

# Change Detection of the North Sinai Coast by Using Remote Sensing and Geographic Information System

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## **Abstract:**

The study area extends along North Sinai coastal plain which is considered an integral part of the Mediterranean Sea. Coastal zones are important issues in the international debate on the environment and sustainable development. The coastal zone generally consists of the interface between land and sea in such an equation where the marine space and resources are as important as terrestrial ones. The coastal zone have become the major site for extensive economic activities where many of the coastal developing countries depend essentially on the scarce coastal resources for economic growth.

The main goal of this study is to assess the coastal hazards that may occurred due to shoreline changes (erosion or / and deposition). This will lead to determination of the hazard magnitude of the unstable coastal area, which will reduce the environmental risk for the national development and natural resources of North Sinai coastal area. The present study provides the end users and decision-makers with the necessary information on long term shoreline behaviors of the study areas. This approach could be applicable to other coastal areas of Egypt, e.g. Red Sea coast through : a) delineating the pattern of shoreline changes within three time intervals 1970, 1984, and 1996. b) delineating the hazard area due to coastal changes and natural hazards affecting use and development of the resources. c) providing maps showing the hazard areas over the coastal zones of the risk area.

The shoreline changes have been delineated along the North Sinai coast by overlying different layers obtained from satellite images of Landsat Thematic Mapper acquired in 1984, 1996 and vector data obtained by vectorizing the shoreline from the topographic sheets scale 1:100,000 . The digital data ( satellite images ) and the topographic maps are geometrically corrected by the use of ERDAS IMAGINE 8.5 software.

## **INTRODUCTION**

Coastal Zones are important issues in the international debate on the environment and sustainable development. The coastal zone generally consists of the interface between land and sea in such an equation where marine space and resources are as important as terrestrial ones. The coastal zone has become the major site for extensive and diverse economic activities. Many of the coastal developing countries depend heavily on the scarce coastal resources for their economic growth. Rapid urbanization and economic development spawn complex resource use conflicts and environmental degradation problems in the coastal zones. Increasing population and market forces normally exert a heavier influence on the resources exploitation and use pattern.

Unexpected environmental hazards have been observed on the water bodies of North Sinai caused by sand movements, sand precipitation and salinization . Traditionally, natural hazards have been viewed in an ecological framework; this distinguishes between natural

events and their interpretation as natural hazards . Since the northern coastal zone of Egypt is a highly dynamic system, most of natural events show a wide range of variation, through time, in the use of energy and materials of environmental processes. The main goal of this study is to assess the coastal hazards that may occur due to shoreline changes (erosion or/and deposition), sand movements on the coastal zone. This will lead to determine the degree of hazard magnitude of the unstable coastal areas, which will reduce the environmental risk for the national development and natural resources of North Sinai coastal areas. This study will provide the end users and decision-makers with the necessary information on long term shoreline behaviors. This approach could be applicable to other coastal areas of Egypt (i.e. South Sinai , North of Eastern Desert and Red Sea coastal zones).

The identification of large-scale pattern of shoreline changes along Sinai coast implies that the coastal areas can be divided into a series of discrete sedimentation compartments called "littoral cells". Each cell contains a complete cycle of littoral transportation and sedimentation, including sources and sinks of sediments and transport paths. These sub-cells are part of the regional Nile littoral cells extending from Alexandria to Akko on the northern part of Haifa Bay, Israel (Inman and Jenkins 1984).

Seasonal variability of wave approach produces converging and diverging current pattern along the Sinai coast, the principal sources of sediments for each littoral sub-cell are the eroded headlands that supply large quantities of sand to the coast. Of particular importance to this study are the north Sinai littoral cells. Each sub-cell begins with a source area and ends by a sink. These cells have been previously identified based on shoreline changes by Frihy and Lotfy (1997). These are the Port Said sub-cell and Bardawil sub-cell. Each sub-cell contains a zone of erosion (sediment source) followed by a zone of deposition Wherein sand eroded from a headland is transported to the east and is mostly deposited in the next embayment, resulting in shoreline accretion.

The Port Said sub-cell includes the eastward transport of sand along the down coast east of Port Said, about 67km, and deposition along the shoreline within Atl Tinah Bay. The latter acts as sediment sink for the erosional products coming from the Port Said headland. For the most part, this sand is wave-driven by eastward littoral currents and currents generated by the east Mediterranean gyre which sweep across the inner shelf (Inman and Jenkins 1984).

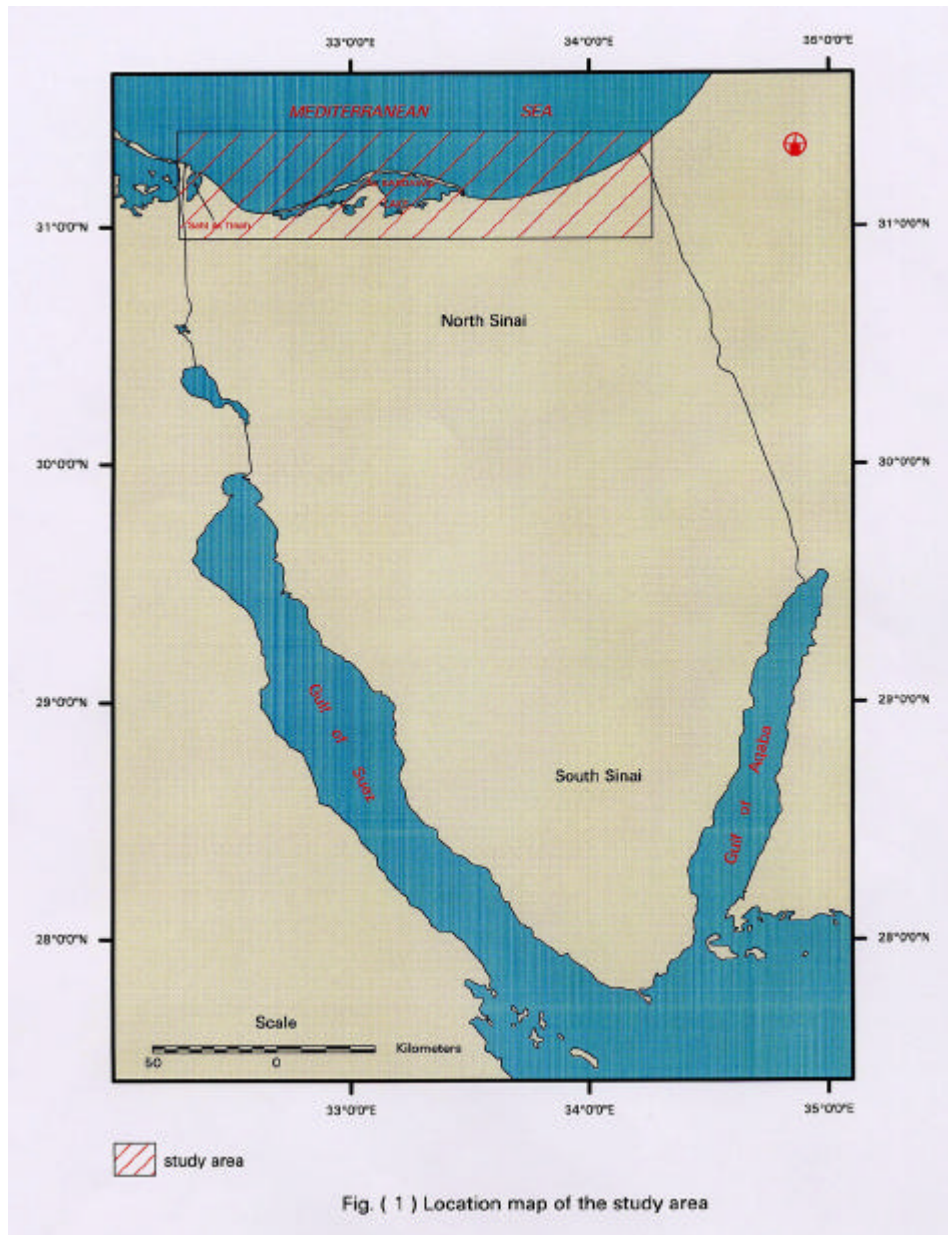
The Bardawil sub-cell represents the general erosion along the central bulge of Bardawil lagoon barrier and the longshore transport of sand to the east, where it is deposited to produce shoreline accretion along the embayment of El Arish-Rafah beach . El Arish-Rafah embayment acts as a sediment sink for sand eroded from the arcuate bulge-barrier of Bardawil lagoon.

## **STUDY AREA**

The study areas represented by North Sinai coast which extends about 175 km. long from Port Fouad in the west to Rafah in the east. This coastal area of Sinai considered as an integral part of the Mediterranean Coast of Egypt (Fig. 1).

The Physio-graphic provinces of the study area characterize the Sinai Peninsula; where

the Mediterranean foreshore province represents all the area of low relief terrain extending along the entire northern coast of North Sinai and inland to the mountains of the-mobile platform province of South Sinai. The landforms are predominantly sand dunes, sand sheets, and coastal depressions ( Swedan , A. et. al., 2001 )



## OBJECTIVES

- Determine the pattern of shoreline changes along North Sinai coastal area .
- Determine the hazard areas due to coastal changes, as well as natural hazards affecting use and development of resources.
- Provide maps showing the hazards areas over the coastal zones of North Sinai.

## **METHODOLOGY**

Several image processing techniques were applied to the TM data of the study area following which visual interpretation and map construction were performed employing the resulting images. These processing techniques included haze correction, destriping, stretching, filtering georeferencing, and band rationing. The result demonstrates that TM data can be used safely for change detection, lithological mapping as well as structural analysis in well exposed arid regions, and to generate detailed maps over large areas by using quantitative remote sensing methods, where prior knowledge is available for a part of the area.

Shoreline changes have been determined along North Sinai using vectors obtained from satellite images of Thematic Mapper (TM) acquired in 1984 and 1996 scenes No. 175/38, 175/39, 176/38 and 176/39 as well as the topographic maps scale 1: 100,000. The topographic maps ( 5 sheets Port Said, Rommanah, Bohairat Al Bardwel, Al Aresh and Rafah ) geometrically corrected using their own control points and the digital image data first of all enhanced by removing weather effects filtered and are geometrically corrected, using software ERDAS IMAGINE 8.5 using ground control points obtained from the topographic maps scale 1: 100,000 ( image to image correction ) and mosaiced ( stitched together to make one image ) figures 2, 3 and 4.

The pattern of erosion versus deposition is interpreted from the relative movement of shoreline in the seaward or landward directions along the study area. The horizontal movements of the shoreline position shifts were computerized measured at several points in the shore line

Fig. ( 7 ) which ranges from few centimeters to 32 meters per year

## **PATTERN OF EROSION AND DEPOSITION IN NORTH SINAI**

Changes in shoreline positions along the Sinai coast are attributed to natural and anthropogenic factors. This could be represented as follows:

### **A- Natural Changes:**

Previous works revealed that the shoreline of the North Sinai is accreted over the last 72 years at an average rate of 11.7 m/ year. Relatively smaller rates were calculated on the historical basis from-dated, accretion ridges (1925 years) and from Tel El Pharma historical site (2000 years). These rates are 1.6m/year and 1.8m/ year, respectively (Frihy, 1994). This difference could be attributed to the difference in time span, thousands of years versus tens used in case of the satellite images. According to wave directions, the shoreline pattern is a response to an southeastward transporting of sand, resulting from the prevailing wave arrival from the NW, generating southeastward flowing long shore currents. Sand is eroded from the east Port Said shore and adjacent shelf area and subsequently transported down coast to the east and southeast, resulting in shoreline and bottom accretion.



Changing shoreline positions along the North Sinai coast (At Tinah Bay) have been determined by comparing the topographic maps and 2 satellite images acquired in 1984 and 1996. The resulted coast-wide patterns of shoreline changes reveal that significant erosion is occurred along down coast east of Port Said followed by accretion along the embayment of At Tinah Bay, the later is interpreted as a "sediment sink". This pattern represents a simple pattern of erosion from the eastern tip of Port Said headland, with the eroded sand moving by waves coming from the NW, generating eastward-flowing long shore currents to the east wherein deposition occurs along the embayment of At Tinah Bay. The erosion processes of the winds accumulating great volumes of sand, which probably is transported to the east by littoral currents. Some of these sediments is transported into the basin causing sedimentation on the seabed.

The horizontal movements of shoreline position shifts are measured computerized . The examined pattern is inferred from the comparison of the following shoreline positions in the next figures

- Shorelines of 1973 and 1984 (Fig. 5 ).
- Shorelines of 1984 and 1996 (Fig. 6 ).
- Shorelines of 1973 and 1996 (Fig. 7 ).

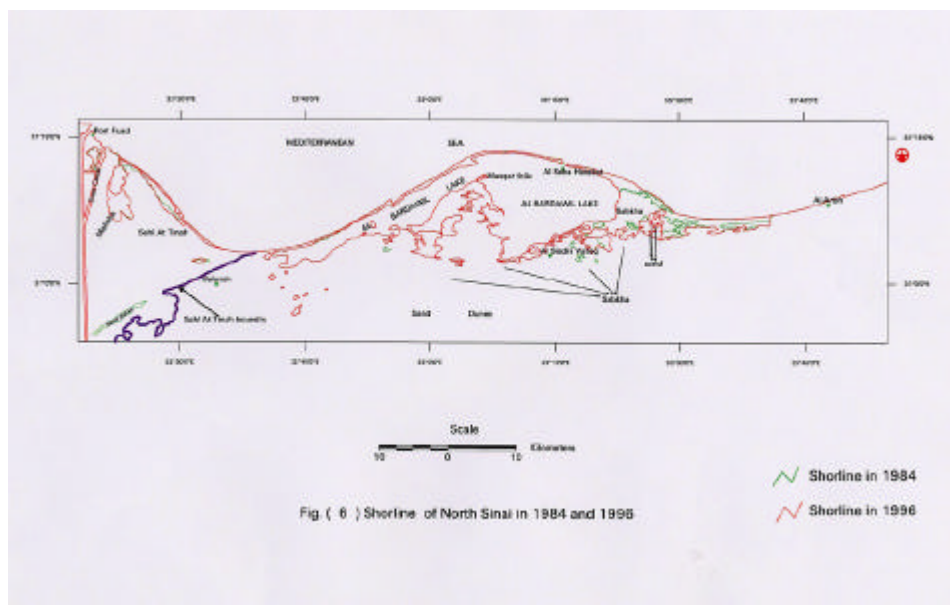
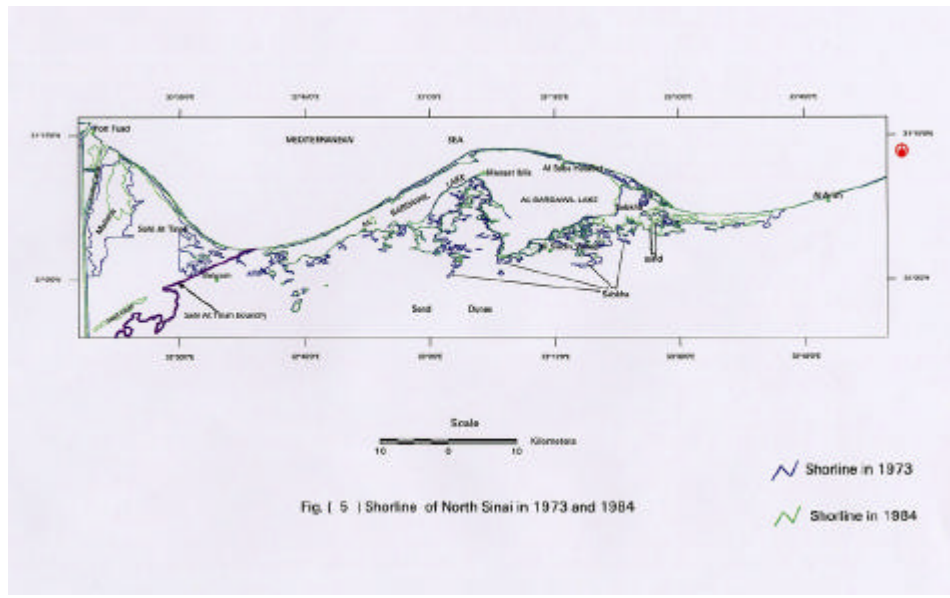
According to the results derived from image processing and comparing the shoreline in 1973 from the topographic sheets and in 1996 from satellite image, the coast shows wide patterns of changes (erosion and accretion). In eleven observation points on the shoreline presented in fig. (7 ). The shoreline changes estimated in table No. ( 1 ) . These measurements reveal that significant accretion occurred along down coast east of Port Said at the net accretion rate of 32 m/year in observation point No. 1 . This is followed by erosion along the embayment of At Tinah Bay and the eastern part of El Bardawil lagoon barrier .

Observation points	1	2	3	4	5	6	7	8	9	10	11
Shoreline Change from 73 to 96	+730	- 297	+83	+420	+154	+61	+113	- 164	- 240	+254	+185
Average in m/year	+32	-13	+4	+18	+7	+3	+5	-7	-10	+11	+8

Table No. ( 1 ) North Sinai shoreline changes in different places

Moving eastward from part of Port Said shows mild net erosion rate of 13 m/year in observation point No.2 . Erosion is reverted to accretion along the coastline of El Tineh plain and the eastern part of Bardawil lagoon barrier up to Inlet. The accretion pattern induced from this study is evidenced from the chronic accretion features documented in this region since about 2000 years ago (Sneh and Weissbrod, 1973). This was indicated from a series of accretion coastal sand ridges parallel to the present coastline of El Tineh Bay and in observation points No. 3, 4, 5, 6 and 7 . The eroded sand moving by waves coming from the NW, generating eastward-flowing longshore currents to the east wherein deposition occurs along the embayment of Tineh Bay.

Further to the east, erosion also occurs in the observation points No. 8 & 9 . Along the arcuate bulge of the central Bardawil coast-barrier with a maximum net rate of 18 m/ year over 23 years.



**CHANGES OF BARDAWIL LAKE :**

Sedimentation unbalance is more pronounced at many sites on the lagoon sandy barrier. This imbalance has impacted the ecosystem in the lagoon by causing serious shoaling problems and thus changing the ecosystem of the lagoon and the fish productivity in particular ( Swedan , A et. al., 2001 ) Several attempts have been carried out since 1972 to combat this problem. Significant changes which occur in down coast orientation at the two inlets produce movable sand bars leading to changes in the shape and the width of the Bardawil Lake inlets.



## **CHANGES OF AT TINAH BAY :**

Changing of the shoreline positions along the Sinai coast (Tineh Bay) have been determined by comparing topographic maps ( 1973 ) and satellite images acquired in 1984 and 1996. The resulted coast-wide patterns of shoreline changes reveal that significant erosion is occurred along down coast east of Port Said followed by accretion along the embayment of El Tineh Bay, the later is interpreted as a "sediment sink". This pattern represents a simple pattern of erosion from the eastern tip of Port Said headland, with the eroded sand moving by waves coming from the NW, generating eastward-flowing longshore currents to the east wherein deposition occurs along the embayment of Tineh Bay.

Sedimentation unbalance is more obvious at many sites on Sahl At Tinah and At Tinah Bay , Fig. ( 9 ). This Sedimentation has impacted the ecosystem in these sites by causing serious shoaling problems and thus changing the ecosystem of them and the fish productivity in particular . The large quantities of the deposited sand , evaporization salinitization and the human activities in these sites cases of this changes

From table No. ( 2 ) and fig. ( 8 ) which shows the areas of North Sinai water bodies in different years ( in Km<sup>2</sup> we can see that the area of At Tinah Bay changes rapidly from year 1973 to year 1984 and the average lose is 83 Km<sup>2</sup> , and changes slowly from year 1984 to year 1996 and the average lose is 1.6 Km<sup>2</sup>

## **SAND MOVEMENT HAZARDS :**

The downwind march of the dunes comes across various features of human targets. Thus, they are continuously causing hazards affects on the sustainable development of the region and threatening the lives of people living there. There is no hope in the foreseeable future that sand supply will be cut, since the source of sand for Sinai dunes is the North Sinai sand sea lying on the plane north of it. It can conclude that the struggle between moving dunes and local people is endless, and that coexistence is unavoidable.

The area of study lies on the northern part of North Sinai sand sea which extends from the Mediterranean coast in the north to the northern slopes of Gebel Maghara and Gebel Halal in the south, and from the eastern borders of Egypt to the Suez Canal.

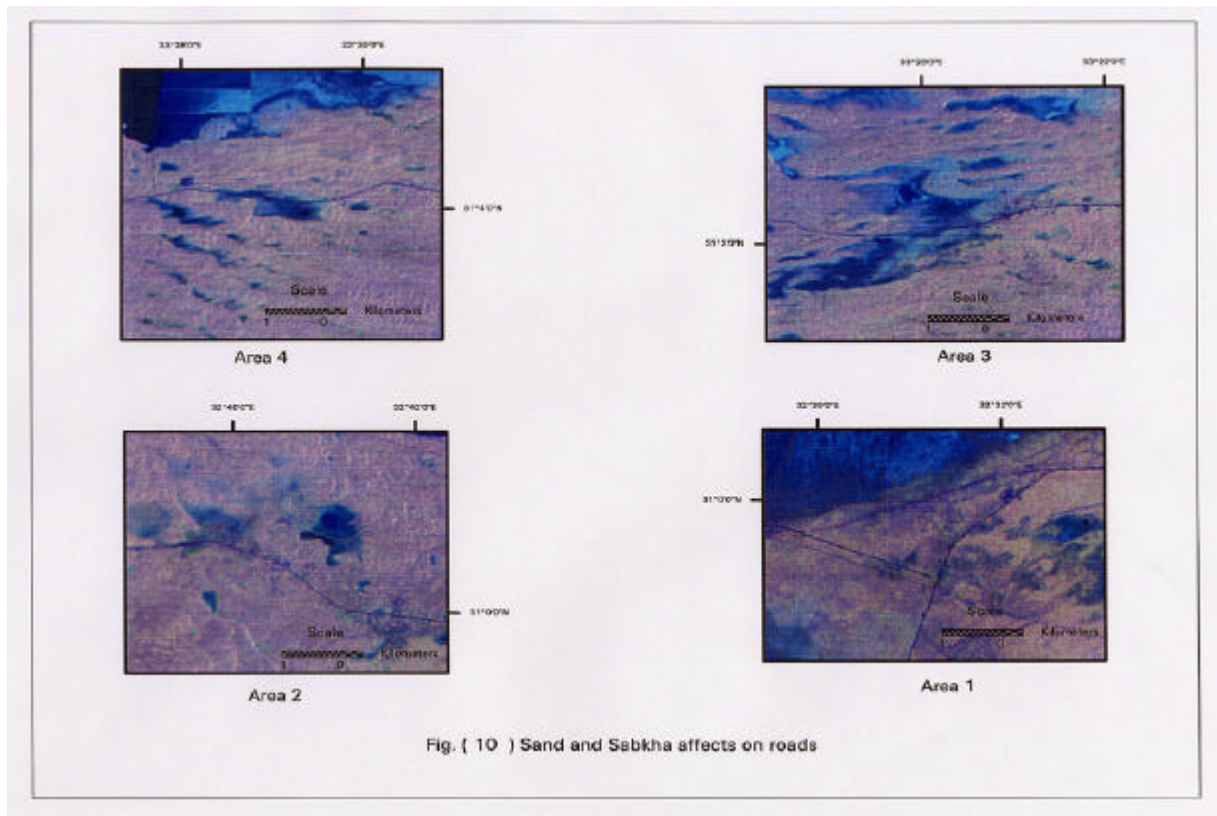
## **Definition of Sand Sea**

In desert geomorphology, definition of sand seas is based on two criteria: Minimum area of a sand sea and percentage of sand coverage of its total area. Embabi (1998) adopted the definition of a sand sea as follows:

A sand sea is an area of wind-blown sand exceeding 5,000 km<sup>2</sup>, where no less than 50% of this area is covered with aeolian sand. This definition is used in the present work, Differentiation between sand seas and dune fields is based on this definition.

The area of a dune field may exceed the above mentioned one, but sand coverage is lower than 50%.

Aim of this study is also to put on light the most threatened areas by sand movement . By using remote sensing techniques we can determine the location of the most threatened areas, which can be presented in this area by 4 sites in which sands affects on the asphaltic roads more obvious figures ( 9 & 10 ).



( Fig No 10 )

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