Mapping the Potential and Risk of a Tsunami Disaster Participatively in Pangandaran District, West Java

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Abstract. Pangandaran Regency, West Java, is one of the districts bordering the South Sea (Indian Ocean) crossed by the Pangandaran fault. This means that earthquakes often hit Pangandaran Regency, and there is the potential for tsunamis because it is directly adjacent to the ocean. The people of Pangandaran Regency will face efforts to prevent and mitigate disasters, especially earthquakes and tsunamis. These efforts must be based on spatial analysis to match actual spatial conditions in the field. The mapping will be carried out in a participatory manner by the community, accompanied by a technical team. The results that will be achieved are a potential and risk map for tsunami disasters based on spatial analysis. In this ponder, we carried out tidal wave modelling or tsunami potential modelling which consists of physical mapping, socio-cultural spatial mapping, and evacuation route mapping. In the end, the information in the form of a tsunami risk map is expected to be able to provide knowledge to the people of Pangandaran Regency regarding the risk status of their area against tsunami attacks. Thus, the range of tsunami-prone zoning is determined to be 40 meters with intervals of 5m, 15m, 25 and 40m respectively. Overlay is carried out by combining processed maps whose data is taken from survey results.
Keywords: Tsunami, Pagandaran, Mitigation

1 Introduction

From an earth science perspective, Indonesia is a fascinating area. This condition is part of the result of the meeting process of three large tectonic plates, namely the Indo-Australian plate, the Eurasian plate, and the Pacific plate. The results from that phenomenon in Indonesia have quite an enormous potential for disaster. [1][2][3]. One of the disasters that often occurs in Indonesia is an earthquake, which can cause a tsunami. An earthquake is a genuine vibration from within the earth, originating within the earth, which then propagates to the earth's surface due to cracks in the earth breaking and shifting violently. [4].Tsunamis usually occur if an earthquake occurs on the sea floor with large vertical movements. A tsunami can also occur if a volcanic eruption or an avalanche occurs at sea. Java is one of the biggest islands in Indonesia with a tall file of seismic helplessness. [5][6][7][8][9][10]. Structurally, Java is an island that's influenced by the subduction of Indo-Australian plates which goes down to the Eurasian plate. This subduction zone happens at approximately 200 km off of the south coast of Java with a speed of 7 cm per year. One curiously region in Java that worth examining is the West Java geographical arrange. Not as it were that it is being affected by world's expansive plates, West Java locale is additionally impacted by blame structures with east-west heading which most of its blame sorts are invert and strike slip blame. [11][12]. Three territorial structures that influencing West Java are Cimandiri Blame, Baribis Blame,

and Lembang Blame. Pangandaran Tidal wave may be a tidal wave earthquake which has characteristics with a quality that's not as well huge but produces a huge tidal wave.[13].
On July 17, 2006, an earthquake occurred south of Pangandaran beach. The National Earthquake Center of the Meteorology and Geophysics Agency stated that the earthquake that occurred in the Pangandaran Beach area at 15.19 p.m. with a magnitude of 6.8 on the Richter Scale (SR), with a tectonic epicenter at a depth of less than 30 km at a point of 9.4 South Latitude, and 107.2 East Longitude. The exact epicenter of the earthquake was to the south of Pameungpeuk at a distance of around 150 km and is the meeting zone of the two Indo-Australian and Eurasian continental plates at a depth of less than 30 km. [14][15][16]. The earthquake also caused a tsunami wave that hit the southern coast of West Java, such as Cilauteureun Ciamis, the south coast of Cianjur, and Sukabumi. Tsunami waves also hit Cilacap and Kebumen beaches, Central Java, as well as the southern coast of Bantul, Yogyakarta. [17][18][19]. On the isthmus as portion of a 300 km long extend of southern coastline was hit by a tidal wave. Of the 668 affirmed fatalities, 413 (130 men, 205 ladies, and 78 children) were in and around the traveler resort. The up to 5-m tall waves overwhelmed Pangandaran up to 400 m inland. ,[20][21][22]. The wooden or bamboo cafes, shops, and homestay offices along the waterfront and up to 20 or 30 m inland were washed absent. There was extreme harm to nearly all structures inside a few hundred meters of the waterfront, where the development was transcendently one- and two-story buildings of unreinforced clay-brick. Harm comprised of collapsed dividers, dividers with expansive gaps where windows and entryway once existed, and huge heaps of flotsam and jetsam comprising of building fabric and little pontoons. In this ponder, we carried out tidal wave modelling or tsunami potential modelling which consists of physical mapping, socio-cultural spatial mapping, and evacuation route mapping. In the end, the information in the form of a tsunami risk map is expected to be able to provide knowledge to the people of Pangandaran Regency regarding the risk status of their area against tsunami attacks.[23]

2 Materials and Method

Pangandaran is located on a peninsula on the south coast of West Java, Indonesia. Pangandaran Regency is one of the districts that has a high risk of tsunami disasters in the South Java Sea because it is located in the subduction zone between the Indo-Australian Plate and the very active Eurasian Plate. The South Java Sea subduction zone is a source of tectonic earthquakes which can be a potential source of tsunamis. This can be seen from the historical tsunami events in southern Java, including on 11^{th} of September 1921 (M7.5) and 17^{th} of July 2006 (M7.7), both of which hit several areas in southern Java, including Pangandaran Regency. Apart from that, almost the entire coast of Pangandaran Regency is a tourism area, both domestic and foreign tourists. In a report from the Indonesian National Disaster Management Agency for the period 2015 to 2023, the disaster risk index value in Pangandaran was 129.21 to 215.20, which means it is in the moderate to high-risk zone.

Fig. 1. The Area of Study

Delineation of tsunami-prone zones is carried out in this study. In delineating tsunami-prone zones, the parameters are based on history that has occurred, namely during an earthquake measuring 6.8 SR. Thus, the range of tsunami-prone zoning is determined to be 40 meters with intervals of 5m, 15m, 25 and 40m respectively. Overlay is carried out by combining processed maps whose data is taken from survey results. Making evacuation routes Making evacuation routes is carried out by looking at the results of the disaster risk map which has been divided into three aspects, namely: high, medium low. and Evacuation route planning aims to minimize the negative impacts produced by disasters and find the shortest route to safe areas for people living in disaster-prone areas. Determining disaster evacuation routes is based on the condition of the road network, residential location, location safe from disasters, distance from disaster-prone areas and land use of evacuation points.

Table. 1. Scoring and Weighting of Parameters

Parameters	Value	Class	Score	Weight	Total Score
Slope(%)	0 - 8	Flat	4	25	100
	8 - 15	Declivous	3		75
	15 - 35	Curvy	2		50
	> 35	Steep	1		25
Distance from Coastline	< 500 m	Near	3	30	90
	500 – 1000 m	Medium	2		60
	> 1000	Far	1		30
Land Height	0 – 20 meters above sea level	Low	3	15	75
	20 – 30 meters	Medium	2		50

	above sea level				
	>30 meters above sea level	High	1		25
Distance from River	0 – 200 m	Very Near	4	15	60
	200 – 500 m	Near	3		45
	500 – 1000 m	Far	2		30
	>1000 m	Very Far	1		15

Table. 2. Disaster Hazard Level Classification

Num.	Total (Score*Weight)	Hazard Level
1	95 – 171.67	Low
2	171.67 – 248.33	Sedang
3	248.33 – 325	High

Table. 3. Level of Preparedness

Aspects of each respondent	Weight
Disaster knowledge/knowledge and attitude/education index	0.45
Regulations and policies/policies and guidelines/rules and institutions	0.15
Family rescue plan/emergency response/preparedness development	0.2
Resource mobilization index/disaster warning system/early warning and risk level assessment	0.15
Early warning index/resource mobilization index/existence and type of reduction	0.05

Table. 4. Capasity Level Classification

Value	Information
80 – 100	Very ready

65 – 79	Ready
55 – 64	Almost Ready
40 – 54	Quite Ready
0 - 39	Not Ready

Table. 5. Physical Vulnerability Scores and Weights

Parameters	Value (IDR)	Class	Score	Weight	Total Score
Housing	<400 million	Low	1	40	40
	400 – 800 million	Medium	2		80
	>800 million	High	3		120
Public Facilities	< 500 million	Low	1	30	30
	500 – 1 billion	Medium	2		60
	> 1 billion	High	3		90
Critical Facilities	< 500 million	Low	1	30	30
	500 – 1 billion	Medium	2		60
	> 1 billion	High	3		90

Table. 6. Social Vulnerability Scores and Weights

Parameters	Value (soul/ha)	Class	Score	Weight	Total Score
Population density	<5	Low	1	60	60
	5 – 1	Medium	2		120
	>10	High	3		180

Gender Ratio	>40	Low	1	10	10
	20 – 40	Medium	2		20
	<20	High	3		30
Ratio of Vulnerable Age Groups	>20	Low	1	10	10
	20 – 40	Medium	2		20
	<40	High	3		30
Poor Population Ratio	>20	Low	1	10	10
	20 – 40	Medium	2		20
	<40	High	3		30
Disabled Population Ratio	>20	Low	1	10	10
	20 – 40	Medium	2		20
	<40	High	3		30

Table. 7. Economic Vulnerability Scores and Weights

Parameters	Value (IDR)	Class	Score	Weight	Total Score
Productive Land	<50 million	Low	1	40	40
	50 – 200 million	Medium	2		80
	>200 million	High	3		120
Gross Regional Domestic Product (GRDP) Based on Market Prices	< 100 million	Low	1	30	30
	100 – 3 million	Medium	2		60
	> 300 billion	High	3		90

Table. 8. Environment Vulnerability Scores and Weights

Parameters	Value	Class	Score	Weight	Total Score
Protected forest	<50 ha	Low	1	10	10
	20 – 50 ha	Medium	2		20
	> 20 ha	High	3		30
Natural Forest	>30 ha	Low	1	10	10
	10 – 30 ha	Medium	2		20
	<10 ha	High	3		30
Mangroves	>30 ha	Low	1	10	10
	10 – 30 ha	Medium	2		20
	<10 ha	High	3		30
Shrubs	>30 ha	Low	1	10	10
	20 – 30 ha	Medium	2		20
	<20 ha	High	3		30
Swamp	>20 ha	Low	1	10	10
	5 – 20 ha	Medium	2		20
	<5 ha	High	3		30

Table. 9. Vulnerability Level Classification

Num.	Total (Score*Weight)	Vulnerability Level
1	233.33 – 366.22	Low
2	366.22 – 499.11	Medium

3	499.11 – 632	High

Table. 10. Risk Level Classification

Num.	Total (Hazard* Vulnerability/Capasity)	Level of Risk
1	233.33 – 366.22	Low
2	366.22 – 499.11	Medium
3	499.11 – 632	High

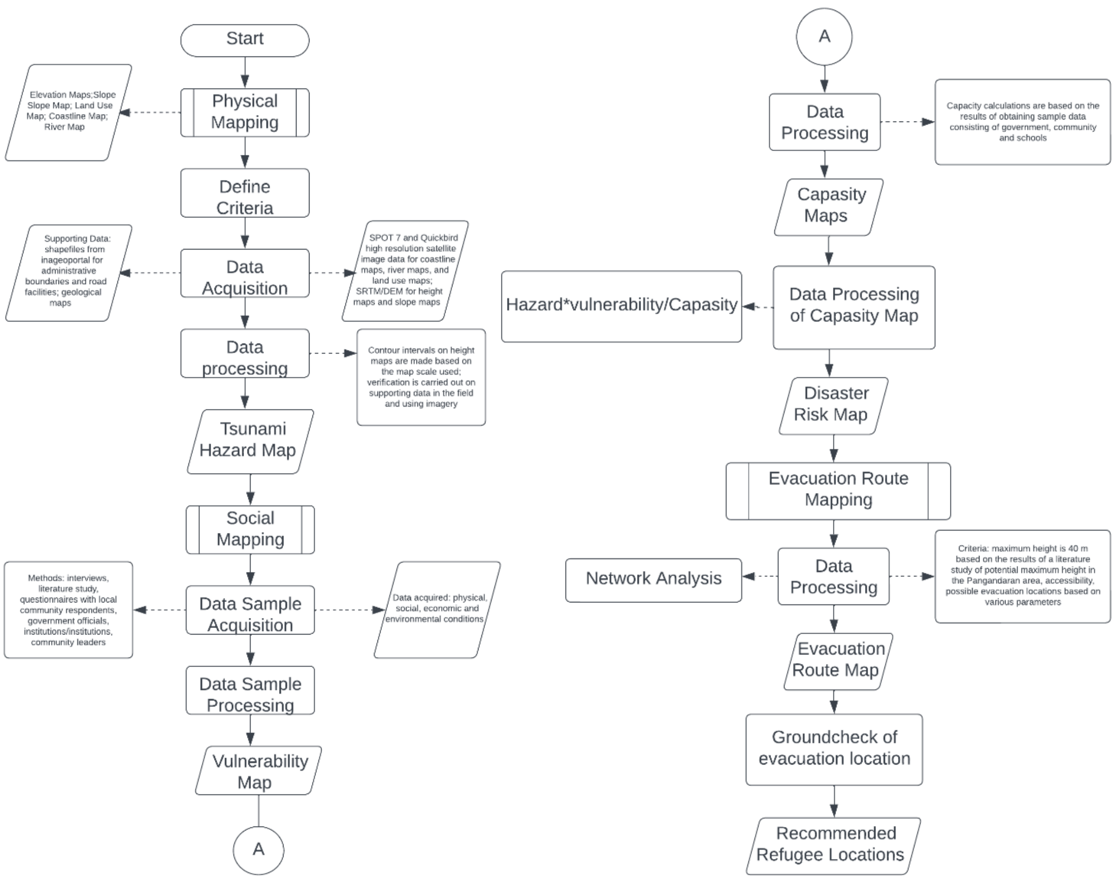

Diagram. 1. Research Flow

Evacuation route planning aims to minimize the negative impacts produced by disasters and find the shortest route to safe areas for people who live in disaster-prone areas. Determining disaster evacuation routes is based on the condition of the road network, residential location, location safe from disasters, distance from disaster-prone areas and land use of evacuation points. Before conducting a research survey to places in the Pangandaran area, the practitioner previously collected secondary data first. Secondary data needs are used to create tsunami disaster hazard maps using scoring and weighting methods, these data include Road Network Maps, Land Use Maps, Slope Maps, Height Maps, River Network Maps, Coastline Maps, Administrative Boundary Maps, Quick Satellite Images Bird. To support social, economic and cultural factors spatially, a social survey was carried out which aims to obtain data which will later be processed into capacity and vulnerability maps. This social survey was carried out by visiting each resident's house and carrying out an interview process. The results of the social survey are vulnerability maps and capacity maps obtained based on interview answers from the community, schools and government (Village Office). The method used is the same as creating a hazard map, namely the scoring and weighting method. In making capacity maps, the results of interviews contain aspects that have value.

3 Result

Based on tsunami inundation modeling with a tsunami wave height (tsunami run up) of 40 meters, the results of the Pangandaran tsunami hazard index map were obtained. In accordance with the tsunami hazard risk zone category, obtain three zones, namely the zone with low hazard risk (green zone), medium hazard risk (yellow zone), and high hazard risk (red zone). From these zones, an analysis is carried out to calculate the predicted loss of property, objects and lives in each zone, with the assumption that no mitigation or overcoming measures for the tsunami disaster are carried out and data on land cover, the number of people living in the tsunami disaster risk zone and the number of tourists visiting are used. is along the Pangandaran coastline.

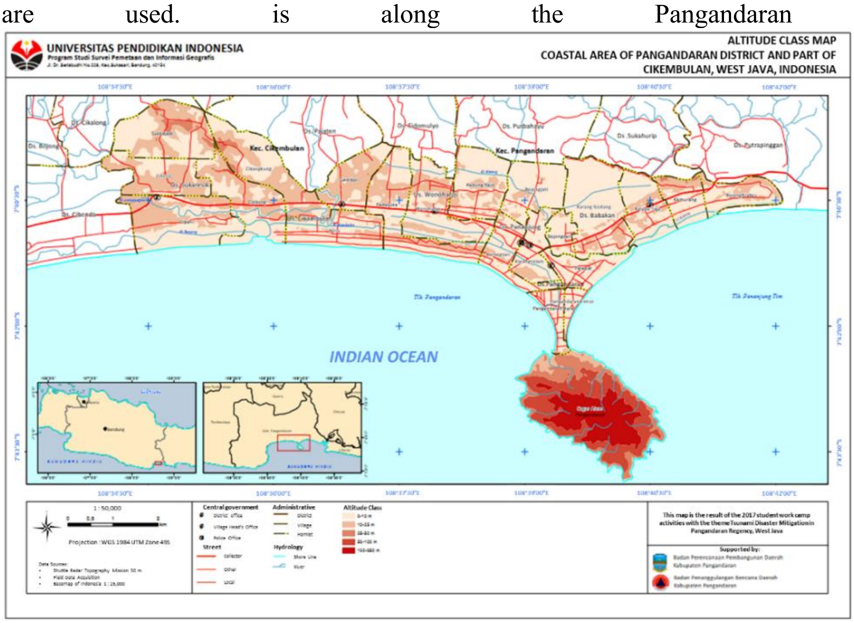

Fig. 2. The Area of Altitude Class Map

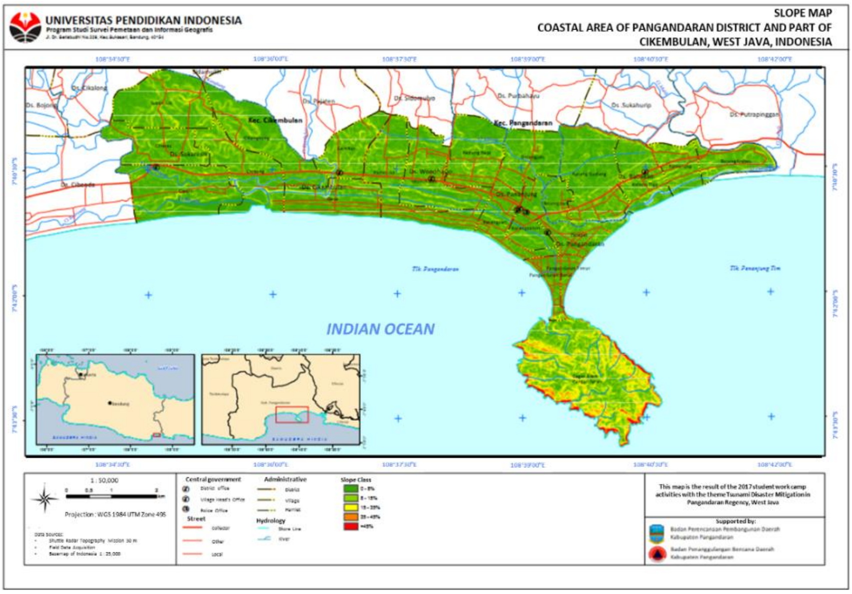

Fig. 3. The Area of Slope

One of the maps that is important as a constituent data for processing in order to analyze the level of tsunami danger in an area is a map of land slope, where elevation is important in driving the speed of water traveling on a surface. Land slope maps can be obtained through detailed mapping of the situation and ground checking processes in the field using terrestrial methods.

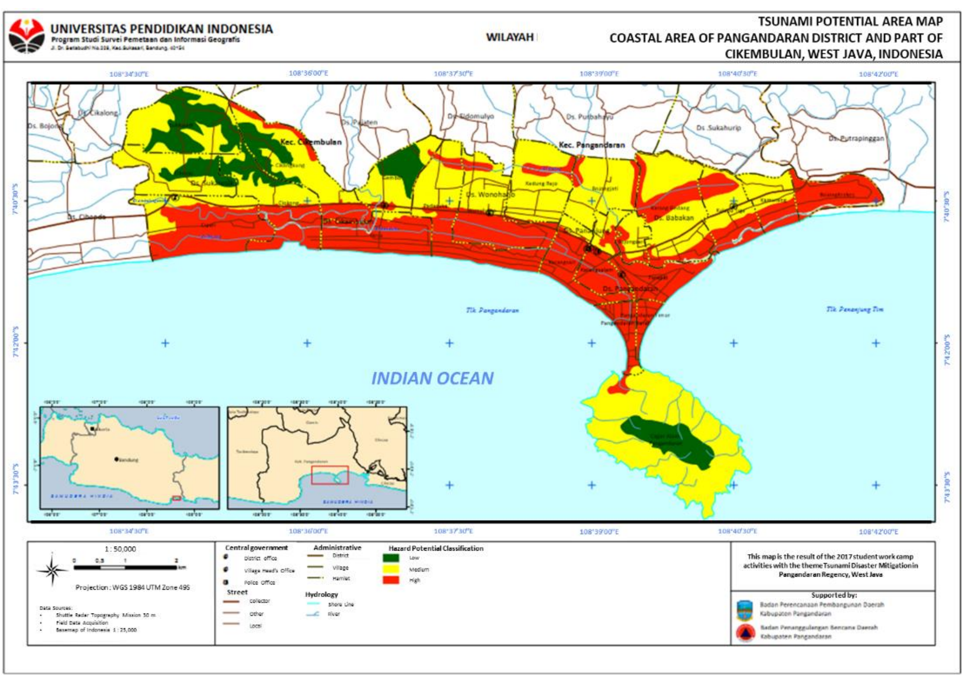

Fig. 4. The Map of Tsunami Potential Area

Delineation of tsunami-prone zones: In delineating tsunami-prone zones, the parameters are based on history that has occurred, namely during an earthquake measuring 6.8 SR. Thus, the range of tsunami-prone zoning is determined to be 40 meters with intervals of 5m, 15m, 25 and 40m respectively. Overlay is carried out by combining processed maps whose data is taken from survey results. Making evacuation routes Making evacuation routes is carried out by looking at the results of the disaster risk map which has been divided into three aspects, namely: high, medium low. and Evacuation route planning aims to minimize the negative impacts produced by disasters and find the shortest route to safe areas for people living in disaster-prone areas. Determining disaster evacuation routes is based on the condition of the road network, residential location, location safe from disasters, distance from disaster-prone areas and land use of evacuation points. Evacuation route planning aims to minimize the negative impacts produced by disasters and find the shortest route to safe areas for people who live in disaster-prone areas. Determining disaster evacuation routes is based on the condition of the road network, residential location, location safe from disasters, distance from disaster-prone areas and land use of evacuation points. Before conducting a research survey to places in the Pangandaran area, the practitioner previously collected secondary data first. Secondary data needs are used to create tsunami disaster hazard maps using scoring and weighting methods, these data include Road Network Maps, Land Use Maps, Slope Maps, Height Maps, River Network Maps, Coastline Maps, Administrative Boundary Maps, Quick Satellite Images Bird. To support social, economic and cultural factors spatially, a social survey was carried out which aims to obtain data which will later be processed into capacity and vulnerability maps. This social survey was carried out by visiting each resident's house and carrying out an interview process. The results of the social survey are vulnerability maps and capacity maps obtained based on interview answers from the community, schools and government (Village Office). The method used is the same as creating a hazard map, namely the scoring and weighting method. In making capacity maps, the results of interviews contain aspects that have value.

In this research, various parameters, socio-spatial data, and maps, especially tsunami hazard zone maps, were obtained, where it can be defined that the areas with red symbology are the zones most indicated to be affected by the tsunami and are in the danger zone, namely in Cikembulan Village, Pangandaran Village, Pananjung Village, and Part of Babakan Village. In the resulting map, the threat level has a tendency to increase at low altitudes, and conversely the threat level will decrease with increasing height or elevation of the earth's surface or the presence of obstacles such as dense vegetation and blockades from objects on the earth's surface. In this research, the results of data analysis show that there is a discovery, that not entirely locations that tend to be closer to the sea will have the same potential danger as those that are spatially far from the sea. There are land areas that are closer to the sea, but the analysis implies zones that have moderate to low danger. This was analyzed further and then found that the elevation in the area was high. Another finding is that even though the distance between the coastline and the sea is quite far, the threat will increase considering that the speed of a tsunami will increase if it hits land without land cover in the form of vegetation or other objects as obstacles or the presence of rivers which trigger an increase in the speed of tsunami water.

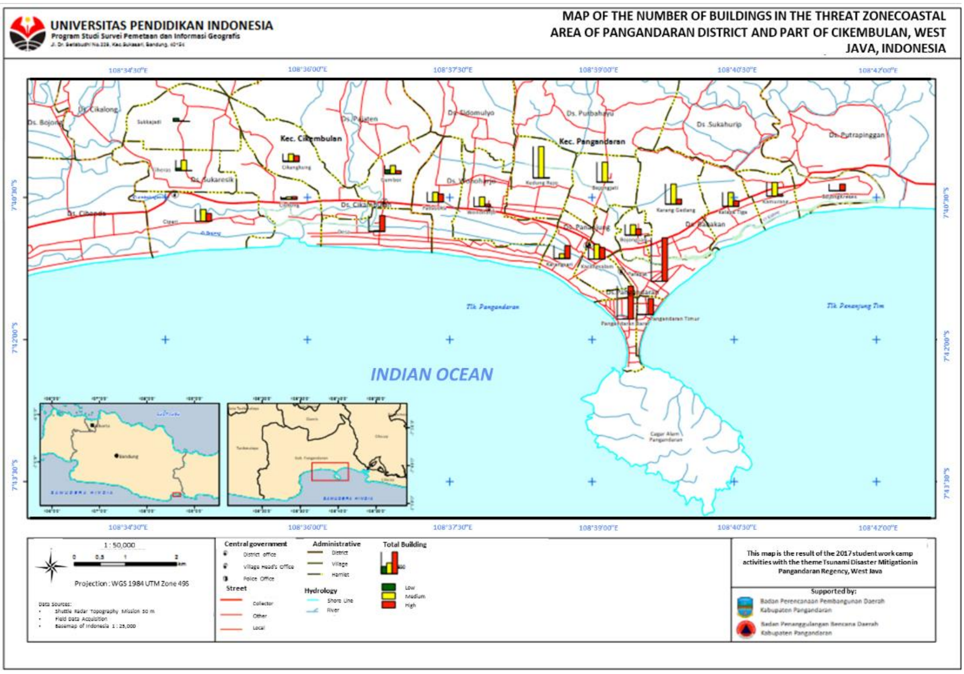

Fig. 5. The Map of Number Building in the threat zone in a Tsunami Potential Zone area along coastaline in Pangandaran

The next analysis carried out was to calculate the number of buildings affected and located in the danger, medium and low danger zones along the Pangandaran Beach line. It was found that a total of 630 buildings were in the danger zone. This is certainly a good finding because the disaster planning and mitigation process can be carried out based on the results of this finding. Both recommendations for evacuation routes, plans for constructing building structures, as well as plans for constructing special shelters, constructing tsunami alarms in strategic locations, as well as placing mitigation elements before, during and after a disaster. Infrastructure development is also adjusted to threat maps and the results of vulnerability mapping based on physical and socio-cultural-spatial aspects.

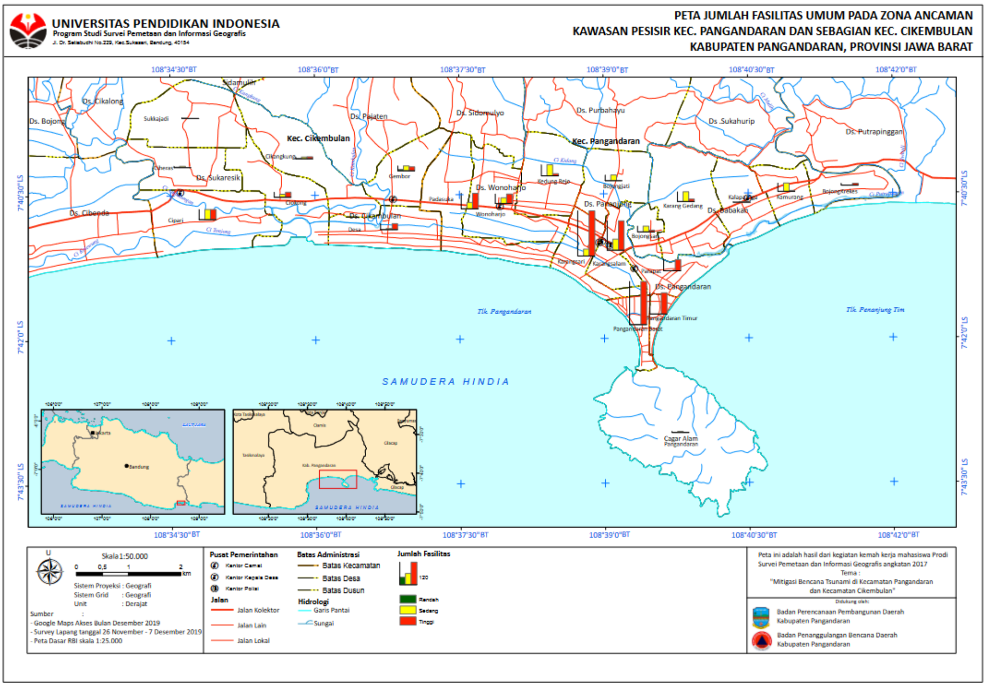

Fig. 6. The Map of Number Public Facilities in the threat zone in a Tsunami Potential Zone area along coastaline in Pangandaran

This includes the land use mapping process, namely carrying out ground checks and spatial analysis related to the number of public facilities in the danger zone. It was found that 120 public facilities were potentially affected and were located in the danger zone. This is important in calculating the impact after a disaster occurs as well as planning the structure of public infrastructure instruments built nearby and how they relate to human, physical, environmental and other aspects.

4 Discussion

Tsunami inundation maps created from height maps, slope maps, land use maps, coastline maps, river maps, SPOT 7 and Quick Bird high resolution satellite images, SRTM/DEM, administrative boundary supporting data, geological maps, contour maps, data social, economic, cultural, educational, population, environmental and other physical instruments. It was found that 630 buildings were located in danger zones spread across Cikembulan Village, Pangandaran Village, Pananjung Village and parts of Babakan Village. The effects of social vulnerability are arranged based on indicators of population density, sex ratio, poverty ratio, ratio of people with disabilities, and age group ratios which have special weighting. Other parameters that support social vulnerability are obtained from official statistical data by the National Central Bureau of Statistics. Physical Vulnerability Scores and Weights are weighted based on data sources from the number of settlements, public facilities and crucial facilities in Pangandaran. Economic Vulnerability Scores and Weights are weighted by referring to the parameters of Gross Regional Domestic Product (GRDP) Based on Market Prices and land productivity. Environmental Vulnerability Scores and Weights are determined based on the parameters Protected forest, Natural Forest, Mangroves, Shrubs, and Swamps, then carry out risk analysis and Vulnerability Level Classification.

Various analyzes and discovery points of view make tsunami mapping crucial because until now tsunami events caused by plate movements and earthquakes cannot be predicted.

However, several previous studies have identified that there are preventive steps that can be taken, including signs that have occurred previously and can be overcome by building an early warning system and developing infrastructure designs and crucial supports that have been adapted to the results of analysis and maps of vulnerabilities and hazards. It is hoped that research on the potential for a tsunami in Pangandaran can help decision makers and social communities themselves in building their preparedness in facing the potential for a tsunami disaster which cannot be avoided if it occurs. Future research is expected to use more accurate and precise mathematical methods and models by adding parameters in calculating tsunami inundation including considering socio-spatial aspects by utilizing geospatial information. Apart from that, the use of precise data, for example using high resolution DEM data such as InSAR to create tsunami threat maps and the use of LiDAR data are good recommendations when applied in the future. Taking into account the presence of rivers as one of the tsunami risk parameters has been carried out, but the sea-bed aspect through bathymetric mapping is also important to consider to determine the characteristics of the sea and coast which are connected to the land. Taking into account the height and direction of the tsunami as well as modeling based on tsunami data and the parameters that influenced it in the past is important. Creating several tsunami wave height scenarios by carrying out 3D modeling and simulation is good support that can be carried out in future research. Forming a 3D model of tsunami risk zoning that can be accessed by the public and decision makers is important based on the results of research that has been carried out. Using real-time validation methods, creating real-time dashboards that can be accessed and taking into account aspects of the roughness of the earth's surface, can also be used as one of the key parameters in modeling tsunami inundation and tsunami hazard maps in the Pangandaran area.

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