matrix with cross-tabulation analysis[8].

Table 4
Cross Tabulation Matrix H x V

V \ H	Low (1)	Medium (2)	High (3)
Low (1)	1	2	3
Medium (2)	2	4	6
High (3)	3	6	9

Result of cross-tabulation calculation between hazard and vulnerability (H x V) have values:

H x V Low (green): 1 – 2
H x V Medium (yellow): 3 – 4
H x V High (red) : 6 – 9

Results of cross-tabulation calculation between hazard and vulnerability (H x V) and Capacity (C) have values:

Low disaster risk (green) : 0.33 - 0.67
Medium disaster risk (yellow) : 0.68 – 1.49
High disaster risk (red) : 1.50 - 3.00

The higher hazard and vulnerability indicators value cause the higher disaster risk potential, while the higher capacity indicators value causes the lower disaster risk potential. All the tsunami disaster risk parameters were under visualization through geospatial analysis using overlaying techniques for each attribute of hazard, vulnerability, and capacity. Figure 1 is a general framework that shows a flow chart analysis of the research study.

Table 5
Cross Tabulation Matrix (H x V)/C

C \ HxV	Low (1)	Medium (2)	High (3)
High (3)	0,33	0,67	1,00
Medium (2)	0,50	1,00	1,50
Low (1)	1,00	2,00	3,00

Results and Discussion

Topographic characteristic in Jember Regency: Jember Regency had an altitude of 0-3,300 meters above sea level with an elevation in the urban area approximately 87 meters above sea level. Most of the region (37.75%) is located at an altitude of 100 to 500 meters above sea level. The other areas (20.70%) had 25 to 100 m altitude above sea level. The rest of the region is at 500 to 1,000 m altitudes above sea level (15.80%). While altitudes more than 1,000 m above sea level spread in a small part of the region (7.80%), the southwest region had a land altitude surface 0-25 meters above sea level (17.95%). Bondowoso Regency was directly adjacent to the northeast area of Jember Regency. The southeast region located at Meru Betiri National Park had 1,000 meters altitude above sea level[6].

Coastal line topography affected tsunami disaster risk. Hollow topography abbreviates the length of immersion (duration of inundation) and is bringing down pressure-driven constraint by the tsunami[19]. Topographical conditions indicated by land slope or elevation in most of Jember Regency area (36.60%) have a land slope between 0 - 2%. Jember's topographic character has fertile ground in the middle and south area surrounded by mountains that stretch from west to east. Jember Regency has several rivers, Bedadung River has an upstream from Iyang Mountain, Mayang River has an upstream from Raung Mountain in the east, and Bondoyudo River has an upstream from Semeru Mountains.

Jember Regency Coastal Area: The scope of the research area covers 12 coastal villages spread across six sub-districts. Geographically, six sub-districts are located on the southern coast of the Jember Regency. The coastal sub-district total area in Jember Regency is 653.94 km^2. The seashore has a line length of approximately +/- 170 km coastline. Table 4 shows the area (km^2) of villages in the Jember Regency coastal area[4].

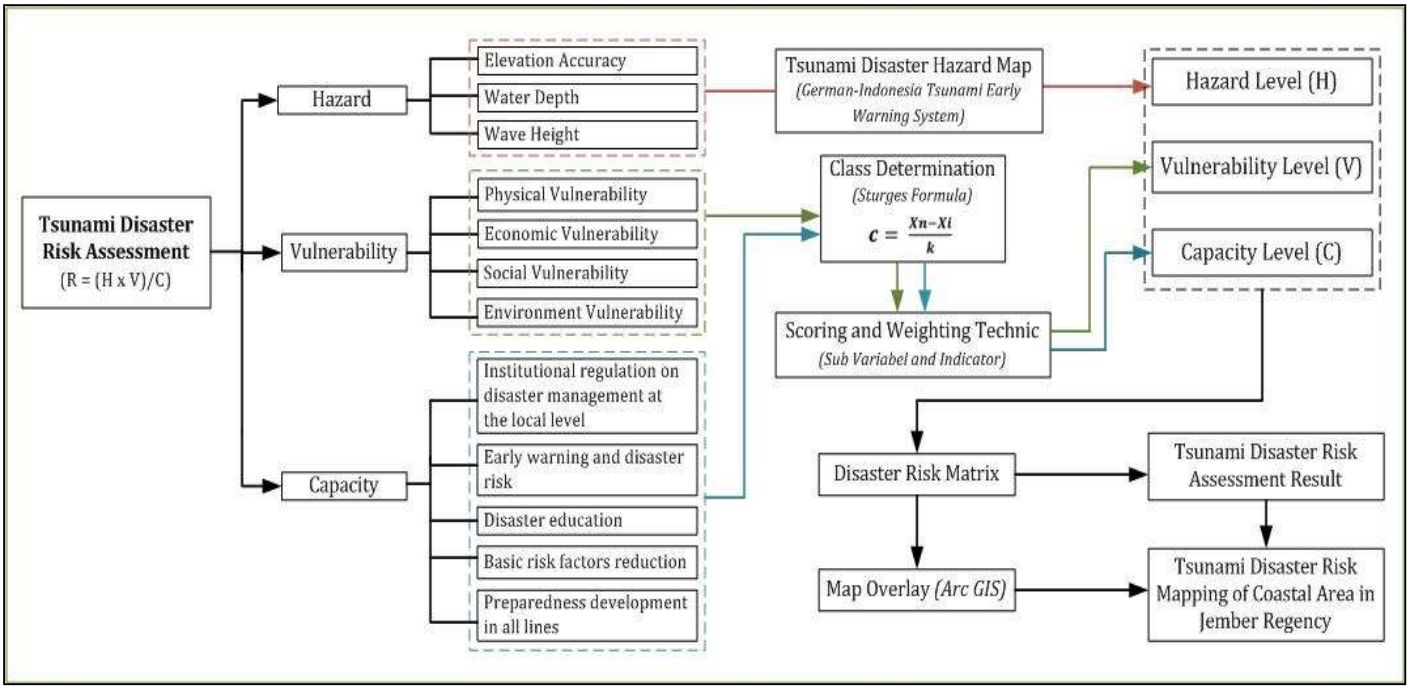

Figure 1: General framework of the study

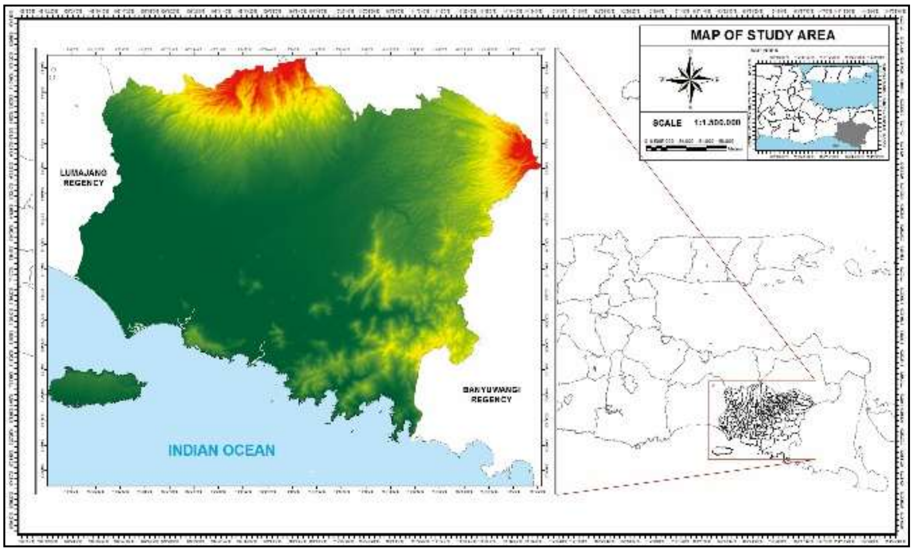

Figure 2: Topographic Map of Jember Regency

Table 6
Coastal Village of Jember Regency

Sub-District	Village	Area (Ha)	Population (People)
Kencong	Paseban	844	7357
Gumukmas	Kepanjen	1478	10613
	Mayangan	1466	10731
Puger	Mojomulyo	744	8568
	Mojosari	872	10106
	Puger Kulon	389	15345
	Puger Wetan	431	10906
Ambulu	Sumberejo	2228	24817
	Andongsari	1843	16993
Wuluhan	Lojejer	1262	20101
Tempurejo	Curahnongko	28339	6432
	Andongrejo	26278	5403
Total		66174	147372

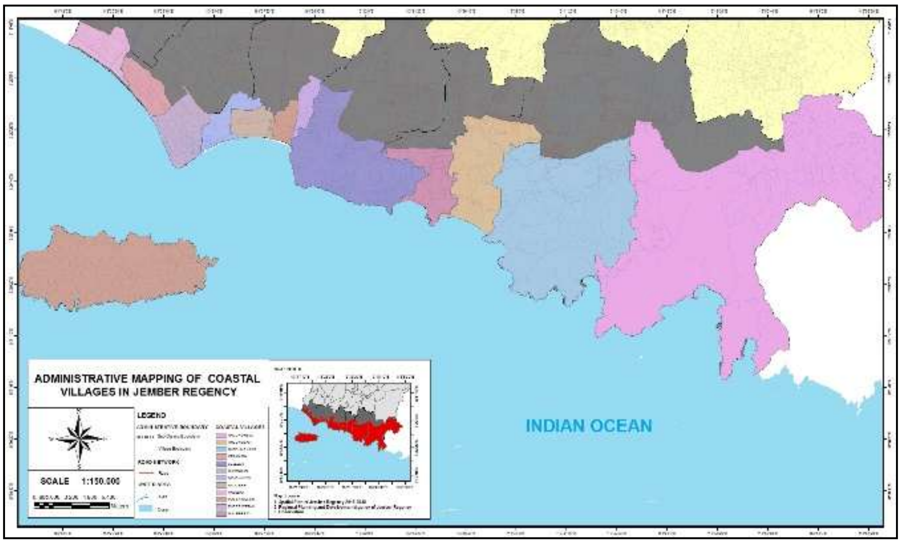

Figure 3: Administrative Mapping of Coastal Village Jember Regency

History of Tsunami Disaster in Jember Regency: According to historical records of the earthquake and tsunami in East Java, especially in Jember Regency, tsunami had hit villages along the coast in 1994. The earthquake that occurred on June 3, 1994, had 7.8 magnitude scale. The earthquake core concentrated in the Banyuwangi Regency Ocean and generated tsunami waves. About 50 minutes after the earthquake, the tsunami wave hit the coast and caused severe damage in several coastal areas of East Java[17]. Tsunami 1994 had the earthquake center in the depth of 33 km with a maximum tsunami run-up[9] height of 26.2 m.

Land Use in the Jember Regency Coastal Area: In several studies related to spatial analysis using geographic information, it shows the effectiveness of spatial analysis using GIS by analyzing maps of land conditions and information on past building damage caused by earthquakes[5]. The identification of land use in tsunami-prone areas aims to see land covers potentially affected by the tsunami disaster. Land use in Jember Regency Coastal Village consists of settlements, yards/ plantations, ponds, dry fields, rice fields and many others.

Tsunami Disaster Infrastructure in Jember Regency Coastal Area: Tsunami had brought fatal damages on many kinds of infrastructures such as ports, roads, bridges, lifelines and other important structures[7]. Disaster infrastructure facilities support tsunami disaster management activities. Jember Regency Tsunami disaster infrastructure located in the coastal area comprised of early warning system (EWS), evacuation route signs, and breakwater structures (Fig. 5).

A tsunami early warning system is used as an information source about tsunami disasters to help the community anticipate tsunami disasters. Jember Regency has seven early warning systems located in each sub-district along the coast. The early warning system is still actively operating and properly functioning. Evacuation route signs are also available at several road points. Another supporting infrastructure for tsunami mitigation is the breakwater building located on Puger Beach. The breakwater has a function as wave barriers to residential areas when a tsunami disaster strikes.

Tsunami Hazard Prone Areas: Tsunami is long-period gravitational ocean waves caused by disturbances such as fault movements, landslides, falling celestial bodies (meteors), volcanic eruptions under the sea, and explosions near sea level[9]. Areas of potential tsunami hazard are used to identify and define locations with high, medium, and low hazard potential[18,23]. Potential areas determination of tsunami disaster hazard in Jember Regency coastal area using the tsunami hazard map was issued by the German-Indonesia Tsunami Early Warning System (GITEWS) based on elevation accuracy (topography), water depth (bathymetry), and wave height.

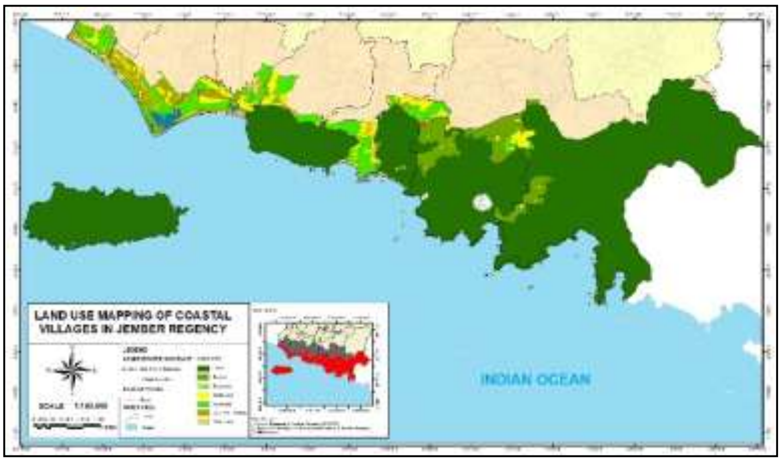

Figure 4: Land Use Mapping of Coastal Village Jember Regency

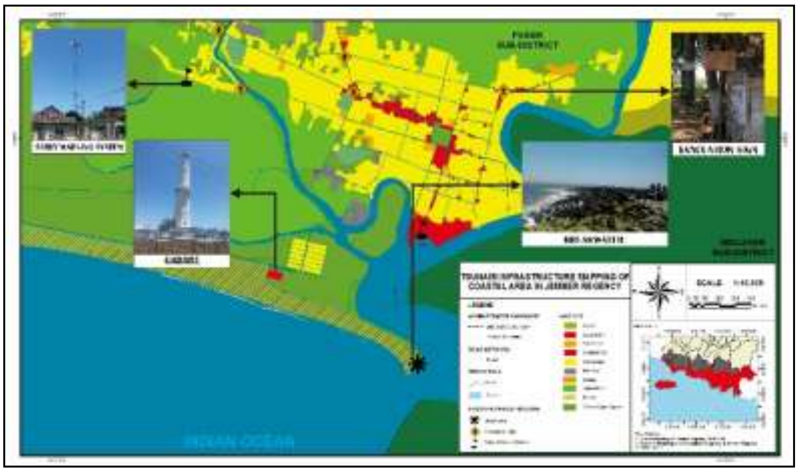

Figure 5: Photo Mapping Tsunami Disaster Infrastructure Facilities in Jember Regency

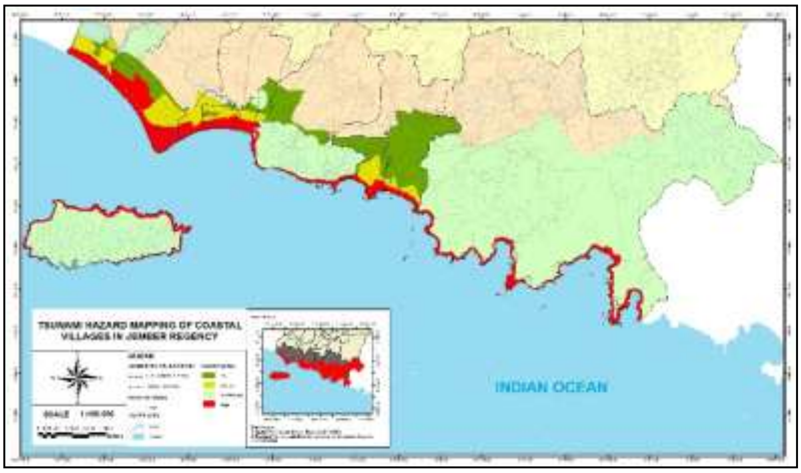

Figure 6: Tsunami Hazard Mapping of Coastal Village Jember Regency

Tsunami hazard mapping provided information about the extent of exposed areas affected by the tsunami. Classification of tsunami hazard showed areas in red colors possibly affected by large tsunamis with high wave heights. Table 7 shows tsunami hazard categories based on the range of tsunami wave height defined by The Climatology and Geophysics Meteorology Agency in Jember Regency Tsunami Hazard Map issued by GITEWS. Village with the largest area of potential tsunami hazard with 1184 Hectare land area is located in Andongrejo Village, considering that this village had the longest coastline in Jember Regency coastal area.

Tsunami Disaster Vulnerability Analysis: Based on Head of BNPB Regulation Number 2 of 2012 concerning General Guidelines for Disaster Risk Assessment, the tsunami vulnerability index has a weighting concept as follows:

Vulnerability = (0.25 x physical vulnerability score) + (0.25 x economic vulnerability score) + (0.4 x social vulnerability score) + (0.1 x environmental vulnerability score).

Evaluation in each vulnerability aspect is an overall measure result of vulnerability scoring in the Jember Regency coastal area. Based on table 8. related to disaster vulnerability aspects and range of vulnerability analysis assessment scores, Mayangan, Puger Kulon, Puger Wetan, and Andongrejo villages had been classified as high vulnerability levels for tsunami disaster. Kepanjen, Mojomulyo, and Mojosari had moderate disaster vulnerability classification while Paseban, Sumberejo, Andongsari, Lojejer and Curahnongko villages had been categorized as low level of disaster vulnerability.

Table 7
Tsunami Hazard Classification Based on Estimated Wave Height

Tsunami Category	BMKG Warning Level	Wave Height at Coastline	Hazard Zone
Tsunami	Warning	≥ 3 meters	Red
Major Tsunami	Major Warning	< 3 meters	Yellow and Green

Source : BMKG in Tsunami Hazard Map (GITEWS)

Table 8
Disaster Vulnerability Assessment

Name of Coastal Village	Physical Vulnerability (0,25)		Social Vulnerability (0,25)		Economy Vulnerability (0,4)		Environmental Vulnerability (0,1)		Total Vulnerability Score	Classification
	N	N x B	N	N x B	N	N x B	N	N x B		
Paseban	5	1,25	9	2,25	4	1,6	1	0,1	5,2	Low
Kepanjen	5	1,25	10	2,5	4	1,6	3	0,3	5,65	Medium
Mayangan	5	1,25	10	2,5	5	2,0	3	0,3	6,05	High
Mojomulyo	5	1,25	10	2,5	4	1,6	2	0,2	5,55	Medium
Mojosari	5	1,25	10	2,5	4	1,6	2	0,2	5,55	Medium
Puger Kulon	7	1,75	8	2,0	5	2,0	2	0,2	5,95	High
Puger Wetan	5	1,25	8	2,0	7	2,8	1	0,1	6,15	High
Sumberejo	7	1,75	7	1,75	5	2,0	1	0,1	5,6	Medium
Andongsari	5	1,25	8	2,0	4	1,6	1	0,1	4,95	Low
Lojejer	6	1,5	7	1,75	4	1,6	2	0,2	5,05	Low
Curahnongko	4	1	9	2,25	5	2,0	1	0,1	5,35	Low
Andongrejo	7	1,75	9	2,25	5	2,0	1	0,1	6,1	High
Highest data	6,15									
Lowest data	4,95									
Interval	0,4									
Classification	1		4,95 - 5,35				Low			
	2		5,36 - 5,75				Medium			
	3		5,76 - 6,15				High			

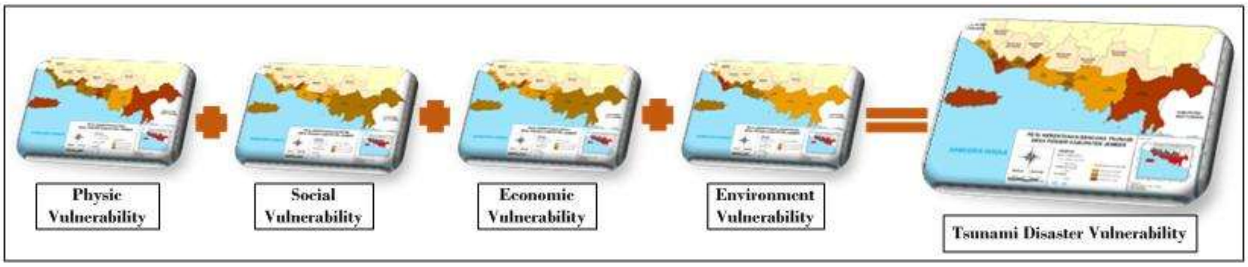

Figure 7: Tsunami Disaster Vulnerability Process of Coastal Village Jember Regency

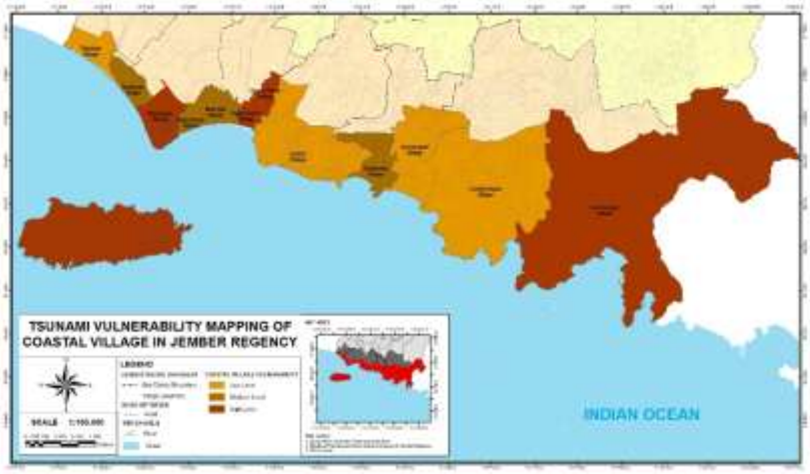

Figure 8: Disaster Vulnerability Mapping of Coastal Village Jember Regency


Figure 9: Focus Grup Discussion in Jember Regency Coastal Area

Densely populated residential area with a high percentage of the built-up area is more vulnerable in facing tsunami disasters. Most of the coastal villages in Jember Regency include Paseban, Mojomulyo, Mojosari, Puger Kulon, and Sumberejo villages inhabited by fishermen with heavily populated settlement areas. High building density areas are more susceptible to damage and losses compared with sparse building density areas. Besides, the potential for building damage that occurs can also disrupt the evacuation[2,21] process during the tsunami disaster because in more densely developed regions, building debris is reluctant to be swept away by the tsunami.

Tsunami Disaster Capacity Analysis: Capacity assessment is conducted by identifying strengths and resources available to each individual, household community and Government to overcome, survive, prevent, prepare, reduce risk, or recover immediately from a disaster[12,13]. The capacity was measured by evaluating each sub variable, and capacity indicator data was obtained through in-depth interviews with the key person. Forum group discussion (FGD)[3] was organized to gain information from local government officers and the community of coastal villages. The forum group discussion was attended by all related stakeholders - such as the Regional Disaster Management Agency (BPBD), soldier and police officers and academic people from Brawijaya University. Forum group discussion concentrated on identifying capacity, coastal community resilience, and tsunami disaster mitigation in Jember Regency coastal area.

Tsunami disaster capacity assessment in villages along the coast considers each indicator weight for assessing government or institutional and community preparedness variables. Weighting technic for tsunami disaster capacity was derived from the indicator in table 3. Table 9 shows disaster capacity assessment in the coastal village of Jember Regency. The recapitulation of the capacity measurement questionnaire (Table 9) means that each "yes" answer in the questionnaire had 1 value score and each "no" answer had 0 value score[10].

The weighting technic was implemented to measure capacity assessment. The question value was multiplied with the indicator weight to calculate each capacity indicator scoring, so each village's capacity level can be classified. Capacity level assessment results of tsunami disasters are shown in table 8. The coastal village category is grouped into three classes using Sturges Formula (Formulas 1):

Class Interval = $\frac{Xn - Xi}{k} = \frac{38-0}{3} = 12{,}6$

Based on class intervals, 0-12 total score had categorized as a low capacity village, 13-24 total score classified into medium-capacity village category, and 25-38 classified into high capacity village category.

Table 9
Capacity Indicator Assessment

Name of Coastal Village	Indicator																
	Institutional regulation on disaster management at the local level				Early warning and disaster risk				Disaster education			Basic risk factors reduction			Preparedness development in all lines		
	1	2	3	4	1	2	3	4	1	2	3	1	2	3	1	2	3
Paseban	0	0	0	0	1	0	1	0	1	1	0	1	0	1	1	1	0
Kepanjen	0	0	0	0	1	0	1	0	1	0	0	1	0	0	1	1	0
Mayangan	0	0	1	0	1	0	1	0	1	0	0	1	0	0	1	1	0
Mojomulyo	0	0	1	1	1	0	1	0	1	1	0	1	0	0	1	1	0
Mojosari	0	0	0	1	1	0	1	0	1	1	0	1	0	0	1	1	0
Puger Kulon	0	0	1	1	1	1	1	0	1	1	1	1	0	1	1	1	0
Puger Wetan	0	0	1	1	1	1	1	0	1	1	1	1	0	1	1	1	0
Lojejer	0	0	0	0	1	0	1	0	1	1	0	1	0	1	1	1	0
Sumberejo	0	0	1	1	1	0	1	0	1	1	0	1	0	1	1	1	0
Andongsari	0	0	0	1	1	0	1	0	1	1	0	1	0	0	1	1	0
Curahnongko	0	0	0	0	1	0	1	0	1	1	0	1	0	1	1	1	0
Andongrejo	0	0	1	1	1	0	1	1	1	1	0	1	0	1	1	1	0

Table 10
Tsunami Disaster Capacity Assessment Result

Name of Coastal Village	Indicator					Scoring Total	Capacity Level
	A	B	C	D	E		
Paseban	0	4	3	4	3	14	Medium
Kepanjen	0	4	1	1	3	9	Low
Mayangan	3	4	1	1	3	12	Low
Mojomulyo	7	4	3	1	3	17	Medium
Mojosari	4	4	3	1	3	15	Medium
Puger Kulon	7	6	6	4	3	26	High
Puger Wetan	7	6	6	4	3	26	High
Lojejer	0	4	3	4	3	14	Medium
Sumberejo	7	4	3	4	3	21	Medium
Andongsari	4	4	3	1	3	15	Medium
Curahnongko	0	4	3	4	3	14	Medium
Andongrejo	7	8	3	4	3	25	High

Community resilience is understood as capacity of the community to bounce back in original state with knowledge, resource, skill and planning preparation[11]. Based on capacity level assessment results (Table 8), low capacity category was found in Kepanjen and Mayangan Villages, while high capacity was found in Puger Kulon, Puger Wetan and Andongrejo Villages. Other villages had medium tsunami disaster capacity classification consisting of Paseban, Lojejer, Curahnongko, Mojomulyo, Mojosari, Sumberejo, and Andongsari Villages. Figure 10 shows the distribution of Jember Regency coastal villages based on their capacity level.

Tsunami Disaster Risk Analysis: Disaster risk analysis shows areas most likely to be hit by tsunami waves. Overlaying tsunami hazard mapping, disaster vulnerability mapping, and disaster capacity mapping produce a tsunami risk map in Jember Regency Coastal Village (Fig. 11).

The calculation operation of disaster risk was conducted using a cross-tabulation matrix based on mathematical concepts for disaster risk level measurement in formula 2. The cross-tabulation matrix in measuring tsunami disaster risk had two-step stages. The first stage of the cross-tabulation matrix was allotted to hazard (H) and vulnerability (V) variables according to table 4.

Then, the result of cross-tabulation calculation between hazard and vulnerability (H x V) was carried out again with capacity (C) of matrix multiplication according to table 5. The tsunami disaster risk in Jember Regency coastal village is classified into three-level, the classification consisted of high risk, medium risk, and low risk. The green color indicates that the matrix value is classified as low risk, yellow for medium risk category and red for high-risk category.

Table 11
Tsunami Disaster Risk Assessment Result in Jember Regency Coastal Village

Sub-District in Coastal Area	Name of Coastal Village	Hazard Score	Vulnerability Score	Capacity Score	Disaster Risk Score	Classification
Kencong	Paseban	1	1	1	1	Medium
		2	1	1	1	Medium
		3	1	1	2	High
Gumukmas	Kepanjen	1	2	1	1	Medium
		2	2	1	2	High
		3	2	1	3	High
	Mayangan	1	3	1	2	High
		2	3	1	3	High
		3	3	1	3	High
Puger	Mojomulyo	1	2	2	0,5	Low
		2	2	2	1	Medium
		3	2	2	1,5	High
	Mojosari	1	2	2	0,5	Low
		2	2	2	1	Medium
		3	2	2	1,5	High
	Puger Kulon	1	3	3	0,67	Low
		2	3	3	1	Medium
		3	3	3	1	Medium
	Puger Wetan	1	3	3	0,67	Low
		2	3	3	1	Medium
		3	3	3	1	Medium
Ambulu	Sumberejo	1	2	2	0,5	Low
		2	2	2	1	Medium
		3	2	2	1,5	High
	Andongsari	1	1	2	0,5	Low
		2	1	2	0,5	Low
		3	1	2	1	Medium
Wuluhan	Lojejer	1	1	2	0,5	Low
		3	1	2	1	Medium
Tempurejo	Curahnongko	3	1	2	1	Medium
	Andongrejo	3	3	3	1	Medium

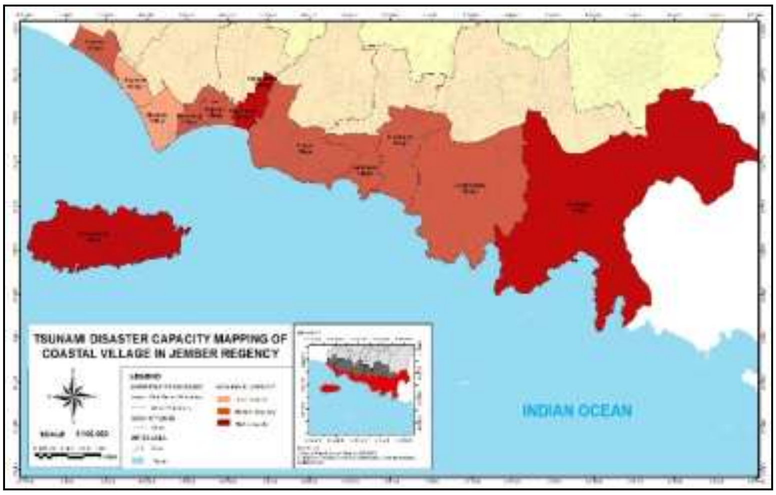

Figure 10: Tsunami Disaster Capacity Mapping of Jember Regency Coastal Village

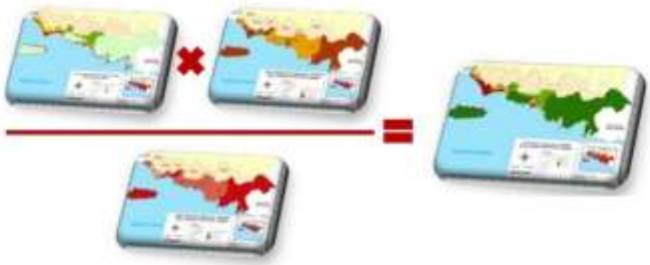

Figure 11: Disaster Risk Mapping Overlay Process of Coastal Village Jember Regency

Table 12
Tsunami Disaster Risk Area in Jember Regency Coastal Village

Name of Coastal Village	Disaster Risk Area (Ha)			Total Area (Ha)
	High	Medium	Low	
Paseban	116	728	0	844
Kepanjen	1174	304	0	1478
Mayangan	1466	0	0	1466
Mojomulyo	230	433	81	744
Mojosari	356	352	164	872
Puger Kulon	0	291	86	377
Puger Wetan	0	106	310	416
Sumberejo	438	627	1163	2228
Andongsari	0	203	1640	1843
Lojejer	0	263	803	1067
Curahnongko	0	513	0	513
Andongrejo	0	1184	0	1184

Interval score of 0.33 - 0.67 was categorized as a low-level tsunami risk classification in Jember Regency Coastal Village, interval score 0.68 - 1.49 was classified as medium risk level, and interval score 1.50 - 3.00 was classified as high-risk level. Jember Regency had twelve coastal villages, and six among them had tsunami disaster high-risk in their particular areas. Six coastal villages consist of Paseban, Kepanjen, Mayangan, Mojomulyo, Mojosari and Sumberejo. Table 12 showed the total area based on tsunami disaster risk level for each classification. Coastal typology as multiple uses of the embankment and vegetation could lower hydraulic force by the tsunami[19]. Coastal typology of six high-risk villages was dominated by low-lying areas with sand lithology mostly fine to coarse.

Inverse to tsunami disaster low-risk areas, the typology is dominated by hilly topography, and mountains that extend along the coast complemented by dense vegetation can become natural embankments. Jember Regency Government also made artificial embankment in the form of a breakwater in Puger sub-district to resist pressure and diminish the impact of tsunami tidal waves.

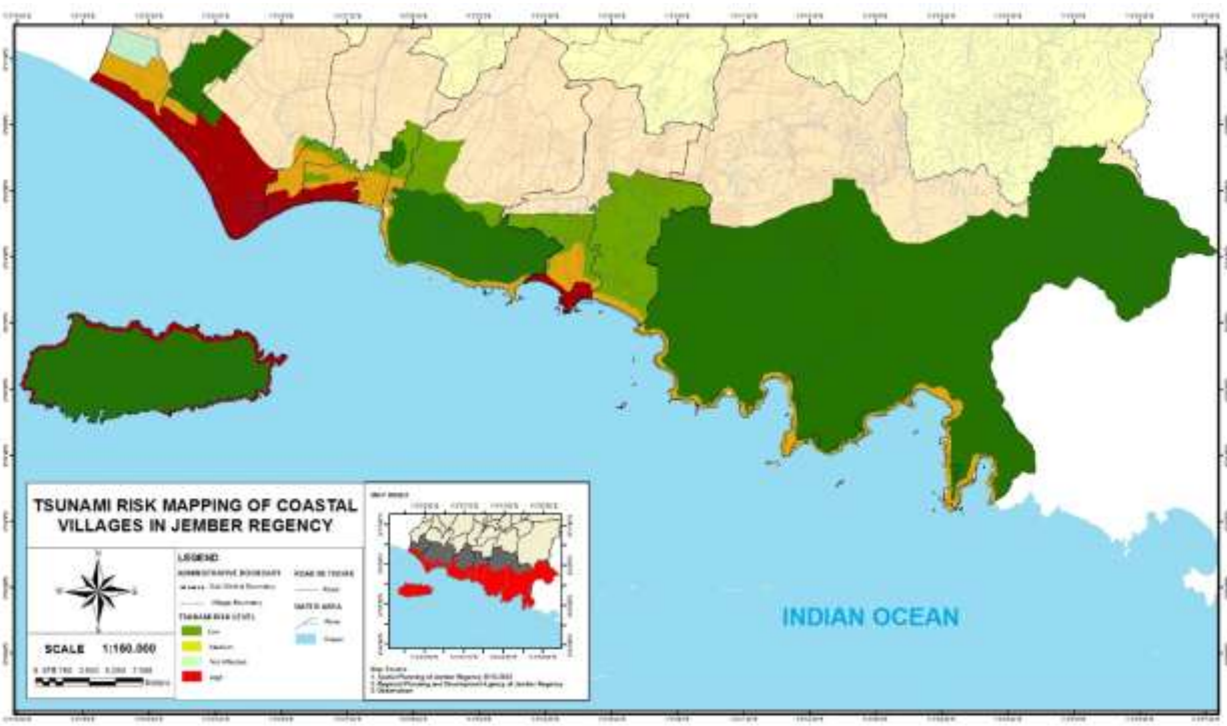

Figure 12: Tsunami Disaster Risk Mapping of Coastal Village Jember Regency

Conclusion

Head of National Disaster Management Agency Regulation Number 02 of 2012 concerning General Guidelines for Disaster Risk Assessment was a technical guideline implemented in this research considering hazard, vulnerability, and capacity as variables. The research area consisted of 12 coastal villages located in the southern region. Results of the tsunami disaster risk assessment showed that Paseban and Kepanjen villages had high and medium-level disaster risk.

Mayangan village had a high level of tsunami disaster risk classification. Mojomulyo, Mojosari, and Sumberejo villages had high, medium, and low levels of disaster risk classification. Puger Kulon, Puger Wetan, Andongsari and Lojejer villages had medium and low disaster risk levels while the last two, Andongrejo and Curahnongko had a medium classification of tsunami disaster risk.

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