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Detection of Coastal Geomorphological Changes Using Remote Sensing and GIS Techniques: A Case Study of the Artificial Inlets of Bardawil Lagoon, Egypt

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INTRODUCTION & AIM

This study investigates four decades of coastal geomorphological changes (1985–2025) along the artificial inlets of the Bardawil Lagoon in Egypt. Multitemporal satellite remote sensing and GIS techniques were applied to monitor variations in shoreline position, inlet morphology, erosion–accretion patterns, and sediment dynamics.

The main objectives of the study are to:

- Detect and quantify shoreline and inlet changes.
- Identify spatial and temporal geomorphological patterns around the inlets.
- Measure erosion and accretion rates and trends along the coastal barrier.
- Evaluate the geomorphological impacts of dredging and inlet engineering.
- Support sustainable coastal zone management of the Bardawil Lagoon.
- Highlight the value of geospatial technologies for long-term coastal monitoring and Assessment.

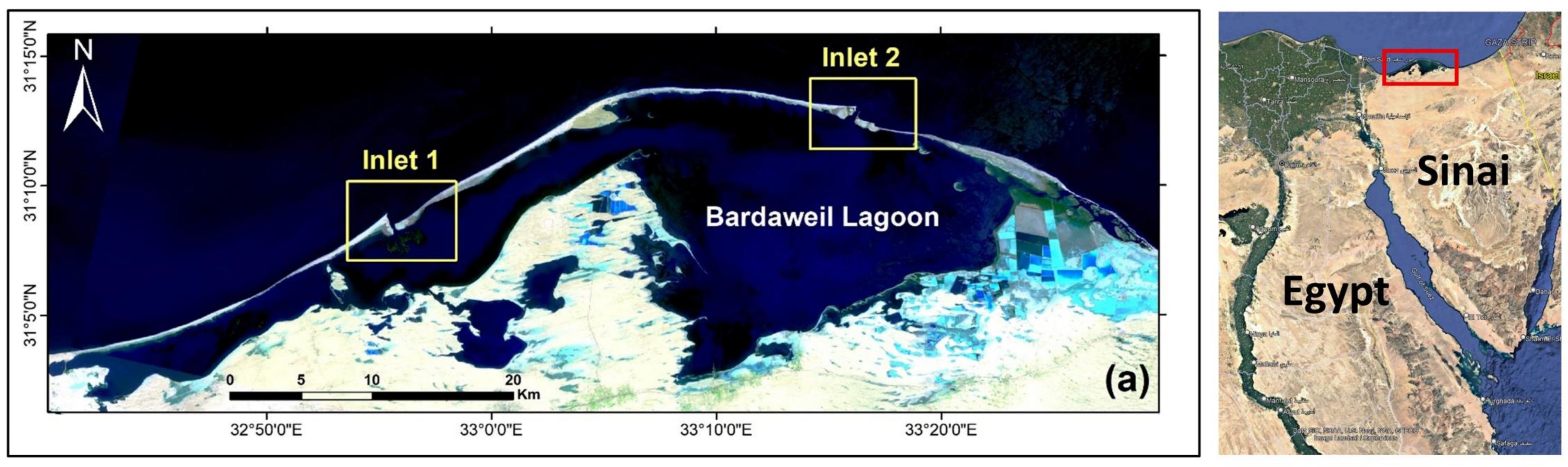

Figure1. Location of Study Area

MATERIALS & METHODS

Landsat surface reflectance imagery (path/row 175/38) from 1985 to 2025, at 5-year intervals, was used to analyze the spatiotemporal geomorphological changes along the Bardawil Lagoon inlets. Only high-quality, cloud-free scenes acquired during the summer season were selected. The dataset comprises Landsat-5 TM, Landsat-7 ETM+, Landsat-8 OLI, and Landsat-9 OLI+ Level-2 GeoTIFF products, all radiometrically and geometrically corrected and downloaded from the USGS Earth Explorer platform. These consistent, defect-free images provide a robust 40-year database for monitoring long-term coastal changes.

To achieve the objectives of this study, a three-step methodological approach was applied.

(1) Remote sensing data preprocessing: Landsat imagery was collected and preprocessed, including band composition, and geometric and radiometric corrections.

(2) Shoreline extraction: Shorelines were delineated before and after the construction of the jetties using the NDWI and MNDWI indices. The accuracy of the extracted shorelines was evaluated using high-resolution Google Earth imagery.

(3) Spatial analysis using DSAS: The Digital Shoreline Analysis System (DSAS), developed by the USGS, was used to compute shoreline change statistics and measure the positional differences between shoreline locations over time. NDWI and MNDWI were implemented using ERDAS Imagine and ENVI 5.3 to extract land–water boundaries through thresholding. NDWI, originally proposed by McFeeters (1996), utilizes the green and near-infrared (NIR) bands to enhance the contrast between water and non-water features.

$$\mathbf{NDWI} = \frac{(Band_{\,Green} - Band_{\,NIR})}{(Band_{\,Green} + Band_{\,NIR})}$$

$$\mathbf{MNDWI} = \frac{(Band_{\,Green} - Band_{\,MIR})}{(Band_{\,Green} + Band_{\,MIR})}$$

RESULTS & DISCUSSION

The results of the multitemporal geomorphological change analysis along the artificial inlets of Bardawil Lagoon revealed similar patterns of shoreline change, trends, and responses to coastal protection works.

Inlet-1: Two distinct zones of coastal change were identified—behind and in front of the Jetty. Behind the Jetty, the shoreline advanced by 179.4 m, with a maximum annual rate of +5.7 m/y and an average rate of +1.8 m/y. In contrast, the zone ahead of the Jetty toward the east experienced shoreline retreat, with a total distance of -183.2 m, a maximum annual rate of -9.2 m/y, and an average rate of -5.2 m/y.

Inlet-2: Two coastal process zones were observed. The first, an accretion zone located behind the Jetty toward the west, showed a total shoreline advance of 310 m, with a maximum annual rate of +8.9 m/y and an average rate of +1.9 m/y. The second zone, situated ahead of the Jetty, experienced erosion, with a total retreat distance of -280.6 m, a maximum annual rate of -8.2 m/y, and an average rate of -4.8 m/y.

Table 1. Statistics of Shoreline Changes between 1985 and 2025

		Inlet-1		Inlet-2	
		Zone I	*Zone II*	*Zone I*	*Zone II*
No. of Transects		120	240	260	311
Length (km)		2.4	4.8	5.2	6.2
NSM (m)	H	+179.4	-321.9	+310.5	-280.6
	M	+62.2	-183.3	+59.2	-169.2
EPR (m/year)	H	+5.97	-9.2	8.9	-8.2
	M	+1.8	-5.2	+1.9	-4.8
LRR (m/year)	H	+6.3	-8.9	+9.4	-7.9
	M	+2.23	-4.9	+2.0	-4.6

Where:

NSM= Net Shoreline Movement,
EPR= End Point Rate,
LRR= Linear Regression Rate.
H= Highest Rate,
M= Mean Rate.
(+) refer to accretion,
(-) refer to Erosion.

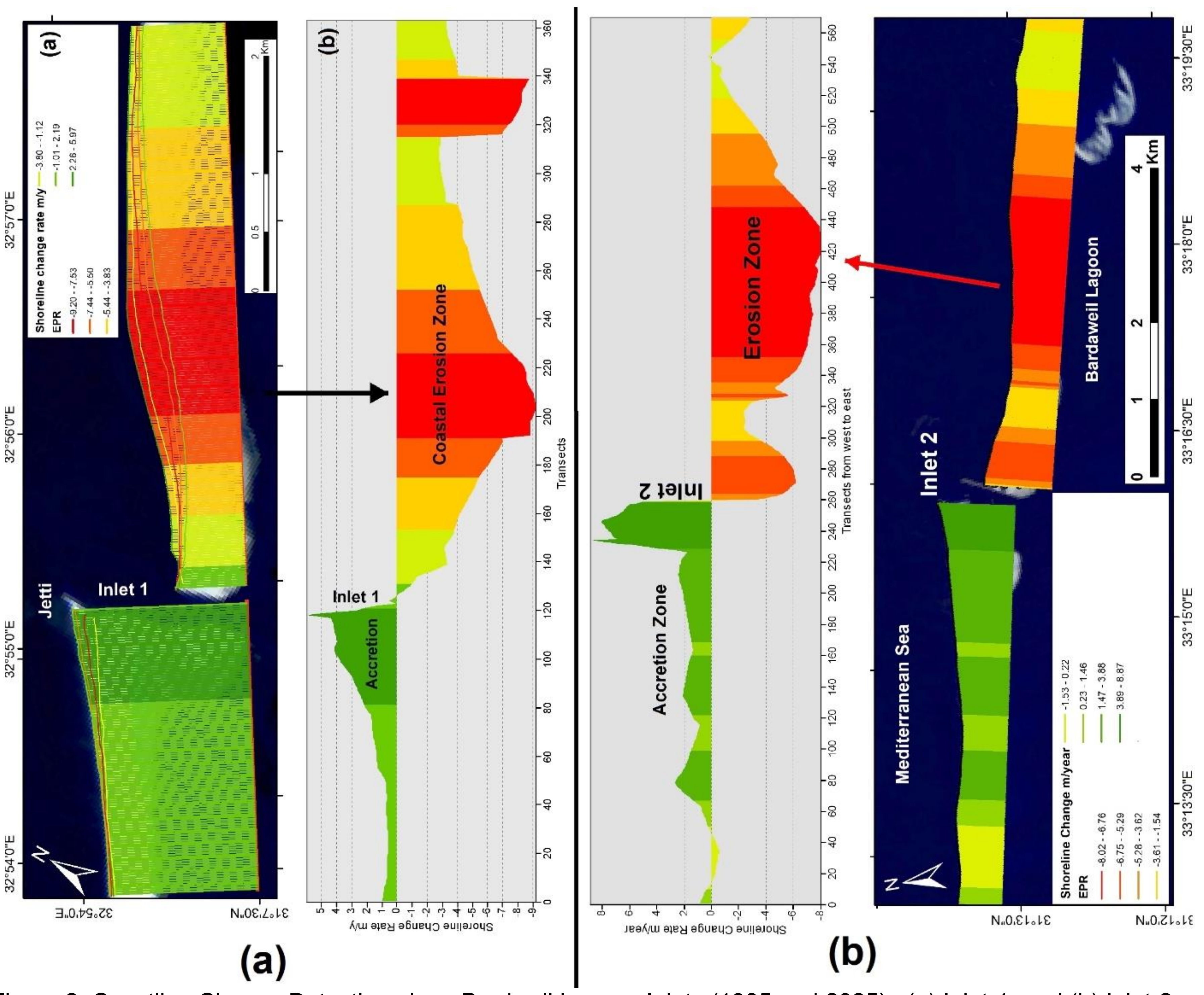

Figure 2. Coastline Change Detection along Bardawil Lagoon Inlets (1985 and 2025). (a) Inlet-1, and (b) Inlet-2

CONCLUSION

Multi-temporal remote sensing and GIS analyses effectively captured coastal geomorphological changes, identifying erosion and accretion zones. Existing coastal protection measures altered sediment flow, leading to new, severe erosion areas. Additional protection structures, such as groins and breakwaters, are recommended to safeguard the coastline. Future work should focus on continuous monitoring and modeling of shoreline dynamics to optimize coastal protection strategies and assess the long-term impacts of implemented measures.