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UTILIZATION OF GEOGRAPHIC INFORMATION SYSTEMS IN ENVIRONMENTAL VULNERABILITY MAPPING TO TSUNAMI DISASTER IN WEST ACEH DISTRICT

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ABSTRACT: Indonesia is a region that is vulnerable to earthquake and tsunami disasters. As a mitigation effort a disaster vulnerability map is needed. This study aims to produce a tsunami vulnerability map of the environment by implementing a geographic information system (GIS) in Aceh Barat District. Tools and materials used are: 1) computer device assisted by ArcGis Software version 10.4.1. 2) Parameter map (Land use map in West Aceh District, Map of river border distance, Beach border distance, Map of Aceh Barat District elevation map, West Aceh District slope map). Data were analyzed by scoring and weighting with overlay techniques. The results showed that the area with a very high vulnerability category was at the mouth of the river and the area of the Woyla River, Bubon River, and Meureubo River with an area of up to 10 Km^2. Areas with a very low vulnerability category are in the Sungai Mas and Pante Ceureumen Districts with an area of 1611Km^2.. Suggestions in this research are the need for more specific mapping, such as mapping of social, economic, and physical vulnerability, so that the impact of the tsunami disaster from various vulnerability factors can be minimized

Keywords: GIS, Environmental Vulnerability, Tsunami Disaster, West Aceh

1. INTRODUCTION

Indonesia is an area that is vulnerable to earthquakes caused by tectonic activities. Earthquakes are one of the factors that cause tsunamis [1-3], so Indonesia is also vulnerable to tsunami disaster.

Tsunamis are ocean waves caused by earthquakes, landslides or volcanic eruptions that occur in the sea [4-5]. The tsunami energy generated from tectonic activities is so large that it can cause casualties and damage to public facilities [6]. Because the impact of the tsunami disaster is very threatening to the survival of life, it is necessary to make efforts to minimize the impact of the disaster, otherwise known as mitigation. In the process of preparing the mitigation planning, the most basic thing is the vulnerability map to the tsunami disaster [7]. One of the factors of vulnerability to a disaster that is studied to obtain one of the vulnerability maps is environmental factors, which are then adapted to be a form of vulnerability, namely environmental vulnerability.

[8], states that vulnerability is a condition that is determined by physical, social, economic and environmental factors or processes that result in a decreased ability to face hazards. Environmental vulnerability maps are generated by processing spatial data in the form of several parameter maps that affect environmental vulnerability to tsunami disasters using a Geographical Information System (GIS).

[9] state that the main characteristic of GIS is the ability to analyze systems such as proximity and overlay analysis which is called spatial analysis which then produces new data from the analysis process so that GIS is deemed suitable for making environmental vulnerability maps to tsunami disasters.

One of the areas in Indonesia that requires an environmental vulnerability analysis to the tsunami disaster is West Aceh District, Aceh Province. The location of the Aceh Province which is surrounded by the ocean and one of the areas closest to the epicenter of the earthquake in the Indian Ocean makes the Aceh region potentially affected by the tsunami [10]. This has resulted in the Aceh Barat District being potentially affected by the tsunami disaster, so it is necessary to map the environmental vulnerability to the tsunami disaster to see which areas are prone to tsunami disasters in West Aceh District.

Based on the description above, a study is needed that emphasizes the application of GIS for mapping environmental vulnerability to tsunami disasters with the title "Implementation of geographic information systems in mapping environmental vulnerability to tsunami disasters in Aceh Barat District. The purpose of this study was to determine the Tsunami disaster vulnerability map by implementing a geographic information system to map environmental vulnerability to tsunami disasters in West Aceh District and to map environmental vulnerability to tsunami disasters in the West Aceh District.

2. METHOD

The data needed to obtain a tsunami vulnerability map includes the data listed in Table 2. These parameters have different magnitudes of influence on tsunami disaster vulnerability, so it is necessary to determine the weight of each parameter and a score for each criterion of each parameter. Determination of the weighting and score in this study refers to [11-15]. The parameters used are grouped into five categories of vulnerability, namely very high, high, medium, low, and very low. The five categories are quantified in the form of a vulnerability score from 1–5. Calculations by giving weight to each parameter are also carried out to determine the level of vulnerability. The determination of the class of these values is based on the following calculation formula

$$N = \Sigma B_i \times S_i \ldots\ldots\ldots(1)$$

Information :
N: Total weighted value
Bi: The weight of each criterion
Si: Score for each criterion.
(Muzaki, 2008: 45)

Mathematically, the calculation of the overlay analysis technique can be written in the form [(elevasi × 0.25) + (slope × 0.2) + (land use × 0.15) + (coastline × 0.2) + (river border × 0.2)]. The calculation of the overlay technique analysis is the multiplication of the weights and scores for each parameter contained in the same row. The sum of the multiplication of weights and scores gives the total number of weighted scores (N). The N value is then used to determine the class interval for the level of vulnerability. The calculation of each class interval is obtained from the multiplication of the maximum value of each weight and the score (Nmaximum) minus the number of multiplication of the minimum value (N minimum) then divided by 5 based on the number of parameters.

$$L = \frac{\Sigma(B_i \times S_i)\ max - \Sigma(B_i \times S_i)\ min}{n} \ldots\ldots\ldots(2)$$

Information :
L: Class Range
n: number of classes

Based on the calculation of formula (2), the class width interval is 0.8 with a minimum N value of 1 and the maximum N is 5. The class interval for the very low level of vulnerability can be obtained by adding up N min with the class interval width of 0.8. Then to get the frequency distribution of the low level of vulnerability, the maximum class interval of the very low level of vulnerability is added to the width of the class interval. And for medium, high, and very high vulnerability levels are also obtained in the same way. In brief, the tsunami vulnerability class intervals are shown in table 1.

Table 1. Tsunami Vulnerability Class Intervals

Kelas	Tingkat Kerentanan	Interval Kelas
R1	Very Low	1 – 1,7
R2	Low	1,8 – 2,5
R3	Medium	2,6 – 3,3
R4	High	3,4 – 4,1
R5	Very High	4,2 – 4,9

3. RESULTS AND DISCUSSION

Elevation

In this mapping, vulnerability based on altitude is divided into five categories of vulnerability, namely very high, high, medium, low, and very low. Areas with a very high vulnerability category are areas located between an altitude of 0–10 m. Areas with a high vulnerability category are areas that are between an altitude of >10–25 m. Areas with the category of moderate vulnerability are areas that are between an altitude of> 25–50 m. Areas with the low vulnerability category are areas between an altitude> 50–100 m. Areas with the very low vulnerability category are those that are located at an altitude of more than 100 m.

Areas with very high vulnerability categories seen by elevation are dominant in the Arongan Lambalek District, Samatiga District, Johan Pahlawan District, Meureubo District. Areas with high vulnerability categories are dominant in the Meureubo District, Kaway XVI District, Panton Reu District, Woyla District, and Samatiga District. Areas with moderate vulnerability categories are dominant in the Kaway XVI District, Pante Ceureumen District, Panton Reu District, Woyla District, East Woyla District, and Bubon District. Areas with the low-altitude vulnerability category are dominant in the Kaway XVI District, Panton Reu District, East Woyla District, West Woyla District. Areas with very low vulnerability categories are dominant in the Pante Ceureumen and Sungai Mas districts.

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Tabel 2. Parameters Of Environmental Vulnerability To Tsunami Disaster

No	Parameter	Weighted (%)	Very High	Score	High	Score	Medium	Score	Low	Score	Very Low	Score
1	Elevation (m)	25	< 10	5	>10-25	4	>25-50	3	>50-100	2	>100-350	1
2	Slope	20	0-2	5	2-5	4	5-15	3	15-40	2	>40	1
3	Land Use	15	Settlement ,rice fields, Swamp, river	5	farm	4	lea	3	Bush, lake	2	forest	1
4	Coastline	20	500	5	>500-1000	4	>1000-1500	3	>1500-3000	2	>3000	1
5	River border	20	100	5	>100-200	4	>200-300	3	>300-500	2	>500	1

Slope

The unit of slope used in this study is percent (%). The vulnerability of slopes to tsunami disasters is divided into five categories, namely very high, high, medium, low, very low. Areas with a very high vulnerability category are areas with a slope of 0–2%. Areas with a high vulnerability category are areas with a slope of> 2–5%. Areas in the medium vulnerability category are areas with a slope of> 5–15%. Areas with a low vulnerability category are areas with a slope of> 15–40%. Areas with very vulnerability categories is an area with a slope> 40%.

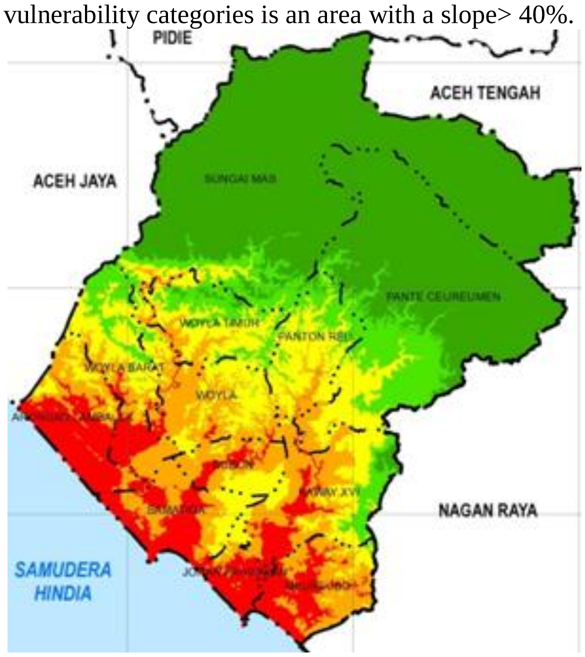

Fig. 1. Elevation Map

Areas that are categorized as very high vulnerability are dominant in Arongan Lambalek District, Samatiga District, Johan Pahlawan District, Kaway XVI District, Bubon District, Woyla District, and Pante Ceureumen District. Areas that are categorized as high vulnerability are dominant in Woyla Barat, Woyla Timur, Panton Reu, and Kaway XVI Districts. Areas included in the medium vulnerability category are dominant in the Pante Ceuremen and Sungai Mas districts. Areas that fall into the low vulnerability category are dominant in the Pante Ceureumen District area.

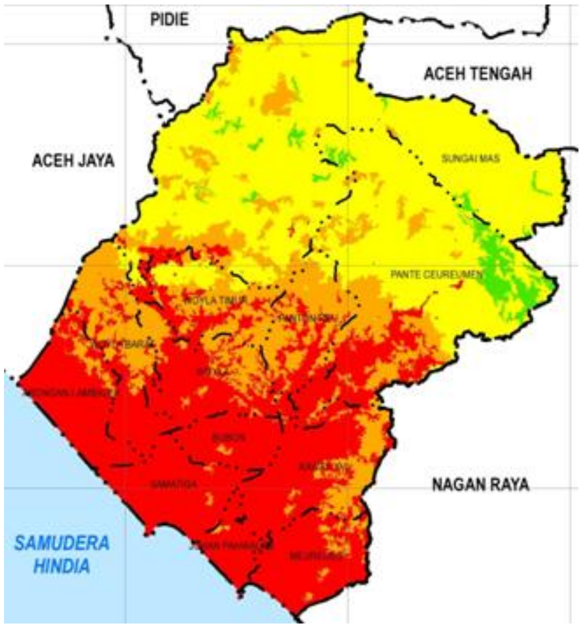

Fig 2. Slope Map

Land Use

Vulnerability of land use to tsunami disasters is also divided into five categories, namely very high, high, medium, low, very low. Areas with very high vulnerability categories are residential areas, rice fields, swamps, and rivers. Areas with a high vulnerability category are plantation areas. Areas with the category of moderate vulnerability are fields/moor areas. Areas with the low vulnerability category are areas in the form of lakes, reeds, fields and shrubs. Areas with the very low vulnerability category are forest areas.

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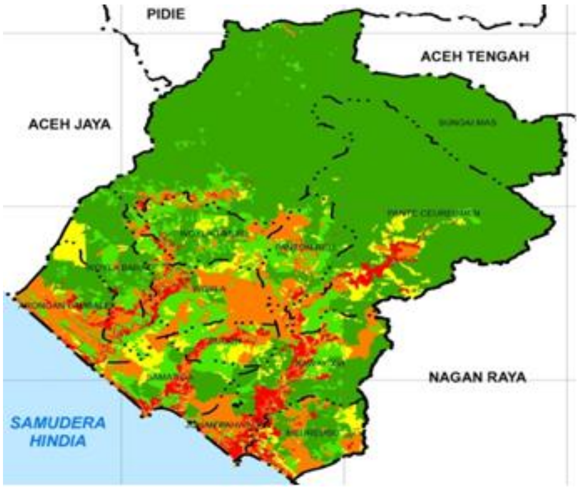

Fig. 3. Landuse Map

Areas that fall into the very high vulnerability category are dominant in the sub-districts of Meureubo, Johan Pahlawan, Samatiga, Arongan Lambalek, Woyla Barat, Woyla, Bubon, Kaway XVI, and Pante Ceureumen. Areas that are categorized as high vulnerability to tsunami disasters based on land use are predominantly in Meureubo, Johan Pahlawan, Samatiga, Arongan Lambalek, Woyla, and Panton Reu Districts. Areas that are categorized as moderate vulnerability are dominant in Meureubo District, Samatiga District, Bubon

Coastline

The map of the distance from the coast is obtained from the buffering results of the coastline vector data. The distance map from the coast used in this study is divided into five categories of vulnerability, namely very high, high, medium, low, and very low. Areas with very high vulnerability categories are areas that are within 500 m from the coast. Areas with a high vulnerability categories are areas that are within 500 m from the coast.

District, Arongan Lambalek District, and West Woyla District. Areas that fall into the low vulnerability category are dominant in the Samatiga District, Bubon District, Woyla District, East Woyla District, Panton Reu District, Pante Ceureumen District, and Kaway XVI District. Areas that are categorized as very low vulnerability are dominant in the Meureubo District, Kaway XVI District, Samatiga District, Arongan Lambalek District, West Woyla District, East Woyla District, Sungai Mas District, and Pante Ceureumen District.

Areas with a high vulnerability category are areas located> 500–1000 m from the coast. Areas with the category of moderate vulnerability are areas located >1000–1500 m from the coast. Areas with a low vulnerability category are areas that are> 1500–3000 m apart. Areas with the very low vulnerability category are those that are> 3000 m away. All categories of vulnerability in the land use distance parameter from the coast are located in the administrative areas of sub-districts that are directly adjacent to the waters of the Indian Ocean, namely Arongan Lambalek, Samatiga, Johan Pahlawan, and Meureubo districts.

Rivers Border

The map of the distance from the river is obtained from the results of buffering the river vector data. The distance map from the river used in this study is divided into five categories of vulnerability, namely very high, high, medium, low and very low. Areas with very high vulnerability categories are within 100 m from the river. Areas with high vulnerability categories are located >100–200 m from rivers. Areas with moderate vulnerability categories are within> 200–300 m. Areas with low vulnerability categories are within> 300–500 m. Areas with a low vulnerability category are located> 500 m. All categories of vulnerability in the distance parameter from the river are found along the river flow that empties into the ocean, namely the Woyla River, Bubon River, and Meureubo River.

Fig 4. Rivers Border

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The result of an overlay of a map of environmental vulnerability parameters to the tsunami disaster in West Aceh produces an overview of the areas that are prone to tsunamis in West Aceh. The level of vulnerability is divided into 5 categories, namely very high, high, medium, low and very low Areas with high vulnerability categories are the result of modeling in areas located at an altitude of 0–25 m with a slope of 0–2%, with dense residential conditions, and there are rice fields, swamps, plantations, fields that are 0–1500 m from the coast and within <100–1000 m from river. In terms of sub-district administrative boundaries, areas with high vulnerability categories are dominant in the Arongan Lambalek District, Samatiga District, Johan Pahlawan District, and Meureubo District.

Fig 5. Tsunami Vulnerability

4. CONCLUSION

Based on the modeling results of the environmental vulnerability parameter map to the tsunami disaster, it can be concluded that the areas with very high vulnerability categories are located in the estuary and areas of the Woyla River, Bubon River and Meureubo River with an area of up to 10 km2. Areas with high vulnerability categories are located in the coastal areas of Arongan Lambalek, Samatiga, Johan Pahlawan, Meureubo sub-districts, with an area of 135 km2. The area of the moderate category is in the Districts of Arongan Lambalek, Samatiga, Johan Pahlawan, Meureubo with an area of 353 km2. Areas with the low vulnerability category are located in almost all sub-district administrative areas in West Aceh District and are dominant in Woyla District with an area of 714 km2. Areas with very low vulnerability categories are dominant in Sungai Mas District and Pante Ceureumen District with an area of 1611 km2.

The suggestion in this research is that more specific mapping, such as social, economic, and physical vulnerability mapping is needed, so that the impact of the tsunami disaster from various vulnerability factors can be minimized.

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