

SPATIOTEMPORAL ANALYSIS OF COASTLINE CHANGES IN KECAMATAN SINGKIL USING LANDSAT 8 SATELLITE IMAGERY

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Abstract: The coastal area of Kecamatan Singkil in Kabupaten Aceh Singkil is an area that is vulnerable to the dynamics of shoreline changes due to abrasion and sedimentation processes. This study aims to analyze shoreline changes in Singkil District during the period 2014 to 2025 by utilizing Landsat 8 satellite imagery and remote sensing technology and geographic information systems (GIS). The research method used involves collecting and analyzing numerical data with a focus on location by creating combined images (bands 5, 6, and 4) and using the NDWI (Normalized Difference Water Index) to clearly distinguish between land and water areas. The results of the multitemporal image overlay show that during the observation period, the area experiencing abrasion was 30.12 hectares, while sedimentation reached 251.78 hectares. These findings show that the sedimentation process is much more dominant than abrasion, which has implications for the growth of coastal land areas. If averaged per year over a period of 11 years, the abrasion rate reaches around 2.74 hectares per year, while the sedimentation rate reaches around 22.89 hectares per year. This research is expected to be the basis for consideration in more adaptive and sustainable coastal area management, as well as increase awareness of the importance of coastal environmental conservation.

Keywords: coastline; abrasion; sedimentation; landsat 8

INTRODUCTION

Coastal areas are transition zones between land and sea ecosystems that have high biodiversity and play an important role in various ecological, economic, and social aspects. According to the Law of the Republic of Indonesia Number 27 of 2007 concerning the Management of Coastal Areas and Small Islands, coastal areas are transitional areas between land and sea ecosystems that are influenced by changes on land and sea (Law of the Republic of Indonesia Number 27 of 2007 concerning Management of Coastal Areas and Small Islands, 2007). Dynamics in coastal areas occur continuously, whether caused by natural processes such as erosion, abrasion, sedimentation, and tides or human activities

such as reclamation and infrastructure development. These changes can cause land reduction (abrasion) or addition (accretion), which has a significant impact on the balance of coastal ecosystems (Sardiyatmo et al., 2013; Sihombing et al., 2017).

The coastline, which is the boundary between marine and terrestrial ecosystems, has a strategic function in the management of natural resources and determining the boundaries of a country. As explained in Law Number 23 of 2003, 2014 Article 27 paragraph 3, the territory of the Indonesian province consists of land and sea areas as far as twelve nautical miles measured from the coastline towards the open sea. Furthermore (Sugihartono, 2018) measures the Indonesian Exclusive Economic Zone (EEZ)

up to 200 miles from the coastline. Therefore, changes in the coastline have a broad impact not only on ecological aspects but also on legal and geopolitical ones.

Coastline changes are phenomena that occur naturally or as a result of human activity (Munandar & Kusumawati, 2017). Coastline changes are phenomena that occur naturally or as a result of human activity (Setyawana et al., 2021). High TSS concentrations can show that there are a lot of tiny particles in the water, making it cloudy and contributing to sediment buildup (Ering et al., 2024). Total Suspended Solids (TSS) are suspended materials measuring more than 1 μm that are retained on a Millipore filter with a pore size of 0.45 μm . TSS includes mud, fine sand, and microscopic organisms, which generally come from erosion or soil erosion carried into the water body (Effendi, 2024).

Based on research conducted by Mika Debora, et al.(2023), the larger the area with very low vegetation density, the higher the TSS concentration in the aquatic environment. In addition, the larger the area with high vegetation density, the lower the TSS concentration value in the water at that location.

Meanwhile, activities such as mangrove deforestation, sand mining, and embankment construction can accelerate the abrasion process (Wahyuningsih et al., 2016; Yulius & Ramdhan, 2013). Abrasion is defined as coastal erosion due to the impact of waves and ocean currents, which causes the coastline to recede (Fitri et al., 2023), while accretion is the process of adding sediment material, which causes land growth around the coast, especially around river mouths (Sihombing et al., 2017).

Uncontrolled changes in the coastline can cause gradual land erosion that results in land narrowing, submerging public infrastructure, and disrupting coastal tourism activities. In addition, this condition reduces the carrying capacity of the coast

and disrupts the ecological, economic, and social functions of coastal communities. If it continues, coastal damage can also worsen the impact of rising sea levels and threaten the sustainability of the environment and the lives of coastal communities (Tasya et al., 2024; Husrin et al., 2021).

Singkil District in Aceh Singkil Regency is one of the coastal areas that is very vulnerable to changes in the coastline. This area borders directly on the Indian Ocean and has physical characteristics in the form of lowlands, swamps, and mangrove ecosystems. Recent reports indicate significant abrasion that has caused agricultural land and settlements to be eroded by the sea, exacerbated by the destruction of the mangrove ecosystem, which acts as a natural fortress (Annafiyah et al., 2022).

To effectively monitor coastline changes, remote sensing technology and geographic information systems (GIS) are very useful tools. The use of multitemporal satellite imagery such as Landsat 8 allows for coastline monitoring with high accuracy, wide area coverage, and time and cost efficiency (Tarigan et al., 2019). Extracting coastlines from satellite imagery at various times is essential to understand patterns of change and support sustainable coastal management.

This study aims to analyze the dynamics of coastline changes in Singkil District by utilizing Landsat 8 satellite imagery. The main focus of this study is to identify the area experiencing sedimentation and abrasion as an indicator of coastline changes during the period 2014 to 2025. The results of this study are expected to be a reference for local governments and policymakers in formulating more effective and sustainable coastal area management strategies. This research is pertinent and important due to the significance of coastal areas and the possible hazards posed by alterations to the shoreline. This project aims to enhance public and

stakeholder knowledge regarding the significance of coastal environmental preservation for future sustainability, whilst delivering precise geographical data.

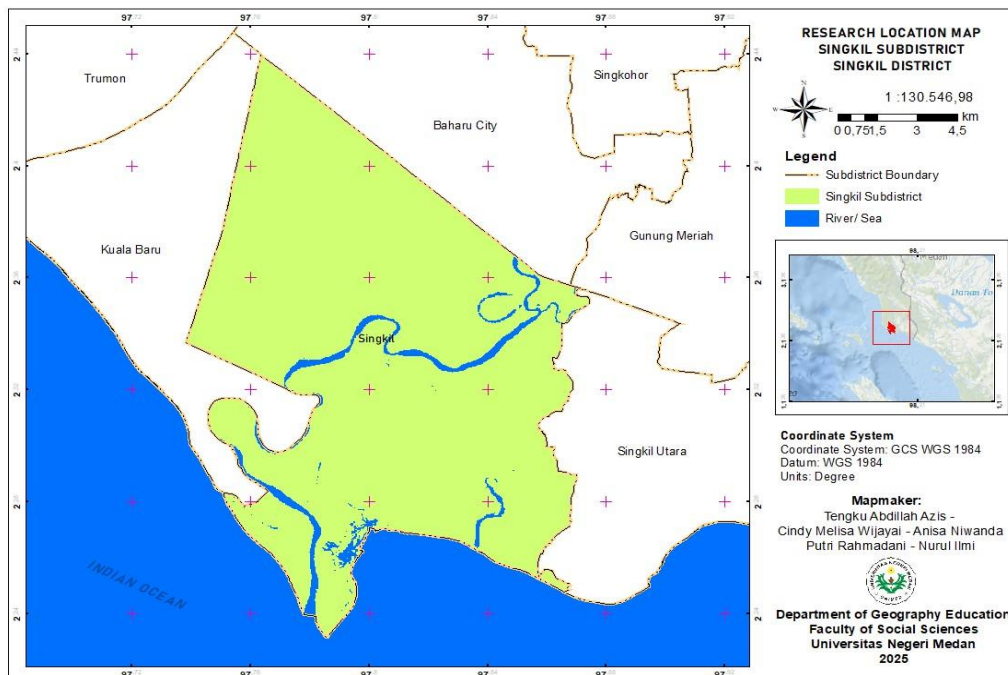
RESEARCH METHODS

This research employs a quantitative descriptive methodology that leverages remote sensing techniques to examine coastal alterations in Kecamatan Singkil, Provinsi Aceh. The project aims to delineate coastal alterations resulting from erosion and sediment deposition during an 11-year period, specifically from 2014 to 2025. The method used aims to create accurate maps of shoreline changes by using the NDWI

(Normalized Difference Water Index), which is effective at clearly identifying where water meets land (Shamsaie & Ghaderi, 2025).

The main data used in this study is Landsat 8 satellite imagery, downloaded through the USGS Earth Explorer portal. To obtain a more optimal visualization in distinguishing land and water areas, this study uses a combination of composite bands, namely band 5 (near infrared), band 6 (shortwave infrared), and band 4 (red) (GIS Learning Class, 2025). We went with this setup because it makes coastal features more noticeable by boosting the contrast between land and water objects.

Picture 1. Research Location Map



Source: Researcher

The research location is in the coastal area of Singkil District, which is one of the important coastal areas in Aceh. The analysis was conducted by comparing Landsat 8 images from two different periods, namely 2014 as the initial image and 2025 as the latest image to see the development or shift of the coastline for more than a decade. The data processing process is carried out through several technical stages. The first is the creation of a composite band, which is

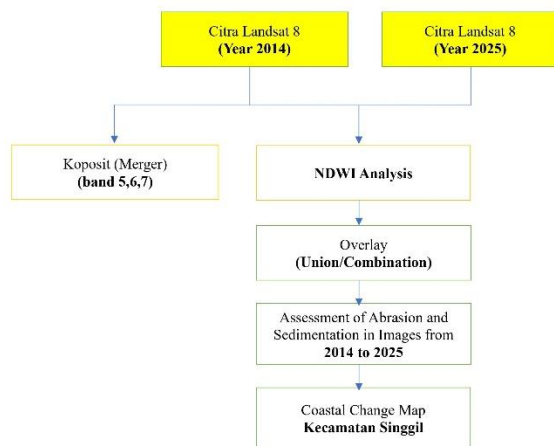
carried out to improve the visual interpretation capability between land and water (Anggraini et al., 2018). Next, an analysis of shoreline changes was carried out using the overlay method using the Geoprocessing (Union) feature in ArcGIS software.

This method allows the merging of shorelines from two different periods to map shifts that occur due to abrasion and sedimentation processes. The next stage is

the classification of land and waters which is carried out by utilizing the NDWI index so that the boundaries between land and water areas can be identified in more detail and accurately.

Data analysis was conducted spatially to detect and measure shoreline changes, both caused by abrasion and sedimentation. The final results of this study will be shown as a special map highlighting areas of erosion and buildup, an NDWI map to display where land and water are located, a graph comparing the sizes of erosion and buildup over time, and a table with numbers on shoreline changes in hectares (ha²).

Picture 2. Research Stages

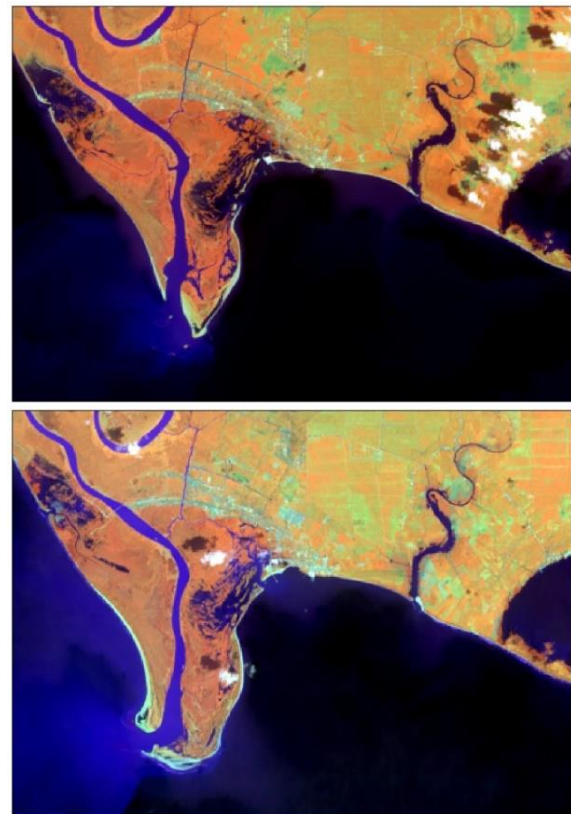


RESULTS AND DISCUSSION

The land/water-themed composite image was obtained by combining Bands 5, 6, and 4 through the composite bands feature in the ArcGIS 10.8 application. The results of this combination produce a multispectral image that shows the differences between land and water areas more clearly. In addition, the image is also able to show areas between the two, such as water bodies mixed with land material or land that is starting to be inundated or affected by water. However, multispectral land/water imagery alone is not enough to analyze abrasion and sedimentation in depth in the coastal area of Singkil District.

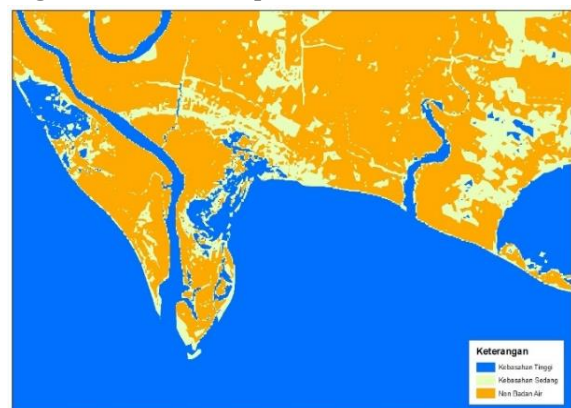
Therefore, an analysis was carried out using the NDWI (Normalized Difference Water Index) index. The results of this analysis were then converted into polygons, which were then overlaid using the Union feature in ArcGIS 10.8. This allows for a clearer view of the coastline, enabling more accurate identification of areas undergoing abrasion or sedimentation.

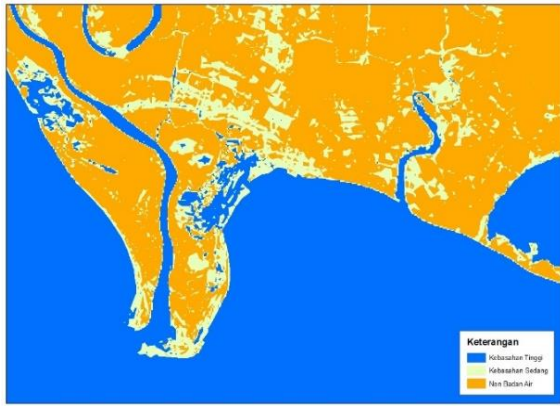
Figure 2. Landsat Image Composite Results
Land/Water 2014-2025



Source: Processed Landsat 8 imagery, 2025

Figure 3. NDWI Map Results 2014-2025





Source: Processed Landsat 8 imagery, 2025

Table 1. Extent of Abrasion and Sedimentation

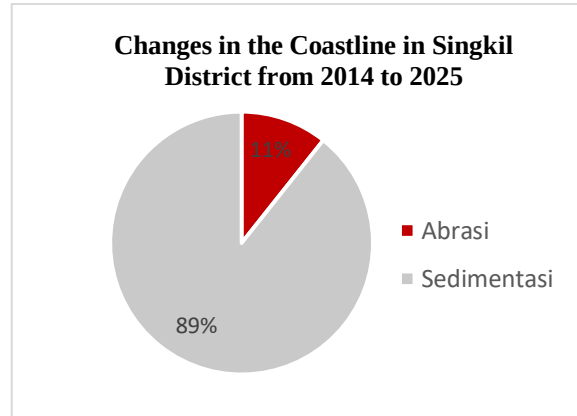
Area (ha ²)	
Abrasion	Sedimentation
30,12174	251,782

Table 1 shows the results of the analysis of coastline changes in Singkil District based on the interpretation of Landsat 8 satellite imagery. Based on the data obtained, the total area experiencing abrasion was recorded at 30.12174 hectares, while the area experiencing sedimentation reached 251.782 hectares.

This value shows that the sedimentation process in the coastal area of Singkil District is much more dominant than abrasion. This high sedimentation can be caused by the accumulation of material from the mainland carried by river flows and deposited around the coast or because of tidal activity and ocean currents that encourage the formation of new land. Although smaller in scale, the abrasion that occurs still needs to be considered because it can threaten the existence of coastal areas, infrastructure, and settlements along the coastline.

The percentages of abrasion and sedimentation along the shoreline in Singkil District from 2014 to 2025 are shown in Figure 4, which is a pie chart. This graphic makes it clear that (1) sedimentation accounts for 89% of all shoreline changes and (2) abrasion is responsible for just 11% of all changes.

Figure 4. Comparison of Abrasion Area and Sedimentation in Kecamatan Singkil in 2014-2025

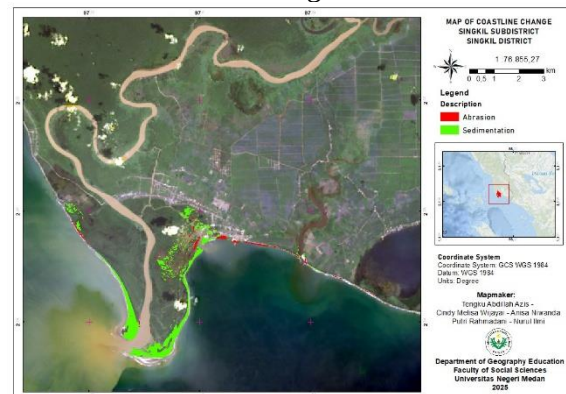


Source: Processed data, 2025

This diagram reinforces the findings in Table 1, which shows that the sedimentation area reached 251,782 hectares, much larger than the abrasion area of only 30.12174 hectares. This finding indicates that during the observation period, there was a significant increase in material deposition in the Singkil coastal area, which has the potential to cause land expansion.

If calculated on average per year over an 11 year period (2014–2025), then: (1) The annual sedimentation rate is estimated at around 22.89 hectares per year; and The annual abrasion rate is around 2.74 hectares per year. This calculation provides a quantitative picture of the rate of shoreline change each year, even though the imagery data used only covers two points.

Figure 5. Abrasion and Sedimentation Map in Kecamatan Singkil 2014-2025



Source: Processed data, 2025

Figure 4 shows a map of the results of a spatial analysis of coastline changes in Singkil District during the period 2014-2025. This map presents the distribution of areas experiencing abrasion and sedimentation identified through Landsat 8 satellite imagery. The red color on the map indicates areas experiencing abrasion, namely land erosion by ocean waves, currents, and other oceanographic factors. The green hue signifies regions undergoing sedimentation, a process that gathers sediment material from both land and sea, leading to the creation of new land along the coastline.

Based on the visualization results, it appears that the most dominant sedimentation process occurs in the southwest of Singkil District, especially around the river mouth and the southern coast. This area shows a significant increase in land, which is most likely caused by the supply of sediment from river flows that flow directly into the sea. On the other hand, abrasion was identified at several points on the east and north coasts, where the coastline appears to be receding toward the land. This pattern indicates that the area is vulnerable to destructive waves and coastal erosion. These changes in the coastline provide a real picture of the dynamics of the coastal area of Singkil District over a period of eleven years. This map also shows that the coastal area of Singkil is not only experiencing land shrinkage but also the formation of new land due to sedimentation.

The local government and relevant stakeholders must prioritize these changes when developing sustainable coastal management strategies, encompassing development planning, coastal protection, and catastrophe risk mitigation measures, including tidal flooding and seawater intrusion. Comprehending the spatial distribution of abrasion and sedimentation enables more precise and data-driven coastal resource management plans.

CONCLUSION

Based on the analysis of coastline changes in Kecamatan Singkil using Landsat 8 satellite images from 2014 to 2025, we can say that the coastal area of Singkil has gone through significant changes due to erosion and the buildup of sediment. Over the 11-year period, we recorded 30.12 hectares of abrasion and 251.78 hectares of sedimentation.

This finding indicates that the sedimentation process is significantly more dominant, accounting for 89% of the total change, while abrasion constitutes only 11%. The primary factors influencing this coastline change include natural processes such as tides, ocean currents, and sediment deposition from river flows, as well as human activities such as changes in land use in coastal areas. These results also emphasize the importance of using remote sensing technology and NDWI analysis in monitoring coastline changes efficiently and accurately.

Coastline changes in Singkil District have a significant impact on environmental conditions and the economic potential of the area. Therefore, the results of this study are expected to be the basis for the preparation of sustainable coastal area management strategies, including development planning, conservation, and mitigation of abrasion and tidal flood risks.

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