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Analysis of Coastline Changes in Padang Pariaman Regency, Indonesia: The Influence of Hydro-Oceanographic, Anthropogenic and Sedimentation Factors on Coastal Dynamics

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ABSTRACT

Shoreline changes on the coast of Padang Pariaman Regency are influenced by hydro-oceanographic and anthropogenic factors. Each village has different dominant factors. This research aims to 1. Analyze the contributing factors to changes in the village-by-village coastline. 2. Analyzing changes in village-by-village land cover in coastal areas. 3. Analyzing existing coastal protection buildings in each village. 4. Analyze the sedimentation contributions from the Limau and Batang Anai Rivers. This research uses a panel data regression method to determine the factors that influence shoreline changes, the Digital Shoreline Analysis System (DSAS) to determine shoreline changes, SAS Planet image analysis to calculate coastal protection structures, and the Jaelani algorithm to analyze sediment concentration. The study revealed that vegetation loss in Katapiang, Pilubang, Ulakan, and Tapakis villages significantly threatens coastal stability. Ineffective coastal protection exacerbates abrasion in these regions. Additionally, climate change increases the risk of threats to coastal areas. Land use changes in the watershed transport sediment to the estuary, causing coastal accretion and increasing the land area around Gisik Shoal. Overall, the coastline at the mouth of the Limau Watershed experienced more dominant accretion than abrasion owing to the high sedimentation process that occurred in 2003-2018. Simultaneously, the dominant shoreline change that occurred in the Batang Anai watershed is (abrasion). Each village has a different dominant shoreline change factor. Therefore, the solution applies to each region. Stakeholders must understand this condition to manage coastal areas more effectively.

INTRODUCTION

The dynamics of Padang Pariaman Beach are strongly influenced by the strong Indian Ocean currents reaching the coast, and the dominant abrasion process occurs along the coast. Padang Pariaman Regency has 6 sub-districts out of 17 sub-districts, which are coastal areas with a coastline length of ± 42.1km. Industrial and human activities characterize this region to fulfill daily life. If developed well, it will support the regional economy with great potential. Abrasion occurs every year due to changes in the wind direction, but in recent years, this has been the worst. Currently, the distance between the shoreline and residents' houses is approximately six meters, and it is feared that this distance is getting closer, considering how strong the waves are still hitting the area. This abrasion threatens several families in the area as well as the residents' coconut and oil palm plantations. Regulations governing coastal/coastal ecosystem problems are currently not available or somewhat weak, or there is a lack of patrolling/monitoring of the sustainability of coastal ecosystem functions; therefore, the use of these ecosystem resources is freer and less controlled. Ultimately, this will reduce the quality of coastal areas/beaches, which can disrupt the sustainability of their function (Val 2007).

Changes in coastlines in the form of accretion (sedimentation/buildup) and abrasion. Problems arise when sedimentation changes the form of the coastline, which can disrupt the coastal ecosystem and expand the area. When river discharge is high, siltation in the estuary can cause flooding. Therefore, it is necessary to carry out this research to determine which parts of this watershed have high abrasion and what the water quality is like, so that it does not disturb the coastal ecosystem. This will also be useful for monitoring coastal areas and their use in managing them more effectively.

The Limau and Batang Anai River Watershed is located in Padang Pariaman Regency. These two watersheds are the longest in Padang Pariaman Regency and economically support irrigation and fish cultivation activities. Along with the development of Padang Pariaman Regency, the pressure on the environment is automatically increasing, and there are fears that its carrying capacity will be exceeded. This will certainly give rise to various environmental problems in this area. The main issues that are of concern to policymakers in this area include critical land and land conversion, water pollution, overexploitation of mining in watersheds, solid waste, coastal ecosystem destruction, and social and health problems, such as concentrated community diseases (concentrated), population growth, poverty, public health, and other social problems (Val 2007).

Coastal dynamics is an ongoing process resulting from various coastal natural phenomena, such as land usage, wave action, longshore currents, and sediment movement. Changes in coastlines are generally caused by two factors: modification by humans (anthropogenic factor) and sea level rise (hydrooceanographic factor). Tides, in addition to permanent changes caused by abrasion and accretion, produce a unique space in that zone that is susceptible to change (Purwanty 2012, Geurhaneu & Susantoro 2016). River estuaries, runoff, and sediment, in combination with the location of the estuary, change the balance of land-sea interactions and cause abrasion or expansion of the coastline in various parts of the delta. Human activity is one of the main factors contributing to water and sediment changes.

The objectives of this study are: 1. Analyze the contributing factors to changes in the village-by-village coastline. 2. Analyzing changes in village-by-village land cover in coastal areas. 3. Analyzing existing coastal protection buildings in each village. 4. Analyze sedimentation contributions from the Limau and Batang Anai Rivers.

This study presents a more comprehensive approach to analyzing shoreline change in Padang Pariaman Regency by integrating hydro-oceanographic, anthropogenic, and sedimentation factors. Unlike previous studies that only focused on hydrodynamic processes or human-induced impacts, this study combined various analysis methods, such as panel data regression, DSAS for shoreline change detection, Planetary SAS for coastal protection assessment, and the Jaelani algorithm for sediment concentration analysis. This comprehensive approach provides a detailed understanding of the relationship between natural and human-induced shoreline changes. In addition, this study offers a site-specific analysis, highlighting local factors that influence erosion and accretion, which have rarely been explored in previous studies. These findings emphasize the importance of integrating land use management, sediment transport dynamics, and coastal protection infrastructure to develop more effective and region-specific coastal management strategies.

MATERIALS AND METHODS

Research Locations

The study was conducted across 10 villages in the Padang Pariaman coastal area to observe sea current patterns, identify influencing factors, and evaluate existing coastal protection structures. The findings can be applied to mitigate risks through the analysis and design of groyne construction. Take the example of the Limau and Batang Anai rivers to see changes in land use and sediment distribution in the Limau and Batang Anai rivers.

Materials and Methods. Remote sensing satellite technology has been used in various disciplines, and there are many satellites in both polar and geostationary orbits (continuously in the same position above the Earth's orbit). One of the polar orbit satellites is the Landsat series satellite, starting with Landsat-4 MSS (Multi-Spectral Scanner) with a spatial resolution of 80 m, Landsat-5 TM (Thematic Mapper), and Landsat-7 ETM (Enhanced Thematic Mapper) satellites with spatial resolutions of 30 m and 15 m, respectively (Prarikeslan et al. 2022). Landsat 8 with a resolution of 30 meters and 15 meters (Prarikeslan et al. 2022). Resolution and band length of Landsat 8 and Landsat 5 images. The separation of land and sea uses threshold values from band 5 on Landsat TM and ETM+ and band 6 on Landsat OLI/TIRS. The European Center for Medium-Range Weather Forecasts (ECMWF) website was used to download the wave data. The downloaded data included deep-sea wave height, breaking wave height, and wave period in netCDF (ns) format (Prarikeslan et al. 2022). The information was downloaded using the Padang Pariaman Regulation zone facility. Each information was at that point changed over utilizing the Sea Information See program. The information handled is everyday information that can later be looked for month-to-month midpoints with the assistance of the Microsoft

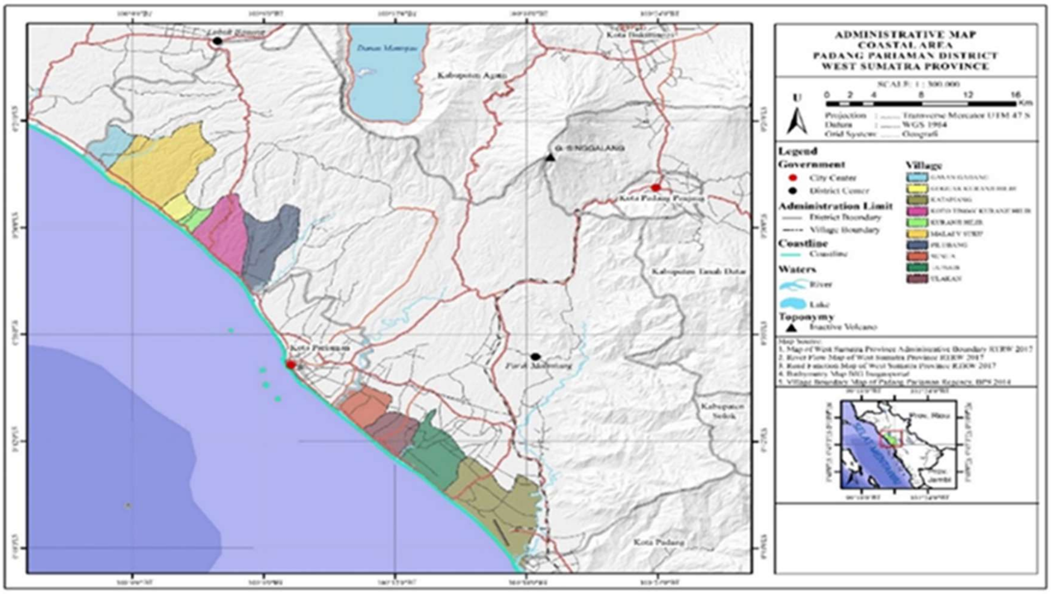

Fig. 1: Map of research locations.

Excel program. The effectiveness of coastal protection was analyzed by overlaying the coastline map before and after the groyne and conducting numerical simulations of the coastline by modeling the existing coastline.

In this study, the analysis of changes in the beach area showed that the distance of a change in the coastline is visible from the calculated statistics value. The method used to measure the distance of coastline changes between the oldest line and the newest coastline. In this method, a positive value (+) indicates that the coastline is advancing, and a negative value (-) indicates that the coastline is retreating. Data with a positive value (+) indicates accretion, and data with a negative value (-) indicates abrasion.

Wave data were obtained from the ECMWF website. The downloadable data are in the netCDF (ns) format and include the wave period, breaking wave height, and deep-sea wave height. The coordinates of the Padang Pariaman Regency region were used to retrieve the data.

Data Processing

Data processing in this analysis was performed using the R Studio program. The method of looking at factors that influence changes in coastlines uses panel data regressions. Panel data regression combines cross-sectional and time-series data to measure the same cross-sectional unit at different times. Therefore, data from multiple identical subjects observed during a specific time span become panel data. With panel data, we will have a total of NT observation units if we have T time periods (t = 1, 2,...) and N persons (i = 1, 2,...).). When all data points have the same number of time units, the data panel is said to be balanced. An imbalance. Other types of data include cross-sectional and time-series data. One or more variables will be tracked over a predetermined length of time in one observation unit in the time series data. In contrast, cross-sectional data consist of observations made at a single time from multiple observation units. (Lilja 2016).

The panel data regression model is expressed in Equation (1) (Li & Yang 2014).

$$y_{it} = X'_{it}\,\beta + Z'_{i}\,\alpha + \varepsilon_{it}$$
$$i = 1, \ldots, K, t = 1, \ldots, T \quad \text{....(1)}$$

where i denotes the unit cross-section of K, and t denotes the time of T. There are p independent variables in xit, excluding constants. Individual-specific effects are where Zi consists of constant and individual-specific effects, both observable and unobservable. β is the slope matrix of size px1.

Land cover changes were analyzed using an overlay of Landsat images and assessment methods. Land use changes were analyzed based on multi-temporal Landsat satellite image identification using the overlay method.

The area and distribution of sedimentation were determined by image processing and Total Suspended Solid (TSS) classification according to the algorithm. Therefore, the reflectance value becomes the TSS value. The TSS value was calculated based on the Jaelani equation (2016) as follows:

$$logTSS\left(\frac{mg}{l}\right) = 1.5212 * \left(\frac{logRrs(b2)}{logRrs(b3)}\right) - 0.3698 \quad \text{.... (2)}$$

Field surveys and statistical analyses were used to analyze the existing coastal structures.

RESULTS AND DISCUSSION

In most countries worldwide, the management of coastal areas, resources, and stakeholder rights is handled separately from watersheds. Including coastal areas as an integral part of watersheds is important because of the mutual relationship between coastal ecosystems and upstream areas. Ambiguities in coastal drainage and lowland boundaries due to multiple connections with estuaries, many small stand-alone coastal catchments, and asymmetry between surface and groundwater boundaries cause difficulties in hydrological delineation. In addition to these natural boundaries, various coastal management framework units, resource dependencies, and livelihoods pose additional boundary issues for sustainable coastal management. Considering multiple coastal zone boundaries within a watershed regime is important for resource sharing and authorized interventions in watershed decisions that compromise coastal ecosystems and livelihoods (Sreeja 2015, Ferrari 2019).

Factors That Influence Changes in Coastlines in Each Village in the Coastal Area of Padang Pariaman Regency

The hydro-oceanographic factor that influences changes in beach areas is the tide. Data from Padang Pariaman Regency from 1988 to 2003 to 2018 show that the tide height is increasing. In 2018, the highest tides were observed in Ulakan and Tapakis villages, whereas the lowest were observed in Gasan Gadang village. Koto Tinggi Kuranji Hilia village has the fastest wave propagation because it is deeper than the other villages, namely, 6.48m. The longshore current velocity was high at Koto Tinggi Kuranji Hilia village in 1988 because it had an angle.

The largest breaking wave occurred in 193 for 2003 and 2018 Gasan Gadang, because it has value because the angle of arrival of the breaking wave is large. Anthropogenic factors that influence changes in beach areas include changes in vegetation along the Padang Paraiaman coast. The largest reduction in vegetation land occurred in Katapiang village for both 1988-2003 and 1988-2018. The largest increase in land area occurred in the Malai V Suku village. Therefore, this reduction in coastal vegetation will increase the danger of

Table 1: Factors influencing changes in the coastline of each village in the Padang Pariaman District.

No.	Village	Factors influencing changes in beach area	
		Abrasion	Accretion
1	Gasan Gadang	Wave speed *** Current speed ** Tides *** Vegetation cover ***	Wave speed ** Current speed ** Tides **
2	Malai V Suku	Wave speed *** Tides ***	Wave speed *** Tides * Vegetation cover **
3	Guguak Kuranji Hilia	Wave speed *** Tides ***	Wave speed *** Vegetation cover *
4	Kuranji Hilia	Wave speed * Current speed **	Wave speed *
5	Koto Tinggi Kuranji Hilia	Wave speed ** Current speed ** Tides **	Tides *
6	Pilubang	Vegetation cover *	Wave speed *** Current speed * Tides * Vegetation cover ***
7	Sunua	Wave speed *** Current speed *** Tides *	Wave speed *** Vegetation cover ***
8	Ulakan	Current speed **	Wave speed ***
9	Tapakis	Wave speed ** Vegetation cover ***	Wave speed ** Vegetation cover ***
10	Katapiang	Vegetation cover **	Wave speed * Tides ** Vegetation cover **

***. Very influential
** . Influential
*. Less Influential
Source: Research data processing 2021

Table 2: Land Cover in Padang Pariaman.

CLASS NAME	Area 1999 [Ha]	Area 2003 [Ha]	Area 2018 [Ha]
Build	4433,00	3094,2	10268,01
Plantation	6769,71	9976,05	6989,49
Vegetation	8674,95	7516,89	282,06
Water	3670,70	2971,8	6221,07

coastal abrasion, terrestrial ecosystems from wind exposure, and reduced land stability due to the binding of sand to the surface by the interwoven roots of vegetation.

The influence of changes in beach area on hydro-oceanographic and anthropogenic factors in village-by-village shows that the 10 villages studied have different factors causing changes in beach area. More details are presented in Table 1.

Changes in Coastal Land Cover in Each Village in the Coastal Area of Padang Pariaman Regency

Over the past decades, the study of land use change has become a dominant research topic, as land use change has been recognized as one of the most important factors of environmental modification worldwide (Kakisina 2014, Sarkera 2019). More details are presented in Table 2.

Longstanding human pressures and fast-paced environmental changes have transformed forests and subtropical regions into some of the world's most threatened ecosystems, resulting in the loss of coastal ecosystem services and ecosystem services worldwide. Coastal vegetation protects us from storms and tidal waves and acts as a refuge for many globally threatened plant and animal species. However, these ecosystems are gradually experiencing high levels of pressure owing to historical and ongoing declines in freshwater flow in river systems and salinity intrusion. The population sizes of many threatened tree species have dropped substantially, mainly because of increasing salinity pressure (Sarkera 2019, Samin et al. 2016).

Planting trees in large numbers and densely along the coastline will form coastal forest stands, which can provide several benefits, including reducing beach abrasion, reducing beach sand abrasion, protecting land ecosystems from wind exposure, and stabilizing land by binding sand to the surface using the network. Vegetation roots accelerate the formation of new soil and habitat for flora and fauna, and improve the microclimate. The establishment of an initial stand of prawn cypress can then develop a supportive site for subsequent types of vegetation and protect the annual crop cultivation area behind the stand (Nugroho 2017, Tuheteru & Mahfudz 2012).

The results of research conducted in Padang Pariaman Regency show that there are several locations with a reduction in vegetation land area, namely Katapiang, Pi Lubang, Ulakan, and Tapakis villages, which will endanger the current condition of the coast. The land use situation and local social conditions, including the coastal land use situation and the daily lives of local communities, both existing and planned, are necessary. Land use data are required to determine the protection and areas available to reduce changes in coastal areas. Furthermore, everyday life situations (e.g., records of current interactions between local people and the forest, whether they extract materials from the trees for daily life) are essential for assessing the sustainability of vegetation and its future management and maintenance. Information about house materials is also important for determining the reduction in flow strength needed to protect houses near the coast (Diposaptono 2012, Pujianiki 2004). The availability of land along the coast for coastal vegetation must be clarified. Considering coastal vegetation as an effort to mitigate the dangers of changes in the beach area, a large area is required to work effectively.

Existing Coastal Protection Developments in Coastal Villages

A breakwater system can be used to protect the coast from waves approaching the shore parallel to the shoreline. The breakwater is composed of a set of separate continuous elements positioned at a distance of one wavelength from each other. Each breakwater dissipates some of the energy and reflects incoming waves, thereby reducing wave height and coastal abrasion. Sediments tend to be deposited in areas with lower wave energy, such as the sheltered area behind the breakwater.

Breakwaters typically have crest heights between +0.5 and +1.5 m and widths that vary depending on the energy scattered. These structures may also be lined with stone or concrete armor units, depending on wave intensity. The depth at the toe varies between 3 and 5 m and commonly matches the depth of the natural trunk (if it is present).

Effective shoreline protection is beneficial for reducing wave action on abrasion. Beach sediment is transported along the coast, moved to sheltered areas behind breakwaters, and deposited in areas with lower wave energy. More details are presented in Table 3.

Based on the data in Table 3, many beaches do not have coastal protection structures. The installation of non-optimal coastal protection will worsen the abrasion that occurs in the surrounding area. The coastal protection system is divided into active and passive defenses. The former results in a localized increase in beach sediment owing to wave reduction, which is often followed by an abrasion process. The second guarantees simple protection of the shoreline by separating the cause (waves) from the object of protection. This is based on the change in the form of the action of hydraulic factors, such as sea level variations and wave action. Hard and soft defense are types of protection systems. Hard-passive protection systems include appropriate breakwaters (elongated protection systems), which are placed on the beach as a reinforcing part of the beach profile. This structure is used in emergencies, is economical, is quickly executed, and provides an immediate protective effect. Split breakwaters and groins or narrow constructions, generally normal to the shoreline, are common constituents of hard-active protection systems. The combination of reflection and dissipation of incoming wave energy reduces the wave action. Breakwaters can be constructed as a set of small emergent or fully submerged structures (coupled breakwaters). Their depth is generally 3-4m, coinciding with the depth of the natural bar (if any). These structures vary in width depending on the energy dissipated.

Groynes are used to reduce the effects of transport along coasts. The effect of a single groyne is beach sediment accretion on the updrift side and abrasion on the downdrift side, both of which extend some distance from the structure. Commonly positioned 23 times its length and intercepting sediment transportation, it can extend from the backshore to the seaward limit of the surf zone (long groins). Parallel and normal breakwaters are usually armored rubble mound structures with stone or concrete protective units; however, there are also examples of structures made with alternative piles or (submerged) groynes made with sandbags. Soft protection systems include artificial ones, which are formed by sediment placed on eroded parts of the coast to compensate for the lack of a natural supply of coastal sediments. Sediment is extracted from seabed deposits or land and sieved to the appropriate size. If possible, grain diameters should be equal to or larger than the in-situ sediment to ensure that the maximum width increases with respect to the fill volume. Otherwise, it will require frequent and costly maintenance interventions. To reduce the number of periodic maintenance interventions, beaches can be protected by breakwaters, which limit sediment loss (generally submerged and parallel to the breakwater shoreline) and control the distribution of beach sediment along the shoreline (Benassai 2006, Nurisman 2018).

Sedimentation Contributions from the Limau and Batang Anai Rivers

Quantifying runoff and soil abrasion is a major challenge not only in water resource management and environmental planning, but also in irrigation, water, and wastewater systems. As water resources and sediment transport problems continue to grow, the demand for innovative approaches that provide a better understanding and management of water resources is increasing. More details are presented in Table 4.

From Table 4, it can be explained that in the 1988 period, the sedimentation value for Batang Anai was -1.37 $mg.L^{-1}$ to 1.77 $mg.L^{-1}$, and the sedimentation distribution area was 945 ha. Meanwhile, in 2003, the sedimentation value decreased to 0.39 – 1.18 mg/l, but the area of distribution increased to 1108 ha over the year period studied. The widest distribution was observed in 2003. Another thing happened in 2018: the sedimentation value increased compared to 2003, namely 0.58 – 1.19 $mg.L^{-1}$, and the distribution area decreased to 1,107 ha, which may be caused by changes in land cover, river currents, and the influence of climate or waves. The TSS analysis results are shown in the following Sedimentation Map: More shown in Figs. 2, 3 and 4.

Table 3: Data on the number of coastal protection structures in the coastal area of Padang Pariaman Regency.

No	Sub-districts	Beach Length [Km]	Village	Coastal Protection Buildings
1	Batang Anai	11.44	Ketaping	-
2	Ulakan Tapakis	8.38	Ulakan	2 jetty and 5 groin
			Tapakis	-
3	Nan Sabaris	1.68	Kurai Taji	-
			Sunua	-
4	Sungai Limau	11.76	Pilubang	1 jetty and 3 groin
			Kuranji Hilir	2 jetty
			Koto Tinggi Kuranji Hilir	-
			Guguak Kuranji Hilir	2 jetty
5	Batang Gasan	8.50	Malai V Suku	2 jetty
			Gasan Gadang	2 jetty

Source: Statistical Analysis System (SAS) Planet Satellite Image Data.

Table 4: Sedimentation in 1998, 2003, and 2018 in Batang Anai.

No.	Year	Sedimentation	
		Value [mg.L^{-1}]	Distribution [ha]
1.	1988	-1,37 – 1,77	945
2.	2003	0,39 – 1,18	1.108
3.	2018	0,58 – 1,19	1.107

Source: Data Analysis using GIS in 2021.

As seen in the map from the TSS analyzed in Figs. 2,3, and 4, around the Batang Anai estuary, the greatest sedimentation occurs, and the brown color indicates a high level of sedimentation, while other colors have smaller values along with changes in ocean bathymetry. The distribution of sediment along the Batang Anai coast from 1988, 2003, and 2018 can be seen. Sedimentation in the Batang Anai Estuary from 1988 to 2018 was caused by geological

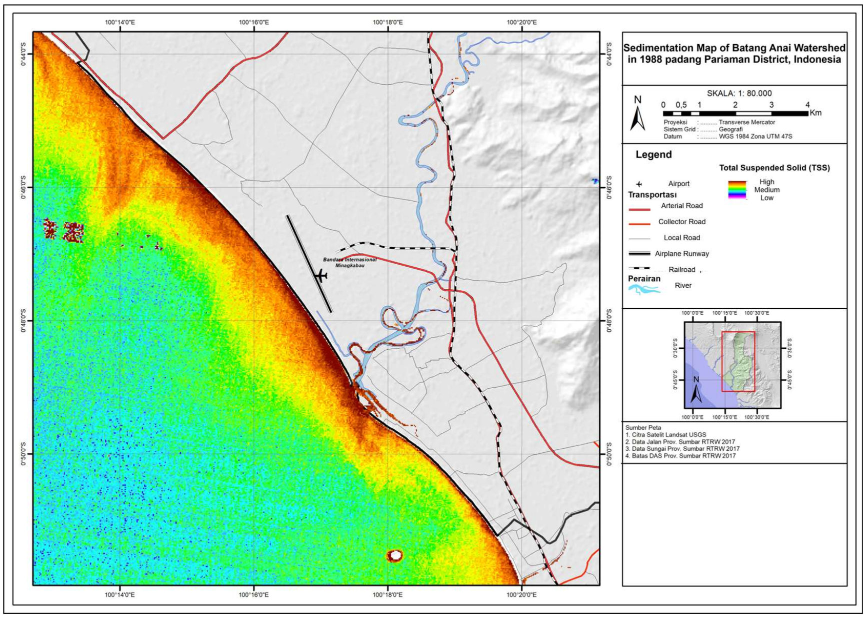

Fig. 2: Map of sediment distribution in 1988 in Batang Anai.

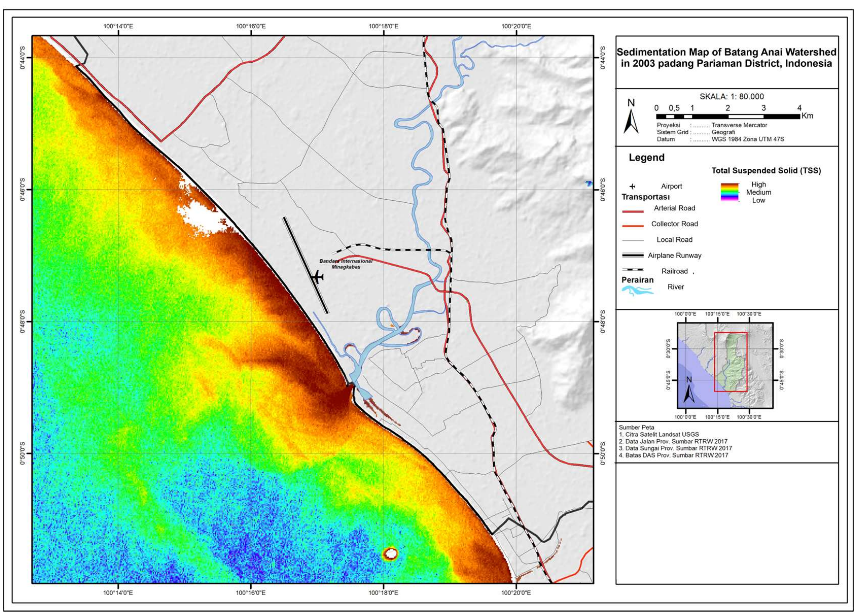

Fig. 3: Map of sediment distribution in 2003 in Batang Anai.

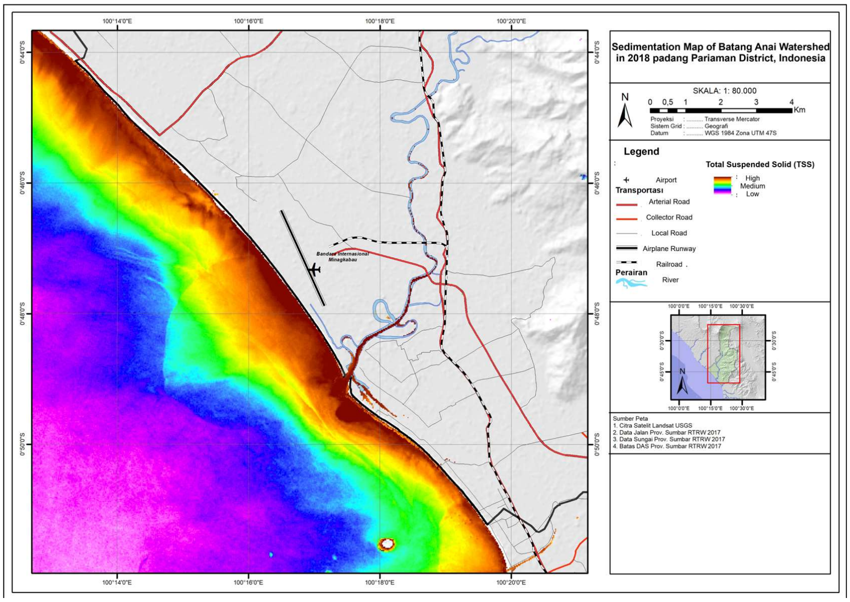

Fig. 4: Map of sediment distribution in 2018 in Batang Anai.

Table 5: Distribution of sediment in Sungai Limau village:

No.	Year	Sedimentations	
		Value [mg.L^{-1}]	Distribution Area [ha]
1.	1988	0,31- 1,91	957,28
2.	2003	0,99 – 1,85	826,32
3.	2018	1,16 – 2,12	1789,00

Source: Data Analysis in 2021

sedimentation processes, which caused changes in the coastline. The dominant coastline change that occurred in the Batang Anai watershed was (abrasion), which was caused by hydro-oceanographic factors. At the mouth of the river, sedimentation was influenced by land cover factors and sea currents, causing accretion at the mouth of the Batang Anai watershed. This is in accordance with the research of Ledheng & Hano'e (2023), who found that river estuaries

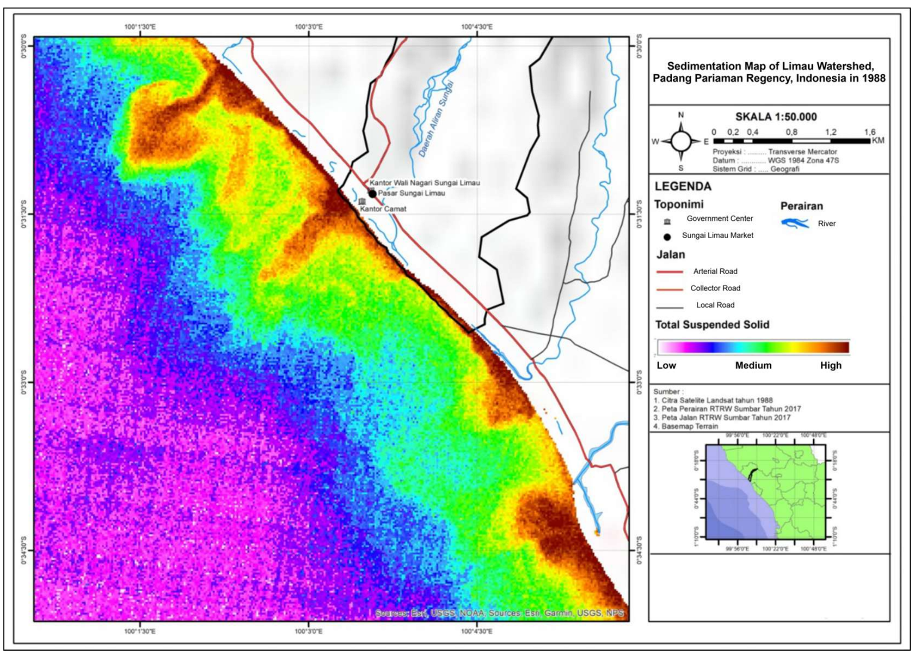

Fig. 5: Sediment distribution map of 1988 in the Limau Watershed.

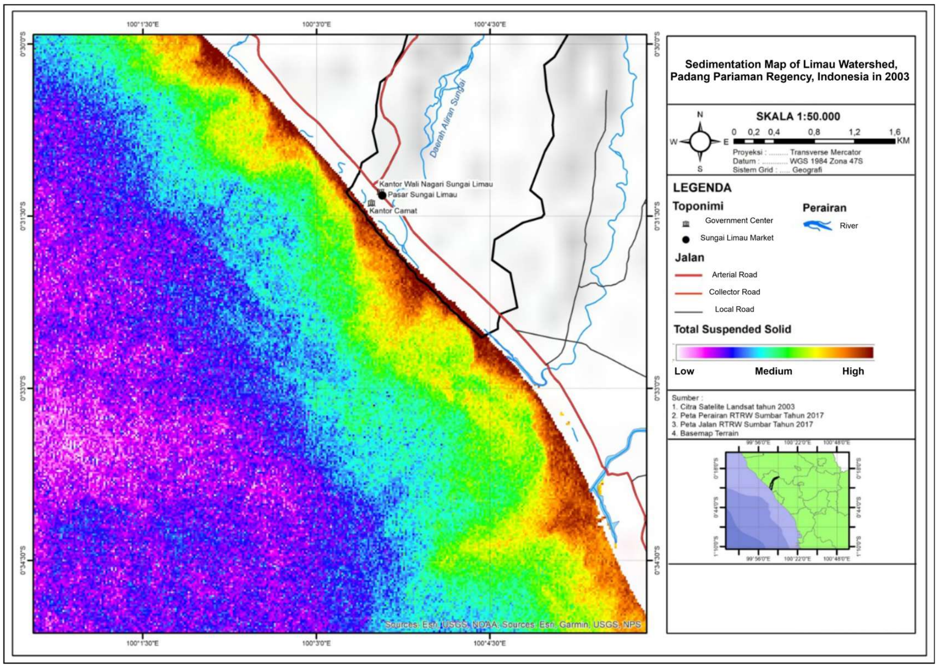

Fig. 6: Sediment distribution map of 2003 in the Limau Watershed.

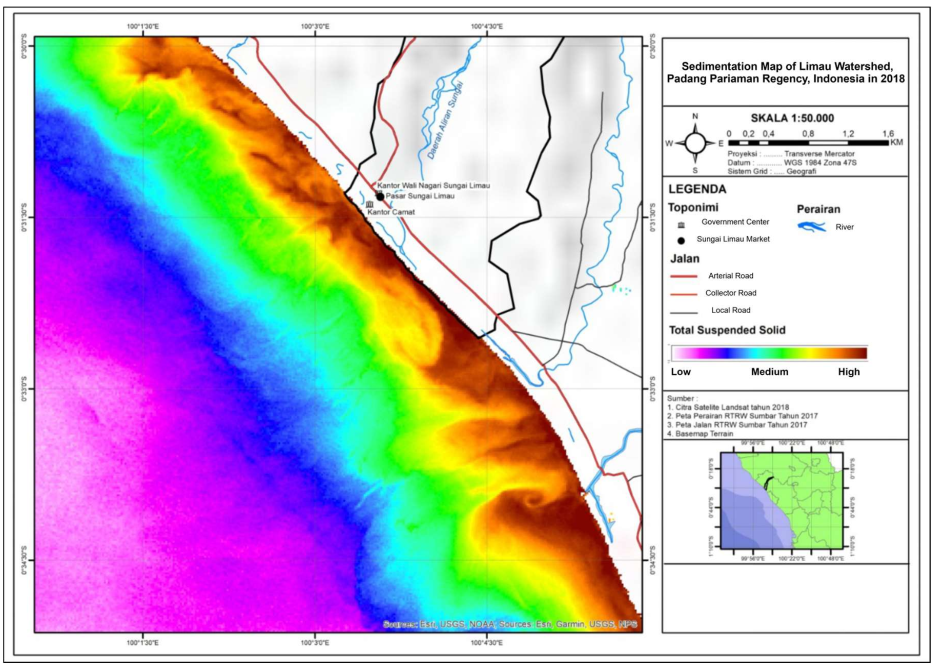

Fig. 7: Sediment Distribution Map of 2018 in the Limau Watershed.

tend to experience greater accretion than abrasion due to the large accumulation of sediment from the river. More details are provided in Table 5 and Figs. 5, 6 and 7.

Based on the research findings, changes in the coastline that occurred in the Limau watershed experienced deterioration (abrasion) and progress (accretion) of the coastline. Changes in coastlines affect the beach area. Changes in coastlines are caused by two factors: abrasion and accretion. The amount of abrasion and accretion brought each year is influenced by several factors, namely, land use change, which is a contributing factor in the center of a watershed that transports sediment material to the river mouth, causing coastal accretion, resulting in an increase in the land area around the Gisik Shoal. The abrasion process that occurs at river estuaries causes the land in the estuary to shrink and reduces the land area in coastal areas. Beach abrasion is caused by the transport of sediment, causing sediment to move from one place to another. Abrasion activity is increasing due to land use changes. Abrasion, an accretion or sedimentation phenomenon, occurs, resulting in land appearing in other places. Overall, the coastline at the mouth of the Limau Watershed experienced more dominant accretion than abrasion due to the high sedimentation process that occurred in 2003-2018. Changes in the coastline in the Limau Watershed occurred because they were influenced by sea waves, ocean currents, land cover changes, and tide events.

Several physical factors determine the biological production process in relation to phytoplankton turnover due to physical factors, including the frequency of destabilization of the water column, which determines the nutrient level in the mixed layer. The second is the average light intensity in the mixed layer, which is a function of freshwater runoff and solar radiation. Third, the average was in the mixed layer. Water bodies that receive runoff with high levels of clay will increase the turbidity of the water for a long time, especially during the rainy season, which will reduce light intensity and disrupt the photosynthetic activity of aquatic plants and reduce the ability of fish to search for food because their vision is blocked by particles. -sediment particles in water.

Global climate change is frequently assumed to be influenced by natural changes, although there is clear evidence that human activities have amplified climate change. As a driving factor, this puts multiple stresses on mangroves and other coastal ecosystems, especially temperature increases/fluctuations (both in air and water), increased CO_2 levels in the atmosphere and hydrosphere, changes in rainfall sometimes followed by flooding, rising sea levels, and extreme events in the atmosphere and hydrosphere, notably storms, hurricanes, cyclones, and El-Nino/Southern Oscillation (ENSO) patterns, all of which lead to increased wave action. Predicted increases in temperature and CO_2 levels will probably increase the photosynthesis and growth rates of mangroves and may, in fact, cause mangroves to move downward, thus increasing their extent. However, the other climate change factors mentioned above may have major negative impacts on mangroves in the future. Climate change and related factors are putting many coastal areas at increased risk, including coastal abrasion, sea inundation and flooding in low-lying areas, changes in sedimentation, and rising water levels. Coastal wetlands, such as salt marshes and mangroves, are expected to be adversely affected by sea-level rise, especially in areas where land is limited or sediment is abundant. This calls for adaptation measures that integrate the protection and conservation of coastal and marine ecosystems in the region. (Salik 2015).

CONCLUSIONS

Hydro-oceanographic and anthropogenic factors influence changes in the coastlines of Padang Pariaman Regency. Where each village has different dominant factors, the results of research conducted in Padang Pariaman Regency show that there are several locations with a reduction in vegetation land area, namely Katapiang village, Pi Lubang village, Ulakan, and Tapakis village, which will endanger the current condition of the coast. The land use situation and local social conditions, including the coastal land use situation and the daily lives of local communities, both existing and planned, are very necessary. The installation of coastal protection that is not optimal will worsen the abrasion that occurs in the surrounding area. Climate change has major negative impacts on mangroves. Climate change and related factors are increasing risks in most coastal areas, such as increased coastal abrasion, inundation and flooding of lowland areas, changes in sedimentation rates, and increased sea levels.

For communities, this research has helped provide a better understanding of the risks posed by shoreline change due to ineffective coastal protection and vegetation degradation. By identifying vulnerable areas, this study promotes community participation in coastal conservation efforts, such as reforestation and sustainable land use practices, to mitigate the impacts of shoreline change. For policymakers, this study is useful as a scientific foundation for more effective shoreline management. By considering the specific factors driving coastal change, whether hydro-oceanographic, anthropogenic, or sedimentation-related, decision-makers can implement targeted policies to address the root causes of shoreline instability that are tailored to the characteristics of each region and ultimately aim to ensure the long-term sustainability of coastal areas.

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