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SPATIAL ANALYSIS OF COASTAL CHANGE AND DISASTER MITIGATION ON MASAKAMBING ISLAND, SUMENEP REGENCY

ANALISIS SPASIAL PERUBAHAN PANTAI DAN MITIGASI BENCANA DI PULAU MASAKAMBING, KABUPATEN SUMENEP

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ABSTRACT

Masakambing Island is one of the small islands in Sumenep Regency which has its own uniqueness and beauty. Small islands easily experience changes, one of which is changes in coastlines. The aim of this research is to determine the changes that occur along the coast and mitigation efforts by utilizing hydro-oceanographic parameters. Measurements of coastline changes were obtained from digitization results using the *Normalized Different Water Index* (NDWI) method with structural and non-structural mitigation efforts based on the parameter data taken. Wind parameters are dominated from the southeast and east with speeds ranging from 0.09 m/s - 22.75 m/s. The wave parameter values obtained were between 0.25 m – 0.83, while the current parameters ranged between 0.006 m/s – 0.642 m/s with the Formhazal number values showing 1.5 – 1.8. The wind was blowing cool and strong, as was the wave height in the slight category. The current flows southwest from the north of the island to the east. Single daily mixed Tide Type. The reduction in the area of Masakambing Island ranges from 0.063 km^2 – 1.933 km^2. Mitigation efforts that can be considered structurally include creating breakwaters and revetments, strengthening coastal buildings and planting vegetation. Non-structural mitigation that can be carried out includes creating standardization policies for disaster-resistant buildings, exploration and economic activity policies, public awareness as well as counseling and outreach regarding disaster mitigation.

Keywords*: coastal changes, Disaster mitigation, Masakambing Island, Small Island*

ABSTRAK

Pulau Masakambing adalah salah satu pulau kecil di Kabupaten Sumenep yang memiliki keunikan dan keindahan tersendiri. Pulau kecil mudah mengalami suatu perubahan, salah satunya adalah perubahan garis pantai. Tujuan penelitian ini adalah untuk mengetahui perubahan yang terjadi di sepanjang pantai dan upaya mitigasinya dengan memanfaatkan parameter hidro – oseanografi. Pengukuran perubahan garis pantai diperoleh dari hasil digitasi menggunakan metode Normalized Different Water Index (NDWI) dengan upaya mitigasi struktural dan non struktural berdasarkan data parameter yang diambil. Parameter angin didominasi dari arah tenggara dan arah timur dengan kecepatan berkisar antara 0,09 m/s - 22,75 m/s. Nilai parameter gelombang diperoleh antara 0,25 m – 0,83, sedangkan parameter arus berkisar antara 0,006 m/s – 0,642 m/s dengan nilai bilangan Formhazal menunjukkan angka 1,5 – 1,8. Angin berhembus sejuk dan kuat, begitujuga tinggi gelombang dalam kategori slight. Arus menuju arah barat daya dari utara pulau mengarah ke timur. Tipe Pasang surutnya campuran harian tunggal. Penurunan luasan wilayah Pulau Masakambing berkisar antara 0,063 km^2 *– 1,933* km^2*.Upaya mitigasi yang dapat dipertimbangkan secara struktural antara lain pembuatan breakwater dan revetment, penguatan bangunan pantai dan penanaman vegetasi. Mitigasi Nonstruktural yang dapat dilakukan antara lain membuat kebijakan standarisasi bangunan tahan bencana, kebijakan eksplorasi dan kegiatan perekonomian, penyadaran masyarakat serta penyuluhan dan sosialisasi mengenai mitigasi bencana.*

Kata Kunci *: mitigasi bencana, perubahan pantai, Pulau Kecil, Pulau Masakambing*

I. INTRODUCTION

A small island is an area that has its uniqueness and beauties. Small islands have something special such as islands that are separated from the main island and are small in size, have several endemics, have high biodiversity, low terrestrial, and have limited freshwater resources. In addition, small islands have a more vast water area than the mainland and are vulnerable and sensitive to external influences and minor climatic variations (Koroy *et al*., 2017). Masalembu Islands are a group of islands administratively belongs to the Sumenep Regency, East Java Province. The archipelago consists of three main islands: Masalembu, Masakambing, and Karamian. According to Law No.1 year of 2014 (is the island with an area smaller than or equal to 2,000 km^2). Along with its ecosystem unit is categorized as a small island. The size of Masakambing Island is 7.79 km^2 (BPS Kabupaten Sumenep, 2018) which causes this island to be included in the Small Island category. In addition, this island is included in an essential ecosystem area due to the potential of abundant marine biological resources with complex ecosystems such as mangroves, seagrasses, and coral reefs surrounding the island. In addition, this island has an endemic species of small yellow-crested cockatoo (*Sulphurea abotti*), one of four types of cockatoos that can only be found in Indonesia and Timor Leste with a total of ± 25 individuals in 2021.

Small island vulnerability can be defined as how easily small islands be damaged. An island's vulnerability level determines whether or not an island is easily damaged (Tahir *et al*., 2012). Furthermore, (Akbar, 2016) stated that small islands are vulnerable to environmental factors (climate change, rising and falling sea levels, tsunamis, earthquakes, and volcanic events).Economic factors (dependence on nature, limited market opportunities, isolation, financial capacity, and low investment). Social factors (malnutrition, limited human resource capacity, high population growth, migration, disease, and food). Coastline changes can occur from time to time on a seasonal or annual scale (Darmiati *et al*., 2020). Changes in the coastline can change an area's territorial waters and cause the site's actual boundaries to become unclear. Shoreline changes due to accretion on the coast are caused by sediments originating from land and deposited on the beach.

In contrast, changes due to abrasion are caused by ocean currents and waves that continuously hit the coast (Siburian *et al*., 2020). Monitoring shoreline changes uses satellite image recording to identify and map changes in the coastline of an area (Halim *et al*., 2016). The utilization of the coastal regions is often not based on an understanding of coastal behavior can cause various coastal problems to appear, such as accretion or abrasion. Abrasion and accretion processes that previously occurred naturally can occur more quickly if the behavior of development interests is not based on knowledge of the dynamics of coastal waters and can result in faster shoreline changes (Syukhriani *et al*., 2017). Monitoring shoreline changes is essential to determine changes along the coast and their mitigation efforts. Masakambing Island, which is the habitat of an endemic species, small yellow-crested cockatoo, is threatened by changes due to abrasion. Based on this, this study was conducted to determine how much the coastline changes on Masakambing Island through observations of satellite imagery and hydro-oceanographic parameters in the island area. The results of this study can later be used to mitigate and protect the biodiversity on the Island of Masakambing.

II. RESEARCH METHODS

2.1. Research Time and Location

The observation was held on Masakambing island, Sumenep Regency, East Java Island, at the village of Ketapang and Tanjung on April 2021 (Figure 1). Data analysis and processing were conducted at the Oceanography Laboratory, Department of Marine Affairs and Fisheries, Faculty of Agriculture, Trunojoyo University, Madura.

2.2. Data Collection

Primary data used were tides, and data of sediment. The secondary data from 2017 – 2020, including wind, wave, current, and satellite image data.

2.3. Data Analysis

2.3.1. Wind

Wind data obtained from BMKG kelas II Tanjung Perak, Surabaya. The coordinates of the wind are 5°26’48” LS 114°25’23” E. The data was processed using the WRPLOT display software with the Windrose method. Classification of wind-based speed using the Beaufort scale (Aji & Cahyadi, 2015) in Table 1.

2.3.2. Wave

Wave data obtained from the site cds.climate.copernicus.eu with a spatial resolution of 0.25° x 0.25°. Wave data using the coordinates of the Java Sea waters ranged from -3° South Latitude to -7° South Latitude and 108° East Longitude to 116° East Longitude. The data was processed to visualize the significant wave height. The classification of significant wave heights using the WMO Sea State (WMO 3700) (Garcia *et al.*, 2018) is in Table 2.

2.3.3. Sea Current

Current data were obtained from site marine.copernicus.eu with a spatial resolution of 0.25° x 0.25°. Wave data using the coordinates of the Java Sea waters ranged from -3°S to -7°S and 108°E to 116°E.

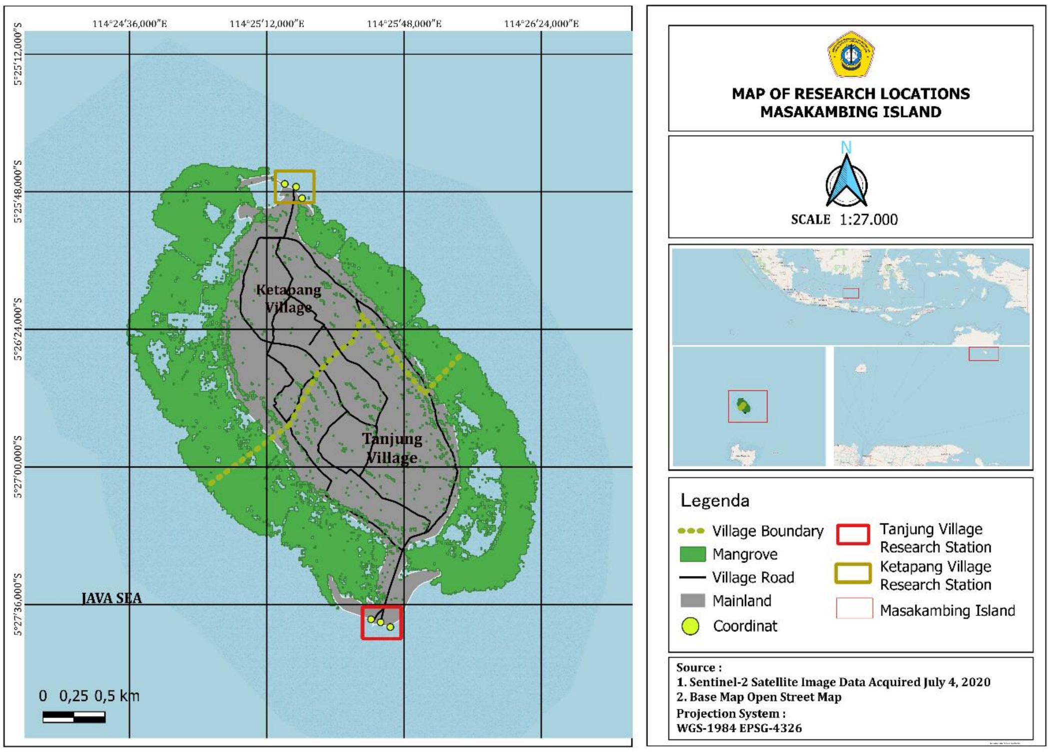

Figure 1. Map of Research Sites on Masakambing Island.

Table 1. Beaufort Scale.

Beaufort Scale	Description	Wind Speed (M/S)
1	Calm	0 – 0.3
2	Light Air	0.3 – 1.5
3	Light Breeze	1.5 – 3.3
4	Gentle Breeze	3.3 – 5.5
5	Moderate Breeze	5.6 – 8
6	Fresh Breeze	8 – 10.8
7	Strong Breeze	10.8 – 13.9
8	Near Gale	13.9 – 17.2
9	Gale	17.2 – 20.7
10	Strom Gale	20.7 – 24.5
11	Storm	24.5 – 28.4
12	Violent Storm	28.4 – 32.6
13	Hurricane	> 32.6

Table 2. WMO Sea State (WMO 3700).

Characteristics	Significant Wave Height (m)
Calm (Glassy)	0
Calm (Rippled)	0 - 0.1
Smooth (Wavelets)	0.1 – 0.5
Slight	0.5 – 1.25
Moderate	1.25 – 2.0
Rough	2.5 – 4.0
Very Rough	4.0 – 6.0
High	6.0 - 9.0
Very High	9.0 – 14.0
Phenomenal	>14.0

2.3.4. Tides

Tides data was obtained from Badan Informasi Geospasial (BIG). The location for tidal observations is the closest station to Masakambing Island, namely Kalianget Station in East Java Province, with coordinates of -7.0756°S 113.943°E. Tidal data was processed using the admiralty method with Microsoft Excel software (Fadilah *et al.*, 2014). Calculation of elevation parameters and formhazal values according to Nugraha *et al.* (2013) using the formula :

$$HHWL\ (Highest\ High\ Water\ Level) = S_0 + (M_2 + S_2 + K_2 + K_1 + O_1 + P_1) \quad \text{................}(1)$$

$$LLWL\ (Lowest\ Low\ Water\ Level) = S_0 - (M_2 + S_2 + K_2 + K_1 + O_1 + P_1) \quad \text{......................}(2)$$

$$MHWL\ (Mean\ High\ Water\ Level) = S_0 + (M_2 + K_1 + O_1) \quad \text{......................................}(3)$$

$$MLWL\ (Mean\ Low\ Water\ Level) = S_0 - (M_2 + K_1 + O_1) \quad \text{..}(4)$$

$$F = \frac{A\,(K1) + A(O1)}{A(M2) + A(S2)} \quad \text{.............................}(5)$$

Determination of the type of tides based on the classification as follows:

$0 < F \leq 0{,}25$ = Semidiurnal tide

$0{,}25 < F \leq 1{,}50$ = Mixed tide prevalling semidiurnal

$1{,}50 < F \leq 3{,}00$ = Mixed tide prevalling diurnal

$F \geq 3{,}00$ = Diurnal Tide

2.3.5. Sediment

The analysis determines the characteristics of the sediment at the sampling location by dry analysis using a sieve shaker or stacked sieve. Determination of the sediment type is done by processing the data from the analysis of sediment samples in Microsoft Excel for Result calculation, % Cumulative, % Passed, and % Retained (Nurainie & Wiyanto, 2021).

Sand = % Retained 5 (5)
Silt = % Retained 6 - % Retained 5 (6)
Clay = % Passed 6 (7)

The sediment analysis results are presented in calculation tables and Sheppard diagrams in Figure 2.

2.3.6. Coastal Changes

Data on shoreline changes obtained from site scihub.copernicus site with Sentinel 2B satellite imagery level 1C with the research location zone 50S. Image data corrected by Bottom of Atmospheric (BOA), resampling to 10m spatial resolution, subset, Normalized Different Water Index (NDWI)

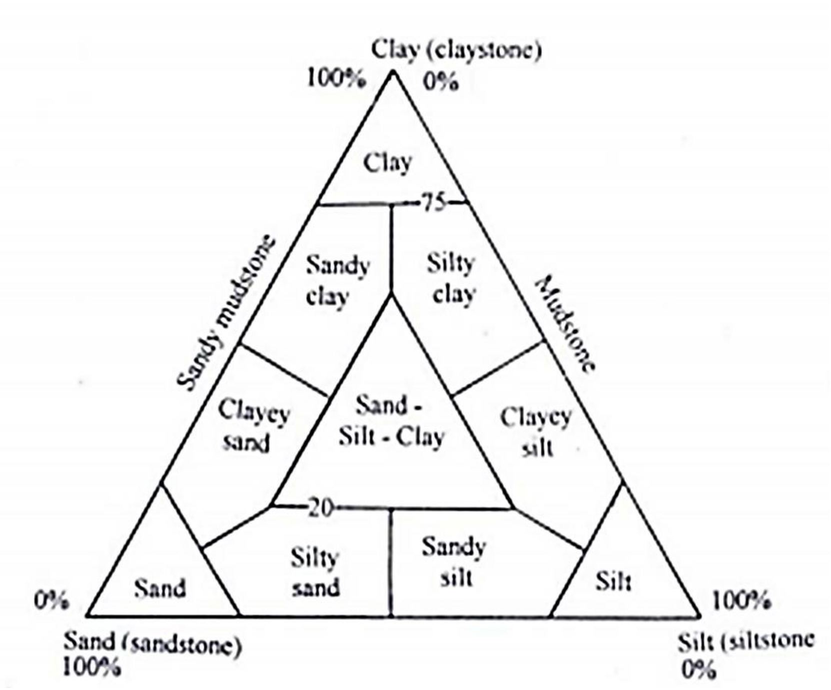

Figure 2. Sheppard's Diagram (Shepard, 1954).

correction, digitization, and calculation of island area. Calculating NDWI according to Almeida *et al.* (2021) using the formula :
NDWI = Band NIR – Band Green – / Band NIR + Band Green (8).

2.3.7. Disaster Mitigation

Mitigation efforts in areas prone to abrasion are based on changes in coastline and parameters obtained through satellite imagery and hydro-oceanographic processing. Based on (Direktorat Jenderal Pesisir dan Pulau - Pulau Kecil, 2004), Structural mitigation includes reducing wave energy, strengthening geological structures, increasing sediment supply, planting coastal forest, and supporting dunes through vegetation. Careful planning is needed for constructing wave retaining walls and groins to avoid long-term changes in wave patterns causing erosion elsewhere. Non -structural mitigation involves setting coastline boundaries and establishing an early warning system for coastal erosion, considering factors like erosion rate, topography, geology and human activities.

III. RESULT AND DISCUSSION

3.1. Wind

The wind movement pattern in an area can be determined using wind direction and speed data. The wind rose is depicted in a circular format or display with the frequency of the wind blowing from a particular direction. The length of each crown represents the frequency with which the wind blows from that direction, is zero at the center of the rose, and continues to circle to the edge of the rose. The color on each crown shows the dominance of wind speed. The classification of winds on Masakambing Island according to the Beaufort scale can be seen in Table 3. The results of using windrose in wind data processing on Masakambing Island are in Figure 3.

The wind speed on Masakambing Island in 2017 – 2020 ranged from 0.09 m/s – 22.75 m/s, where according to the Beaufort scale, the wind speed range was categorized as calm to storm gale (Table 1). The average wind speed in 2017 was 10.67 m/s. In 2018 it was 12.98 m/s. In 2019 it was 10.41 m/s, and in 2020 it was 11.92 m/s. The wind speed classification based on the Beaufort scale shows fresh breeze wind gusts in 2017 and 2019 and strong breeze wind gusts in 2018 and 2020. The wind direction in 2017 is east and southeast, while from 2018 to 2020 is southeast. Conditions provide an overview of wind conditions on Masakambing Island where the wind speed on Masakambing Island is relatively higher than previously research, where Aji & Cahyadi, (2015) pyhsical condition of Java Sea showed a scale 1 -6. The wind blows continuously and causes waves (Sopamena & Joseph, 2019). And high wind speeds can cause strong currents and large waves (Prarikeslan, 2016).

Table 3 Wind Direction and Speed (BMKG kelas II Tanjung Perak, Surabaya).

Year	Wind Direction	Wind Speed			Classification
		Min	Max	Mean	
2017	East and Southeast	0,12	22,55	10,67	Fresh Breeze
2018	Southeast	0,32	22,75	12,98	Strong Breeze
2019	Southeast	0,25	21,84	10,41	Fresh Breeze
2020	Southeast	0,09	22,54	11,92	Strong Breeze

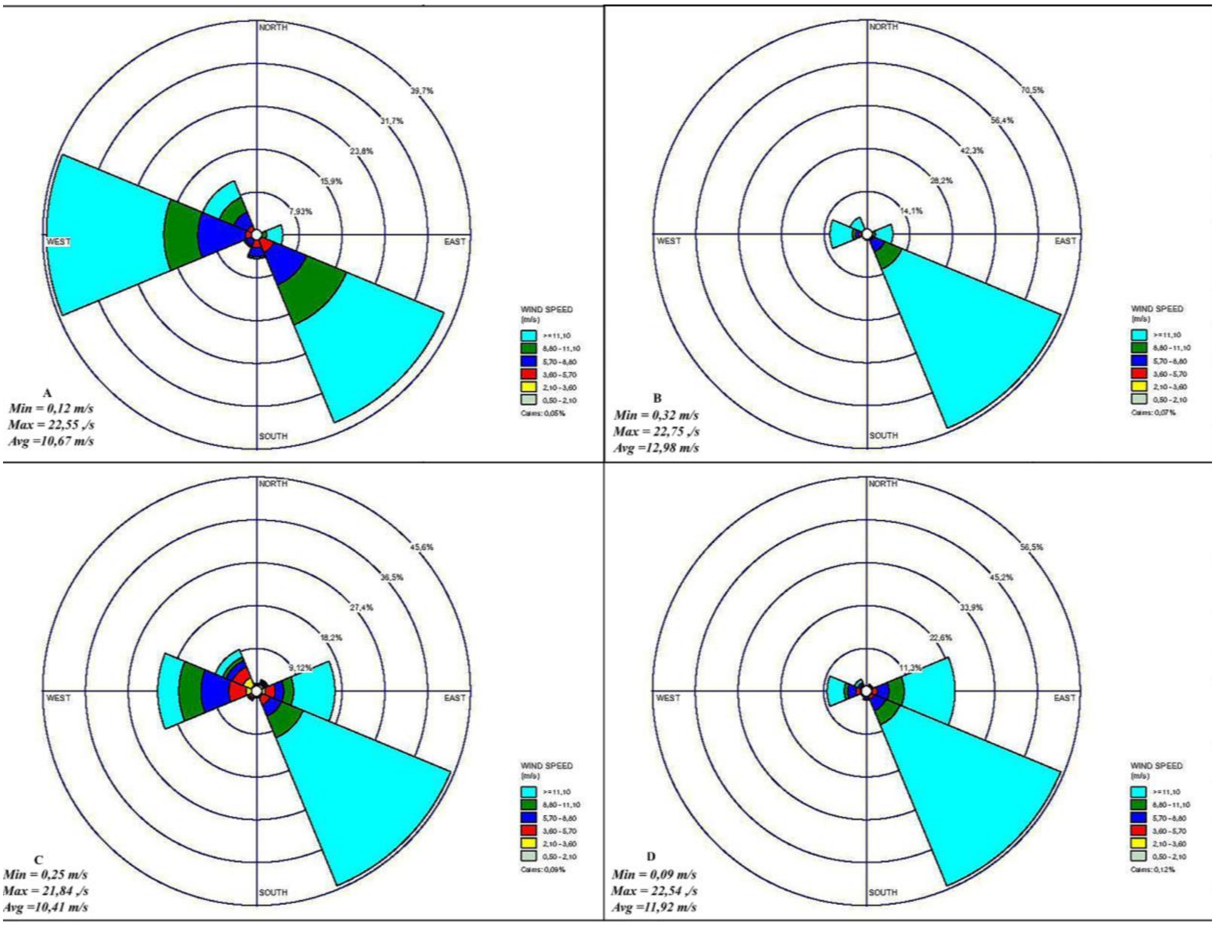

Figure 3. Wind Direction and Speed (a) Wind 2017, (b) Wind 2018, (c) Wind 2019, Wind 2020.

3.2. Wave

Wind, as the main cause of waves in the sea, can be sea waves (waves) and swells (waves), where the waves are very irregular in shape and according to wind conditions. Otherwise, the waves move slowly toward the beach, even on windless days (Prarikeslan, 2016). The color difference in the visualization results shows the average significant wave height. The location of masakambing island is indicated by a checkmark on the visualization results.The average significant wave height in Java Sea waters in 2017 - 2020 is 0.66 m, with a minimum wave height of 0.25 m and a maximum wave of 0.83 m. The wave characteristics in the waters of the Java Sea in 2017 - 2020 are slight, with a range of 0.5 – 1.25m. The classification of the average wave height on Masakambing Island according to WMO Sea State (WMO 3700) can be seen in Table 4. The visualization results of the average significant wave height are in Figure 4.

The wave heights in Java Sea in 2017 ranged from 0.26 m to 0.80 m, with an average height of 0.65 m. In 2018 the range of wave heights in the Java Sea waters ranged from 0.27 m to 0.83 m, with an average height of 0.67 m. In 2019 the range

Table 4 Average Significant Wave Height (cds.climate.copernicus.eu).

Year	Min	Max	Mean	Characteristics
2017	0.26	0.80	0.65	Slight
2018	0.27	0.83	0.67	Slight
2019	0.25	0.82	0.67	Slight
2020	0.26	0.78	0.64	Slight

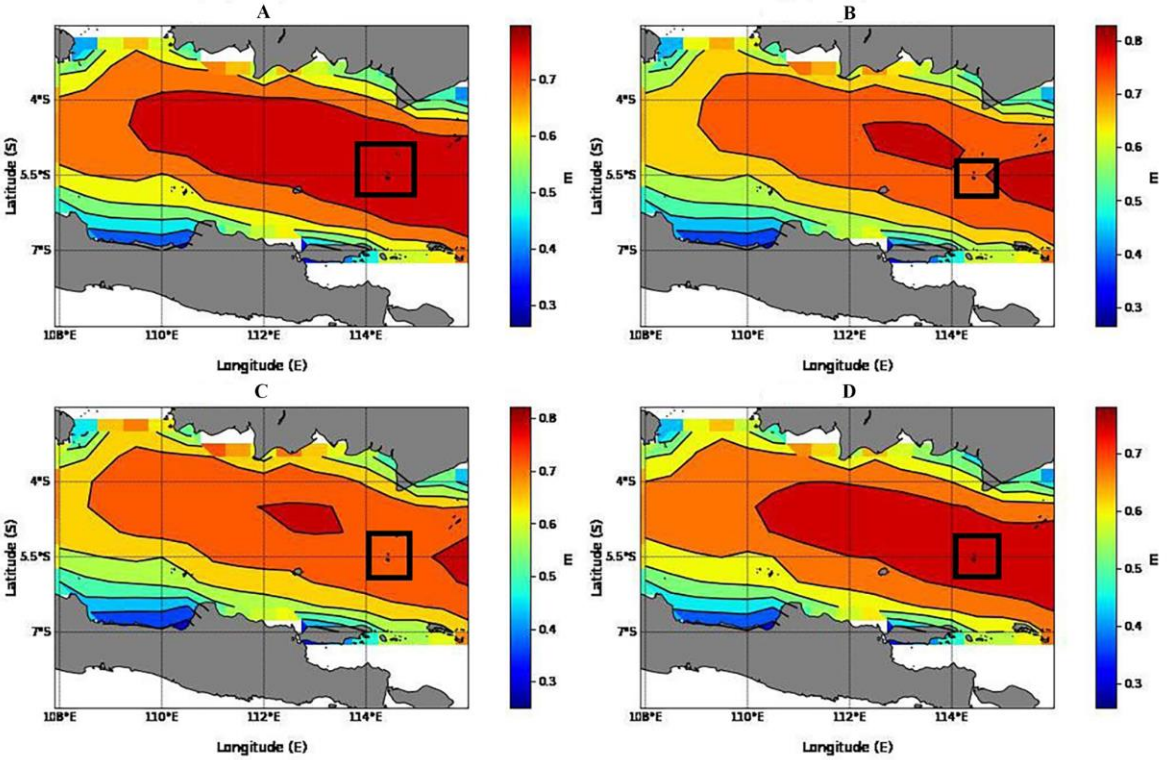

Figure 4. Significant Height Wave (a) Wave 2017, (b) Wave 2018, (c) Wave 2019, Wave 2020.

of significant wave heights in the waters of the Island of Java ranged from 0.25 m to 0.82 m, with an average height of 0.67 m. In 2020, the range of significant wave heights in the waters of the Island of Java ranged from 0.26 m to 0.78 m, with an average height of 0.64 m. Condition provides an insight into the significant wave height in Masakambing island, where the wave height is relatively low` and doesn't have a substantial impact on shoreline changes. The results of significant wave heights in the Java Sea are by the results Habibie *et al*. (2019) where significant wave heights range from 0 – 1m.

3.3. Sea Current

Current is the movement of air masses vertically and horizontally and occurs throughout the world's oceans caused by wind blowing, wave movement, or density differences. High wind speed can cause strong currents and big waves (Prarikeslan, 2016). Wave transformations on the high seas generated by winds can trigger the occurrence of alongshore currents that cause sediment transport and shoreline changes (Angkotasan *et al*., 2012). Different colors indicate wave speed, while arrows indicate wave direction on the visualization results. Location of Masakambing Island is indicated by a checkmark on the visualization results. The average annual current velocity of the Java Sea waters in the 2017-2020 range ranges from 0.006 m/s – 0.642 m/s with an average yearly speed of 0.160 m/s. The average annual current and current direction are in Table 5.

Direction of the annual average current in the Masakambing Island area is towards the southwest of Masakambing Island, and the northern location of Masakambing Island has a current that leads to the east. The data obtained in 2017 ranged from 0.006 m/s to 0.440 m/s with an average current velocity of 0.160 m/s. In 2018, average annual current velocity ranged from 0.006 m/s – 0.465 m/s with an average current velocity of 0.156 m/s. In 2019, the average annual current velocity ranged from 0.016 m/s – 0.642 m/s with an average current velocity of 0.174 m/s. In 2020, annual average current velocity ranges from 0.006 m/s – 0.540 m/s with an average current velocity of 0.161 m/s. In these conditions, a current flows towards Masakambing Island, where this current direction undergoes severe abrasion, and if left unchecked, it will worsen coastal stability.The average current speed of the Java sea (Daruwedho et al., 2016), where the speed ranges from 0-4 m/s. The results of the visualization of wind direction and speed are in Figure 5.

3.4. Tide

Tides are rising and falling sea levels periodically accompanied by horizontal movements of seawater masses. Tidal caused by the attractive attraction of astronomical objects such as the moon, sun, and earth (Prarikeslan, 2016). The admiralty method uses calculations based on existing Schemes. Results of the constant calculation using the admiralty method to produce the average annual harmonic component values are in Table 6. The annual elevation parameter values are based on the harmonic components in Table 7.

Table 5. The average annual current and current direction (marine.copernicus.eu).

Year	Min	Max	Mean	Direction
2017	0.006	0.440	0.160	Southwest and East
2018	0.006	0.465	0.156	Southwest and East
2019	0.016	0.642	0.174	Southwest and East
2020	0.006	0.540	0.161	Southwest and East

Table 6. Average Annual Tidal Harmonic Component (Badan Informasi Geospasial (BIG)).

Year	S_0	M_2	S_2	N_2	K_1	O_1	M_4	MS_4	K_2	P_1
2017	155	33	11	9	43	22	2	2	3	14
2018	161	35	15	9	54	25	2	2	4	18
2019	150	33	14	9	53	27	1	1	4	18
2020	133	31	14	9	53	26	2	1	4	18

Table 7. Parameters of Annual Elevation of Waters (Badan Informasi Geospasial (BIG)).

Year	MSL	HHWL	LLWL	MHWL	MLWL	F
2017	1.55	2.81	0.72	2.53	0.57	1.5
2018	1.61	3.12	0.64	2.75	0.47	1.6
2019	1.50	2.99	0.54	2.63	0.37	1.7
2020	1.33	2.79	0.40	2.43	0.23	1.8

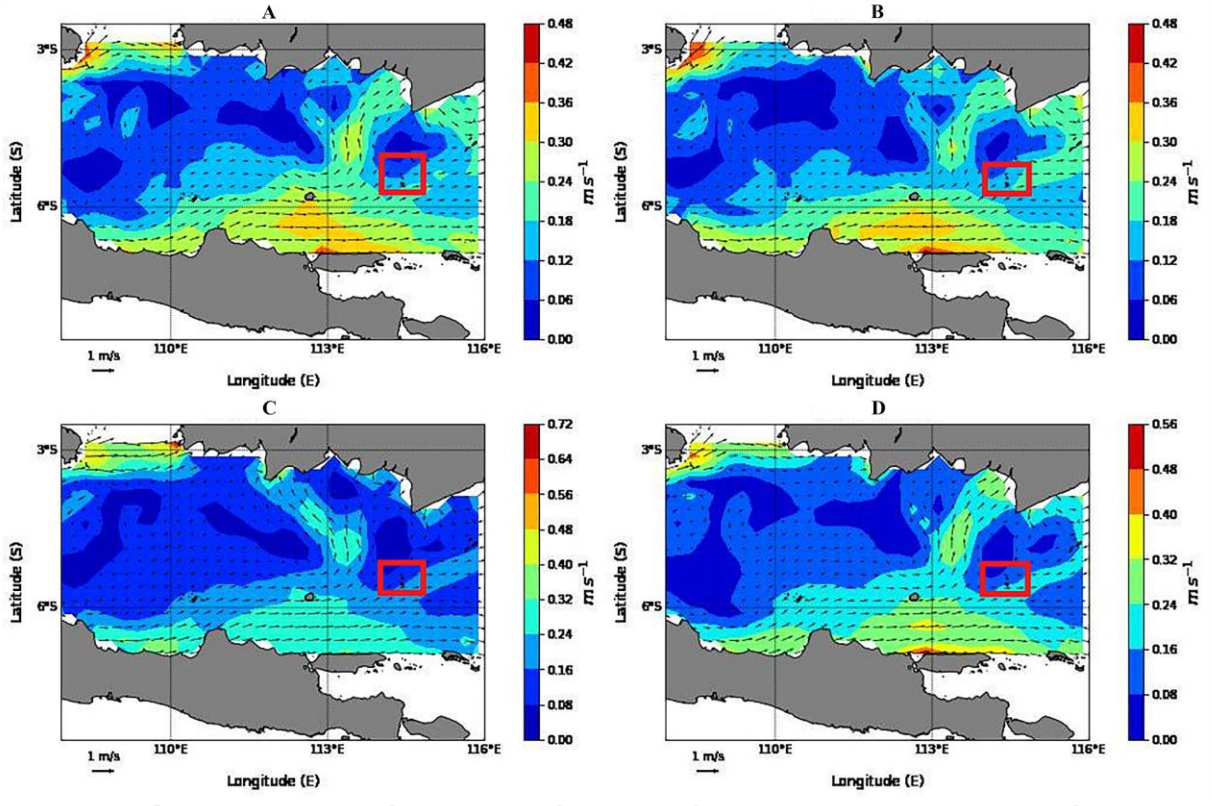

Figure 5. The average annual current and current direction (a) Current 2017, (b) Current 2018, (c) Current 2019, (d) Current 2020.

Mean Sea Level (MSL) values in 2017 – 2020 range from 1.33 m - 1.61 m. Highest High Water Level (HHWL) ranges from 2.79 m – 3.12 m. The Lowest Low Water Level (LLWL) ranges from 0.40 m – 0.72 m. Mean High Water Level (MHWL) ranges from 2.43 m – 2.75 m. Mean Low Water Level (MLWL) ranges from 0.27 m – 0.57 m. The formhazal value ranges are 1.5 to 1.8, including the mixed tide prevailing diurnal category. The tidal type corresponds to (Pariwono, 1989), where type mixed tide prevailing diurnal. Understanding the specific type of tide can be effectively integrated with historical data to provide valuable insights for coastal regions' scientific planning and development, aligning them precisely with the real environmental conditions.

3.5. Sediment

Sediment is a solid material derived from rock that has undergone a process of weathering, melting, transport by water, wind, and gravity, as well as deposition or collected by natural processes or agents to form a solid surface layer of the earth (Prarikeslan, 2016). Sediment analysis was carried out to determine the types of sediments on the island of Masakambing. The sediment analysis used is dry analysis because it has a solid texture. The results of the calculation of sediment samples obtained from sediment types and their characteristics are in Table 8.

Based on Table 8, the type of sediment at the two stations has the same types: sand. Sheppard's triangle at Tanjung station point 1 shows the type of sand sediment. Silt content at this location is a minor grade of 0.16% and one with the largest sand content of 99.80%. Tanjung Station points 2 results from a Sheppard triangle of sand type. Clay content is the minor content of 0.02 and one of the largest sand content at 99.80%. Tanjung Station point 3 shows the results of the Sheppard triangle of sand type with a sand content of 98.95% and a silt content of 1.02%. The Ketapang Station point 1 shows the yield of the Sheppard triangle with a sand type of 98.23%. The Ketapang Station point 2 shows the results of the Sheppard triangle of sand type of 99.18%. Ketapang Station point 3 offers the yield of the Sheppard triangle with a sand type of 92.78%, silt content of 6.19%, and clay of 1.03%. Silt and clay content at this point is at the highest level at the research site. Sheppard's triangle from the research location is in Figure 6.

3.6. Coastline Changes

Global climate change affects coastal communities in various parts of the world. An accelerating sea level rise can cause other impacts, such as coastal erosion, increased flooding, ecological process changes, and small islands' submerge. The mapping of changes in the coastline of Masakambing Island in Figure 7 and the area of Masakambing Island in Table 9.

Results from interpretation based on analysis was carried out using an open street map and coastline maps in each research year show that changes in coastline and total areas on the Island of Masakambing are a reduction. Masakambing Island in 2017 had an area of 9,879 km^2 and continued to experience a reduction in the island until 2020. In 2018 the area of Masakambing Island was 7,935 km^2. The changes in the area of Masakambing Island were 1,932 Km^2 in 2017 – 2018. Masakambing Island, in the range of 2018 – 2019, experienced a change in the island's area 0.117 km^2 and has an area of 7,818 km^2. Masakambing Island in 2020 had an area of 7,755 km^2 and shared a reduced area of 0.063 km^2.

Table 8. Sediment Characteristic.

Station	Point	Sand	Silt	Clay	Characteristics
Tanjung	1	99.80	0.16	0.04	Sand
	2	99.80	0.18	0.02	Sand
	3	98.95	1.02	0.03	Sand
Ketapang	1	98.23	1.53	0.24	Sand
	2	99.18	0.77	0.05	Sand
	3	92.78	6.19	1.03	Sand

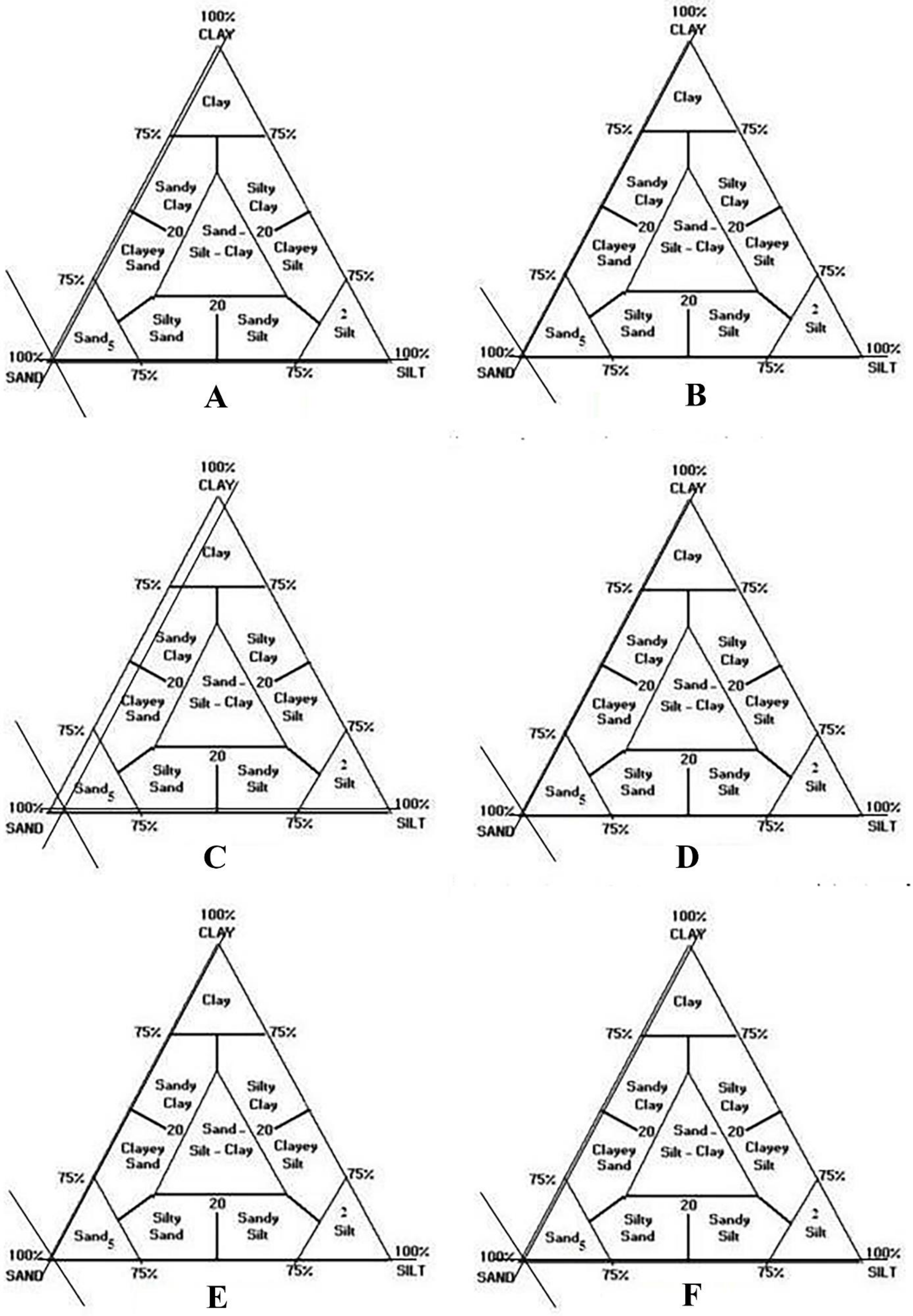

Figure 6. Sheppard's Triangle Research Site (A) Ketapang 1 (B) Ketapang 2 ,(C) Ketapang 3,(D) Tanjung 1 (E) Tanjung 2 (F) Tanjung 3 (Shepard, 1954).

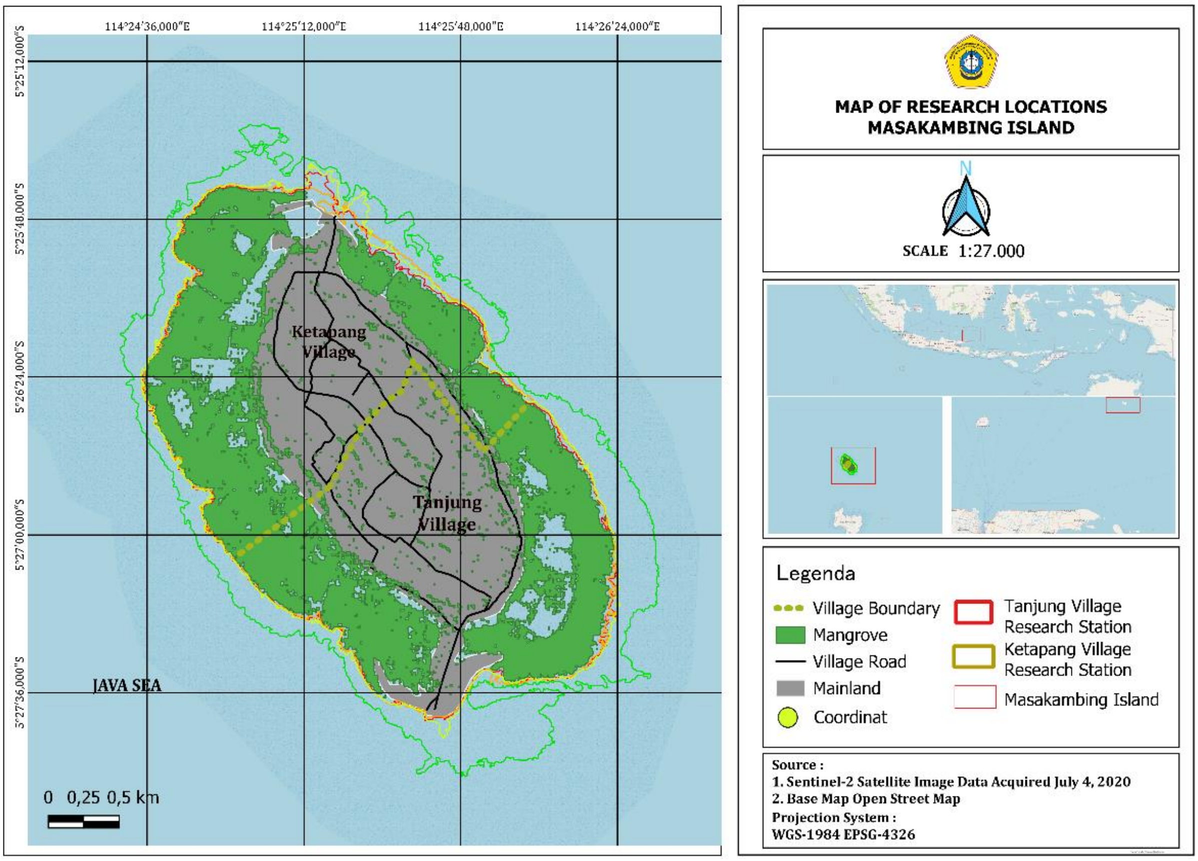

Figure 7. Change of the Coastline of Masakambing Island.

Table 9**.** The Area of Masakambing Island.

No	Date	Area (km^2)
1	28/10/2017	9,867
2	03/09/2018	7,935
3	29/08/2019	7,818
4	12/10/2020	7,755

Reduction of the area in 2017 – 2020 by 2,112 km^2. Based on the interpretation of Sentinel – 2 satellite imagery results, the principal factor attributed to abrasion is the influence of current direction, as deduced from observations along the coastline of Masakambing Island. The northward current flow is notably associated with abrasion in the northern region of the island, while similar conditions prevail in the eastern sector, resulting in substantial abrasion. This phenomenon primarily affects areas in close proximity to the wharves in both villages. The results show a continuous decrease in an area on Masakambing Island and will continue to penetrate the mainland, which is a serious threat. Therefore, disaster mitigation is needed to resolve the problem immediately (Apriyanti *et al.*, 2021).

3.7. Disaster Mitigation

Based on the analysis, the prevailing current flows southwestward relative to Masakambing Island, exerting its influence predominantly upon the island's southern sector. Conversely, the northern region of Masakambing Island experiences an eastward-directed current flow, consequently contributing to alterations in the coastal landscape. It is imperative to consider sediment composed of sand in disaster mitigation endeavors. Field surveys indicate that both wave barriers and abrasion have been compromised.as shown in Figures 8 and Figure 9.

Figure 8. Breakwater Breakdown (Personal Documentation).

Figure 9. Abrasion (Personal Documentation).

Structural disaster mitigation measures feasible for implementation on Masakambing Island to mitigate the impact of ongoing events encompass constructing a breakwater in the area most severely affected. This breakwater should be strategically positioned near the piers of the two villages. Additionally, the establishment of coral reefs as a natural wave barrier around the abrasion-affected region is recommended. The lowlands of Masakambing Island have the same type of sediment as Mauritius Island is expected that the construction of revetments and water could adapt to risks, use of coastal areas, and simple construction methods with high effectiveness (Onaka *et al*., 2015). Reinforcement of wave–retaining buildings should be sought on each coast to minimize erosion events (Wahyuningsih *et al*., 2016). Planting vegetation is expected to provide opportunities for the formation of mangrove communities that enhance the function of coastal protection (Geurhaneu & Tri, 2016).

Non-structural mitigation can be adjusted and regulates human activities in line with structural mitigation efforts, among others. Solving disaster problems requires a combination of structural (facility and infrastructure) and non-structural efforts in terms of implementation that must involve relevant agencies (Diposaptono, 2003). The formation of a disaster-resilient community needs to be pursued by a disaster-prepared community (Wahyuningsih *et al.*, 2016). Offering informative materials, in the form of both visuals and data, regarding oceanographic dynamics in a simplified manner is aimed at facilitating better public comprehension. (Riswal *et al.*, 2021).

IV. CONCLUSION

Based from the analytical outcomes and the geographic context, coastal abrasion on Masakambing Island emerges as a key catalyst for shoreline transformations, primarily instigated by prevailing currents. The affected zones coincide with the pronounced current direction towards the island. In response to this predicament, the installation of breakwaters and coral reef propagation stands as a promising mitigation strategy against the ongoing abrasion. Furthermore, community awareness initiatives must disseminate information concerning shoreline alterations, fostering a heightened understanding of potential ramifications.

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