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RESEARCH ARTICLE

Space-borne technology for monitoring temporal changes along Damietta shoreline, Northern Egypt

Ahmed El-Zeiny[1], Abd-Alla Gad[1], Maie El-Gammal[2] and Mahmoud Ibrahim[2]

1. Division of Enviornmental Studies and Land Use, National Authority for Remote Sensing and Space Sciences (NARSS), Cairo, Egypt
2. Department of Environmental Science, Faculty of Sciences, Damietta University, Damietta, Egypt

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***Corresponding Author**

Ahmed El-Zeiny
aelzeny@narss.sci.eg

Abstract

In this research, remote sensing and GIS techniques were employed to monitor and quantify annual changes along Damietta shoreline, Egypt. Coastal landforms are highly dynamic in nature; however urbanization and population rapidly increase on these areas due to the abundant natural resources. A set of Landsat and SPOT multispectral images acquired at different dates (i.e. TM.1984, SPOT3 1997, SPOT4 2011 and OLI 2014) were used to monitor the shoreline changes. Onscreen digitizing was simply used for shoreline mapping at different years, using ArcGIS software V 10.1. Conversion of polyline into polygon was utilized in order to calculate areas characterized by erosion and accretion. The results showed that the study area was subjected to remarkable and non-expected changes during the study periods. Recorded eroded and accreted areas were 6.993 and 4.429 km^2, respectively during 1984-1997, 8.111 and 3.283 km^2 during 1997-2011 as well as 1.242 and 3.455 km^2 during 2011- 2014. The annual rate of erosion during the periods of study showed relatively similar values recording 0.538, 0.579 and 0.414 km^2 at 1984-1997, 1997-2011 and 2011-2014, respectively. However, the annual rate of accretion recorded the maximum value at 2011-2014 (1.152 km^2/year), while the minimum rate was remarked at 2011-2014 (0.234 km^2/year) followed by 0.341 km^2 at 1997-2011. The study recorded that the construction of breakwater in the study area has decreased the annual rate of erosion particularly from the period of 1997-2011 to 2011-2014 (i.e. from 0.579 km^2 to 0.414 km^2, respectively). This decrease was synchronized with an increase in the annual accreted areas from 0.234 km^2 to 1.152 km^2, respectively. Due to the shoreline dynamism, the constructed breakwaters have created new areas of erosion which were responsible for drowning deaths of about 75 swimmers.

INTRODUCTION

Coastal areas are very important for human beings, as they witness culture and economic exchanges between different nations. Most of the big cities, having famous harbors around the world are situated at coastal areas. About one-third of the human populations are living in and around the seashore areas. Due to abundant natural resources, urbanization and population rapidly increase on coastal areas. Various developmental projects are installed in the shoreline areas, placing great pressure on it, leading to diverse coastal hazards like sea erosion, seawater intrusion, coral bleaching, shoreline change; etc. Coastal landforms are highly dynamic in nature (**Kumaravel, 2013**).

Shoreline is one of the unique features of earth surface, recognized by the International Geographic Data Committee (IGDC), among 27 ones. It is defined as the line of contact between land and water body. It is easy to define, however difficult to capture due to its dynamic nature. Accurate demarcation and monitoring of shorelines (seasonal, short-term and long-term) are necessary for understanding various coastal processes (**Nayak, 2002**).

Remote sensing technology has proven to be of great importance in acquiring data for effective resources management and hence could also be applied to coastal monitoring and management. Further, the application of Geographical Information System (GIS), in analyzing the trends and estimating the changes that have occurred in different themes, helps in decision making process (**Ramachandran, 1993 and Ramachandran *et al.*, 1997**). Availability of repetitive, synoptic and multi-spectral data from various satellite platforms (e.g. IRS, LANDSAT, SPOT) have helped to generate information on varied aspects of the coastal and marine environment (**Nayak, 2002**). Remote sensing has also widely been used in environmental change detection studies. The integration of different modern scientific tools (i.e. remote sensing, GIS and GPS) are extremely valuable in development and analyzing of databases. Such integration is also valuable development and elaboration of management action plans (**Mass, 1999**). In this research, remote sensing and GIS techniques were utilized to monitor and quantify the periodic and annual changes occurred along shoreline of Damietta, Northern Egypt. The studied changes include eroded and accreted areas (km^2), in addition to retreat and progress (m) of the shoreline.

1. Study Area

The study area is located along the Mediterranean Sea coast of Damietta Governorate, Northern Nile Delta of Egypt. It lies between longitudes 31^o 30' to 32^o 6' E and latitudes 31^o 20' to 31^o 34' N. It is extended for about 10 km offshore the coastline of Damietta, covering a total area of 739.68 km^2 (Figure 1). It is bordered from the North by Mediterranean Sea, from the West and Western South by Daqahlia Governorate, from the East and Eastern South by Manzala Lagoon. The coastline of the study area is extended for about 65.72 km from Gamasa city (Daqahlia Governorate) at the east to Port Said city at the west.

The natural and man-made changes in the coastal zone of the Nile Delta have induced variable processes. The most expressive process refers to shoreline erosion, associated with sedimentation inside the coastal lagoon inlets, estuaries and harbors. Erosion has negatively affected the agriculture and urban areas along the delta promontories at Rosetta, Burullus and Damietta. The coastal zone of Damietta, as a part of the Nile Delta, is a promising area for energy resources and industrial activities. It also contains important wetland ecosystems. Unfortunately, this water resource is facing unprecedented environmental degradation (**Abou El-Magd and El-Zeiny, 2014**). Damietta Governorate consists of four districts (i.e. Kafr Saad, Damietta, Faraskour and Azarqa). In the present study, only the two coastal districts (i.e. Damietta and Kafr Saad) are investigated. The study areas are considered the most affected area by Mediterranean Sea climate and activities (Figure 2). There are different activities practiced in and around the shoreline; fishing at Manzala Lagoon, recreation activities in coastal cities (i.e. Ras El-Bar and New Damietta cities), industrial activities concentrated in the industrial zone of New Damietta city, navigation in Damietta Harbor, commercial activities in different cities particularly Damietta and New Damietta while agricultural activities are dominant in different parts of the area, especially in the central and eastern parts (**El-Zeiny, 2015**).

The climatic condition of the area is typical Mediterranean environment with moderate temperature most of the year. The predominant wind direction in the area of study is almost northwest direction most of the year, which creates a general eastward-flowing longshore current (**El-Asmar and Hereher, 2010**). Statistically, it was found that 81% of these waves originate from the northwest direction, 14% from the northeast and just 5% from southwest (**Frihy *et al.*, 2003**). Winter season almost records the maximum wave height of 4.2 m which predominantly from the west-north-west wave direction; whereas spring season records the minimum wave height of 1.16 m which originates from the northwest direction (**El-Banna, 2007**). A tidal difference is semi-diurnal and ranges between 25 and 30 cm along the delta coast (**El-Gammal *et al*., 2015**).

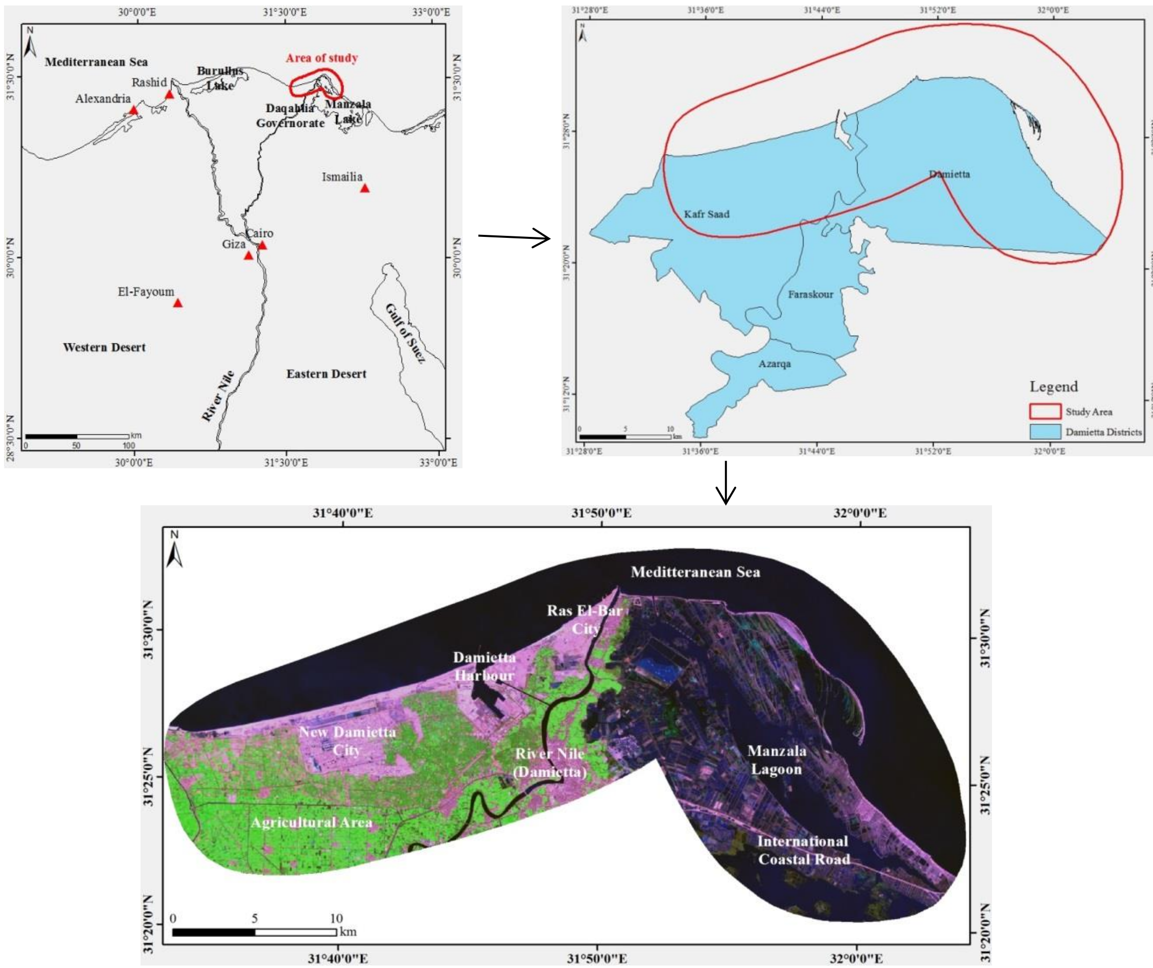

Figure (1): Location map for the study area

2. Materials and methods

2.1. Satellite Images

In the current research, images of various space-borne multispectral sensors were utilized for tracking and mapping the changes occurred in the shoreline. They include Landsat TM (1984), SPOT (1997), SPOT (2011) and Landsat 8 (2014). Landsat imageries were freely downloaded from USGS website (***http://glovis.usgs.gov/***); however SPOT images were acquired from NARSS. Table (1) summarizes the technical specifications of the sensors utilized in the current study. Image processing and geospatial procedures were carried out using ENVI 5.1 and ArcGIS 10.1 Software respectively.

Table (1): Technical specifications of the employed optical sensors

Satellite	Sensor	Bands	Wavelength (micrometers)	Spatial Resolution (meters)	Acquisition Date
Landsat 4	Thematic Mapper (TM)	Band 1- Blue	0.45-0.52	30	September 1984
		Band 2- Green	0.52-0.60	30	
		Band 3- Red	0.63-0.69	30	
		Band 4-NIR	0.76-0.90	30	
		Band 5- SWIR 1	1.55-1.75	30	
		Band 6- Thermal Infrared 1	10.40-12.50	120	
		Band 7- Thermal Infrared 2	2.08-2.35	30	

SPOT	SPOT 3	Band1- Green	0.50-.59	20	July 1997
		Band 2-Red	0.61-0.68	20	
		Band 3-NIR	0.79-0.89	20	
		Band4-Panchromatic	0.61-0.68	10	
	SPOT 4	Band 1- Green	0.50-.59	20	August 2011
		Band 2-Red	0.61-0.68	20	
		Band 3-NIR	0.79-0.89	20	
		Band 4-MIR	1.58-1.75	20	
		Band5-Panchromatic	0.61-0.68	10	
Landsat 8	Enhanced Thematic Mapper Plus (OLI)	Band 1 - Coastal aerosol	0.43 - 0.45	30	April 2014
		Band 2 - Blue	0.45 - 0.51	30	
		Band 3 - Green	0.53 - 0.59	30	
		Band 4 - Red	0.64 - 0.67	30	
		Band 5 -NIR	0.85 - 0.88	30	
		Band 6 - SWIR 1	1.57 - 1.65	30	
		Band 7 - SWIR 2	2.11 - 2.29	30	
		Band 8 - Panchromatic	0.50 - 0.68	15	
		Band 9 - Cirrus	1.36 - 1.38	30	
		Band 10 - TIRS1	10.60 - 11.19	100	
		Band 11 -TIRS2	11.50 - 12.51	100	

2.2. Image processing and monitoring shoreline changes

Image processing procedures were applied to obtain information, which is difficult to be detected from the raw data (**Sabin, 1997)**. The obtained images were geometrically and radiometrically calibrated, thus the performed image pre-processing steps included only layer stacking and image sub-setting. Remote sensing and GIS technologies have been largely used for mapping shoreline and for monitoring the coastal processes (**El-Asmar *et al.*, 2014**). In the current study, quantification of the erosion/accretion rates and areas of eroded and accreted regions were carried out using on-screen digitizing of features that are obvious in the multi-temporal satellite data (i.e. Shoreline). GIS thematic layer was built where areas of erosion and accretion were computed. Simply, a conversion of GIS polyline into polygon was carried out to separate areas of erosion and accretion. To facilitate the study of erosion and accretion, the region would be divided into four equal sectors (Sector A, Sector B, Sector C and Sector D). Sector A is the west part of the Damietta Shoreline where New Damietta city is located. Moving a little eastward, Sector B was located where Damietta Harbour and Ras El-Bar city are found. Sector C represents Deiba and Damietta promontory tip, while Sector D is the east part of Damietta Shoreline at the western borders of Port Said shoreline (Figure 2).

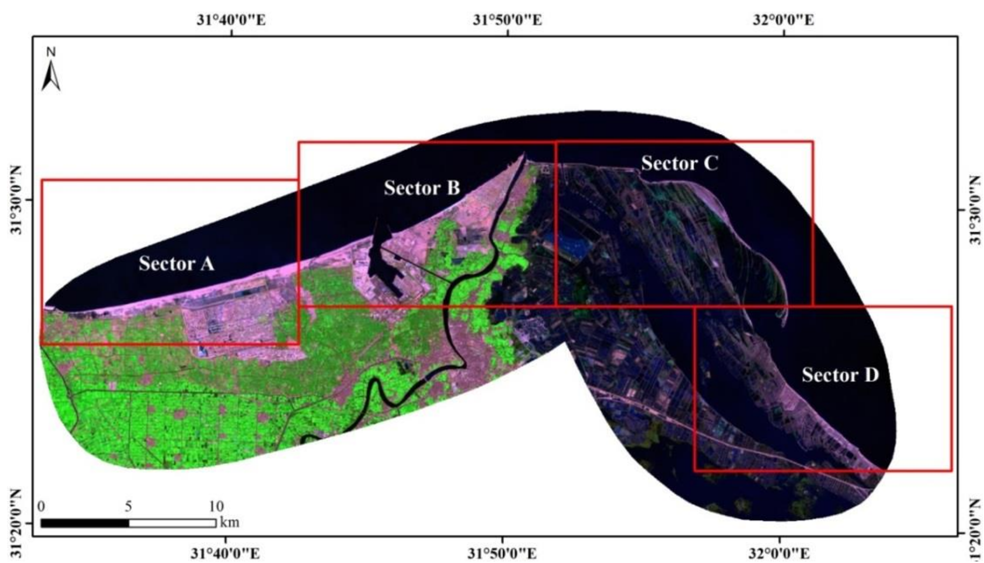

Figure (2): Sectors of shoreline erosion and accretion

3. Results and Discussions

3.1. Assessment and mapping of Damietta shoreline erosion and accretion

Several studies have been conducted to monitor the erosions and accretions occurred in the Nile Delta region; **Smith and Abdel-Kader (1988), Sestini (1989), El-Asmar (1995), Abou El-Magd (1995), Fanos (1992), El-Asmar (2002a), El-Banna (2007)**, **El-Asmar *et al.*, (2014)** and **El-Zeiny (2015).** Damietta shoreline is one of the most dynamic parts which undergo remarkable and non-expectable changes (i.e. erosion and accretion) during the three studied periods of time (i.e. 1984-1997, 1997-2011 and 2011-2014). The total eroded and accreted areas during the whole period (i.e. 1984 to 2014) were 16.246 and 11.166 km^2, respectively (Figure 3).

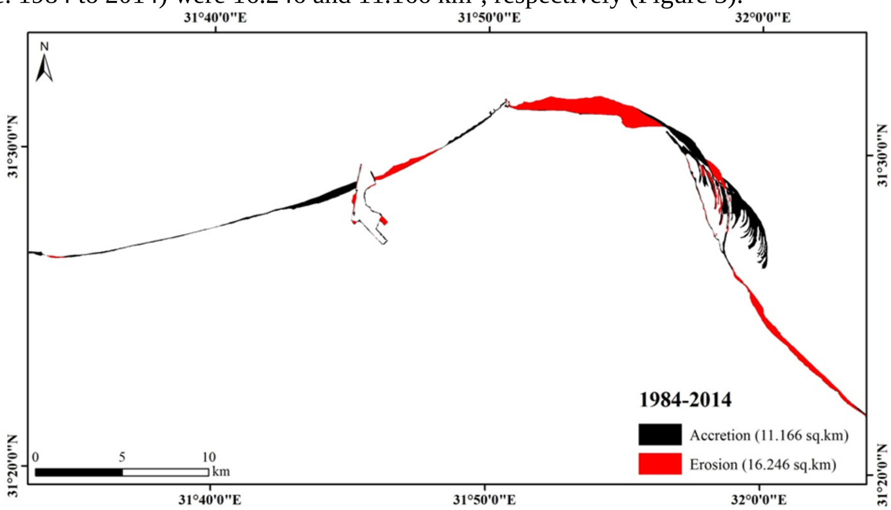

Figure (3): Total area of erosion and accretion between 1984 and 2014

As illustrated in table (2) and figures (4, 5, 6 and 7), total areas of erosion and accretion were 6.993 and 4.429 km^2, respectively during 1984-1997, 8.111 and 3.283 km^2 during 1997-2011 as well as 1.242 and 3.455 km^2 during 2011-2014. The annual rate of eroded area during the periods of study has showed relatively similar values; 0.538, 0.579 and 0.414 km^2/year at 1984-1997, 1997-2011 and 2011-2014, respectively. However, the annual rate of accreted area recorded changeable values at the studied periods where the maximum rate was detected at 2011-2014 (1.152 km^2/year), while the minimum rate was remarked at 2011-2014 (0.234 km^2/year) followed by 0.341 km^2/year at 1997-2011.

Table (2): Total area (km^2) and annual rate (km^2/year) of erosion and accretion

Period	Erosion		Accretion	
	Total Area	Annual Rate	Total Area	Annual Rate
1984-1997	6.993	0.538	4.429	0.341
1997-2011	8.111	0.579	3.283	0.234
2011-2014	1.242	0.414	3.455	1.152

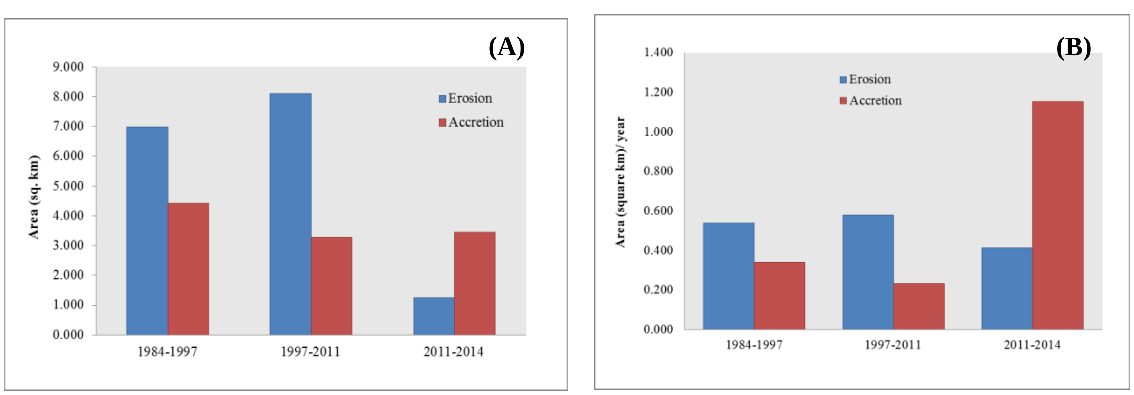

Figure (4): Eroded and accreted areas at different periods (A), annual rate of erosion and accretion (B)

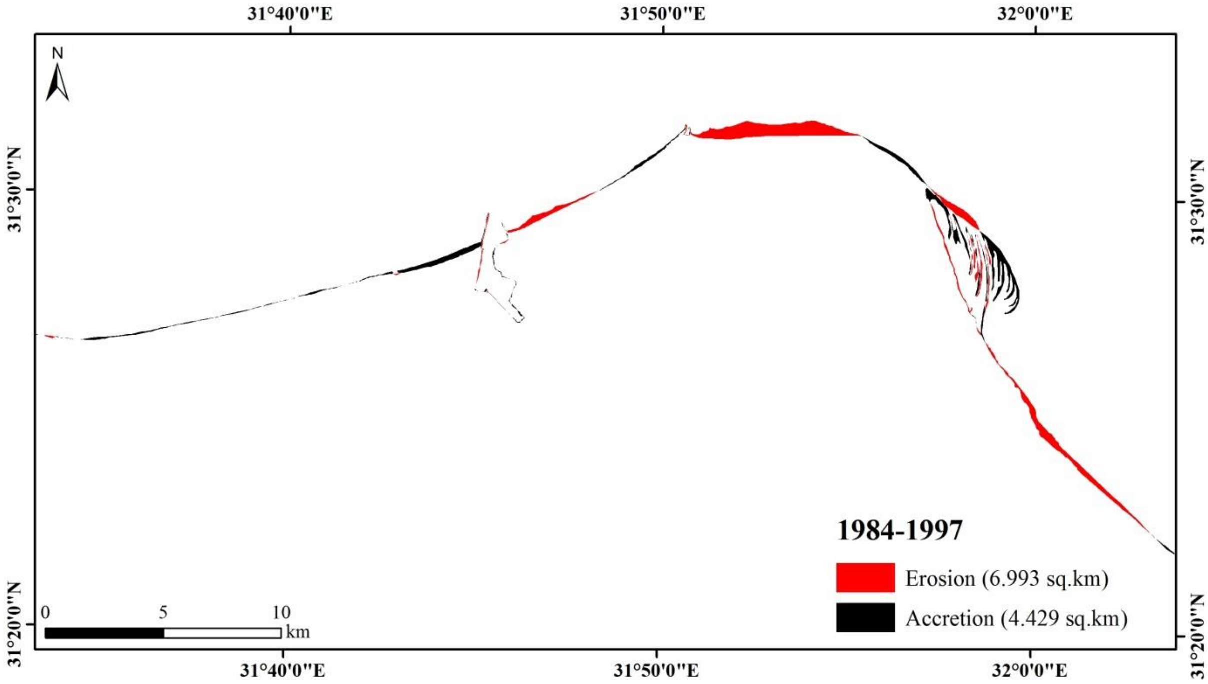

Figure (5): Total areas of erosion and accretion between 1984 and 1997

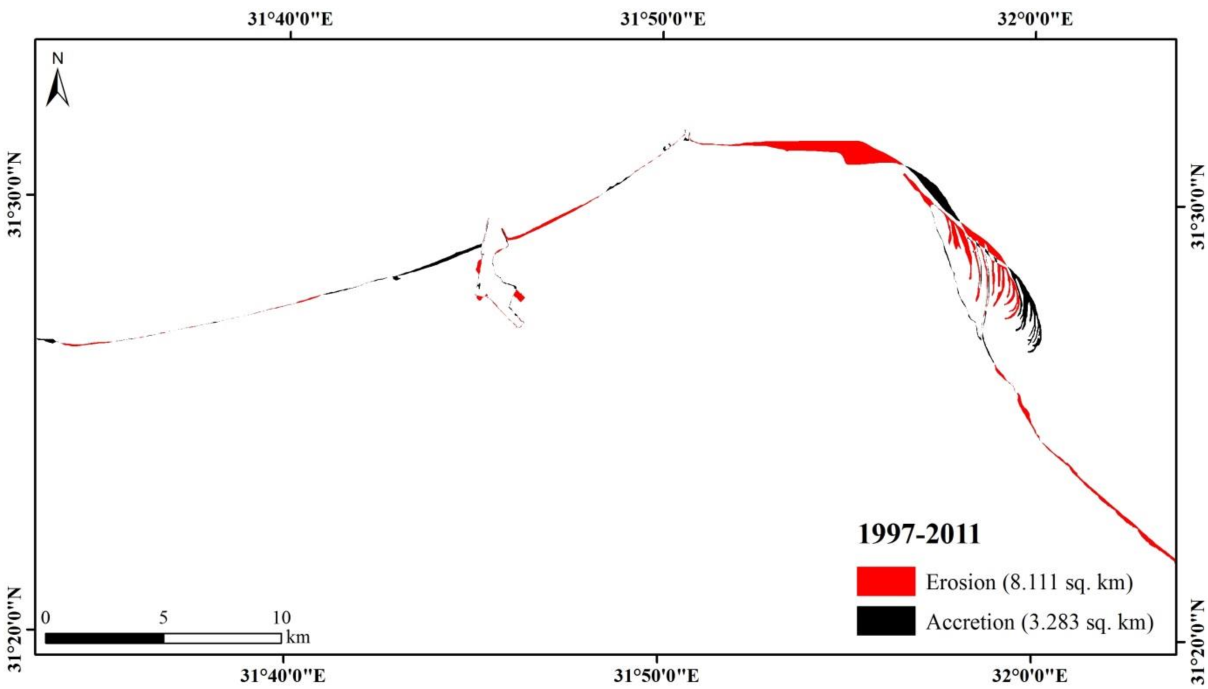

Figure (6): Total area of erosion and accretion between 1997 and 2011

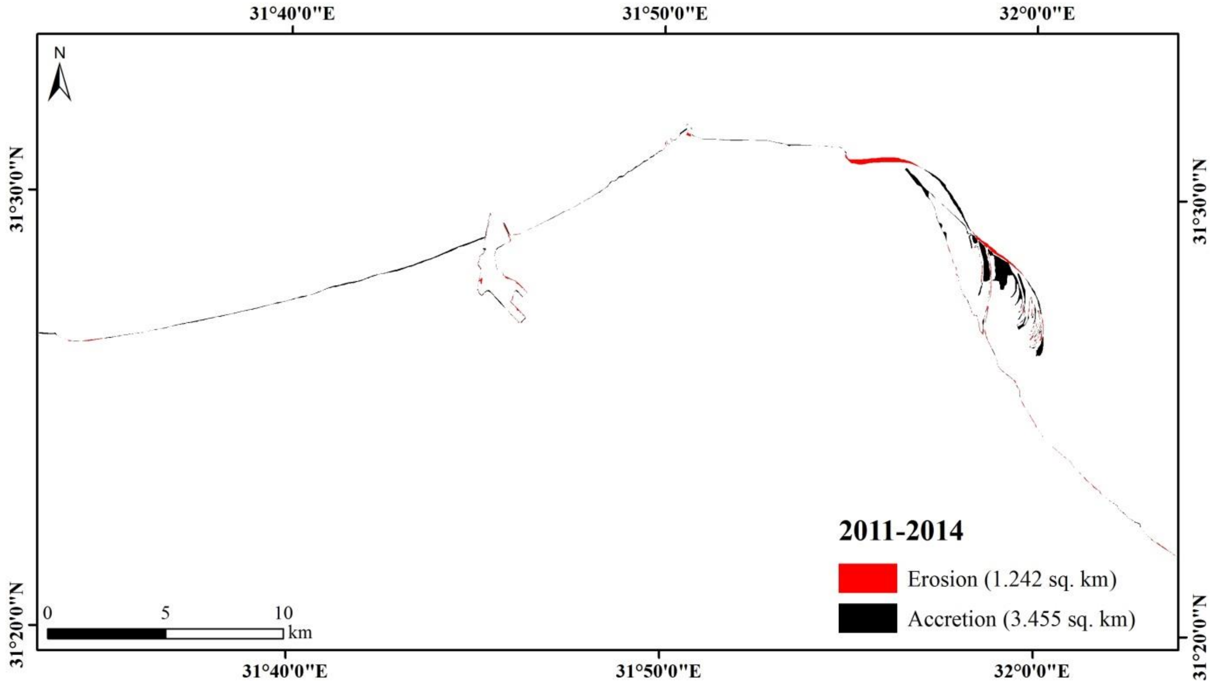

Figure (7): Total area of erosion and accretion between 2011 and 2014

3.2. Impacts of constructing breakwaters

To reduce rates of erosion, four detached breakwaters were constructed in the period of 1990 - 1993; they were positioned 75 m to the east of the third groin and extend westward at a depth of 4 m below sea level and a distance of 400 m from the shoreline. The length of each was about 200 m, with a gap width of 200 m and a crown height of 2.5 m above the sea level. Each was armored by 4–7 ton dolosse units (**El-Asmar *et al.*, 2014**). In the current study, the protected coast (Sector B) showed a decrease in the annual eroded area from 0.101 km^2 between 1984 and 1997 to 0.066 km^2 between 1997 and 2011.

Several studies, including **El-Asmar *et al.*, (2014), El- Banna (2006)**, **El-Asmar (1994)** and **El-Zeiny (2015)** had criticized the method of construction of the detached breakwater system in front of Ras El-Bar. They claimed that the detached breakwater system in this area creates new erosion associated with abnormal bathymetry and develops areas of high and low bottom topography. The latter were responsible for the drowning deaths of about 75 swimmers. They interpreted this case as a consequence of eddies resulting from the collision of waves with the detached breakwater system and rebounding in the opposite direction. On the other hand, construction of a 6.5 km long seawall at sector C before 2000 had resulted in an increase in the maximum annual shoreline advance from 24.85 m during the period of 1984-1997 to 30.86 m during the period of 1997-2011. In this sector, the maximum annual shoreline retreat was 52.38 m at the period of 1984-1997 where similar rates of erosion for this sector were detected; 50 to 60 m/y between 1973 and 1984 (**Smith and Abdel-Kader, 1988**), 35 to 50 m/y between 1945 and 1973 (**Sestini, 1989**), and 37 m/y (**Abou El-Magd, 1995**) and 41.4 m/y from 1984 to 1991 (**El-Asmar, 2002a**).

The coastline of Damietta is considered as highly dynamic environment which is greatly affected by different natural processes such as sea level rise, effects of waves and currents in addition to climatic change consequences. As a result of monitoring and mapping changes in such dynamic environment, it has clearly been noticed that changes (i.e. erosion and accretion) are still existed even after seawalls constructions. Obviously, construction of the detached seawalls in the area of study has decreased the annual eroded areas particularly from the period of 1997-2011 to 2011-2014 (i.e. from 0.579 to 0.414 km^2). This is consequently synchronized by an increase in the annual accreted areas from 0.234 km^2 to 1.152 km^2. The studied sectors confirmed the same result where the annual eroded areas at sectors A, B, C and D have remarkably decreased from 0.248 to 0.032, from 0.920 to 0.178, from 5.775 to 0.895 and from 1.168 to 0.137 km^2 respectively from period 1997-2011 to 2011-2014. The annual accreted areas have showed an increase at two sectors; from 0.181 to 0.319 km^2 at Sector A and from 2.173 to 2.395 km^2 at Sector C respectively from the period 1997-2011 to 2011-2014.

3.3. Monitoring shoreline changes at sectors of study

The maximum shoreline retreat (2011 m) and progress (1441 m) were recorded at Damietta apex (Sector C) followed by Ras El-Bar and Damietta Harbor (Sector B) recording 886 m and 492 m, respectively during the whole period of study (1984-2014) as illustrated in figure (8). Furthermore, the total eroded and accreted areas were 16.246 km^2 and 11.166 km^2, respectively. As shown in figure (9), the highest percentage of eroded and accreted areas (64.88 and 64.45 %, respectively) was recorded at sector C. Percentage of eroded areas ordered as follows; 64.88 % (Sector C) > 18.44 % (Sector D) > 14.77 % (Sector B) > 1.90 % (Sector A) %. However, the accreted areas percentage ordered as follows; 64.45 % (Sector C) > 22.95 % (Sector B) > 8.83 % (Sector A) > 4.12 % (Sector D).

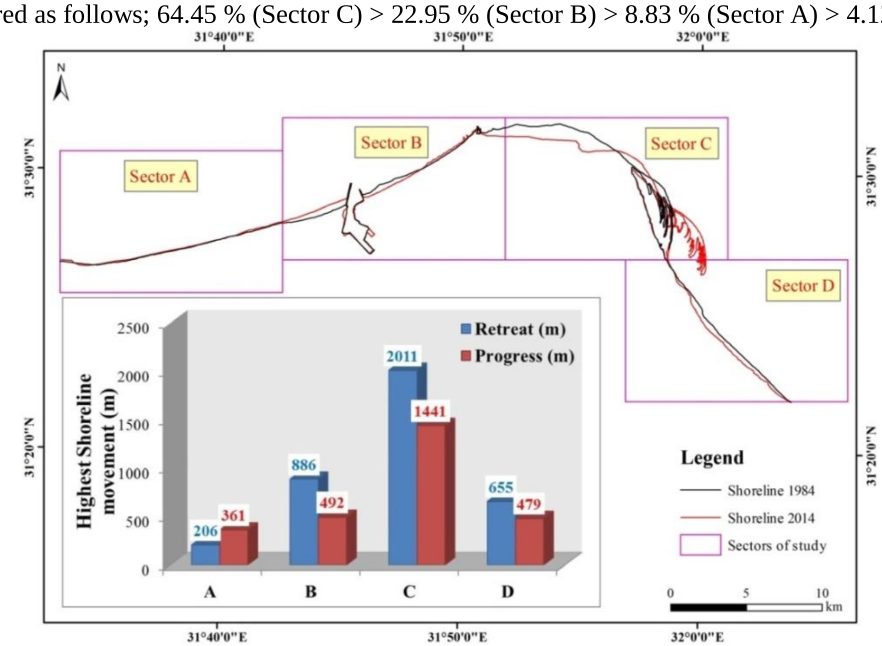

Figure (8): Damietta shoreline retreat and advance during the period from 1984 to 2014

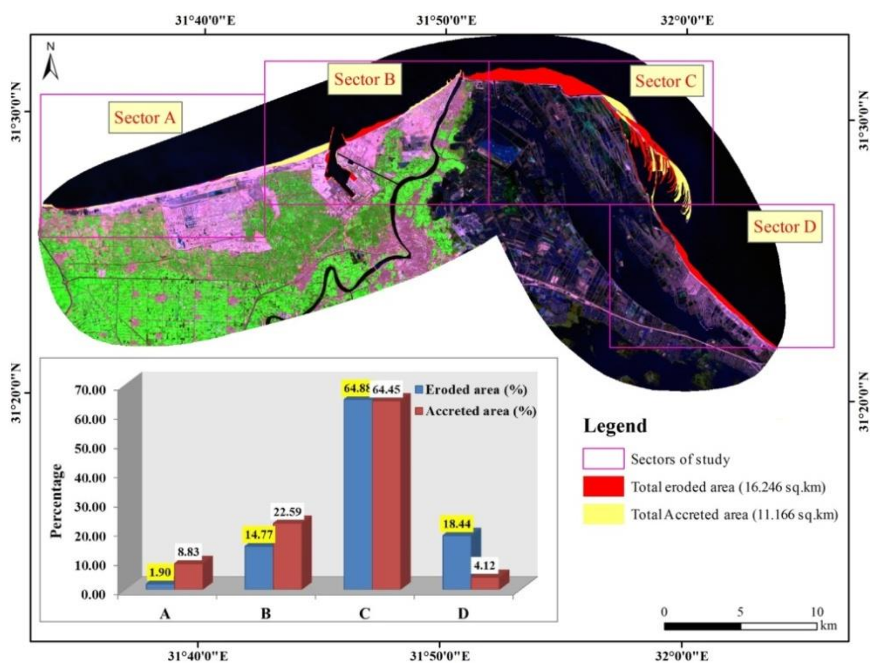

Figure (9): Damietta shoreline eroded and accreted areas during the period from 1984 to 2014

4. Conclusion

One third of the human population lives in and around coastal areas as most of the developmental projects are built. Therefore, monitoring and quantifying total rates of Damietta shoreline changes and the annual rate are very necessary in coastal resources management and conservation. Space-borne technologies offer a powerful tool in studying coastal environments. It was observed that Damietta shoreline is considered a very dynamic environment during the study periods where noticeable erosion and accretion rates have been recorded. There are multiple factors influencing the rate of shoreline changes such as topography, sea level rise, climate effect, waves, winds, etc. Rates of erosion and accretion were changeable at each studied sector, where sector C (Damietta Apex) represented the most dynamic part along Damietta shoreline showing high levels of erosion and accretion during the study. Conversely, sectors A (New Damietta City Sector) was the minimum affected sector by erosion and accretion. This was mainly attributed to the previously mentioned affecting factors that extremely affect sectors C and B more than Sectors A and D. Same sectors also recorded highest and lowest shoreline retreat and progress, respectively. To reduce shoreline erosion, Seawalls (Break waters) were constructed but it consequently resulted in creating new areas of erosion because Nile Delta Coastal zone, particularly Damietta, is a very dynamic area. Due to this dynamism, the constructed breakwaters have created new areas of erosion which were responsible for drowning deaths of about 75 swimmers. Until now there is no effective solution for reduction of coastal changes without creating adverse impacts.

5. Acknowledgement

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