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Analysis of Disaster Risk of Sea Level Rise in Ujung Tanah District, Makassar City

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A B S T R A C T

Global climate change has caused significant sea level rise, primarily due to melting polar ice caps and thermal expansion of seawater. Makassar City, particularly Ujung Tanah District, which has a coastal area, is highly vulnerable to the impacts of this sea level rise. This study aims to analyze the level of disaster vulnerability due to sea level rise in five coastal villages in Ujung Tanah District using ArcGIS-based spatial analysis methods. The parameters analyzed include slope gradient, land use, wave height, current speed, wind speed, and tides, then classified into three levels of vulnerability: low, medium, and high. The results show that most coastal areas (around 53%) are categorized as high vulnerability, while the other 44% are categorized as medium vulnerability. This vulnerability is caused by a combination of geographic factors and ocean dynamics that influence coastal conditions. This study recommends increasing community participation in coastal environmental conservation and integrated disaster mitigation planning to reduce the risk of sea level rise in Ujung Tanah District

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INTRODUCTION

Climate change has been a global environmental issue since 1979 and is now a major concern for the international community. This phenomenon refers to long-term changes in global weather and temperature patterns caused by human activities, particularly the burning of fossil fuels, deforestation, and other ecosystem damage. The two main phenomena causing sea level rise are melting ice and thermal expansion. Based on the IPCC (International Panel on Climate Change) report, the average global surface temperature has increased by 0.3-0.6oC since the end of the 19th century and by 2100 the earth's temperature is expected to rise by around 1.4-5.8oC. The increase in global surface temperature causes the melting of ice at the north and south poles of the earth, resulting in sea level rise.(Pörtner et al., 2021)

The phenomenon of sea level rise itself is a result of changes in ocean currents and density, which are closely related. According to a 2021 report from the Intergovernmental Panel on Climate Change (IPCC), from 1901 to 2018, global sea levels have risen by approximately 15 cm. The average rate of sea level rise during this period was approximately 1.7 mm per year. From 1901 to 1993, the rate of sea level rise was measured to be slower, at approximately 1.4 mm per year. However, from 1993 to 2018, the rate increased to approximately 3.3 mm per year, indicating an acceleration in sea level rise in recent decades. (Masson-Delmotte et al., 2021)

Makassar City, a metropolitan city with a 36.1 km long coastline in the west, is clearly significantly affected by sea level rise. Due to climate change, sea level rise in Makassar City is increasing at a rate of approximately 0.6-0.8 cm per year, which can impact residential areas, infrastructure, and ecosystems in coastal areas and small islands.(Hidayat, 2012)The Makassar Regional Disaster Management Agency (BPBD) recorded that sea level rise by 2100 will reach 110 centimeters, or more than one meter. Furthermore, Makassar's coastal geography, which slopes gradually toward the city center, poses a significant risk. Makassar, situated at an elevation of 0-25 meters above sea level, places it at high risk of disaster if sea levels reach 112 centimeters.(Kurdish, 2024).

One of the areas located in the northern coastal part of Makassar City is Ujung Tanah District, which also faces the threat of rising sea levels. Based on available information, a sea level increase of approximately 7.9 cm was recorded in 2020 and is estimated to reach approximately 18.9 cm in 2040. This surge reflects a trend of sea level rise of approximately 11 cm over the past two decades, which has the potential to trigger tidal flooding, accelerate coastal abrasion, and endanger residential areas and infrastructure located on the coast of Ujung Tanah District (Morell et al., 2025). This study is limited in the sense that it does not cover the entire Ujung Tanah District, but rather those affected by the interaction between land and sea, consisting of Ujung Tanah Village, Tamalabba Village, Gusung Village, Totaka Village, and Cambaya Village.

Given the evolving conditions resulting from the impacts of climate change, particularly the phenomenon of sea level rise in coastal areas, it is crucial to conduct a more focused analysis of the level of vulnerability to potential disasters. Ujung Tanah District, with its vulnerable geographic characteristics and location in an area of direct interaction between land and sea, is one of the

locations with a high potential to experience such impacts. Therefore, this study aims to analyze the level of disaster vulnerability due to sea level rise in Ujung Tanah District, Makassar City. The results of this study are expected to provide a basis for disaster mitigation efforts, coastal area planning, and protection of communities and infrastructure in vulnerable areas.

LITERATURE REVIEW

Climate Change

According to the 2007 International Panel on Climate Change (IPCC), climate change refers to significant changes in global temperature and weather patterns that occur over a long period of time. These changes can be caused by natural factors such as volcanic eruptions or variations in solar activity. However, in the modern context, most climate change is caused by human activities, particularly greenhouse gas emissions from the combustion of fossil fuels.(Change, 2007)

Coastal Disaster

United Nations Office For Disaster Risk ReductionThe United Nations Development Programme (UNISDR) defines coastal disasters as catastrophic events occurring in coastal areas. These events can be caused by natural factors, such as underwater earthquakes or storms, or by human activities, such as land reclamation or environmental degradation. These disasters have significant impacts on infrastructure, human life, and coastal ecosystems.(Unisdr, 2012)

A 2019 report from the International Panel on Climate Change (IPCC) identified various types of coastal disasters predicted to become more frequent due to climate change. Some of these include:

1. Sea level rise
2. Tropical storms and strong winds
3. Coastal erosion
4. Seawater intrusion
5. Coastal flooding

Sea Level Rise

Sea level rise is the movement of waves from the ocean toward the shore, causing fluctuations in coastal water levels compared to resting water levels. Relative sea level rise generally involves six factors, which vary from place to place.(Indriyanti et al., 2024)

The Intergovernmental Panel on Climate Change (IPCC) provided results regarding a review of research related to the main factors causing sea level rise, including:

1. Global warming and climate change
2. Melting of glaciers and land ice sheets
3. Land subsidence
4. Changes in ocean circulation patterns and changes in ocean dynamics
5. Coastal development

METHODOLOGY

Ujung Tanah District is one of 14 districts in Makassar City with an area of 136.87 km² or approximately 2.5% of the total area of Makassar City. Of the nine villages within it, this study focused on five villages that have a high potential to be affected by sea level rise, namely Ujung Tanah Village with an area of 25.69 km², Totaka Village with an area of 25.34 km², Tamalabba Village with an area of 20.47 km², Gusung Village with an area of 16.09 km², and Cambaya Village with an area of 10.28 km². These five villages were chosen because they have coastal characteristics that are vulnerable to the dynamics of sea level changes and their accompanying environmental impacts.

In this study, the analytical method applied is spatial analysis (mapping) using ArcGIS 10.8 software. The stages in the analysis process for managing sea level rise vulnerability data include:

Scoring (awarding)

Each parameter has the same value: 1–5 Parameters used in compiling the vulnerability to sea level rise in Ujung Tanah District. The weighting values for each indicator are as follows:

Table 1. Assessment of Sea Level Rise Vulnerability Indicators

No.	Indicator	Weight	Scoring
1	Slope Gradient	20	1 = 0 – 8% 2 = 8 – 15% 3 = 15 – 25% 4 = 25 – 45% 5 = >45%
2	Land use	10	1 = Forest, tourist area, vacant land, swamp 2 = Domestic tourist area, traditional fish ponds 3 = Intensive rice fields and ponds 4 = Residential, Port, Office, etc. 5 = Cultural heritage, foreign exchange tourism, industry, etc.
3	Wave Height	15	1 = <0.5 meters 2 = 0.5 – 1 meter 3 = 1 – 1.5 meters 4 = 1.5 – 2 meters 5 = >2 meters
4	Current Speed	25	1 = 0 – 5 m/s 2 = 5 – 10 m/s 3 = 10 – 15 m/s 4 = 15 – 20 m/s 5 = >20m/s

No.	Indicator	Weight	Scoring
5	Wind	10	1 = 0 – 5 knot 2 = 5 – 10 knot 3 = 10 – 15 knot 4 = 15 – 20 knot 5 = >20 knot
6	Ups and down	20	1 = <0.5 meters 2 = 0.5 – 1 meter 3 = 1 – 1.5 meters 4 = 1.5 – 2 meters 5 = >2 meters

Overlay analysis

This process involves combining data from different layers. Simply put, overlay can be described as a visual operation that requires the physical merging of more than one layer. (Darmawan et al., 2017). The overlay and weighting process for the indicators is added up with the following equation formula:

Total SLR Score = (S1 x B1) + (S2 x B2).....(1)

Classification of vulnerability levels to sea level rise

Compiling class interval values for sea level rise vulnerability using the arithmetic method, where the sum of the highest and lowest values will then be classified into 3 classes, with the following steps for compiling class intervals:

$$\mathbf{Ki} = \frac{Xt - Xr}{k} \quad \text{.....(2)}$$

RESULTS AND DISCUSSION

Analysis of Scoring Indicators of Vulnerability to Sea Level Rise

Slope Gradient Parameter Scoring Analysis

The slope conditions in Ujung Tanah District are divided into two categories: low (0-2%) and gentle (2-5%). The following table shows the area covered:

Table 2. Slope Gradient Parameters in Ujung Tanah District

No	Slope	Weight	Score	Area (Ha)
1	0 – 2%	20	1	135.04
2	2 – 5%			1.82
Total				136.87

Land use parameter scoring analysis

Based on land cover data, Ujung Tanah District is dominated by activity areas, with a coverage area of 52%. This is detailed in the following table:

Table 3. Land Use Parameters of Ujung Tanah District

No	Land Cover Types	Weight	Score	Area (Ha)
1	Road	10	1	8.10
2	Channel		1	0.95
3	Settlement		4	52.08
4	Green open space		1	0.93
5	Shrubs		1	1.29
6	Open Land		1	2.32
7	Activity Venue		4	71.20
Ujung Tanah District				136.87

Wave Height Parameter Scoring Analysis

Wave height is influenced by wind speed in different seasons. This is detailed in the following table:

Table 4. East Season Wave Height Parameters
(June – August 2024)

No	Year	Wave Height (M)	Weight	Score
1	2024 – 6	2,605	15	5
2	2024 – 7	2,611		
3	2024 – 8	2,581		
Wave height		2,599 (>2 meters)		

Table 5. West Season Wave Height Parameters
(December 2024 – February 2025)

No	Year	Wave Height (M)	Weight	Score
1	2024 – 12	2,721	15	5
2	2025 – 1	2,684		
3	2025 – 2	2,696		

No	Year	Wave Height (M)	Weight	Score
Wave height		2,701 (>2 meters)		

Current velocity parameter scoring analysis

The following are the scoring details for the average current speed parameters in one year in Ujung Tanah District:

Table 6. Current Speed Parameters in Ujung Tanah District in 2024

No	Year	Current Velocity (m/s)	Weight	Score
1	January	0.2420	25	1
2	February	0.3039		
3	March	0.2569		
4	April	0.1597		
5	May	0.1713		
6	June	0.2073		
7	July	0.2557		
8	August	0.2926		
9	September	0.3059		
10	October	0.3124		
11	November	0.3289		
12	December	0.1645		
Current Speed		0.2498		

Wind Parameter Scoring Analysis

The following are the details of the annual average wind speed scoring, namely:

Table 7. Wind Speed Parameters in Ujung Tanah District in 2024

No	Month	Wind Speed (Knots)	Weight	Score
1	January	3	10	1
2	February	3		
3	March	3		
4	April	2		
5	May	2		
6	June	2		
7	July	3		
8	August	3		
9	September	4		
10	October	2		
11	November	4		
12	December	3		
Wind velocity		3		

Tidal Parameter Scoring Analysis

The following are the scoring details for the highest high tide height and lowest low tide height in Ujung Tanah District:

Table 8. Parameters of the Highest Tide Height in Ujung Tanah District in 2024

No	Year	Highest Tide Height MSL (m)	Weight	Score
1	May	0.13	20	2
2	June	0.17		
3	July	0.10		
4	December	0.31		
Highest Tide Height		0.71 (1 meter)		

Table 9. Parameters of Lowest Low Tide Height in Ujung Tanah District in 2024

No	Year	Lowest low tide height MSL (m)	Weight	Score
1	January	-0.10	20	2
2	February	-0.03		
3	March	-0.12		
4	April	-0.01		
5	August	-0.07		
6	September	-0.07		
7	October	-0.08		
8	November	-0.08		
Lowest low tide height		-0.56		

Classification of vulnerability levels to sea level rise

After obtaining the total score from the sea level rise vulnerability indicator, the next step is to determine the vulnerability class interval value:

$$\text{Class Interval} = \frac{\text{Highest score} - \text{lowest score}}{\text{Number of Classes}}$$

$$\text{Class Interval} = \frac{205 - 155}{3}$$

$$\text{Class Interval} = 16.7$$

Table 10. Classification of Sea Level Rise Vulnerability Levels in the Coastal Area of Ujung Tanah District

No.	Vulnerability Class	Vulnerability Score	Vulnerability Description
1	Class I	155 – 171.7	Low Vulnerability
2	Class II	171.8 – 188.4	Moderate Vulnerability
3	Class III	188.5 – 205	High Vulnerability

With the classification level divided into three classes, the level of vulnerability to sea level rise per sub-district is:

Table 11. Results of Sea Level Rise Vulnerability Analysis in the Coastal Area of Ujung Tanah District

No	Ward	Area (Hectares)		
		Low Vulnerability	Moderate Vulnerability	High Vulnerability
1	Land's End	0.42	13.79	11.47
2	Totaka	1.49	10.55	13.30
3	Tamalabba	1.43	9.11	9.93
4	Gusung	0.19	6.74	9.17
5	Cambaya	-	2.82	7.46

Table 12. Classification Area of Sea Level Rise Vulnerability Level in the Coastal Area of Ujung Tanah District

No.	Vulnerability Class	Wide	Percentage
1	Low Vulnerability	2.92	3%
2	Moderate vulnerability	43.01	44%
3	High Vulnerability	51.34	53%
Total		97.27	100%

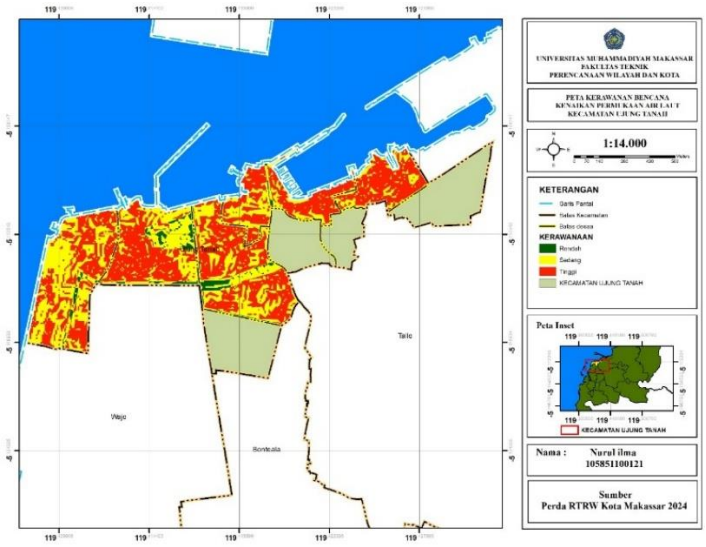

Figure 1. Map of Disaster Vulnerability for Sea Level Rise in Ujung Tanah District, Makassar City

Based on the analysis of the total score of the vulnerability indicators to sea level rise, a vulnerability classification was performed using an arithmetic method. The score range was divided into three classes with an interval of 16.7, resulting in three vulnerability categories: low (score 155–171.7), medium (171.8–

188.4), and high (188.5–205). This division aims to group areas based on the level of potential risk posed by sea level rise in the coastal area of Ujung Tanah District.

The classification results show that all of the sub-districts focused on in the study—Ujung Tanah, Totaka, Tamalabba, Gusung, and Cambaya—have areas categorized as moderate to high vulnerability, with varying extents. Several areas, such as Ujung Tanah and Totaka, have significant areas categorized as high vulnerability, covering 11.47 hectares and 13.30 hectares, respectively. Meanwhile, Cambaya is entirely categorized as moderate and high vulnerability, with no areas categorized as low vulnerability.

Overall, of the 97.27 hectares of land analyzed, 51.34 hectares (53%) were classified as high-risk, 43.01 hectares (44%) were classified as medium-risk, and only 2.92 hectares (3%) were classified as low-risk. These findings indicate that most coastal areas in Ujung Tanah District are vulnerable to the impacts of sea level rise, requiring appropriate mitigation and adaptation measures to reduce the risk of future disasters.

CONCLUSION AND RECOMMENDATION

This study revealed that sea level rise in Ujung Tanah District, Makassar City, exhibits a relatively high level of vulnerability, with most of its coastal areas categorized as moderate to high. Of the total 97.27 hectares analyzed, approximately 53% falls into the high vulnerability category and 44% into the moderate vulnerability category. The main factors influencing this vulnerability include gentle slopes, land use dominated by settlements and other activities, and significant wave and tidal conditions.

Recommendations for the Ujung Tanah sub-district community to be moreIncreasing active involvement in coastal environmental conservation activities, carrying out household-scale environmental infrastructure maintenance, encouraging the formation of community-based coastal alert groups, participating in local planning forums such as the Development Planning Conference (Musrembang), citizen forums and community dialogues.

FUTHER STUDY

To increase the depth of the analysis, it is recommended to develop a prediction model for changes in coastal vulnerability spatially with historical data to provide long-term projections, identify the factors causing sea level rise whether it is predominantly caused by land subsidence or sea level rise, and then monitor time series data related to changes in coastlines and land elevation.

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