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MAPPING THE LEVEL OF TSUNAMI HAZARD FOR DETERMINING SHELTER POINTS AND EVACUATION ROUTES AS AN EFFORT TO MITIGATE THE MEGATHRUST THREAT IN TASIKMALAYA REGENCY

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ABSTRACT

The threat of megathrust, which has the potential to cause a tsunami with waves as high as 34 meters on the coast of South Java, is undoubtedly worrying and must be mitigated as best as possible. This research aims to map the tsunami hazard with locations in Tasikmalaya Regency. The method used in this research is remote sensing and geographic information systems with quantitative descriptive analysis techniques. The data used are land use, distance from the coastline, distance from the river line, slope, and land elevation. The results of this research show that the coast of Tasikmalaya Regency, based on five parameters, namely elevation, slope, distance from the beach, distance from the river, and land use, has a high level of danger and for disaster mitigation ten temporary shelter points have been produced which are distributed along the coast of Tasikmalaya Regency. This research also produces an evacuation route to the temporary shelter point created, and an estimated road 1.8 km from the temporary shelter can be reached in 20 minutes on foot.

A. INTRODUCTION

Astronomically, the Indonesian Archipelago is in the position 07° N – 12° S and 95° E – 141° E. With this, Indonesia has a position with various conditions on the face of the earth, for example, on plates, continents, and oceans. These things give Indonesia an excellent potential for disasters to occur. Natural disasters include volcanoes, tsunamis, earthquakes, and others. Reporting from bpbd.go.id, Natural disasters, according to Law Number 24 of 2007 concerning Disaster Management, are disasters caused by events or a series of events caused by nature, including earthquakes, tsunamis, volcanic eruptions, floods, drought, and wind. Typhoons and landslides. A natural disaster is a natural event that significantly impacts the human population (Hardiyanto & Pulungan, 2019).

Furthermore, Indonesia is in the collision area of three plates of the earth's crust: the Eurasian plate, the Pacific plate, and the Indian-Australian plate. Apart from that, Indonesia's territory is located at the confluence of continental plates, namely the Pacific Circum and

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Transasiatic Alpide. It causes Indonesia's position to become vulnerable to earthquake disasters (Munir, 2017). An earthquake is a vibration caused by movement on the earth's surface due to the sudden release of energy. The sudden release of energy causes seismic waves that can damage everything on the earth's surface, such as buildings and trees, and even cause fatalities. (Bahri & Maybe, 2019).

A large earthquake can cause a tsunami disaster. Earthquakes are the primary impact of seismic activity, followed by tsunamis, secondary hazards (Wibowo et al., 2017). A tsunami is a huge sea wave triggered by an earthquake on the seabed due to plate thrusting or subduction, movement of faults, volcanic eruptions on the seabed, or collisions with space objects (Santius, 2015). A tsunami disaster is a vast sea wave produced by vertical changes in water masses and is caused by sudden disturbances of water masses in the deep sea (Sunarto & Marfai, 2014) (Adri et al., 2020). Moreover, Indonesia is the largest archipelagic country in the world, making it a country that has approximately 17,504 islands with a land area of 1,922,570 km2 and a water area of 3,257,483 km2 or around 70% of Indonesia's area is water, while the remaining 30% is land (Handayani et al., 2022). Until now, no technology can predict this tsunami disaster so that it could happen at any time.

According to the Regional Regulation (PERDA) (West et al. Region, 2010) concerning Regional Spatial Planning (RTRW) for West Java Province 2009-2029 Article 35 concerning Areas Prone to Geological Natural Disasters in points b. two and b.5. It is stated that areas are prone to earthquakes tectonic earth, spread in earthquake-prone areas Bogor Puncak - Cianjur, earthquake-prone areas Sukabumi - Padalarang Bandung, earthquake-prone areas Purwakarta-Subang-Majalengka, and earthquake-prone areas Garut-Tasikmalaya-Ciamis Regency. In contrast, tsunami-prone areas are spread in Ciamis Beach, Tasikmalaya Regency, Garut Regency, Cianjur, and Sukabumi Regency. It can be concluded that Tasikmalaya Regency is an area prone to earthquake and tsunami disasters.

Tasikmalaya Regency is located in the Southeast of West Java Province, with coordinates 107°56'-108°8' East Longitude, 7°10'- 7°49' South Latitude. Tasikmalaya Regency has a coastline of 59.5 km (As'ari et al., 2019). This district borders directly on the Indian Ocean where this district is in the southern part of Java Island. It directly faces the meeting of the Indo-Australian plate and the Megathrust of the Sunda Strait and southern Java (Kasman & Triokmen, 2021). This district is geographically vulnerable to earthquake and tsunami disasters. Therefore, proactive efforts are needed in the disaster risk control process. One effort to reduce the impact of disaster risk is through disaster mitigation (Sulistyo, 2016).

Reporting to Kumparan.com (2017) there have been at least three large earthquakes in the south of West Java that triggered tsunamis in the last 115 years, including threatening the coastal areas of Tasikmalaya Regency, namely the first large earthquake with the potential for a tsunami in West Java on February 27 1903 with an earthquake strength of 8 .1 magnitude, the second major earthquake that caused a tsunami, especially in Pangandaran Regency with a magnitude of 7.8 occurred on July 17 2006, and finally in 2009 with a magnitude of 7 with the epicenter of the earthquake being 142 kilometers southwest of Tasikmalaya.

Research shows that the maximum height of a tsunami could reach 34 m along the western coast of southernmost Sumatra and the southern coast of Java near the Ujung Kulon Peninsula. This estimate is comparable to the maximum tsunami height estimated by a study in southern Java, where the earthquake source came from GPS data inversion (Supendi et al., 2022). Reporting to Detik.com (2022), ITB geodesy expert Heri Andreas said that the risk of a tsunami as high as 34 meters on the southern coast of Java Island could occur based on several expert studies. He has a similar model that states that there is a risk of a tsunami due to megathrust.

The high threat of tsunami disasters on the coast of Tasikmalaya Regency requires modeling and action. The modeling and actions are for disaster mitigation purposes. In Law No. 24 of 2007 concerning Disaster Management, disaster mitigation is essential to reducing disaster risk. It is explained that disaster mitigation is a series of efforts to reduce the risk of disasters through physical development and awareness and by increasing the ability to face the threat of disasters (Roskusumah, 2015). Tsunami prevention systems, in general, can provide education and warnings. Actions that can be taken include creating disaster mitigation documents such as creating risk maps and evacuation maps and providing outreach to the public through the media (Sugito in Mudin et al., 2015). Reducing the risk of coastal disasters can be done in many ways; determining evacuation routes and developing disaster management areas need to be done to minimize the damage that occurs (Asyari et al., 2021). Tsunami disaster mitigation is needed to support coastal area processes 3 in the context of minimizing the negative impacts that will occur due to the tsunami disaster (Wijanarko et al., 2022)

Natural disasters, especially tsunamis, can be analyzed using remote sensing technology and geographic information systems. The use of remote sensing satellites and Geographic Information Systems (GIS) has become an integrated, well-developed, and successful tool in disaster research for the effectiveness of risk management and mitigation of existing disasters (Sambah et al., 2018). Creating hazard level maps for tsunami-prone areas can be designed with the help of geographic information systems (GIS) and remote sensing technology (Fachri et al., 2022). According to Aronoff (1989), a geographic information system is a computer-based system that processes and stores data or information. Remote sensing is obtaining information or data regarding the physical condition of an object or object, target, targets or areas and phenomena without touching or direct contact with the object or target (Soenarmo in Lasmi et al., 2015). The connection with the tsunami disaster is that the geographic information system (GIS) is a tool that can visualize the level of tsunami risk (Sengaji et al., 2009), and remote sensing can also visualize several parameters in mapping the level of tsunami danger.

Fachri et al. (2022) conducted research related to mapping tsunami hazard levels using a geographic information system on the coast of Bengkulu City. The research results show that a high level of tsunami danger is found in sub-districts bordering the coast; the physical condition of Bengkulu City also influences this. Putra et al., (2023) research related to the use of geographic information systems to contour tsunami disaster evacuation routes in Way Muli Village, South Lampung Regency. The result of this research is the presentation of an evacuation route map with an open layer service so that you can choose the destination route to the command post point.

Based on the description of the problem above regarding the threat of a tsunami disaster, which is feared to be experienced by Tasikmalaya Regency, the researcher intends to conduct research regarding the level of tsunami danger in Tasikmalaya Regency with the title "Mapping Tsunami Hazard Levels for Determining Shelter Points and Evacuation Routes as an Effort to Mitigate Megatrust Threats Using the Method Geographic Information System on the Coast of Tasikmalaya Regency." This research aims to analyze the level of tsunami danger on the coast of Tasikmalaya Regency to minimize the threat of megathrust tsunamis accompanied by preventive mitigation, namely evacuation routes and temporary shelters.

In particular, studies regarding mapping the level of tsunami hazard within the Tasikmalaya area and using remote sensing technology methods and geographic information systems using five parameters, namely slope, distance from rivers, distance from coastline, land elevation, and land use, have never been carried out. Furthermore, it is hoped that the output of this research can be used as reference material in decision-making (decision support system) by stakeholders to mitigate the tsunami disaster more effectively and efficiently in Tasikmalaya to face this megathrust.

B. METHOD

The research location is in the Tasikmalaya Regency, West Java Province. The administrative boundaries of Cipatujah District are to the north with Tasikmalaya City, Ciamis Regency, and Majalengka Regency; south by the Indian Ocean; to the west with Garut Regency; and the east with Pangandaran Regency and Ciamis Regency. Based on its astronomical location, Tasikmalaya Regency is at coordinates 107°56'-108°8' East Longitude, 7°10'- 7°49' South Latitude. Tasikmalaya Regency has an area of 2,709 km². Administratively, Tasikmalaya Regency consists of 39 sub-districts consisting of 351 villages. Three sub-districts have coastal and marine areas with a total area of 200.72 km2 or 7.41 percent of the area of Tasikmalaya Regency.

This research uses spatial analysis as a weighted overlay, calculated using scoring or weighting techniques, and uses several parameters whose processes are processed using Geographic Information System (GIS) software. The geographic information system method is a method that uses map media with different resolutions and scales for research that is focused on stages and spatially (Somantri, 2021), one of which is the overlay method, including weighted overlay. The weighted overlay is a weighting method that overlays several maps related to factors that influence the assessment of the level of danger (Wulandari Adininggar et al., 2016).

The parameters used in this research are altitude, slope, distance from the beach, river, and land use. Unlike previous research, these parameters were chosen because they correspond to the physical conditions of the location or area studied in this research, namely Tasikmalaya Regency. These five parameters each influence the level of tsunami danger. The parameters of slope and elevation are used because they can determine how far tsunami waves can reach land. Distance from the beach is used because the closer to the beach, the higher the threat. Distance from the river is used because rivers run off when a tsunami reaches land, so the speed will be faster, while land use will impact how the tsunami water can be distributed (Isdianto et al., 2021). Score and weight of each parameters can be seen in Table 1.

Table 1. Score and weight guidelines for Tsunami Potential Mapping

Parameter	Description	Class	Score	Weight	Total Score
Distance from Coastline (Meters)	< 500	Near	3	30	90
	500 – 1000	Intermediate	2		60
	> 1000	Far	1		30
Slope (%)	0 – 8	Flat	4	25	100
	8 – 15	Sloping	3		75
	15 – 35	Wavy	2		50
	> 35	Steep	1		25
Elevation (Meters)	0 – 20	Low	3	25	75
	20 – 30	Intermediate	2		50
	> 30	Tall	1		25
Distance from River (Meters)	0 – 200	Very close	4	15	60
	200 – 500	Near	3		45
	500 – 1000	Far	2		30
	>1000	Very far	1		15

Source: Modification of Haghizadeh et al., (2017)

Parameter	Description	Class	Score	Weight	Total Score
Land Use	Settlement	Very dangerous	5	15	75
	Agriculture	Danger	4		60
	Empty land	quite dangerous	3		45
	Waterbody	Less Danger	2		30
	Forest	No danger	1		15

Source: Modification of Jedlovec in Isdianto et al., (2021)

C. RESULT AND DISCUSSION

C.1. RESULT

Tasikmalaya Regency is one of the West Java regions with direct administrative boundaries with the Indian Ocean. It has 39 sub-districts, three of which directly border the Indian Ocean: Cipatujah District, Karangnunggal District, and Cikalong District.

This research is based on the most significant possibility of a tsunami occurring on the coast of Java, namely the megathrust with a tsunami height reaching 34 meters above sea level. As previously explained, spatial technology has developed with advantages such as time effectiveness, low cost, and processing that can be carried out before going to the field. This time, the parameters used are slope, elevation, distance from the coastline, and distance to the river so that a tsunami hazard map will be obtained. Apart from these maps, other advanced thematic maps were also produced, such as shelter maps and maps of evacuation routes and shelter affordability. Data processing and analysis are carried out on each parameter that is classified or reclassified using overlay and weighting techniques. It means that the existing parameters can indicate and obtain the level of tsunami danger in the research area. Following are the results for each parameter.

a. Distance from Coastline

Distance parameters from the coastline are grouped into three classes, namely near (0-500 m), medium (500-1000 m), and far (>10,000 m) classes. The results of this parameter analysis show that the coastal area in Tasikmalaya Regency has a pattern of the near class (0-500 m) dominating the area near the coast, the medium class (500-1000 m) in the center of the area, and the far class in the northern area (>1000 m). Three sub-districts are affected by red areas or have a high level of danger or near class: Cipatujah Sub-district, Karangnunggal Sub-district, and Cikalong Sub-district. Like the near class or high level of danger, the yellow area or medium distance also affects these three sub-districts. They are included in the area with a medium level of danger based on the classification used. Meanwhile, for the other 36 sub-districts at a distance from this coastline, the entire area is green or class with low danger and far from the beach.

b. Land elevation

Land elevation will affect how far the tsunami waves will reach it, so the higher the elevation, the lower the tsunami level, and vice versa.Land elevation parameters are grouped into three classes: low (0-20 m), medium (20-30m), and high (>30 m) elevation classes.

The results of the analysis of this parameter, the coastal areas in Tasikmalaya Regency have a pattern of low elevation (0-20 m) dominating the area near the coast, visible as red symbology on the map, then medium elevation (20-30 m) is in the middle of the area, its existence tends to be narrow in area. , and high elevation (>30 m) or green in the Tasikmalaya Regency area, farther from the coast. The areas that have red or low elevation areas, as well as yellow or medium elevation, are three sub-districts, which border the Indian Ocean, namely Cipatujah Subdistrict, Karangnunggal Subdistrict, and Cikalong Subdistrict. In comparison, the other 36 sub-districts have elevations >30 meters.

c. Slope

The slope parameter is the percent slope of an area. The steeper the slope, the higher the tsunami danger; conversely, the steeper the slope, the lower the danger. The slope of the land is grouped into five classes that are visible on the map, namely flat (0-8%), gentle (8% - 15%), wavy (15% - 35%), and steep (>35%). The slopes in Tasikmalaya Regency have a spreading pattern for each class. Tasikmalaya Regency generally has a land slope between 15-35% or included in the sloping class. In particular, the coastal areas of Tasikmalaya Regency are predominantly sloping (0-8%), with red symbols visible along the coast.

d. Distance from River

Large rivers flow along the coast of Tasikmalaya Regency, namely the Cilangla River, Cipatujah River, Cimedang River, Cisanggiri River, Citanduy River, and Ciwulan River. These rivers make Tasikmalaya Regency a tsunami danger area because they greatly influence propagation. The sloping shape of the Tasikmalaya Regency's coastline also influences the tsunami danger level.

Distance parameters from the coastline are grouped into four classes, namely the very close class, distance from the river 0-200 m, close class, distance from the river 200-500 meters, and long-distance class. It is 500-1000 meters from the river, and the class distance from the river is very far, at> 1000 m. It can be seen on the map that there are many rivers in Tasikmalaya Regency, making areas near rivers very dangerous, mainly because all rivers empty into the sea. Generally, river distances dominate the very far class > 1000 meters. However, the classes are diverse for coastal areas, considering that every coast will have a river where it flows.

e. Land Use

The classification given to these land use parameters is that settlements are in the very vulnerable category because there are residents in them, disasters are said to be disasters if there are fatalities in them, rice fields are in the vulnerable category, the land is in the moderately vulnerable category, water is in the less vulnerable category, and forests are in the not vulnerable category. The vulnerability class is based on the high risk and losses caused by the tsunami disaster. Agriculture, followed by forests, dominates the Tasikmalaya Regency area. In general, land use for settlements tends to spread out, while settlements near the coast of the Tasikmalaya Regency area live along the coastline. Further north, the dominance becomes agriculture, and forests, water bodies, and rice fields are relatively few.

f. Tsunami Hazard Level Map

The analysis results of the five parameters have been processed and reclassified into four classes of tsunami disaster hazard levels, shown in the map in Figure 1. These classes are safe zone, low danger zone, medium danger zone, and high danger zone.

The analysis results show that from the five parameters, Regency. It is said that the megathrust that occurred was 34 meters high, so the assumption is that if a tsunami occurs, a land height of 34 meters can be considered safe.

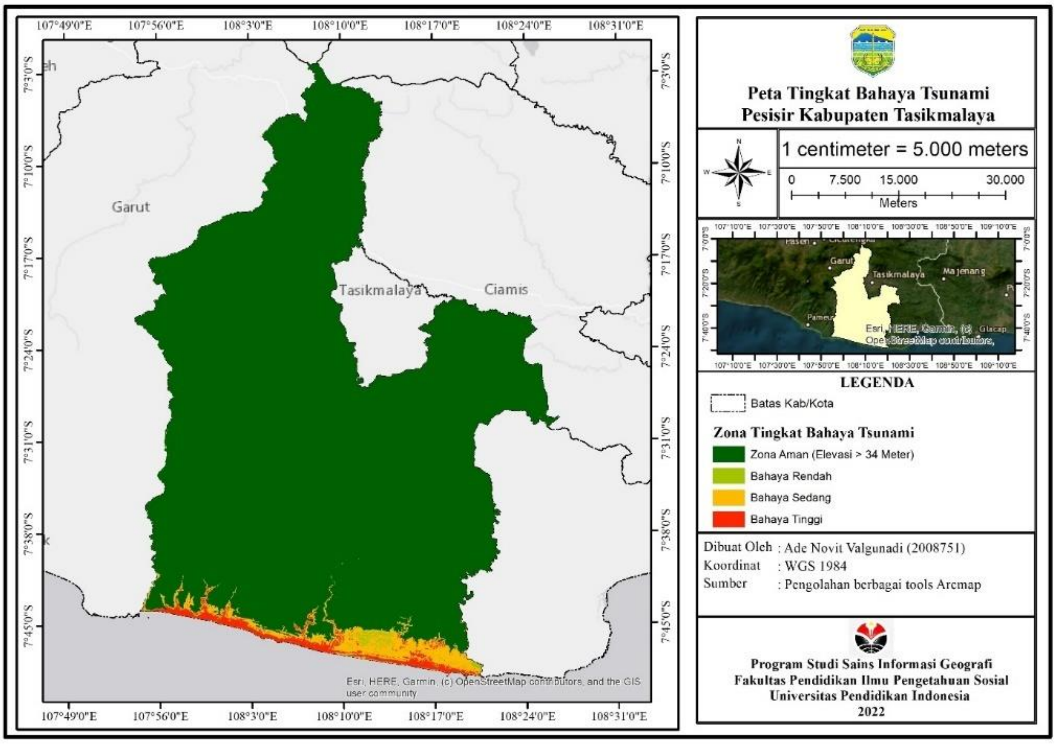

Figure 1. Tsunami Hazard Level Map

However, especially for coastal areas, the danger level is high. It is because the elevation and slope are low, and land use spread across the coastal areas of Tasikmalaya Regency is dominated by agriculture, which is in the vulnerable class. The distance from the coastline is very close, and there are quite a lot of rivers that flow into the coastal areas of Tasikmalaya Regency. According to BPBD, the coast of Tasikmalaya Regency is an area with low topography, an average of 12 meters above sea level, and a tsunami with a height of 11 m.

g. Shelter Points and Evacuation Routes

Determining the shelter point is undoubtedly vital in disaster mitigation. Shelters are public facilities that can be used if a disaster occurs. As explained above, this megathrust earthquake is estimated to be around 34 meters. In the modeling, there is an elevation above 30 meters, and it is said to be a safe zone; of course, this shelter must be oriented towards areas that have a tsunami hazard level, namely safe zones.

Ten shelters are facilities in the safe zone but are closest to coastal areas.

Referring to the 2007 Sea Defense Consultants (SDC) evacuation shelter planning standard, these shelters are included in the safe class and located at an altitude of > 35 meters above sea level. Some of these shelters are places of worship and educational facilities. They have a capacity of approximately 50 people. The shelter point can be seen in Table 2.

Table 2. Temporary Shelter Point

Name	Longitude	Latitude
Al-Falah Mosque	108.028698	-7.726101
Al-Huda Sukamaju Mosque	108.048834	-7.729283
Gunung Sabeulah Primary School	108.049925	-7.739717
Jamie Nurul Ulum Mosque	108.140220	-7.755727
DKM Al-Itihad Mosque	108.184669	-7.742679
Nurul Huda Mosque	108.216825	-7.756374
As-Salam Mosque	108.276721	-7.766106
Sukahurip Primary School	108.291126	-7.771225
Nurul Hikmah Ganda Mekar Mosque	108.316467	-7.778219
Al-Furqon Mosque	107.970973	-7.701603

Source: Author (2024)

An evacuation route is a rescue route designed to connect all areas to a safe area as a gathering point for residents or communities. Evacuation routes mobilize residents from the threat of danger to a safer place when a disaster occurs. Evacuation is the most crucial part of the mitigation plan; this action is vital to save human lives. After knowing the evacuation shelter, the next step in getting the evacuation route is network analysis.

This method is used to find the fastest and closest route that the general public will use as an evacuation route to evacuation locations if a tsunami disaster occurs**.** In this case, the network analysis methods used are service area analysis and closest facility analysis.

The results show the evacuation route, symbolized in red; the road near the beach as point 0 is directed upwards to get to the temporary shelter that has been determined, and the resulting road is also 1.8 km from the shelter facility or around 20 minutes. You can reach the shelter point by walking the distance, symbolized in blue.

The maximum travel time reference used is based on the arrival time of the tsunami according to BNPB, which is 20 minutes so that it can be estimated with the help of Google Maps. The evacuation route is determined without looking at the type of road, only the fastest route. Mapping the tsunami hazard level in this practicum is one method for determining how the tsunami will impact the area. Relocation, adaptation, and protection measures can minimize the tsunami's impact.

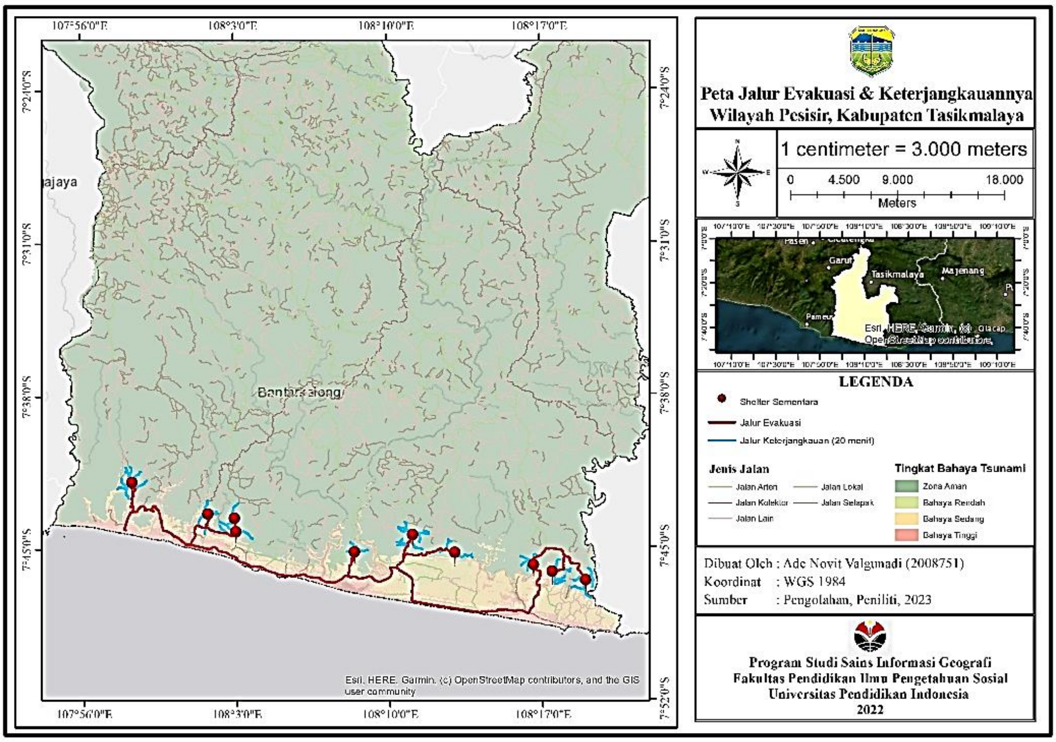

Figure 2. Map of Shelter Points and Evacuation Routes

C.2. DISCUSSION

The research results above show that Tasikmalaya Regency has four classes: high danger, medium danger, low danger, and safe zone. The determination of tsunami hazards in Tasikmalaya is processed with the help of a geographic information system based on five parameters: height, slope, distance from the coastline, distance from rivers, and land use. High-danger classes are generally found in sub-district areas directly adjacent to the coastline.

Apart from the parameters used, other factors can increase the tsunami's danger, namely beach characteristics and morphology. The characteristic of the coast in Tasikmalaya Regency itself is that it has a river that flows directly into the beach. In line with previous studies, Andisolina (2020) states that this can influence the level of tsunami danger.

The morphology of the Tasikmalaya coast does not have bays. It tends to be straight and elongated. It agrees with earlier research by Yudhicara and Robiana (2016), which states that coastal areas with a straight and elongated morphology will produce tsunami waves with water masses that spread in all directions.

Based on the tsunami danger level results, Tasikmalaya Regency has a wide safe area from the central to the northern part. This is because Tasikmalaya Regency borders the ocean only in the south. This is consistent with previous research by Santius (2015), which states that the height of a tsunami wave will decrease with increasing distance when the wave is on the coastline. This is also reinforced by the elevation of Tasikmalaya district, the northern part of which is mountainous. In contrast, the southern part is lowland, making the southern area a high tsunami hazard area. This finding agrees with the result by Subardjo & Ario (2016), which states that the lowlands near the coast have the highest level of danger from tsunami disasters compared to the highlands.

Unlike previous research from Rohman (2015), which showed that a study in Cipatujah District, Tasikmalaya Regency had only two levels of danger, namely high and moderate. This research demonstrated that a district-wide study shows that Tasikmalaya Regency has four zones: high danger, medium danger, low danger, and safe zone. Specifically, the results in Cipatujah District also show four levels of tsunami danger, not just two: high, medium, low, and safe zone.

Furthermore, research from Rohman (2015) also states that using garden land has a high level of tsunami hazard; contrary to the literature, Rohman (2015) states that settlements are land used with a high tsunami hazard. Apart from that, research from Rohman (2015) used tsunami landfall data of only 12.5 meters. In contrast, in this study, the megathrust tsunami threat was 34 meters, so the village, as Rohman (2015) said, had a moderate level of danger. In this study, the dominant level was great danger.

Contrary to literature from research, Frederika (2023) states that the main parameter that increases the risk of disaster is height, whereas, in this study, the main parameter is the distance from the coastline, the results of which can be implied that the entire coast of Tasikmalaya Regency has a high level of danger. Research by Mardiyanto et al. (2013) where the results show that there are coastal areas that do not have a high level of tsunami vulnerability, which is different from this research, where all coastal areas have a high level of danger due to the main parameters apart from physical and morphological differences between locations. Research (Mardiyanto et al., 2013), namely Bantul, is conducted in Tasikmalaya Regency. Distance from the coastline in this study has the highest weight and is the main parameter, as mentioned previously. The emphasis on coastline distance is the same as research conducted by Kurniawan et al. (2022), which made it the main parameter.

D. CONCLUSION

The results show that the slope value of 0-8% is classified as gentle, the land elevation between 0 - 20 meters is classified as low, and the distance from the coastline (coastal proximity) is classified as very dangerous if it increases. Close to the beach, the distance from the river is on average in the very close class (0-200 meters), and land use tends to be agricultural. Here are the details: 1) Mapping the tsunami hazard level in the coastal areas of Tasikmalaya Regency is included in the high hazard class, especially in areas with low elevation and slope. 2) The designated evacuation route is the fastest route to the shelter; the information is that 20 minutes on foot can reach the shelter point. 3). ten shelters have been designated and are in the safe zone.

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