Analysis of Shoreline Changes in the Coastal Area Between Batang Anai Estuary and Batang Mangur Estuary West Sumatra Province

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ABSTRACT

This study aimed to determine the rate of change of the coastline and the effect of sedimentation processes, currents, and waves on the coastline in the coastal area between Batang Anai Estuary and Batang Mangur Estuary, West Sumatra Province. End Point Rate (EPR) is a method that can be used to calculate the rate of change of coastline by displaying transects according to their categories (high abrasion, medium abrasion, low abrasion, stable, and accretion). In 1993–2023, there was a change in the coastline in the form of abrasion, which reached ±150 m with a change rate of ±1.63 m/year. The abrasion at the research station is classified into high, medium, and low categories. Accretion also occurs in the area around the research station, and some areas do not experience significant changes or remain in a stable condition. Currents in the coastal area between Batang Anai Estuary and Batang Mangur Estuary, Padang Pariaman Regency, are included in the slow-moderate category with an average value of 0.19-0.28 m/s. Wave height is included in the low–low category with an average value of 0.1–0.58 m. Although currents and wave heights are included in the low category, some areas lacking coastal vegetation and no breakwaters can experience abrasion and accretion.

Keywords: Shoreline Changes, Currents, Waves, Padang Pariaman Regency

1. INTRODUCTION

Coastal zones are transitional areas between terrestrial and marine ecosystems that are affected by land changes and sea changes (Guntur, 2017). Coastal areas are vulnerable to various natural phenomena such as tides, waves, and currents that play a role in changing coastal areas. For example, waves moving toward the coast undergo a wave transformation process that can damage the coastline (Nurlianti et al., 2022). Changes in the coastline can cause coastal damage and changes in the coastal land area (Kusumaningtyas, 2020). Other parameters, such as tide currents, influence water dynamics (Joesidawati, 2016). Changes that occur can be caused by abrasion or sedimentation that can disrupt coastal ecosystems and shipping activities. This problem must be addressed because coastal areas have many benefits, especially for the community or other parties who carry out activities around the coast. The many activities carried out around the coastal area will increase the coastal area's vulnerability to environmental changes.

Coastline change is a natural process that occurs continuously, caused by land use, currents, waves, and sediment movements (Istiqomah et al., 2018). Coastlines that experience accretion are indicated by land deposition, while abrasion is indicated by smaller land areas (Hadiyan & Nirwana, 2016). Coastline changes are caused by abrasion resulting from waves and ocean currents hitting the shoreline. In contrast, accretion occurs due to the accumulation of sediments originating from the mainland and deposited, mainly sediments passing through estuaries (Sihombing et al., 2017). River estuaries are vulnerable to shoreline changes because most coastal areas can experience sedimentation (Setiani et al. 2017).

Changes in the coastline take place in Padang Pariaman regency because it is on the coast or west coast of the island of Sumatra, which has relatively large waves. The dynamics of the west coast of the island of Sumatra are strongly influenced by waves from the Indian Ocean that reach the coast and cause an attrition process. At the same time, in the upstream areas, intensive land erosion is characterized by an ample supply of sediment supplied by the river flows to the sea (Solihuddin, 2011). The existence of natural and human factors causes the beach to suffer from environmental degradation from year to year in the form of abrasion, causing damage to various facilities and infrastructure for beach tourism objects and the coastal ecosystem (Azman, 2010).

Sedimentation or accretion is a process of expanding new land or a process of siltation tending towards the sea due to sediments undergoing deposition and then being carried away by seawater (Satyanta, 2016). Abrasion is a natural process in the form of soil erosion in coastal areas caused by waves and currents that can disrupt the natural balance in the area. Natural factors and human factors cause the phenomenon of abrasion in coastal areas. Natural factors were occurring in coastal areas, such as changes in current patterns, tides, and waves, as research shows that the activity of currents, waves, and sea tides causes increased wear problems in coastal areas. In addition, human factors influencing wear are community activities around coastal areas, such as development resulting in subsidence and shoreline changes (Mahendra et al., 2017).

2. RESEARCH METHODS

Time and Place of Research

This survey was conducted in February - April 2023. Sampling occurred in the coastal area between Batang Anai Estuary and Batang Mangur Estuary, Padang Pariaman Regency, West Sumatra Province. Primary data collection was performed directly at the study site, and data analysis was performed at the Physical Oceanography Laboratory, Department of Marine Science, Faculty of Fisheries and Marine Sciences, University of Riau.

Method

The method used in this study is a survey method, i.e. direct observation and sampling in the field to obtain primary data. Observation points are determined by a purposive sampling method based on the representativeness of the object under study. Data were analyzed using descriptive analysis methods via remote sensing systems. Analysis of remote sensing data was performed using DSAS, an End Point Rate (EPR) approach used to calculate the rate of change of the shoreline by dividing the distance between the oldest shoreline and the current shoreline over time where a positive distance (+) means that the coastline is advancing. Data that is negative (-) means that the coastline is receding (Setiani et al., 2017).

Procedure

Determination of Research Stations

This research was carried out in the coastal area between the mouth of the Batang Anai and the mouth of the Batang Mangur in the province of West Sumatra. The two estuaries are about 20 km apart. For data and sample collection will be divided into 5 stations: station 1 is located at the mouth of Batang Anai estuary, station 2 is located in an area where aquaculture activities are around it, stations 3 and 4 are located in coastal areas where there is visitor activity and station 5 is located in the mouth of the Batang Mangur estuary (Figure 1).

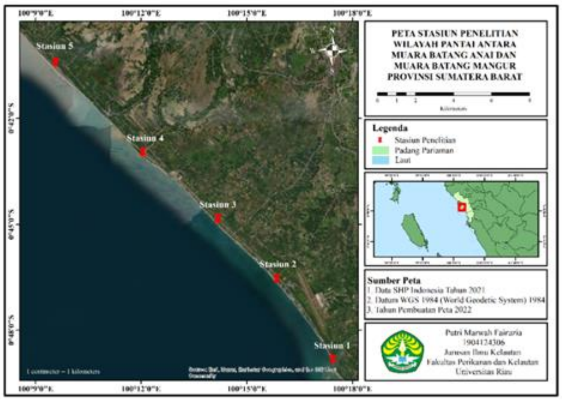

Figure 1. Research station map

Current Measurement

The current speed is measured using a current lead with a rope length of 2 m. The current pilot is simultaneously released into the water by activating the stopwatch. Then, wait for the rope to stretch and record the time fully. The current speed is measured using a current drogue three repetitions at each station so that the measurement results obtained do not have too significant a deviation. A compass is used to determine the direction of the current. The current speed is measured at 5 station points in the coastal area between Batang Anai Estuary and Batang Mangur Estuary. Actual speed data obtained in the field is processed using the equation (Manik, 2017), namely:

$$v = \frac{s}{t}$$

Information:

v = current speed (m/s)
s = distance
t = time (s).

Measurement of Wave Parameters

The wave height is obtained by using a scaling pole by floating a scaling pole in the water, then recording the water boundary at the time of the trough and the wave crest within a specific period where the wave trough is the lowest point of the wave and the wave crest is the highest point of the gulf. Receive wave data 3 repetitions at each station so that the measurement results obtained have little deviation. The acquired wave data is then processed using the equation, namely:

Wave height : $H = H_{max} - H_{min}$

Wavelength : L = 1,56 x T2

Wave period : $$T = \frac{t}{n}$$

Wave energy : $$E = \frac{\rho g h^2}{8}$$

Information :

H	=	Average wave height (m)
H_{max}	=	Highest wave height (m)
H_{min}	=	Lowest wave height (m)
T	=	Wave period (seconds)
t	=	Wave observation time (sec)
N	=	Number of wave observations
L	=	Wavelength (m)
T	=	Wave period (seconds)
E	=	Total energy (Nm/m^2)
ρ	=	Density of seawater (1024 kg/m^2)
g	=	Gravitational force (9.8 m/s^2)
h	=	wave height (m)
1/8	=	A constant value of wave energy crashes

Sediment

Sediment sampling using a sediment trap installed for 14 days. Sediment traps are installed at 5 points at the observation site. Sediment samples caught in the sediment trap are placed in plastic and analyzed at the Physical Oceanography Laboratory, Department of Marine Science, Faculty of Fisheries and Maritime, Universitas Riau. The calculated sediment accumulation is the weight and volume of the deposited sediment per unit volume of the sediment trap per time, referring to the procedure of Rifardi (2012). The formula calculates the weight of sediment deposited per unit area:

$$KA = \frac{W/V}{t}$$

Information :

KA	=	Speed of accumulation ($g/cm^3/day$)
W	=	Dry weight of sediment (g)
V	=	Sediment trap volume (cm^3)
t	=	Installation time of the sediment trap (day)

Sediment fractions were analyzed using sieve or wet sieve methods. The results of the analysis of sediment fractions from the wet sieve method were used to obtain the mean diameter or mean size (Mz) obtained from the graphical method (Rifardi, 2001).

Image Data

The secondary data used in this study was downloaded from the website https://earthexplorer.usgs.gov/. The image data used in processing this data is Landsat 5 image data for 1993, 2003, 2013, and Landsat 8 2023.

Shoreline Changes

Coastline changes are identified by digitizing the shoreline on each image using on-screen digitization. Numerical changes are made using DSAS (Digital Shoreline Analysis System). The necessary data consists of two primary data, namely shoreline and baseline data, which are manually digitized over the image. After all the necessary data is available and the procedures are performed, the results are obtained, i.e., transverse lines along the baseline. The distance between the two coastlines is entered to calculate shoreline speed using the EPR (End Point Rate) statistical method.

$$EP = \frac{\text{The distance between the two coastlines (m)}}{\text{The second-year span of the coastline (year)}}$$

Data Analysis

The analysis of the obtained data will be processed quantitatively and then described descriptively based on the literature regarding bank changes. The processed data is then presented in map form. The analyzed data will produce accretion and beach wear values classified into 3 categories: high wear, medium wear, and low wear. Subsequently, the primary and secondary data were analyzed using Microsoft Excel. Image data for shoreline changes were analyzed using DSAS (Digital Shoreline Analysis System) software and

ArcGIS 10.4. The wear calculation is statistically analyzed using the EPR (End Point Rate) method. The analysis results of shoreline changes processed using ArcGIS 10.4 are associated with sedimentation processes, currents, and waves in the study area and are discussed descriptively.

3. RESULT AND DISCUSSION

General Conditions of Research Locations

Padang Pariaman is a district with the smallest area of West Sumatra. The topography of Padang Pariaman Regency includes a sizeable tropical climate with a very short dry season, and the marine area is strongly influenced by winds coming from the sea. The dynamics of the Padang Pariaman beach are strongly influenced by strong waves and currents that reach the coast from the Indian Ocean (P3GL, 2004). The dominant abrasion process takes place along the coast. In contrast, the sedimentation process takes place in the upstream region, characterized by an ample supply of sediment carried to the sea by rivers.

Wave

Wave data obtained at each station can be seen in Table 1.

Table 1. Average wave parameters

Station	Height (m)	Period (s)	Length (m)	Fast propagation (m/s)	Energy (nm/m^2)
1	0,52	5,58	48,58	8,7	331,97
2	0,49	5,37	45,12	8,37	299,13
3	0,36	5,82	53,05	9,09	162,56
4	0,13	4,7	34,51	7,33	22,54
5	0,58	4,16	27,1	6,5	408,21

Table 2. Average speed and direction of current

Station	X (Longitude)	Y (Latitude)	Current speed (m/s)	Current direction
1	100.289504	0.812256	0,28	311^o NW
2	100.260516	0.773660	0,27	213^o SW
3	100.200993	0.717996	0,28	252^o SW
4	100.183241	0.699905	0,19	305^o NW
5	100.158524	0.675833	0,21	240^o SW

Table 3. Sediment accumulation rate data

Station	Sediment Weight (g)	Sediment Trap Volume (cm^3)	Accumulation Rate (g/cm^3/day)
1	679,48	769,3	0,06309
2	641,28	769,3	0,05954
3	563,48	769,3	0,05232
4	330,33	769,3	0,03067
5	370,72	769,3	0,03442

Based on the observations made, the average wave height in the coastal area between Batang Anai Estuary and Batang Mangur Estuary consists of low and very low categories. The average wave height in the low category ranging from 0.5 – 1 m can be found at stations 1, 2, and 5 and the very low category <0,5 m can be found at stations 3 and 4. The highest average wave period is at station 3 with a value of 5.82 s and the lowest is at station 5 with a value of 4.16 s. The highest average wavelength is at station 3 with a value of 53.05 m and the lowest is at station 5 with a value of 27,1 m. The highest average wave speed is found at station 3 with a value of 9.09 m/s, while the lowest value is at station 5 with a value of 6.5 m/s. The highest average wave energy is at station 5 with a value of 408.21 nm/m^2 and the lowest value is at station 4 with a value of 22.54 nm/m^2.

Current Speed and Direction

The current speed and direction data obtained at each station can be seen in Table 2. Based on the observations made, the current velocity in the coastal area between Batang Anai Estuary and Batang Mangur Estuary consists of slow and medium categories. The average flow velocity of the slow category ranges from 0–0.25 m/s at stations 4 and 5.

Meanwhile, the average flow velocity in the medium category is 0.25 – 0.5 m/s at stations 1, 2, and 3. The highest average flow rate is at station 1, and the lowest is at station 4.

Sediment

The results of the sediment accumulation rate obtained at each station are shown in Table 3. The analysis results performed in the laboratory, the sediment accumulation rate at each station ranges from 0.03067 – 0.06309 g/cm^3/day, with the highest accumulation rate being at station 1. The lowest at station 4 estuary area the river is a high productivity area because the estuary area experiences the addition of organic and inorganic materials originating from the land flowing through the river and the surrounding waters that occur continuously. Sedimentary material, including organic material carried by water currents and sedimentary material, is carried to the river estuary and will settle in that area. The accumulation rate can be caused by several factors, such as the area of the estuary, river discharge, currents, and tides in the area (Srijati et al., 2017).

Sediment Characteristics

The results of the analysis of the average diameter value (Mz) of sediments in the coastal area between Batang Anai Estuary and Batang Mangur Estuary range from 0.15 – 0.83 which are included in the coarse sand category.

Table 4. Average diameter value (mean size)

Station	Mean Size (Φ)	Classification
1	0,83	Coarse Sand
2	0,63	Coarse Sand
3	0,4	Coarse Sand
4	0,15	Coarse Sand
5	0,16	Coarse Sand

Shoreline Changes in 1993-2003

Shoreline changes at each research station from 1993-2003 are shown in Table 5. Table 5 shows a change in the shoreline in the High Abrasion and Accretion categories. Accretion took place at station 1 (10.09 m/year), station 2 (4.87 m/year), station 4 (13.82 m/year) and station 5 (6.08 m/year). Shoreline changes categorized as high abrasion occur at station 3 with a value of –5.33 m/year.

Table 5. Shoreline changes at each research station 1993-2003

Station	Value (m/year)	Category
1	10.09	Accretion
2	4.87	Accretion
3	-5.33	High Abrasion
4	13.82	Accretion
5	6.08	Accretion

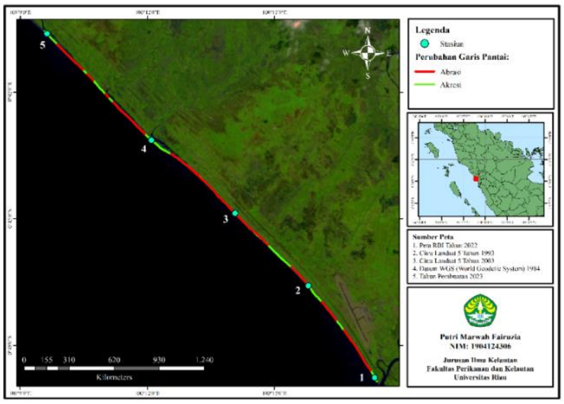

Figure 2. Shoreline changes in 1993-2003

The results of the percentage change in coastline status from 1993 to 2003 in the coastal area between Batang Anai Estuary and Batang Mangur Estuary can be seen in Table 6.

Table 6. Percentage of shoreline change status 1993-2003

Shoreline Changes in 1993-2003		
Status	Number of Transects	Percentage (%)
High Abrasion	6	3.35
Moderate Abrasion	12	6.7
Low Abrasion	62	34.63
Stable	62	34.63
Accretion	36	20.11
Total	179	100 %

The shoreline changes from 1993 to 2003 had 179 transect lines with a distance of 100 m between lines that can be observed based on the occurrence of high abrasion, moderate abrasion, low abrasion, stable, and accretion in the coastal area between Batang Anai Estuary and Batang Mangur Estuary. The transect line that forms the intersection with the coastline has coordinate values and the difference in distance. From the value of the difference in distance to the calculation basis, the basis for calculations is the 1993 coastline. The results showed that changes in the coastline occurred in the coastal area between Muara Batang Anai and the mouth of Batang Mangur from 1993 to 2003 was dominated by low wear (34.63%; on 145 transect lines), stable (34.63%; on 62 transect lines) and accretion (20.11%; on 26 transect lines).

Shoreline Changes in 2003-2013

Shoreline changes at each research station from 2003-2013 are shown in Table 7.

Table 7. Shoreline changes at each research station 2003-2013

Station	Value (m/year)	Category
1	-1.53	Moderate Abrasion
2	2.65	Accretion
3	0.09	Stable
4	13.82	Accretion
5	6.19	Accretion

Based on the table above, there is a change in the coastline in the moderate abrasion, stable, and accretion categories. Moderate abrasion occurs at station 1 (-1.53 m/year), station Changes in the coastline categorized as accretion occurs at station 2 (2.65 m/year), station 4 (13.82 m/year), and station 5 (6.19 m/year). Changes in the coastline that are categorized as stable occur at station 3 with a value of 0.09 m/year. However, changes in the high abrasion moderate abrasion coastline category also occur at several other points along the coastal region between Batang Anai Estuary and Batang Mangur Estuary, as seen in Figure 3.

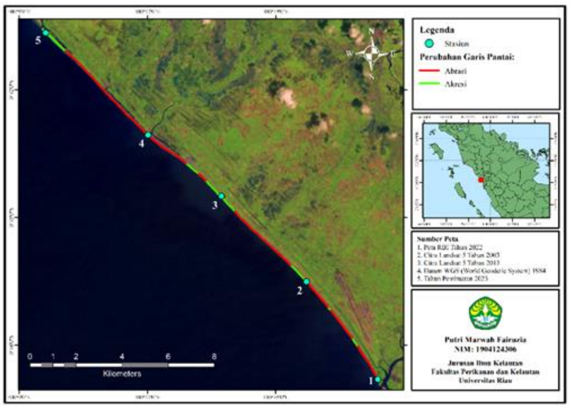

Figure 3. Shoreline changes in 1993-2003

The results of the percentage change in shoreline status in 2003-2013 in the coastal area between Batang Anai Estuary and Batang Mangur Estuary can be seen in Table 8.

Table 8. Percentage of Shoreline Change Status in 2003-2013

Shoreline Change Status in 2003-2013		
Status	Number of Transects	Percentage (%)
High Abrasion	67	31.01
Moderate Abrasion	33	15.27
Low Abrasion	53	24.53
Stable	29	13.42
Accretion	33	15.27
Total	216	100

Shoreline changes in 2003-2013 had 216 transect lines with ten distances between lines that can be observed based on the occurrence of high wear, moderate wear, low wear, stable, and accretion in the coastal area between Batang Anai Estuary and Batang Mangur Estuary. The basis for calculations is the 2003 coastline. The results showed that the coastline changes that occurred in the coastal area between Batang Anai Estuary and Batang Mangur Estuary from 1993 to 2003 were dominated by the high abrasion category (31.01%; on 67 transect lines) and low abrasion (24.53 %; at 53 transect lines).

Shoreline Changes in 2013-2023

Shoreline changes at each research station from 2013-2023 are shown in Table. 9

Table 9. Coastline changes at each research station in 2013-2023

Station	Value (m/year)	Category
1	-1.57	Moderate Abrasion
2	2.21	Accretion
3	-1.39	Moderate Abrasion
4	-3.46	High Abrasion
5	0.25	Low Abrasion

Based on Table 9, there is a change in the coastline in the categories of high wear, Moderate wear, Low wear, and accretion. High wear occurs at station 4 with a value of -3.46 m/year. Moderate wear occurs at stations 1 (-1.57 m/year) and 3 (-1.39 m/year). Low abrasion occurs at station 5 with a value of 0.25 m/year. Coastline changes categorized as accretion occurred at station 2 with a value of 2.21 m/year.

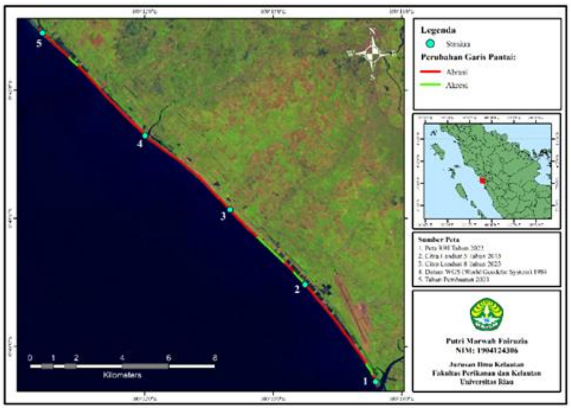

Figure 4. Shoreline changes in 2013-2023

The results of the percentage change in coastline status in 2013-2023 in the coastal area between Batang Anai Estuary and Batang Mangur Estuary can be seen in Table 10.

Shoreline changes in 2013-2023 have 216 transect lines with 10 distances between lines that can be observed based on the occurrence of high wear, moderate wear, low wear, stability, and accretion in the coastal area between Batang Anai Estuary and Batang Mangur Estuary. The basis for calculations is the 2013 coastline. The results showed that the coastline changes that occurred in the coastal area between Batang Anai Estuary and Batang Mangur Estuary from 1993 to 2003 were dominated by the high abrasion category (41.66%; on 90 transect lines) and low abrasion (24.53 %; at 53 transect lines).

Table 10. Percentage of shoreline change status in 2013-2023

Shoreline Change Status in 2013-2023		
Status	Number of Transects	Percentage (%)
High Abrasion	90	41,66
Moderate Abrasion	25	11,57
Low Abrasion	53	24,53
Stable	25	11,57
Accretion	23	10,64
Total	216	100

Shoreline Changes in 1993-2023

Shoreline changes at each research station from 2013-2023 are shown in Table 11. Based on Table 11, there is a change in the coastline in the moderate wear and low wear categories. Moderate wear occurs at station 2 with a value of -1.6 m/year. Low wear occurred at station 1 (-0.3 m/year), station 3 (0.46 m/year), station 4 (-0.25 m/year) and station 5 (0.07 m/year).

Table 11. Changes in coastline at each research station in 2013-2023

Station	Value (m/year)	Category
1	-0,3	Low Abrasion
2	-1,6	Moderate Abrasion
3	0,46	Low Abrasion
4	-0,25	Low Abrasion
5	0,07	Low Abrasion

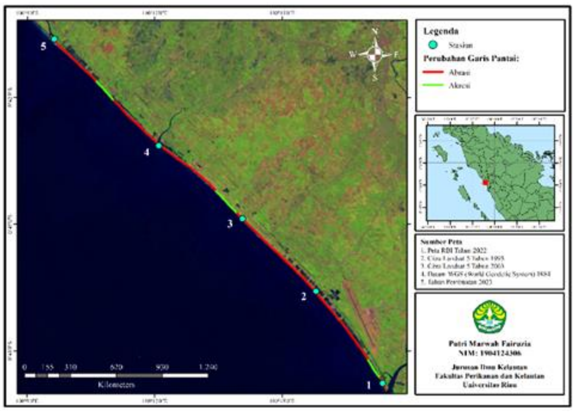

Figure 5. Shoreline changes in 1993-2023

The results of the percentage change in coastline status from 1993 to 2023 in the coastal area between Batang Anai Estuary and Batang Mangur Estuary can be seen in Table 12.

Table 12. Percentage of shoreline change status in 1993-2023

Shoreline Change Status in 1993-2023		
Status	Number of Transects	Percentage (%)
High Abrasion	11	5,14
Moderate Abrasion	43	20,09
Low Abrasion	131	61,21
Stable	25	11,68
Accretion	4	1,86
Total	214	100

The coastline change from 1993 to 2023 has 214 transect lines with 10 distances between lines that can be observed based on the occurrence of high abrasion, moderate abrasion, low abrasion, stability, and accretion in the coastal area between Batang Anai Estuary and Batang Mangur Estuary. The basis for calculations is the 1993 coastline. The results showed that the coastline changes that occurred in the coastal area between Batang Anai Estuary and Batang Mangur Estuary from 1993-2023 were dominated by the low abrasion category (61.21%; on 131 transect lines) and moderate abrasion (20,09 %; at 43 transect lines). The wear that occurs reaches ±150 m with a rate of change of ±1.63 m/year.

Coastline Change Analysis

Based on the results of image data processing on the shoreline change map, information is obtained that along the coastal area between Batang Anai Estuary and Batang Mangur Estuary, Padang Pariaman Regency, shoreline changes appear to be in the form of abrasion and accretion. In 1993-2023, there was a change in the coastline dominated by Low Abrasion. Currents and existing coastal vegetation influence abrasion in coastal areas (Aris et al., 2015).

The wear over 30 years has reached ± 150 m with a rate of change of ± 1.63 m/year. During the 1993-2003 coastline, wear reached -3.62 m/year with an average rate of change of 2.67 m/year, while accretion reached 2.67 m/year with an average rate of change of 2.29 m/year. At the five research station points, the average rate and distance of changes occurring are caused by the lack of community activities around the research station and the influence of currents and waves that are not too high in the river estuary area. In 2003-2013, the coastline changed with wear to -5.22 m/year with an average rate of change of 3.09 m/year, while accretion reached 9.93 m/year with an average rate of change of 4.3 m/year.

In 2003-2013, the coastline experienced relatively high abrasion caused by natural phenomena, namely a magnitude 7,6 earthquake with the location of the earthquake near Padang Pariaman Regency, which made the beach abrasion relatively high compared to previous years. Challenging waves are one of the causes of the rapid wear process, especially in areas that need to be protected by complex infrastructure to withstand wear and coastal protection plants (Octavian et al., 2022). At stations 2, 3, 4, and 5, located in coastal tourist areas and an estuary, fouling occurs due to coastal defense structures almost along the coast, proving that the groins function effectively as coastal stability buildings. Still, at Station 1, there are no coastal defense structures. The environment is subject to wear and tear. Currents and waves at the site are relatively low, so they do not cause high abrasion, but abrasion occurs due to factors of other natural phenomena. In addition to the threat of disasters that often occur in coastal areas and sudden threats such as earthquakes, tsunamis, tidal waves, and others, there is also a graded threat, namely abrasion (Wisyanto, 2019).

Due to changes in the coastline in 2013-2023, wear reached -6,68 m/year with an average rate of change of 3,78 m/year, while accretion reached 4,33 m/year with an average rate of change of 2,88 m /year. In 2013 – 2023, the coastline will experience a lot of wear due to various causes such as sea tides, relatively high waves, sea level rise, and a lack of breakwaters in some areas. Extreme weather that occurs can also cause the wear process to accelerate (Octavian et al., 2022), while siltation occurs in areas around estuaries, caused by the movement of sediment from estuaries and the sea, resulting in silting. Abrasion is also caused by changes in coastal morphology due to community and tourism activities around the coastal area. Various developments around the coastal area can be a factor in the occurrence of wear. Lack of coastal protective vegetation and breakwaters can cause abrasion as beach material is carried to the ocean by waves and currents (Setiani et al., 2017).

Based on the research results, the most significant change on the coast occurs as abrasion caused by the interaction of hydro-oceanographic factors. The movement of ocean currents parallel to the coast causes wear. Parallel currents generally experience abrasion because parallel currents carry sediment. The direction of the current is influenced by the direction of the waves coming to the beach, where the wind generates the waves and causes beach erosion. In addition, the beach at the research location is sloping and sandy, so the giant waves that come ashore from the sea cause beach erosion. Accretion occurs in estuaries, caused by sediment movement from estuaries and the sea, causing silting.

Accretion occurs relatively quickly in a coastal area adjacent to a river estuary, forming new land and enlarging the existing land area (Muryani, 2010). Accretion occurs in coastal waters adjacent to estuaries and areas of low wave and storm energy (Istiqomah et al., 2016). Accretion occurring in coastal areas is due to marine sand sedimentation by coastal areas and various development factors implemented in coastal areas to improve the quality of tourism (Driptufany, 2020). The coastline has a dynamic character, so it can quickly change. Coastal waters are areas still affected by activities from the mainland. Coastline changes also occur due to the movement of coastal currents, sediment movements, waves, and anthropogenic activities (Istiqomah et al., 2018).

Effect of Currents and Waves on Abrasion and Accretion

Based on observations at the study site, the current speed at each station falls into the slow to moderate category, with values ranging from 0.18 – 0.28 m/s. The wave height at each station is classified as low and very low, with values ranging from 0.1 to 0.6 m. The data available on the Agency for Meteorology, Climatology, and Geophysics website for 2023 corresponds to the data obtained at the research location. The relatively low currents and waves are believed to be due to the sloping topography of the coastal area. Currents and waves carry sediment particles from the river, causing accretion in several coastal areas.

Factors that can influence wear and fouling are waves and currents. Coastal abrasion in the area is believed to occur due to natural processes such as sea waves, tides, wind, and coastal currents. Waves are created by the movement of water masses and are generated by winds perpendicular to the coast. The greater the speed of the wind blows, the greater the waves are generated. When the waves reach the shore, they will propagate in all directions carrying energy and then be released as waves. The waves form an angle of attack towards the coast, which can cause coastal currents, and these currents play an essential role in the distribution pattern of sediment along the coast and cause wear and accretion. The waves in the breaking wave area contain powerful energy and play a crucial role in forming coastal morphology. Breaking waves can move or transport material from the sea to the beach, resulting in material build-up on the beach.

Waves in accretion areas are constructive or beach-forming, so these waves tend to deposit beach material. There are several areas of accretion with slow currents and close to estuaries. According to Setiani et al. (2017), sedimentation from estuaries can also cause fouling. Currents in the slow category indicate an area of accretion protected from currents and waves. In areas of abrasion, some waves are destructive to the beach and can erode the beach. Although waves and currents are low in the dominant coastal area, other factors can cause abrasion in some areas, such as minimal vegetation to protect the coast and a lack of breakwaters (Putra, 2019).

The Effect of Sedimentation on Shoreline Changes

Sedimentation is a process of silting up or adding coastal land due to sediment deposition carried by seawater, deposition occurring naturally through the sedimentation process (Halim et al., 2016). Oceanographic factors such as currents and waves can influence sediment size distribution, especially for suspended sediments (Purnawan et al., 2012). The difference in the size of the sediment diameter affects the speed of the sediment transport process. Coarse particles will be deposited near the source, while the finer currents and waves transport the particles, the further they will be deposited from the source (Rifardi, 2012).

Coastline changes in an area can occur due to sedimentation that upsets the balance of coastal ecosystems. As a result of sedimentation, the coastline tends to shift. High sedimentation can also cause the shape of the beach to become sloping. A sloping beach shape occurs on several beaches between Batang Anai Estuary and Batang Mangur Estuary, making it easier for currents to carry suspended particles to the beach, causing sedimentation. Fresh water that enters upstream and carries sediment from the land will settle in the mouth of the river, and the rest will be directed to the sea.

Based on the observations made, the sediment diameter at each station in the coastal area between Batang Anai Estuary and Batang Mangur Estuary, Padang Pariaman Regency, is classified as coarse sand with a value of 0.1 – 0.83 Φ and is included in the unstable sediment category with relatively rapid transfer. According to Dianawati & Santosa (2016), beaches with fine particles have a high level of resistance to beach abrasion, while large particles (sand) are an essential factor in the abrasion process. The sediment accumulation rate at each station ranges from 0.03067 – 0.06309 g/cm^3/day, with the highest accumulation rate at station 1 and the lowest at station 4. Accretion is occurring, and the Padang Pariaman Regency area is watching directly out to the Indian Ocean so that sediment sources from the high seas undergo a transport process that is ultimately deposited in sediments.

4. CONCLUSIONS

Based on image processing using the Digital Shoreline Analysis System (DSAS), it is known that there has been a change in the coastline dominated by Low Abrasion. In 1993 – 2023, there was a change in the coastline in the form of wear reaching ± 150 m with a rate of change of ± 1.63 m/year. 1993-2003, with a maximum change of 3.63 m/year and accretion with a maximum value of 2.67 m/year. In 2003-2013, changes in the coastline were dominated by High Abrasion with a maximum value of 5.11 m/year and accretion with a maximum value of 9.93 m/year. In 2013-2023, it is dominated by High Abrasion with a maximum value of 6.68 m/year and accretion with a maximum value of 4,33 m/year. The wear at the research station is classified into high, medium, and low categories. Accretion also occurred around the research station, and some areas did not undergo significant changes or remain stable from 1993 to 2003. Currents in the coastal area between Batang Anai Estuary and Batang Mangur Estuary, Padang Pariaman Regency, fall into the slow - moderate category with an average value of ± 0.19 – 0.28 m/s. Wave height falls into the shallow–low category with an average value of ± 0.1 – 0.58 m. Although currents and wave heights belong to the low category, some areas without coastal vegetation and breakwaters may experience erosion and silting.

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