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# Coastline Change in the Banyuasin Estuary Over the Last Three Decades

Heron Surbakti[1], I Wayan Nurjaya[2], Detriech G Bengen[2], Tri Prartono[2], Andi Agussalim[1], Riris Aryawati[1], Robinson Sitepu[3], and Raisyah Salsabilah[1]

[1]Department of Marine Science, Faculty of Mathematical and Natural Sciences, Universitas Sriwijaya, Indonesia; e-mail: heronsurbakti@unsri.ac.id
[2]Department of Marine Science and Technology, Faculty of Fisheries and Marine Science, Institut Pertanian Bogor, Indonesia
[3]Mathematics Department, Faculty of Mathematics and Natural Sciences, Sriwijaya University, Indonesia

**ABSTRAK**

Pesisir atau garis pantai merupakan lokasi dengan aktivitas yang dinamis, dimana fenomena gelombang, pasang surut, masukan sedimen, perubahan muka air laut, dan karakteristik morfologi daerah tersebut berperan penting dalam membentuk ekosistem pesisir. Penelitian ini bertujuan untuk mengkaji perubahan garis pantai di sepanjang Estuari Banyuasin, Sumatera Selatan, Indonesia, selama 30 tahun (1989-2019). Penelitian ini menggunakan pendekatan penginderaan jauh, *machine learning* dan perangkat DSAS untuk menganalisis perubahan historis (1989-2019). Citra Landsat diperoleh dari United States Geological Survey (USGS) melalui Google Earth Engine API serta dianalisis menggunakan perangkat lunak ArcGIS dan DSAS 6.0. Hasil penelitian menunjukkan bahwa laju perubahan garis pantai terbesar terjadi di Pulau Anakan, dengan laju pertambahan sebesar 118,98 m/tahun yang menyebabkan penambahan garis pantai sebesar 2012,33 m selama 30 tahun. Perubahan garis pantai terkecil ditemukan di daerah Pulau Telang dan Pulau Payung yang terletak di Muara Sungai Musi. Besarnya perubahan garis pantai maksimum di kedua lokasi tersebut masing-masing sebesar 62,72 m dan 92,34 m dengan laju perubahan maksimum berkisar antara 2,09 - 3,08 m/tahun. Hasil penelitian ini juga menggambarkan bahwa pola umum akresi-abrasi di Muara Sungai Banyuasin terbagi dalam tiga tahap, yaitu tahap akresi cepat (1989-1994), tahap penyesuaian akresi-erosi (1994-2009), dan tahap erosi lambat (2009-2019).

***Kata kunci*:** Garis pantai, Eatuari Banyuasin, DSAS, akresi, erosi

**ABSTRACT**

Coasts or shorelines are sites of dynamic activity, and phenomena such as wave and tidal action, sediment supply rate, sea level changes, and the morphological characteristics of the area play a critical role in shaping coastal ecosystems. This study examines coastal changes along the Banyuasin Estuary in South Sumatra, Indonesia, over 30 years (1989–2019). We use remote sensing data, machine learning, and the DSAS tool to analyze historical changes (1989-2019). Landsat images obtained from the United States Geological Survey (USGS) via the Google Earth Engine API are analysed using ArcGIS and DSAS 6.0 software. The largest rate of change occurred at Anakan Island, with the most significant accretion rate being 118.98 m/year, causing a shoreline change of 2012.33 m over 30 years. The smallest shoreline changes were in the Telang and Payung Island areas, which are located in the Musi River Estuary. The magnitude of maximum shoreline change in both locations was 62.72 m and 92.34 m, respectively, with maximum rates of change ranging from 2.09 - 3.08 m/year. The results show that the general pattern of accretion-abrasion in the Banyuasin Estuary is divided into three stages: rapid accretion stage (1989-1994), accretion-erosion adjustment stage (1994-2009), and slow erosion stage (2009-2019).

***Keywords*:** Coastline, Banyuasin estuary, DSAS, accretion, erosion

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## 1. INTRODUCTION

Estuaries are complex and exciting ecosystems to study from ecological (McLusky and Elliott, 2004), physical (Dyer, 1989), chemical (Holland et al., 2009), and combinations such as ecohydrology (Wolanski et al., 2006), and management (McLusky and Wolanski, 2012; McLusky and Elliott, 2004) aspects. The importance of estuarine ecosystems is closely linked to their biological productivity and their function in providing the resources needed for survival, which is generally linked to the presence of other ecosystems such as mangroves, explicitly ranging from the function of providing food (fish, shellfish, and shrimp), shelter (timber), to the development of interconnected areas through trade and shipping networks. The latter function generally has consequences in the form of changes in environmental characteristics that lead to the decline or disappearance of populations and communities that were previously common and easily found in the estuarine area, as well as damage to nature, such as reduced or permanent loss of natural habitat. The study of estuarine ecosystems, in today's era of advanced technology and rapid change, requires a new approach that emphasizes how critical environmental processes in estuarine physical ecosystems support and interrelate with mangrove biogenic ecosystems so that the integration of scientific fields and their combination has the opportunity to formulate new knowledge that is of practical use to address increasingly complex environmental problems and support the sustainability of areas that have essential ecosystems that have strong resilience to stay healthy and productive.

The Banyuasin Estuary, especially the Banyuasin River Estuary and the Musi River Estuary, like the characteristics of other estuarine waters on the Banyuasin coast, has an important role as a public transportation route that connects coastal areas around the Bangka Strait and is used by the community for various activities. In terms of bathymetry, Banyuasin River Estuary waters have varying depths. The morphology of the waters is mainly formed by sediment deposition from rivers (DKP, 2001). It is composed of sedimentary materials such as sand, mud, and clay, which are influenced by the dynamics of water movement, such as currents, waves, and ocean tides, in addition to the physical properties of the sediment. Human activities in rivers and watersheds also change the magnitude and nature of materials carried into the estuary (Hopkinson and Vallino, 1995). These conditions can cause sedimentation in estuaries.

The results of previous research related to the deposition rate found on Anakan Island (Banyuasin River Estuary) in the north are 2,645 x $10^{-11}$ $m^3/s$, the southwest is 1,421 x $10^{-10}$ $m^3/s$, and the south is 1,625 x $10^{-9}$ $m^3/s$. The highest deposition rate is in the southern part of Anakan Island, which faces the mouth of the Lalan River (Aritonang et al., 2016). The highest deposition rate is in the southern part of Anakan Island, directly opposite the mouth of the Lalan River. The significant input of sediment from the river certainly affects deposition and changes in depth around the mouth of the river. The magnitude of this deposition rate causes a delta's emergence at the river's mouth. The growth of new vegetation in the area will follow the formation of deltas and sedimentation areas.

To better understand the shoreline changes in the Banyuasin Estuary over the past three decades, remote sensing data were collected from 1989 to 2019. Remote sensing data is used because it can provide information on changes in a reasonably large area, and the ability to monitor the earth's surface for multi-temporal, multispatial, and multispectral analysis is excellent. Remote sensing data is also indispensable in assessing and monitoring mangrove forests because many points are inaccessible or difficult to observe directly. Areas that are difficult to access and calculate their size make field observations constrained (Kuenzer et al., 2011). Mapping and monitoring these areas pose a series of problems due to the object location's remoteness, the ecosystem's complexity between the sea and land, and the vastness of the habitat. This study used a field data approach and satellite image analysis to describe changes in the Banyuasin Estuary. This study aims to assess the dynamics of sedimentation and shoreline changes in the Banyuasin Estuary.

## 2. METHODS

This research was conducted in a study area in the waters of the Banyuasin Estuary, which is limited to the Banyuasin and Musi Rivers. The study area is shown in Figure 1. Data processing stages were carried out at the Oceanography Laboratory and the Marine Remote Sensing and GIS Laboratory at Sriwijaya University.

### 2.1. Sedimentation Rate Measurement

Sediment traps were installed at several locations strongly suspected of sedimentation in the Banyuasin Estuary to determine the sedimentation rate in the Banyuasin Estuary. The sediment trap tubes used were PVC pipes with a diameter of 5 cm and a height of 11.5 cm, divided into four tubes at each location (Figure 2). Sediment trap tubes were placed at the bottom of the water, and one sediment trap tube was taken every one-week interval; then, the trapped sediment was dried in an oven at 60 $^oC$ for 24 hours (English et al., 1997). The laboratory analyzed the sediments to determine the sedimentation rate expressed in mg $cm^{-2}$ $day^{-1}$.

The sedimentation rate that occurs at each location where sediment traps are installed is calculated using the equation (Kozerski, 2002):

$$\text{Sedimentation rate} = A - B/\text{sediment trap area/week (gr/sediment trap area /week)} \quad (1)$$

$$\text{Sedimentation rate} = \left(\frac{10000}{\pi r^2}\right).(A - B)(\text{gr m}^{-2}\text{day}^{-1}) \quad (2)$$

$$\text{Sedimentation rate} = \left(\frac{10}{\pi r^2}\right).(A - B)(\text{kg m}^{-2}\text{day}^{-1}) \quad (3)$$

where A is the weight of aluminium foil + sediment after 105 °C heating (gram); B is the initial weight of aluminium foil after 105 °C heating (gram); $\pi$ is 3,14 and r is the radius of the sediment trap circle.

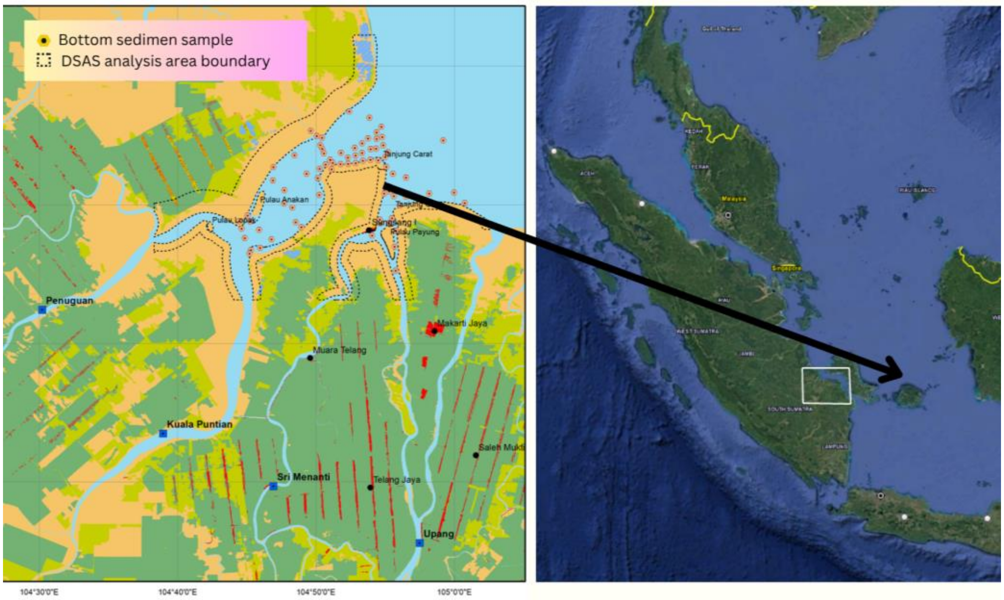



**Figure 1**. Map of TSS Data Collection Location, Bottom Sediment, and DSAS Analysis Area Boundary in Banyuasin Estuary

**Figure 2.** Sediment Traps used in the Research

## 2.2. Shoreline Change of Banyuasin Estuary

Shoreline changes in the Banyuasin Estuary during the period 1989 - 2019 were calculated using satellite image data. The image data used are Landsat 5, Landsat 7, and Landsat 8 satellite image data. The initial process is done by selecting image data free from clouds, image cropping, and image restoration in geometric correction. Data selection and processing were done using Google Earth Engine (GEE). GEE is a cloud-based facility with significant computing and storage capabilities. GEE is accessed and controlled through online integrated development that enables faster prototyping and visualization of spatial analysis for complex conditions (Gorelick et al., 2017). The GEE data catalogue stores available geospatial datasets that are publicly accessible, such as the entire Landsat archive. This research accessed and analyzed Landsat data covering the study area using facilities provided by the GEE JavaScript API. The GEE API is used to make requests to the GEE server. API access is done through a web-based editor using JavaScript programming.

Image cropping limits the area to be processed according to the research location. Geometric correction is done to correct inconsistencies between the coordinates of the image data location and the actual location coordinates (P.Dave et al., 2015). This study's Modified Normalized Difference Water Index (MNDWI) formula separates water objects from land. Some previous studies state that this method is considered better than using the Normalized Difference Water Index (NDWI) formula to separate water from land and has been widely used in coastline extraction because the gray level gradient of the boundary between water and land can be increased through MNDWI (Tesfaye and Breuer, 2024; Khalifeh et al., 2019; Guo et al., 2017; Wang et al., 2017). This formula provides more precise results for edge detection. The equation used to calculate MNDWI is as follows (Xu, 2006):

$$MNDWI = \frac{(Green - SWIR)}{(Green + SWIR)} \quad (4)$$

where NDWI is nilai *Modified Normalized Difference Water Index* ; Green is band green (band 2 for Landsat 5 and Landsat 7, and band 3 for Landsat 8); SWIR is band *Short Wave Infared* (band 5 for Landsat 5 and Landsat 7, and band 6 for Landsat 8).

The results of the coastline of the mainland and islands in the Banyuasin Estuary from 1989 to 2019, which the NDWI formula has analyzed, are further extracted and analyzed by integrating Canny edge detection and the Otsu method. The Otsu method is an algorithm used to separate water from soil using a threshold selection method from the grey-level histogram (Hu and Wang, 2022). The basic idea of this method is to select an appropriate threshold value and then use the maximum value of inter-cluster variance to separate the background and the intended object. In this study, the Otsu method is used to eliminate the influence of background values and reduce the internal influence of objects to obtain more accurate results by combining Otsu and Canny edge detection in extracting coastlines.

Shoreline changes in the Banyuasin Estuary were analyzed using satellite images from the Google Earth Engine database. Shoreline changes in the Banyuasin Estuary were identified using Landsat satellite images over 30 years (1989 – 2019). The changes were categorized based on 10-year and 30-year periods to describe the condition of the Banyuasin Estuary.

### 2.3. Shoreline Correction to Tides

Different conditions and positions of the water table during image recording will cause shoreline shifts and are influenced by the slope of the beach, so tidal correction is needed in each shoreline extraction and analysis of change information (Cham et al., 2020). The FES 2014 global tidal prediction data is used in this correction process. This research uses the mean sea level (MSL) field reference in the shoreline adjustment. Each shoreline feature obtained will be shifted towards the sea during high tide and towards land during low tide (Suhana et al., 2016). The process and stages of shoreline correction of tidal data were carried out using the CoastSat tool. This tool can be used for shoreline extraction over a long period and directly retrieves satellite image data from the Google Earth Engine database (Vos et al., 2019).

### 2.4. Analysis of Shoreline Change

The shoreline corrected with tidal data is then used to analyze shoreline changes and the average rate of change of the shoreline each year using DSAS (Digital Shoreline Analysis System) tools. This method begins with making transects to determine the size of the shoreline change. The distance of change of each shoreline point is analyzed using the Net Shoreline Movement (NSM) method by measuring the distance of shoreline change between the oldest shoreline and the newest shoreline. Calculation of average shoreline changes each year using the End Point Rate (EPR) method, which is calculated by dividing the displacement distance of a shoreline position based on the period/year (Seto et al., 2002; Thieler et al., 2009; Thinh & Hens, 2017; Himmelstoss et al., 2018; Baig et al., 2020).

The results of this DSAS analysis are then used to determine which beaches are experiencing abrasion and accretion. Abrasion occurs when the resulting calculation value is negative, which means a reduction in coastline. Accretion occurs if the resulting calculation value is positive, which means the addition of coastline. The equation used in the EPR method follows (Thieler et al., 2009).

$$R_{se} = \frac{X_0}{t} \quad (5)$$

where $R_{se}$ is EPR change (m/year); $X_0$ is the distance of shoreline change (m) and $t$ is the period of shoreline position (year).

The final results of the DSAS analysis show the rate and total shoreline change in a specific period. Analysis of shoreline changes using the DSAS method in each transect that experienced changes < 30 meters was categorized as no change because it was smaller than the spatial resolution of the Landsat image (30 m).

## 3. RESULT AND DISCUSSION

### 3.1. Sedimentation Rate in Banyuasin Estuary

To determine the rate of sediment deposition in the Banyuasin Estuary, this study installed sediment traps at several locations strongly suspected of sedimentation in the Banyuasin Estuary. The results of installing sediment traps at several locations are shown in Figure 4.

The mouth of the inner Banyuasin River and Anakan Island are the areas where most sediment is trapped. The deposition rate at the mouth of the inner Banyuasin River was 5.59 - 7.31 kg $m^{-2}$ $day^{-1}$ on the eastern side and 2.56 kg $m^{-2}$ $day^{-1}$ on the western side. The southern part of Anakan Island experienced sediment deposition rates of 4.90 - 5.31 kg $m^{-2}$ $day^{-1}$, and 2.96 kg $m^{-2}$ $day^{-1}$ in the northern part of Anakan Island.

The Tanjung Sereh area, located south of Anakan Island and between two river mouths, the Lalan River and Banyuasin River, experienced a sediment deposition rate of 2.56 kg $m^{-2}$ $day^{-1}$. The Bungin River estuary is also an area that experiences high sedimentation. This is indicated by the deposition rate in the Bungin River Estuary of 3.5 - 6.15 kg $m^{-2}$ $day^{-1}$, while the northern part of the Bungin River mouth experienced deposition of 2.31 - 3.88 kg $m^{-2}$ $day^{-1}$.

This indicates that stations closer to sediment sources such as river mouths, eroded river banks, or anthropogenic discharges typically receive higher sediment loads, resulting in higher deposition (Walling, 2005; Ariawan, 2016; Firdaus et al., 2025).. Conversely, stations located further away from sediment sources may experience lower deposition. These stations also experience lower tidal flushing than downstream, allowing suspended sediments to settle effectively. In addition, it has been shown that sedimentated areas around the research site are areas that have low velocities (Aritonang et al., 2016; Ariawan, 2016). Areas with slower velocities favour sediment deposition and accumulation, while higher velocities favour sediment resuspension and transport downstream (Friedrichs and Wright, 2004). Other factors can influence sedimentation rates, including riverbed relief, slope, watershed conditions, season, vegetation cover, climate, regional geology and human activities (Sulistiyani et al., 2019).

The area north of Tanjung Api-api experienced a fairly high sediment deposition rate of 3.0 - 5.04 kg $m^{-2}$ $day^{-1}$. The high sedimentation rate in this area needs attention because it faces the mouth of the Bungin River, which is the shipping entrance to Tanjung Api-api harbour and the Banyuasin River. The area around Tanjung Buyut, the Musi River Estuary outlet, experienced sediment deposition of 3.43 - 4.01 kg $m^{-2}$ $day^{-1}$. Unlike the other areas with sediment traps, the sediment trapped around Tanjung Buyut was dominated by magnificent sand. This indicates the high energy of water movement in the area due to currents and waves (Affandi and Surbakti, 2012).

### 3.2. Shoreline Change in Banyuasin Estuary

The total addition of beach due to accretion in the Banyuasin Estuary amounted to 2,012.33 Ha from 1989 to 2019, while the change due to abrasion during the same period amounted to 327.92 Ha (Figure 5). Areas experiencing sedimentation are shown in red in Figures 6 and 7 and include Anakan Island, Eastern Banyuasin River Estuary, North of Tanjung Api-api to Tanjung Carat; Bungin River, Banyuasin Peninsula, and Tanjung Gede. Some areas will also experience abrasion in the western Banyuasin River Estuary, Sungsang to Tanjung Carat, and northern and southern Payung Island.

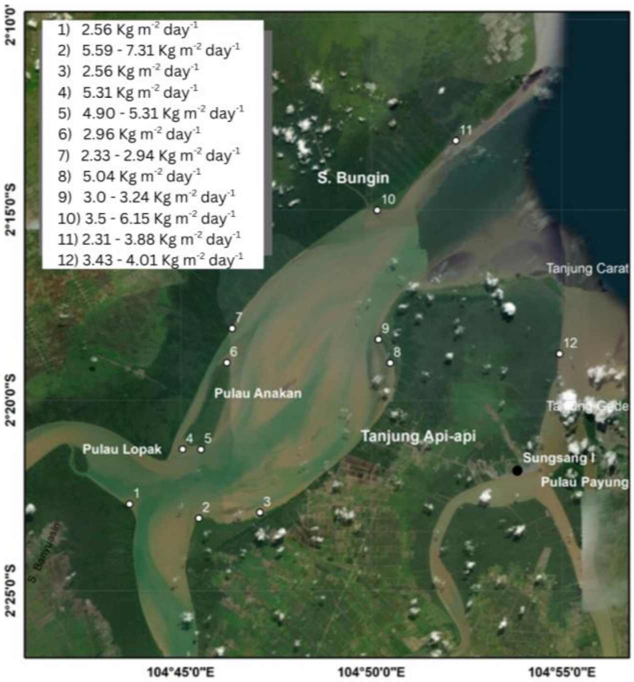
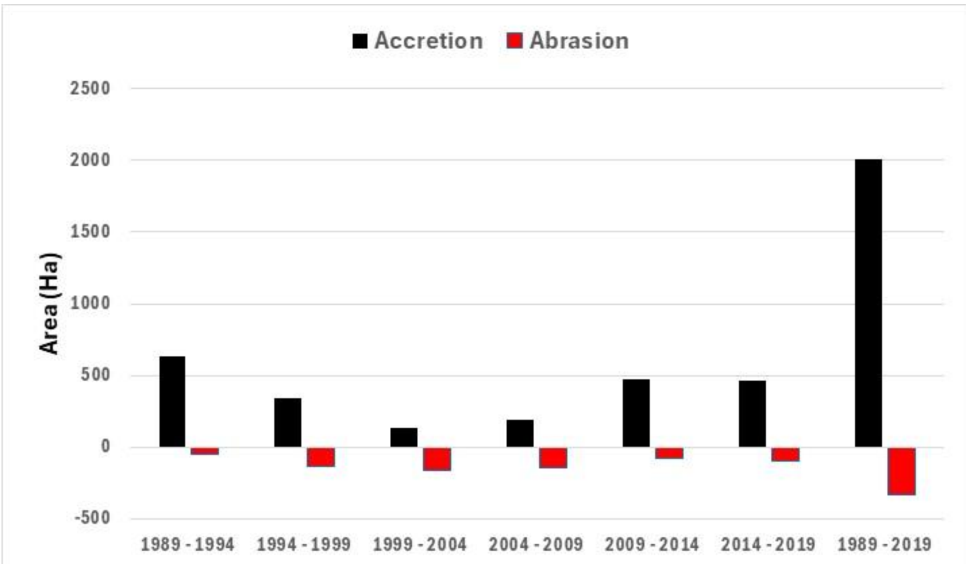



**Figure 4**. Sediment Deposition Rate at Several Locations in the Banyuasin Estuary




*Sign (-) indicates the occurrence of the abrasion process*

**Figure 5**. Changes in Sedimentation and Abrasion Area in Banyuasin Estuary

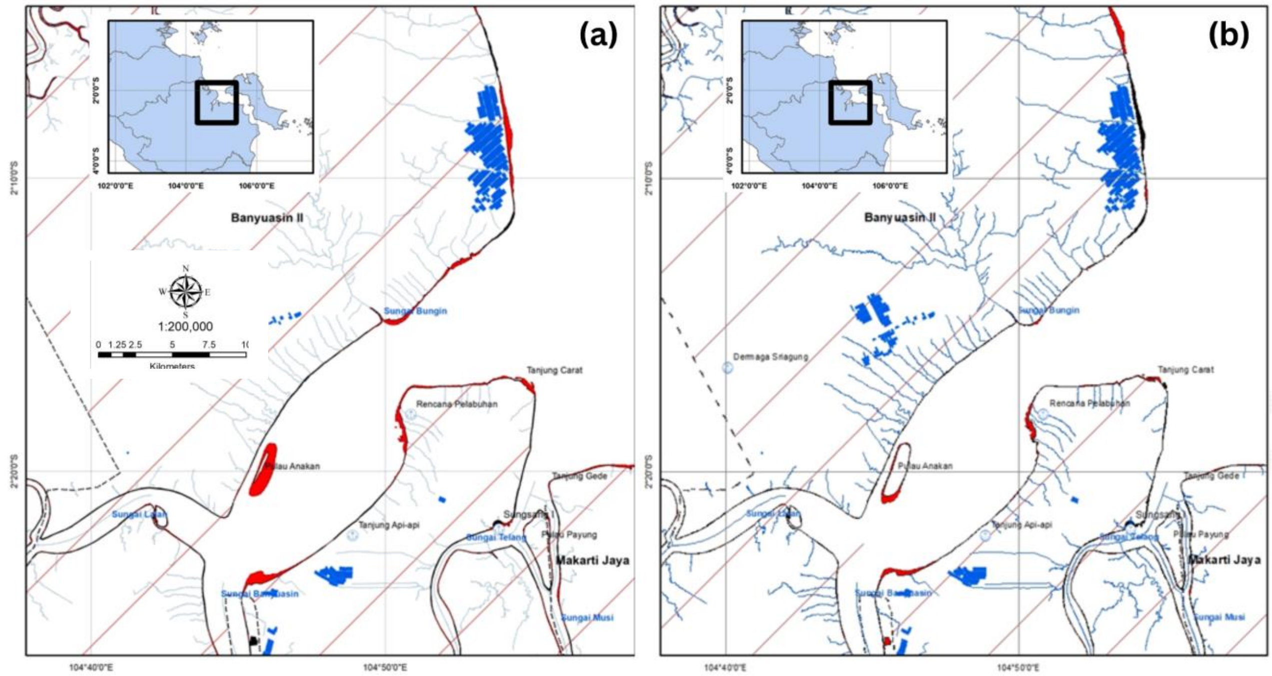



**Figure 6.** Shoreline Changes that Occurred in the Banyuasin Estuary (a) Period 1989 – 1999 (B) Period 1999 – 2009. The Red Color Depicts the Area that Experienced Sedimentation

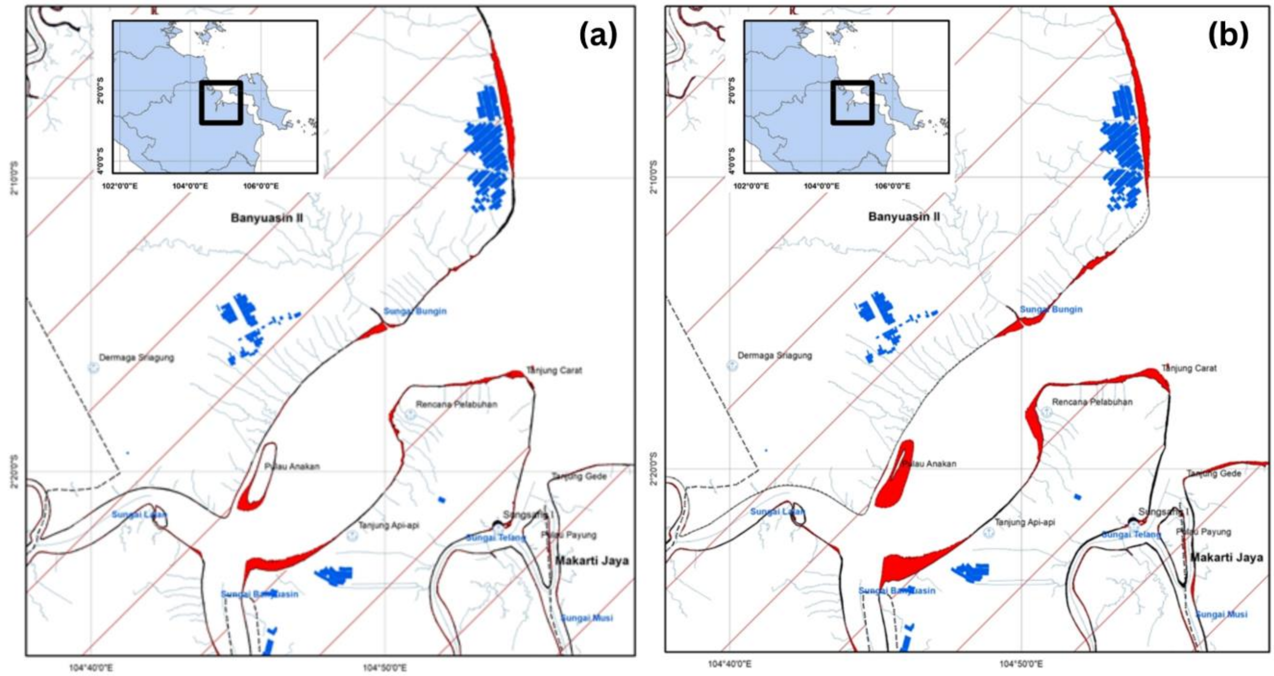



**Figure 7.** Shoreline Changes that Occurred in the Banyuasin Estuary (a) Period 2009 – 2019 (B) Period 1989 – 2019. The Red Color Depicts Areas that Experienced Sedimentation

Shoreline changes due to abrasion in the Banyuasin estuary area based on the NSM method were greatest along the Banyuasin Peninsula, Sembilang National Park area, where there was a reduction in shoreline of 322.71 m with rates of change of 10.8 m/year. Furthermore, the following most significant change due to abrasion is the southern part of Payung Island, with a shoreline change of 213.83 m during the 1989-2019 period, with an average change due to abrasion on Payung Island of 1.16 m/year and the maximum change condition is 7.13 m/year.

Based on the 1989 – 2019 change analysis results, the Anakan Island area has not experienced changes due to abrasion. The area experiencing the most minor abrasion is in the Banyuasin River area to Tanjung Api-api, with a change of 40.86 m, and the rate of change due to abrasion can reach 1.36 m / year. Table 1 shows an overview of the changes that occur in each location due to abrasion.

The results of the shoreline change analysis show that the Banyuasin River Estuary region experienced the most significant shoreline change due to accretion compared to the Musi River Estuary. Shoreline changes due to accretion are found in the Banyuasin River to Tanjung Api, Anakan Island, Sembilang National Park area (S. Bungin estuary), and the area along Tanjung Api-api to Tanjung Carat.

The largest change occurred in S. Banyuasin to Tanjung Api-api, causing a shoreline change of 1998.5 m over 30 years, with the most significant addition rate of 66.62 m/year. The largest rate of change occurred at Anakan Island, with the most significant rate of increase being 118.98 m/year, causing a shoreline change of 2012.33 m over 30 years. The smallest shoreline changes were in the Telang and Payung Island areas located in the Musi River Estuary. The magnitude of maximum shoreline change in both locations was 62.72 m and 92.34 m, respectively, with maximum rates of change ranging from 2.09 - 3.08 m/year. An overview of the changes that occurred at each location due to accretion is shown in Table 2.

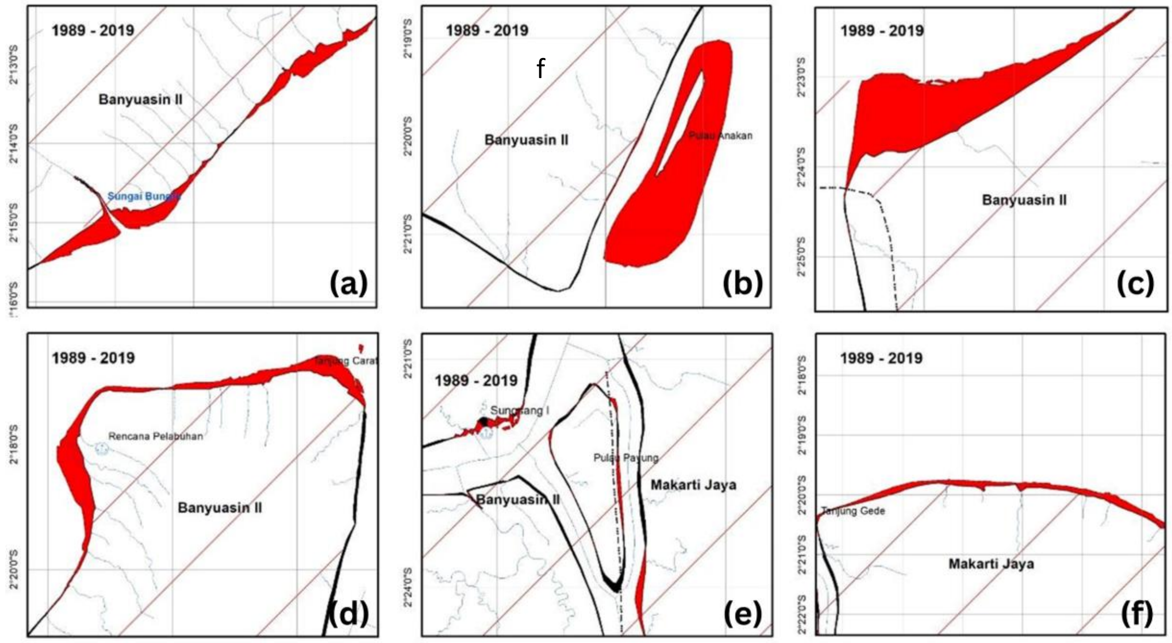



**Figure 8**. Shoreline Changes in the Banyuasin Estuary for the Period 1989 – 2019. (A) Bungin River Estuary; (B) Anakan Island; (C) Banyuasin River Mouth; (D) Tanjung Api-Api to Tanjung Carat; (e) Payung Island and (f) Tanjung Gede.

**Table 1**. Shoreline Change and Abrasion Rate in the Banyuasin Estuary from 1989 – 2019

| No | Location | Accretion | | | |
|---|---|---|---|---|---|
| | | EPR (m/year) | | NSM (m) | |
| | | Mean | Max | Mean | Max |
| 1 | Region of Sembilang National Park | -1.35 | -10.76 | -40.42 | -322.71 |
| 2 | Lalan River to Banyuasin River | -0.74 | -2.47 | -22.07 | -74.13 |
| 3 | Anakan Island Area | - | - | - | - |
| 4 | Inner Banyuasin River to Tanjung Api-api | -0.71 | -1.36 | -21.29 | -40.86 |
| 5 | Tanjung Api-Api to Tanjung Carat | -0.85 | -1.82 | -25.37 | -54.74 |
| 6 | Tanjung Carat to Telang River | -1.27 | -3.21 | -38.08 | -96.37 |
| 7 | Telang Area | -0.67 | -1.90 | -20.01 | -57.03 |
| 8 | Payung Island | -1.16 | -7.13 | -34.91 | -213.83 |
| 9 | Tanjung Gede | -1.07 | -2.47 | -32.00 | -74.03 |

*Sign (-) indicates the occurrence of the abrasion process.*

**Table 2**. Shoreline Change and Accretion Rate in the Banyuasin Estuary from 1989 – 2019

| No | Location | Accretion | | | |
|---|---|---|---|---|---|
| | | EPR (m/year) | | NSM (m) | |
| | | Mean | Max | Mean | Max |
| 1 | Region of Sembilang National Park | 7.23 | 31.65 | 217.00 | 949.37 |
| 2 | Lalan River to Banyuasin River | 1.99 | 12.31 | 59.64 | 369.30 |
| 3 | Anakan Island Area | 23.90 | 118.98 | 435.63 | 2012.33 |
| 4 | Inner Banyuasin River to Tanjung Api-api | 23.72 | 66.62 | 711.61 | 1998.50 |
| 5 | Tanjung Api-Api to Tanjung Carat | 9.08 | 27.59 | 272.37 | 827.69 |
| 6 | Tanjung Carat to Telang River | 2.11 | 9.90 | 63.36 | 296.97 |
| 7 | Telang Area | 0.77 | 2.09 | 23.11 | 62.72 |
| 8 | Payung Island | 1.11 | 3.08 | 33.25 | 92.34 |
| 9 | Tanjung Gede | 5.74 | 9.98 | 120.85 | 299.43 |

The results show that the general pattern of accretion-abrasion in the Banyuasin Estuary is divided into three stages: rapid accretion stage (1989-1994), accretion-erosion adjustment stage (1994-2009), and slow erosion stage (2009-2019). Equilibrium throughout the estuary tends to maintain its shape and equilibrium area or experience accretion, but estuaries can also be in a state of erosion due to abrasion (Cui and Li, 2011).

The results explain that the extent of coastline changes in the Banyuasin Estuary is suspected to be caused by natural factors such as tides, ocean currents, wave heights, erosion, and accretion (Apriansyah et al., 2019), as well as human factors in the form of land use in the upstream area and the interests of port development, which also contribute to coastline changes (Bidayani and Kurniawan, 2020). The coastline changes occurring in areas experiencing erosion are suspected to be caused by the open coastal characteristics. Waves directly influence this dynamic water characteristic. Coastal areas that protrude into the sea usually experience wave diffraction phenomena and eddy motion, so the erosion process tends to be more intensive.

Oceanographic factors have a dominant influence during the sediment transport process to marine waters. The sedimentation process in the waters is affected by various water dynamics such as tides, waves, coastal currents, mixing of water masses due to differences in density between freshwater and seawater, and biological and chemical processes. The sedimentation process is also influenced by the sediments' properties, such as sediment particles' size, shape, and density (Rifardi, 2008). Weak/low current velocities have a small sediment transport capacity, resulting in a high deposition rate of deposited particles. The rate of deposition caused by suspended matter is influenced by its physical structure, such as volume and particle shape related to sinking direction, density, and porosity (Tomascik et al., 1997). Rifardi (2008) explains that sedimentation is also influenced by the physical properties of seawater, such as density, salinity, and temperature, as well as the hydrological conditions of the area, such as current velocity, shear stress, the vertical position of suspended particulate matter (SPM) in the water column, particle settling velocity, and turbulent mixing.

Mangrove ecosystems can function as sediment traps and prevent coastal erosion. This function as a sediment trap can expand the area of accretion and mangrove habitat and enhance the growth and development of mangroves (Furukawa and Wolanski, 1996). The characteristics of mangrove ecosystems, with muddy soil, dense vegetation, and distinctive roots, make this ecosystem effective in capturing and depositing soil particles from land erosion (Ghufran; and Kordi, 2012). Mangrove roots trap particles and deposit sediment, preventing sediment from being washed away by currents and waves due to increased friction and reduced current speed of incoming tides in the mangrove area (Wolanski and Elliott, 2015). The root systems of mangroves also play a role in sediment accumulation, trapping litter, and contributing to soil formation while expanding the area experiencing accretion (Kennish, 1999).

The results showing significant accretion and abrasion processes in the Banyuasin Estuary indicate dynamic sedimentary changes that pose several future risks for fisheries and shipping activities. For fisheries, sediment accretion can lead to the burial and alteration of benthic habitats essential for the spawning and feeding of aquatic species. This sediment buildup often degrades water quality by increasing turbidity and reducing light penetration, negatively affecting primary productivity and fish nursery grounds (Walling, 2005; Wright, L.D, and Friedrichs C.T, 2006). Conversely, abrasion or erosion can destabilize these habitats by removing sediment layers, further increasing turbidity and stress on aquatic fauna, potentially leading to changes in species composition and declines in fish populations (Firdaus et al., 2025). Such habitat disruptions threaten the sustainability of fisheries and the livelihoods of communities depending on them. Regarding shipping, sediment accretion in navigation channels may reduce water depths, restrict vessel access, and increase the risk of grounding and delays (Andhy et al., 2022; Cáceres et al., 2016; Guarnieri et al., 2021; Rahman and Ali, 2022). This situation typically necessitates more frequent and costly dredging operations, which may also have environmental consequences. Meanwhile, abrasion can weaken riverbanks and port infrastructure, leading to structural damage and heightened maintenance needs. These sediment dynamics emphasise the need for regular monitoring and adaptive management to maintain safe and efficient maritime transport.

Factors such as land use changes, deforestation, and climate change can increase sediment loads and exacerbate erosion and accretion processes (Walling, 2005; Wright, L.D., and Friedrichs, C.T., 2006), heightening future risks. Thus, integrated coastal zone management approaches combining sediment monitoring, habitat conservation, and infrastructure resilience are critical to mitigating these impacts. Collaboration among environmental agencies, fisheries managers, and port authorities will be vital to ensure the ecological health and economic viability of the Banyuasin Estuary region.

## 4. CONCLUSION

The results show that the general pattern of accretion-abrasion in the Banyuasin Estuary is divided into three phases: fast accretion phase (1989-1994), accretion-erosion adjustment phase (1994-2009), and slow erosion phase (2009-2019). In the last 30 years, the Banyuasin Estuary has experienced significant coastal expansion of 2,012.33 hectares.

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