Monitoring Changes of Damietta-Port Said Coast Using Remote Sensing and GIS

رصد تغيرات ساحل دمياط - بورسعيد باستخدام الاستشعار عن بعد ونظم المعلومات الجغرافية

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الملخص العربى : أصبح تآكل الشواطئ مشكلة خطيرة فى دلتا النيل منذ سد مجرى النيل فى عام 1970 ، وخاصة بمحاذاة فرعى النيل (دمياط ورشيد). ومنذ تشييد السد العالى بأسوان عام 1964 . فالسد قد حجز بالفعل الطمى المحمول بواسطة مياة النيل لتوصيله للبحر الأبيض المتوسط ، ومن ثم ترك الساحل بدون قدرة على البناء التراكمى. تهدف الدراسة الحالية إلى تقييم مدى التدهور الساحلى الذى ألم به بسبب التغير فى الشاطئ نتيجة (التعرية والترسيب). ومن خلال تحليلات أربعة صور تم التقاطها بالأقمار الصناعية بواسطة ماسحات ضوئية للعديد من مجالات الطيف (MSS) ، والخرائط الموضوعية (TM)، والخرائط الموضوعية المحسنة (+ETM) وكذلك (MODIS) بواسطة إجهزة الإستشعار فائقة الدقة التى تم استخدامها جميعاً لتقدير التغيرات المكانية عبر الفترات الزمنية التى حدثت فى خط الشاطئ بين فرع النيل بدمياط وبورسعيد فى الفترة الممتدة من 1975 حتى 2011. استعانت الدراسة بالتطبيقات على معالجة الصور بما فى ذلك التقويم الجيومترى ، والتصحيح المناخى ، وعمليات التنقية على الشاشات لتحويل البيانات إلى معلومات رقمية من الصور الأربعة لتتبع موقع الشاطئ بين فرعى دمياط وبور سعيد. وقد أظهرت النتائج أن الشاطئ بين فرع دمياط وبور سعيد يتميز بنسبة تآكل ملحوظة وأكدت على أن التآكل الساحلى كان فادحاً بالقرب من فرعى دمياط بينما قل نشاطه كلما إتجهنا شرقاً ويظهر ملحوظاً بالقرب من بور سعيد.

Abstract

Shoreline erosion has been a major problem in the Nile Delta since the full damming of the Nile River in 1970, especially along the two Nile promontories (Rosetta and Damietta). Since that construction of the Aswan High Dam in 1964, there has been concern that the Egyptian coastline

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along the Mediterranean Sea would suffer from increased erosion. The dam effectively stopped the supply of sediment carried by the River Nile to the Mediterranean and so left the coastline without shore building capability. The main goal of this study is to assess the coastal hazards that may occurred due to shoreline changes (erosion or / and deposition). Through analysis of four satellite images from the multi-spectral scanner (MSS), thematic mapper (TM), The Enhanced Thematic Mapper Plus (ETM+) sensors and the Modis sensor were utilized in order to estimate the spatio-temporal changes that occurred in the shoreline between Damietta Nile branch and Port-Said between 1975 and 2011.Image processing applied in this study included geometric rectification; atmospheric correction; and filtering processes on-screen shoreline digitizing of the four satellite images for tracking the shoreline position between Damietta promontory and Port-Said. Results showed that shoreline between Damietta and Port Said is characterized by appreciable erosion and accretion the coastal erosion was severe near Damietta promontory and decreased eastward, while accretion was observed near Port-Said.

Keywords: Damietta-Port Said Coast, Remote sensing, Change detection.

Introduction: The study area is a part of Egyptian shoreline of the Nile Delta of Egypt which extends for about 73.64 Km between the mouth of Damietta branch and Port-Said along the inlet of the Suez Canal. (Fig. 1) At this coastal plain, there are two important Egyptian harbors:The Damietta and Port-Said. Beside urban centers, there are many industrial facilities were constructed for gas liquefaction at this coastal strip. In addition, the new International Coastal Highway is a new important axis for development at the region. The beaches of the Nile Delta coast are backed by coastal dunes and coastal flats with low-relief surface interrupted by sabkhas and salt marshes. These beaches are made up of loose quartz sand mixed with small amounts of heavy minerals and shell fragments. The grain size of the beach and coastal-flat sand varies between fine and medium sand **(Frihy and Dewidar 2003).** Waves move in N-S to NNW direction perpendicular to some segments of the coast during the winter NW-SE direction and obliquely to the shore line in summer. When waves strike the shore obliquely the longshore currents will be predominantly in one direction **(Summerfield, 1991)** mainly W-E. Prevailing wind were acting on The Damietta-port said is in NW-SE direction with an angle to the west from April to November. The waves strike the beach obliquely in some months. When the angle of wind changes to more easterly direction, a drift of deposit to the east takes place. **Frihy et al. (2003)** indicated that waves from the northwest direction dominate (81%), with small components from the northeast (14%) and the southwest (5%) directions. **El Banna (2007)** reported that in spring, maximum wave height reaches 1.16 m and waves come mostly from the northwest direction, whereas in winter, maximum wave height reaches 4.2 m and the predominant wave direction is west northwest. At Ras El Bar, storm waves have a general WNW or NE-SW, and NW-SE direction with average height of 60 cm (Fig. 2) Landsat-7 image shows the directions of wind and waves along coast of the study area, as well as the directions of coastal segments and their lengths. The Nile Delta of Egypt is considered as wave dominated **(Coleman et al. 1981)** and includes 25% of the total Mediterranean wetlands **(Sestini 1992)**. During the second half of the previous century, the coastal area of the Nile Delta has been experiencing significant land use/cover change due mostly to the control of the River Nile flooding regime and the extensive population growth. Most prominent environmental changes include enhanced coastal erosion and conversion of wetland ecosystems to agricultural lands. **Syvitski (2008)** mentioned that between 1800 and 1900, the River Nile mouth at Damietta promontory advanced seaward by 3.0 km, while today the entire Nile Delta coastline is retreating landward due to coastal erosion. **El Banna and Frihy (2009)** reported that both natural and anthropogenic factors have influenced the Nile Delta coastal area. Among these factors are: change in the Nile sediment supply, coastal processes, land subsidence and deterioration of natural habitats. Most of the worlds shorelines suffer from coastal erosion **(Pilkey, 1991)**. Coastal erosion is a natural process that causes the shoreline to retreat through forces executed by wind, water and ice. This process can be a big threat to human settlements and to fragile natural ecosystems. Global warming and the resulting sea level rise have a great impact on the rate of shoreline retreat. This is supported by studies that suggest an increased global erosion pattern **(Bird, 1985)**. These developments indicate the need for strategies and tools that allow monitoring of shoreline morphodynamics. A monitoring system that can compare large parts of the shoreline would help to identify unstable coastal areas and give insight in the processes that determine the spatial variability of coastal erosion. Furthermore, such a system will help to plan mitigation strategies and assist in the development of models that can facilitate the prediction of future coastline dynamics. Remote sensing can serve as a valuable tool for coastal erosion monitoring purposes. Satellite imagery is very suitable for change detection because of repetitive coverage of the same region. Furthermore, satellite images cover large areas, which make them an excellent device to study large spatial patterns. As the spatial resolution of earth resource satellites is increasing even minor can be detected through satellite imagery. Because of this trend, the general availability of satellite imagery and its large ground coverage, satellite remote sensing provides a good tool for detecting shoreline changes **(Chen and Rau, 1998)**. Detecting changes is most straightforward using images of the same sensor at different dates. Starting from 1973 with the launch of Landsat-1, a variety of earth observation Satellites have been acquiring imagery. Each sensor has its own characteristics like resolution (spatial and temporal), frequency and bandwidth. In this study, satellite images of various sensors are used to monitor shoreline changes at different dates, they are MSS 1975, TM 1985, ETM 2000, and MODIS 2011. For this, a procedure is needed to extract the coastline from the imagery. A simple way to do this is through on-screen digitization Here, a procedure is needed that will allow to extract shorelines from a variety of images and compare them.

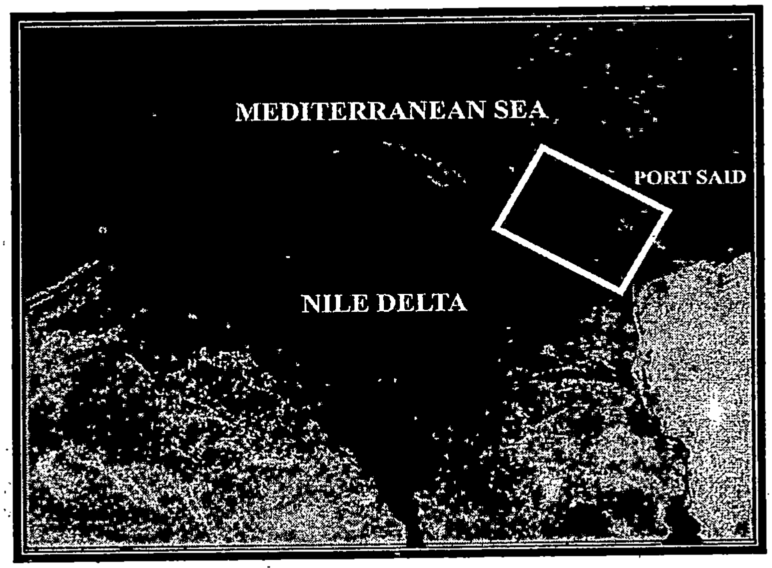

Fig .1: MODIS image of Delta Nile shows the study area

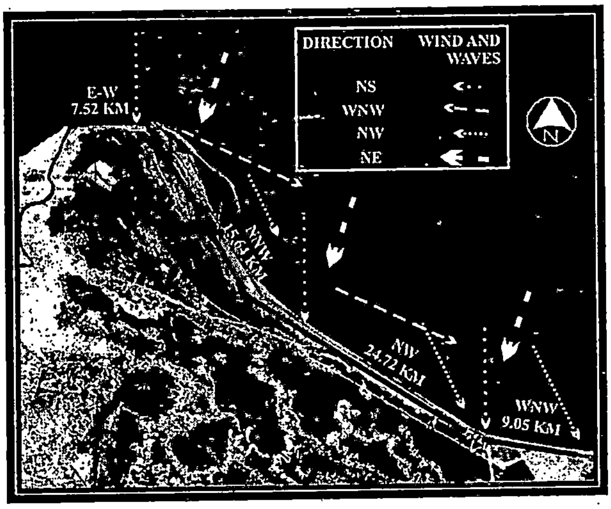

Fig .2:Landsat-7 image shows the directions of wind and waves along coast

Objectives of study

The objectives of the present study are to apply remote sensing in mapping and addressing spatial coastline position changes between Damietta and Port-Said between 1975 and 2011. The input shore line layers of the different periods were manipulated using overlap processes to compare changes that occurred along the shoreline during period 1975-1985, 1985-2000, and 2000 to 2011. Each layer was input in digital form (shapefile), and treated in different scale to recognize and estimate areas of changing.

Materials and methods

Satellite data

In order to quantify changes along the shoreline, four satellite images were utilized: one from the Landsat MSS (57 m spatial resolution) acquired in 1975 (Fig .3-A), TM (30 m spatial resolution) acquired in 1985 (Fig .3-B), Landsat ETM+ (30 m for spectral band and 15 m for panchromatic spatial resolutions) (Fig .3-C) and MODIS (1 km to 250 km) (Fig .3D). The MSS image consists Spectral Bands: Band 1: (visual green, 0.50-0.60μm) Band 2: (visual red, 0.60-0.70μm) Band 3: (near IR, 0.70-0.80μm) Band 4: (near IR, 0.80-1.10μm). The sub-image used is combiled from band 1, 2, 3 in RGB. The TM image consists of Spectral Bands: Band 1: (visual blue, 0.45-0.52μm), Band 2: (green, 0.52-0.60μm), Band 3: (red, 0.63-0.69μm), Band 4: (near IR, 0.76-0.90μm), Band 5: (mid IR, 1.55-1.74μm), Band 6: (thermal IR 10.40-12.50μm), Band 7: (mid IR, 2.08-2.35μm). The ETM+ image is combiled from band 4, 3, 2 in RGB. MODIS image is combiled Spectral Bands: Band 1: (visible red, 0.58-0.68μm), Band 2: (near IR, 0.725-1.10μm), Band 3: blue 0.4- 0.5 μm, Band 4: Green 0.5-0.6 μm, Band 5: NIR: 1.23-1.25 μm, Band 6: MIR: 1.628-1.652 μm, Band 7: MIR: 2.15-2.155 μm.

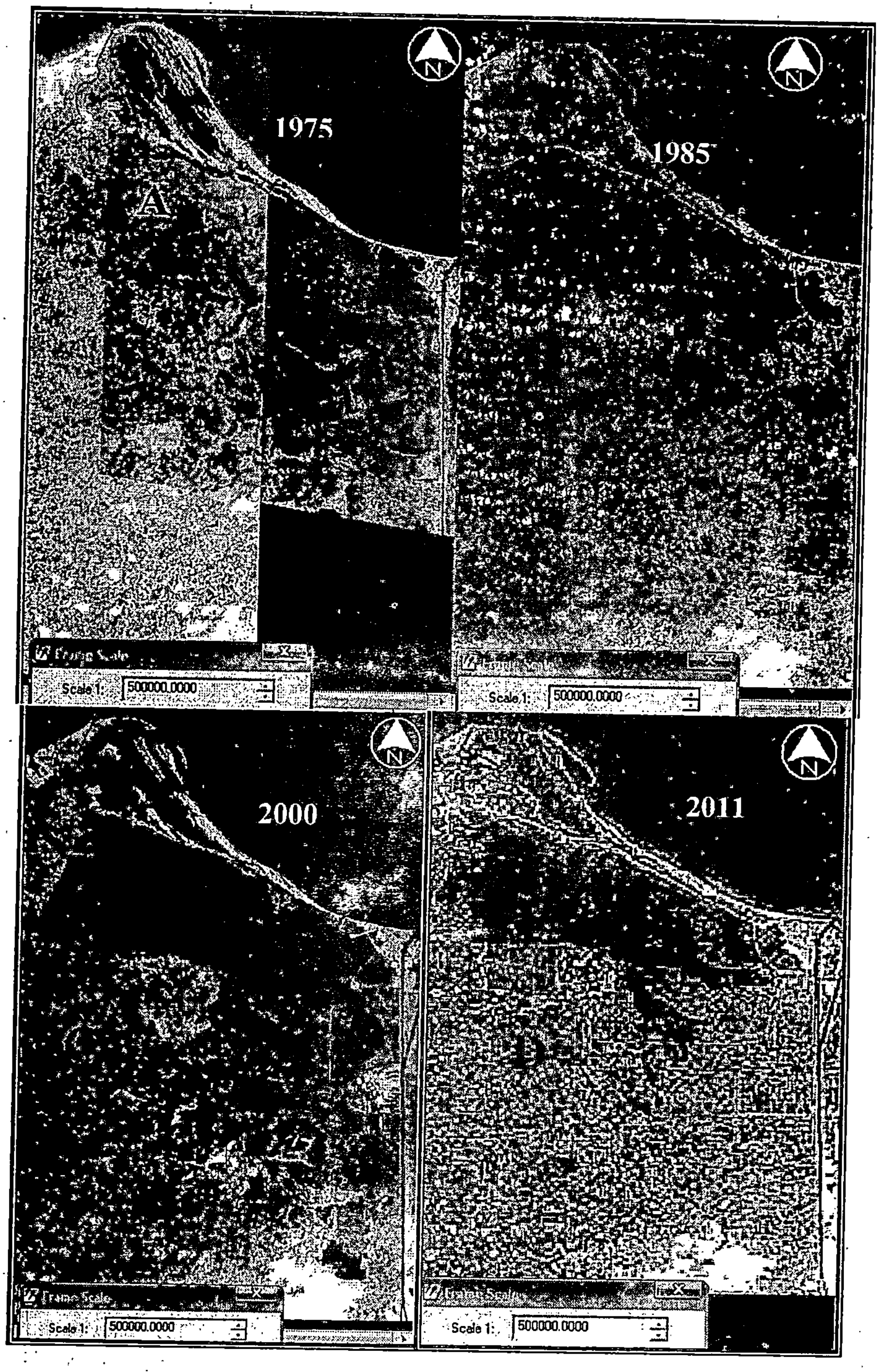

Fig .3 Four satellite images of the study area

Image processing

All the images were warped to a specific map projection, namely the Universal Transverse Mercator (UTM/zone 36, WGS 84) using a first order polynomial transform algorithm in order to assure that each permanent feature is exactly at the same location in all images. A total of at least 20 prominent ground and river channels. After rectification, the route mean square error (RMSE) does not exceed 0.5 pixels revealing a high geometric matching of the images. The images were then corrected for any atmospheric interference caused by haze, dust, smoke, etc. using the dark-object subtraction method **(Chavez 1996)**. Image processing approaches were applied in order to identify the changes of shoreline digitizing for mapping erosion/accretion pattern between Damietta promontory and Port-Said.

Shoreline digitizing

For tracking the changes that occurred along the coastline control points (GCP) were examined and matched in all images. These points included road intersections, prominent geomorphologic features between Damietta promontory and Port-Said, the Landsat MSS image of 1975 and the TM image of 1985 were used, two images of ETM+ and MODIS were used. The four satellite images displayed using ArcGIS Software. A careful on-screen digitizing of the shoreline was applied at each image the four layer were overlained and creating a shapefile layer for the shoreline in each date the shoreline position was highlighted to infer the erosion/accretion sectors along the coast. Shoreline displacements between 1975 and 2011 were done using the measurement tool in ArcGIS and expressed in kilometers.

THE RESULTS

Historical Shoreline Change Analysis

The input shoreline layers of the different periods were manipulated using overlap processes to compare changes that occurred along the shoreline during period 1975-1985, 1985-2000, and 2000 to 2011. Each layer was input in digital form (shapefile), and treated in different scale to recognize and estimate areas of changing.

A- Changing occurred Between (1975 and 1985) :

This period is characterized by changing of the concave shape of Damietta head as well as the great rate of growing of spits. It is characterized by dominating of process of deposition in the western side of the coast and small erosion processes in the eastern one the great rate of deposition leads to put a new sandy spit (Fig. 4). Recently, a new seawall revetment was constructed by the Shore Protection Authority (SPA) to protect the head of Damietta. Estimation of erosional and deposition areas, the deposition area are reached 3.44 km² while the erosion areas are reached 7.93 km² through that ten years from dates 1975 to 1985 shown that erosional and deposition areas .

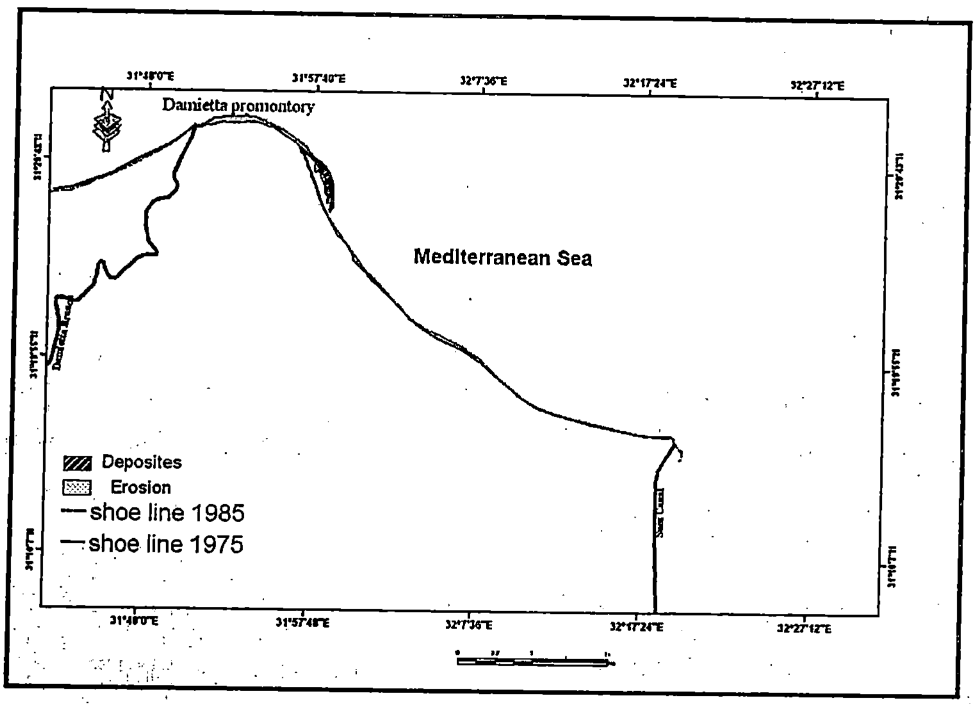

Fig .4: Changes of shoreline from the mouth Damietta Branch and Port-Said Between Dates 1975 to 1985

B- Changing occured Between (1985 To 2000) :

This stage is distinguished with an apparent exchange between the cells of both erosion and accretion. But generally the rate of these processes is smaller than the rate during the past years. The depositional areas are reached 4.4 km² and the erosion areas are reached 12.72 km² (Fig. 5) Figure shows that the areas of deposition and erosion are the same in periode 1975-1985, but with smaller rate.

C- Recent Shore line Change Analysis (2000 To 2011) :

This Period extended from 2000 to 2011, it is distinguished with an apparent exchange between the cells of both erosion and deposition. The depositional areas are reached 7.7 km² and the erosion areas are reached 4.4km² Shown in (Fig. 6) and the calculating areas of deposition and erosion are shown in table (1).

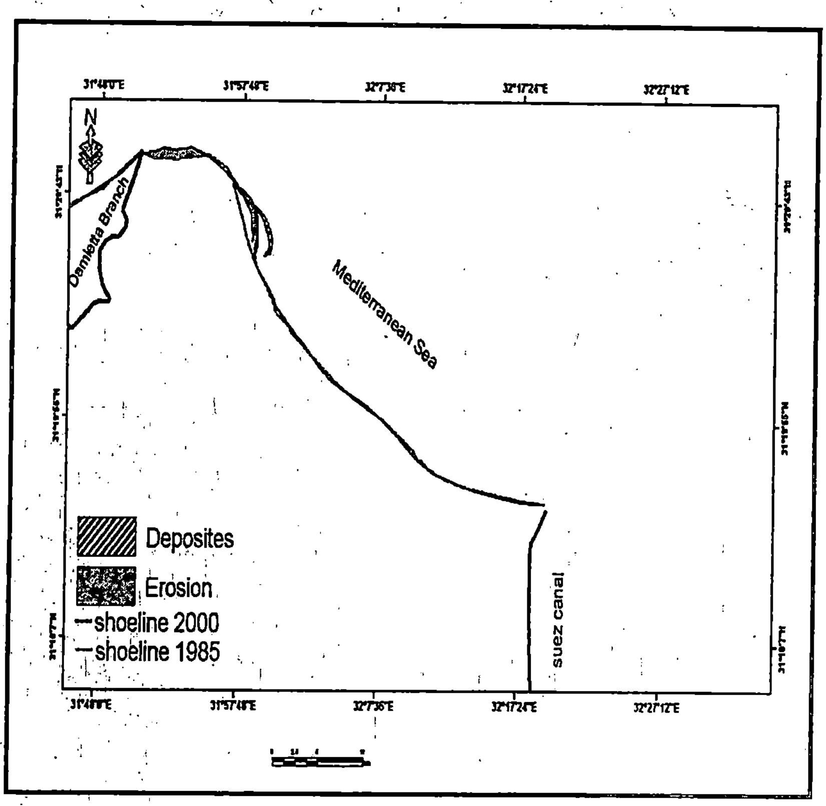

Fig .5: Changes of shoreline from the mouth Damietta Branch and Port-Said Between Dates 1985 to 2000

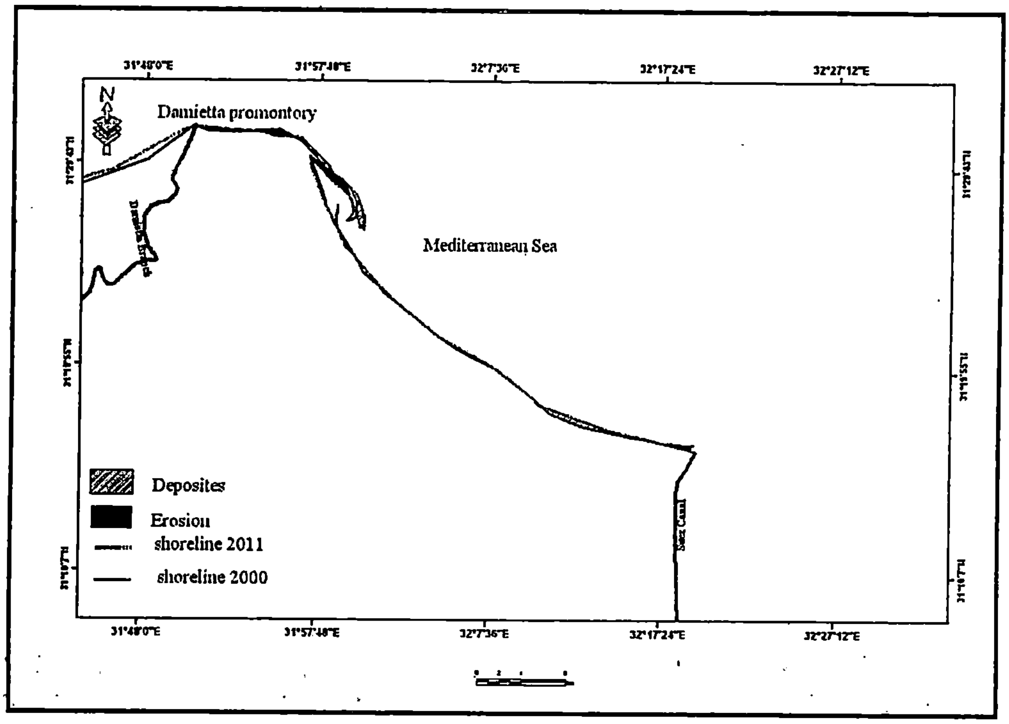

Fig .6: Changes of shoreline from the mouth Damietta Branch and Port-Said Between Dates 2000 to 2011

Table (1) presents the estimated the area of deposition and erosion between dates 1975 until 2011.

Depositional area (km²)	Depositional area /year	Erosional area (km²)	Erosional area /year	Dates
2.7	0.344	7.93	0.793	1975 to 1985
4.4	0.29	8.81	0.84	1985 to 2000
3.2	0.77	3.01	0.301	2000 to 2011
10.3	-	19.7	-	1975 to 2011

The spit of Manzala lake consists of a main arm heading generally toward the south eastern along northern part of the beach line. Damietta spit is regarded as a compound one as the main tongue protrudes from the group of branching and crooked tongues directing to the land. One of these tongues may is connected with El-Manzala barrier forming a small lagoon which has been resopened by carving processes. The length of the spit was monitored in 2011 long forming a straight line starting from the exit of the tongue extending to its extreme end of 8.8 km long. The development of the spit was monitored for 36 years through the four visual satellite maps of the years 1975, 1985, 2000, and 2011 which shows the following (Fig. 7):

1945 to 1967:

From the topographic map of the year 1945, it seems that sudden change had occurred to the beach direction at the take off point of Damietta tongue. This might have helped in forming the tongue later on. It is also apparent that the beach stepped forward heading for the sea by the end of the stage of 1967, although the tongue was still under formation then.By the end of this stage, the average rate of precipitation at the growing area in the tongue reached 0.13 km^2/ year. This rate is equal to that which happened at the peak of Damietta protrusion during this very stage to reach 0.17 km^2/ year. **Amro Mohamed Saleem, (2009).**

1967 to 1975: In 1975, the total area of the cape was 1.6 km^2. The spit then stepped forward at a rate of 0.2 km^2/year. The cape might have gained a huge amount of its sedimentation from the peak of Damietta promontory.

1975 to 1985:

In 1985, the total area of the spit was 2.3 km^2. Then a new net precipitation was added to the spit body might have gained some of the carved precipitation from the peak of Damietta promontory during the same period.

1985 to 2000:

By 2000, the spit area has amounted to 2.3 km^2, while the spit is obvious that the body dimensions have been greatly afflicted by the rate of deposition. This is evident as for example in the decreasing area of the cape as well as the decrease in the mean width of the spit and its direction toward elongation throughout the time. The cape throughout the time. The cape development in the previous form may lead to its disappearing especially with the exposure of the complete peak of Damietta protrusion to vanishing which has always represented a source of providing precipitation.

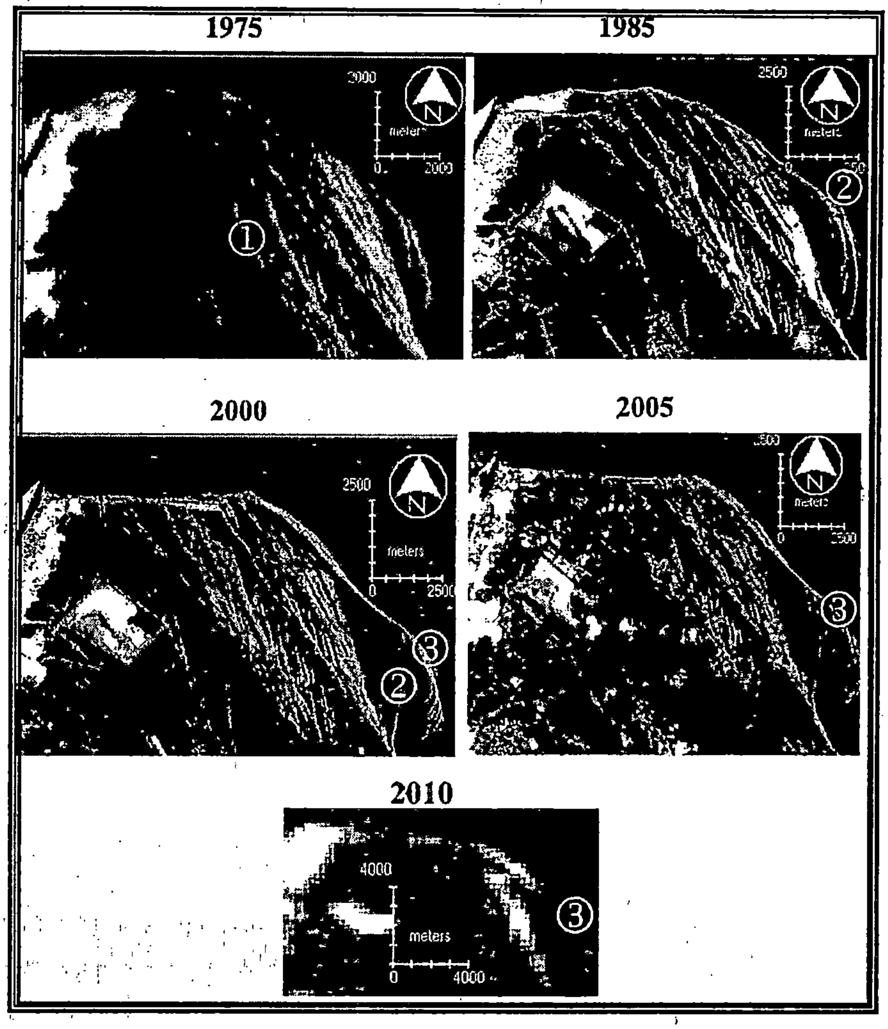

Fig .7: Shows the development of Damietta spite from 1975 to 2011.

Discussions and Conclusions

Every year before construction of the Aswan Dam, water flood Nile during was occurring during August-October period through its branches (Rosetta and Damietta). But after building it a huge of water and alluvial sediments storage behind the Dam since 1964, the mean annual of Nile water reduced from 34 billion cubic meters to less than 1/3 its amount before construction the dam, the sediment load is reduced too from million tons to less than 15 million tons after building it. This sediment was the main source of accretion on the coast line and the two promontories of Rosetta and Damietta, but it removed gradually from this date **(Sharaf El Din, 1977).** The construction of the Aswan High Dam in 1964 in Upper Egypt has both tremendous positive and negative socio-economic and environmental impacts upon the Nile Delta. For example: the dam has stopped sediments from reaching the Mediterranean Sea.

Erosion along the coastal strip between Damietta promontory and Port-Said occurs at different rates. Most erosion is encountered close to the River Nile mouth and decrease eastward. **El-Fishawi (1989)** reported that the total land loss at Damietta promontory was 21 km² between 1909 and 1988. Damietta promontory About 3 km west of Ras El Bar, at the new port of Damietta, the coastline advanced at a rate of 8 m/year between 1934 and 1973, but had no appreciable change between 1973 and 1984. Erosion at a rate of 270 m/year was found to occur between 1975 to 2011 just east of the mouth of the Damietta. The coastline east of the Damietta generally acts as a drain site for sediments eroding from the Damietta promontory. This area is characterized by a growing spit which first formed in 1955 and it has been migrating southeast since then. This area advanced at a rate of 90 m/year between 1975 and 1985, 113 m/year between 1985 and 2000, 100 m/year between 2000 and 2011. The Damietta does not show regular patterns of change, but instead it shows alternating pockets of erosion and accretion. Many of the accretion pockets eventually erode away within a few years. However, the mouth of the Damietta promontory continuously eroded at a moderate rate between 1934 and 1973 **(Smith and Abdel-Kader, 1988)** to higher rates between 1975 and 2011 as shown in (Fig .8). This is similar to the general trend of the eroded areas affected by cessation of River Nile sediment after the Aswan High Dam. The coastline between Damietta and Port Said is characterized by appreciable erosion and accretion. Indeed, erosion rates along this stretch average 16 m/year between 1934 and 1984 **Amro Mohamed Saleem, (2009)**. The shoreline undulation had shifted markedly to the southeast. It was noted by satellite imagery that areas of advance occur southeast (downstream) from areas of retreat. At Port Said, the shore had advanced west of the west breakwater prior to 1984, but since 1984, this pattern is no longer dominant and slight erosion is now occurring. The pattern of shoreline change along this stretch indicates that at least part of the sediment eroded from the Damietta mouth before the High Dam had been transported eastward.

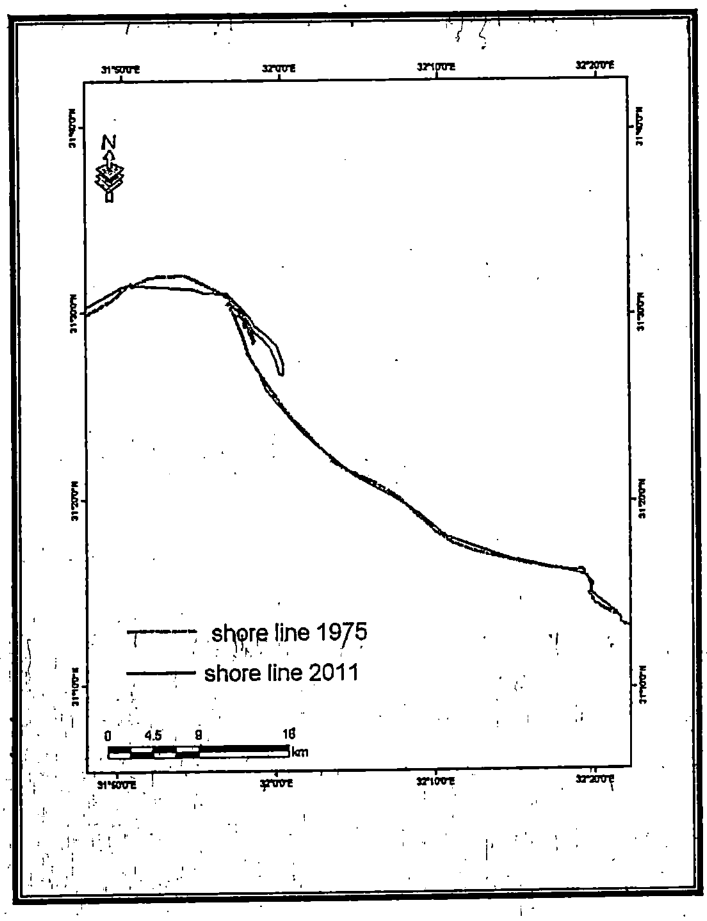

Fig .8: Changing of Damietta-Port said shoreline during the period between 1975 until 2011

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