Study of shoreline changes using Landsat Satellite Imagery in Tanjung Tengah and Saloloang Villages, Penajam District

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ABSTRACT

The coastal areas of Tanjung Tengah and Saloloang sub-districts that used as ecotourism, this research needed to determine changes in the coastline at these locations. The study aims to determine the shift of the coastline along with the extent of abrasion and accretion for 15 years on the coast in Tanjung Tengah and Saloloang Villages, Penajam District, Penajam Paser Utara Regency. The study was conducted from October 2023 to November 2023. The method used is the Digital Shoreline Analysis System (DSAS) analysis using Landsat 7 ETM and Landsat 8 OLI satellite imagery obtained from the USGS site. The results of the study showed that during the period 2009 - 2023 along the coastal areas of Tanjung Tengah and Saloloang Villages, was greater accretion than abrasion, period 2009-2015 the coast experienced a shift towards the sea (Accretion) reaching 311.95 meters. Then experienced a retreat towards the land reaching 267.11 meters from the period 2015-2023. The total area of the area experiencing accretion and abrasion respectively is 81.42 ha and 41.68 ha.

INTRODUCTION

The coastal area is a dynamic region that is highly susceptible to continuous changes. It is one of the most utilized areas due to its abundant natural resources. Penajam Paser Utara Regency has a coastline of approximately ±15 km, which signifies a vast potential for coastal and marine resources (Ardhyastuti, 2019). A large portion of Penajam Paser Utara faces the sea and the bay, providing significant fishery potential for both capture and aquaculture fisheries. As a result, many coastal areas in Penajam Paser Utara Regency are utilized for tourism due to their great potential. Coastal areas are often used for aquaculture, tourism, reclamation, settlements, and public infrastructure such as roads (Hidayanti, 2017).

The shoreline is defined as the meeting point between seawater and land during the highest tide (Azhar et al., 2012). Understanding the impacts of shoreline changes on the environment and human life, particularly for communities living near coastal areas, requires a comprehensive study of shoreline dynamics (Suharyono & Hidayah, 2019). To date, no research has been conducted on shoreline changes along the coast of Tanjung Tengah and Saloloang Villages in Penajam District, Penajam Paser Utara Regency. Therefore, this study serves as a baseline dataset for local and central government decision-making regarding coastal area management.

This research aims to determine the shoreline displacement distance in Tanjung Tengah and Saloloang Villages, Penajam District, over the period 2009–2023. Identify the area affected by changes, including erosion (abrasion) and accretion. Assess shoreline degradation over the past 15 years, considering

the impact of erosion control structures installed along the coastline of Penajam Paser Utara District, using remote sensing (satellite imagery).

METHODOLOGY

This study was conducted from October 2023 to November 2023. The research site is located along the coastal area of Tanjung, Penajam District, Penajam Paser Utara Regency. Astronomically, Penajam Paser Utara Regency is situated between 0°48'29" – 1°36'37" South Latitude and 116°19'30" – 116°56'35" East Longitude. The observation area spans approximately ±15 km, extending from Tanjung Tengah Village to Saloloang Village. Image analysis and data processing were conducted at the Hydro-Oceanography Laboratory, Faculty of Fisheries and Marine Science, Mulawarman University.

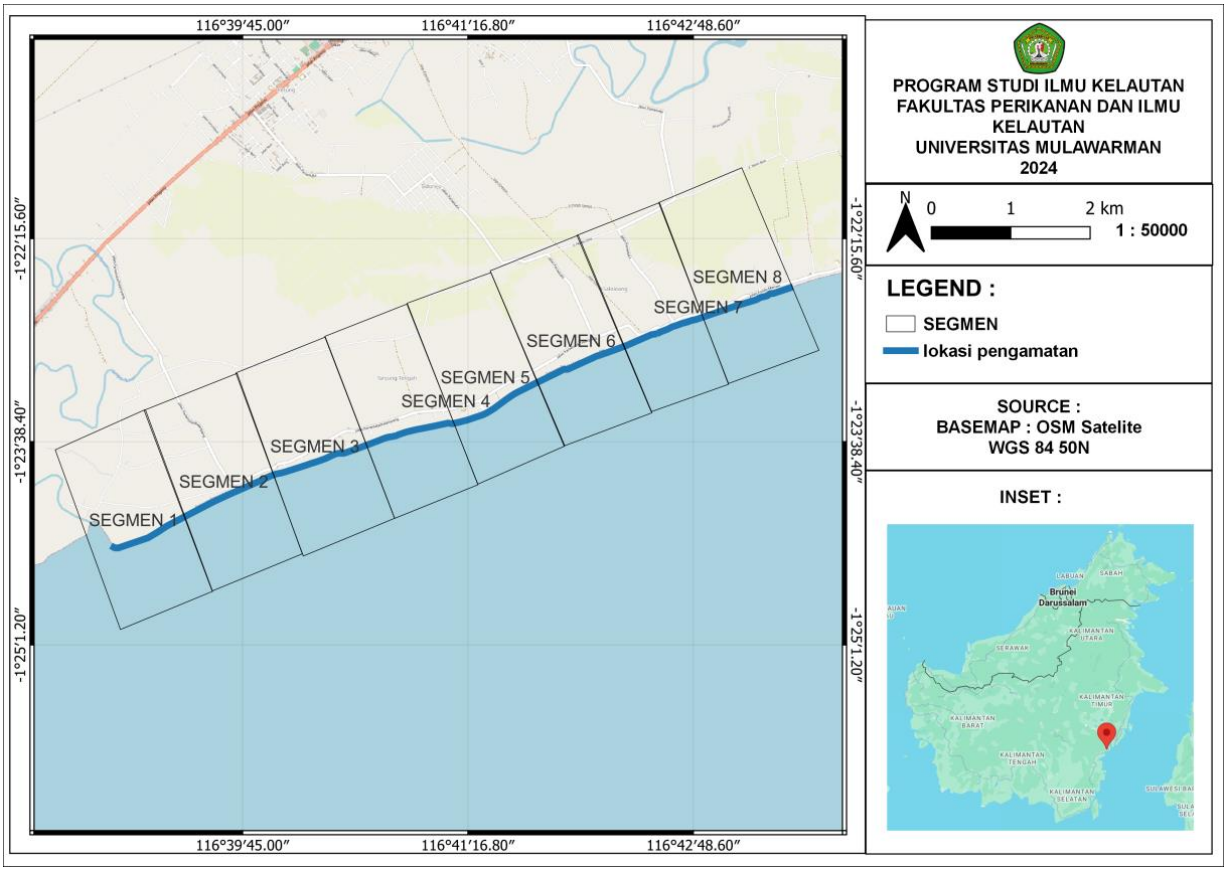

Figure 1. Study location map

The tools used in this research include GPS, a camera, a laptop, and writing instruments. The materials used in this study are Landsat 7 ETM and Landsat 8 OLI satellite images, ArcGIS software, and QGIS software. The workflow of this research is the following:

1. Field Survey

The field survey was conducted by tracing the coastline within the study area. The coastal coordinate points were obtained through shoreline tracking using GPS. Observations were made along the coastline to assess shoreline conditions, the effects of accretion and abrasion, the location of erosion control structures, vegetation boundaries, and land use around the coast. The field data collected was then compared with satellite image processing results and shoreline models to verify the accuracy of the extracted shoreline positions.

2. Data Collection

The data used in this study consists of Landsat 7 ETM and Landsat 8 OLI satellite images, obtained from Earth Explorer USGS.

3. Geometric Correction

Geometric correction was performed to minimize errors caused by the sensor's viewing angle and relief displacement (variations in Earth's surface appearance) (Priyanto et al., 2021).

4. Radiometric Correction

This procedure aims to enhance the visual quality of the image and correct pixel values that may not be accurate (Sasmito et al., 2020).

5. Image Cropping

Image cropping was performed to limit the study area, facilitating easier analysis on a computer. Additionally, cropping reduces memory usage, making satellite image processing more efficient.

6. Shoreline Extraction

Shoreline extraction was conducted using the NDWI (Normalized Difference Water Index) method. This method differentiates between land and water to obtain more consistent shoreline extraction results by comparing the brightness levels of the Green spectral band (Kurniadin & Fadlin, 2021). According to Danoedoro (2012), infrared imagery can effectively distinguish between water and non-water objects, making it highly useful for shoreline mapping. An overlay process was carried out by superimposing extracted shoreline data. This overlay analysis plays a crucial role in assessing shoreline changes and calculating the extent of shoreline variations.

7. Shoreline Change Analysis

Shoreline change analysis was performed using the Net Shoreline Movement (NSM) method. The NSM and End Point Rate (EPR) methods, available in the Digital Shoreline Analysis System (DSAS) tool, were used to measure the distance between the oldest and the most recent shoreline positions. NSM values represent the extent of shoreline displacement. EPR values indicate the rate of shoreline change. A negative NSM value (-) signifies coastal erosion (abrasion), while a positive NSM value (+) indicates accretion. The total area affected by erosion and accretion was determined by converting the extracted shoreline into a polygon using the Feature to Polygon tool.

8. Digitization

A digitization process was conducted to create a shoreline change map for Tanjung Tengah and Saloloang Villages, Penajam District, Penajam Paser Utara Regency. This map visualizes shoreline displacement and the extent of changes (accretion and erosion) over two periods: 2009–2015 and 2015–2023.

RESULT AND DISCUSSION

General Description of the Research Location

Penajam Paser Utara Regency is astronomically located between 0°48'29" – 1°36'37" South Latitude and 116°19'30" – 116°56'35" East Longitude. Corong Beach and Tanjung Beach are situated in Tanjung Tengah and Saloloang Villages, Penajam District, Penajam Paser Utara Regency. These beaches directly face the Makassar Strait and serve as popular tourist destinations due to their proximity to the city center, attracting many visitors.

Access to the coastal area is convenient, as the roads leading to the beaches are paved and in good condition. Additionally, the beaches are equipped with several facilities, including toilets, a prayer room (mushola), gazebos, and parking areas.

Field observations conducted at several research locations, starting from the coastline of Tanjung Tengah to Saloloang, indicate that both accretion and erosion have occurred in the area. These changes are influenced by the presence of several small rivers along the research site and breakwaters installed in certain sections. Several streams and drainage channels flow into the coastline from Tanjung Tengah Village to Saloloang.

Shoreline Changes

Shoreline extraction was performed using the NDWI (Normalized Difference Water Index) method over a 15-year period. The extracted shoreline data from 2009, 2015, and 2023 were overlaid to clearly observe shoreline changes in Tanjung Tengah and Saloloang Villages. The digitization process resulted in the following maps:

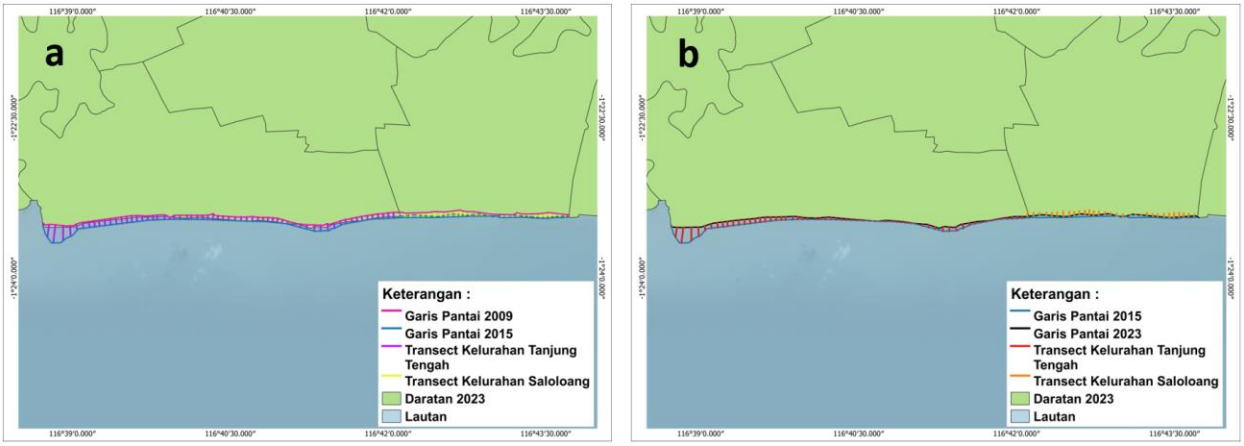

Figure 2. Shoreline changes for the periods 2009–2015 (a) and 2015–2023 (b)

The calculation of shoreline shift distance was performed using the Net Shoreline Movement (NSM) and End Point Rate (EPR) methods. The 2009 shoreline was used as the baseline, as it represents the oldest recorded shoreline. If the distance has a positive value (+), it indicates shoreline advancement (accretion). If the distance has a negative value (-), it indicates shoreline retreat (erosion/abrasion).

Table 1. Shoreline Change Distance and Shoreline Change Rate

Period	NSM (Net Shoreline Movement) (m)	EPR (End Point Rate) (m/Year)
	Accretion (+)	Erosion (-)
2009–2015	7.42 – 304.11	-
2015–2023	0.59 – 1.29	3.66 – 267.11

Based on Table 1, the minimum and maximum NSM values from Tanjung Tengah to Saloloang during the 2009–2015 period were 7.42 m and 304.11 m, respectively. For the 2015–2023 period: Minimum and maximum accretion values were 0.59 m and 1.29 m, respectively. Minimum and maximum erosion values were 3.66 m and 267.11 m, respectively.

Table 2. Shoreline Change Classification Based on EPR (Umami, 2018)

Shoreline Change Classification	EPR (m/Year)
Very High Erosion	EPR ≤ -2
High Erosion	-2 < EPR < -1
Stable	-1 < EPR ≤ 1
Moderate Accretion	1 < EPR < 2
High Accretion	EPR ≥ 2

Based on Table 1, the shoreline change rate (EPR) in Tanjung Tengah and Saloloang during the 2009–2015 period falls into the high accretion category (EPR ≥ 2, as shown in Table 2). During the 2015–2023 period: The shoreline change rate is classified as stable accretion (-1 < EPR ≤ 1). Erosion (abrasion) falls into the very high erosion category (EPR ≤ -2).

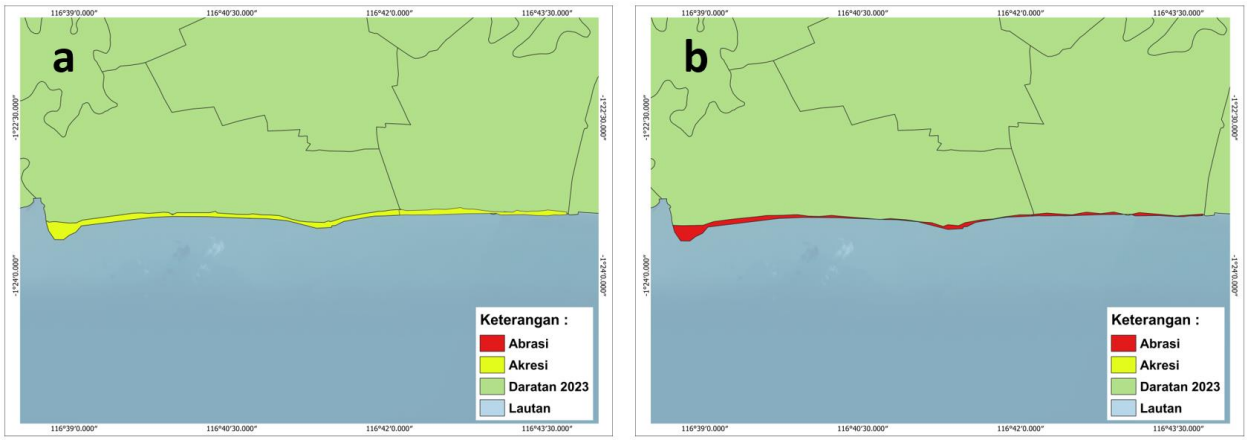

Figure 3. Shoreline Change Area for the Period 2009–2015 (a) and 2015–2023 (b)

The image above represents the modeled extent of accretion and abrasion along the coast of Tanjung Tengah and Saloloang, based on analysis results. It was found that during the period 2009-2015, the accretion area reached 81.28 ha, whereas in the period 2015-2023, the accretion area was only 0.13 ha, while the abrasion area reached 41.68 ha.

In Figure 3, the marked area (the tip of Tanjung Tengah Village's coast) tends to experience significant changes because this region is a river estuary. Additionally, land-use changes have occurred in this area, where mangrove forests have been converted into fishponds at the Lunan River estuary. This conversion significantly impacts the area because mangroves play a role in slowing coastal erosion.

According to Hidayah & Apriyanti (2020), high sedimentation (deposition) around estuarine areas is caused by sediment accumulation forming alluvial plains (deltas). This sedimentation consistently occurs near the river, leading to shoreline changes. Rapid sedimentation near estuaries advances the shoreline as deposited sediments gradually form new land, expanding the existing landmass (Muryani, 2010). Meanwhile, erosion caused by wave energy can also lead to shoreline retreat (Arief et al., 2011).

Along the coastline of Tanjung Tengah to Saloloang, several structures have been built along the shore to prevent erosion. These structures were installed in 2009, and in 2016, the Penajam Paser Utara Regency Government replaced them with concrete culverts. According to Pasaribu (2023), erosion control structures cause sediment deposition, and over time, these deposits contribute to the formation of a new shoreline. If sediment accumulates differently each year due to these structures, it results in continuous shoreline changes.

Based on research findings on shoreline changes, the coastline of Tanjung Tengah and Saloloang experienced accretion from 2009 to 2015 and abrasion from 2015 to 2023. These changes were likely caused by the open nature of the coast, direct exposure to the Makassar Strait, the presence of estuaries and tributaries, the installation of erosion control structures, and the absence of mangrove vegetation, which naturally prevents erosion, making the coastline vulnerable to changes.

CONCLUSION

Based on research findings on shoreline changes along the coast of Tanjung Tengah and Saloloang, the following conclusions were drawn:

1. Analysis of Landsat satellite imagery from 2009 to 2023 revealed shoreline shifts in Tanjung Tengah and Saloloang. The shoreline advanced seaward by up to 311.95 meters from 2009 to 2015. However, from 2015 to 2023, the shoreline retreated landward by up to 267.11 meters. The total accretion area reached 81.28 ha, while the total abrasion area was 41.68 ha.
2. Erosion control structures were installed along parts of Tanjung Tengah and Saloloang in 2009. Then, in 2016, the Penajam Paser Utara Regency Government replaced the wave barriers with concrete culverts to prevent further abrasion. From 2009 to 2015, accretion in Tanjung Tengah and Saloloang totaled 81.41 ha, while abrasion reached 41.68 ha. These findings indicate that the erosion control structures installed between 2009 and 2023 contributed to accretion in Tanjung Tengah and Saloloang.

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