Using RS&GIS to Study the Change Detection in the Geomorphological Features of the Nile Delta Coastal Plain

Tolba B. Abdel-Hady(*)

Abstract

A change detection of the geomorphological feature involves analysis of a series of images of different dates. In water resources studies, land cover is a most commonly studied feature. The analyst might be interested in both short–term (e.g., flood inundation or snow cover) as well as long-term (e.g., deforestation or expansion of urban area) changes (**Jensen, et.al** , **2010**).

In this sense, this research deals with the change detection in the geomorphological features of the Nile Delta coastal plain using geographical information system and remote sensing, by monitoring shoreline changes, sabkhas, sand dunes and, finally changes in coastal lakes. The study of shoreline changes revealed the prevalence of erosion in the places of the Delta promontories and Manzala lake barrier. The area exposed to erosion reached 19.6 km^2, or 62% during the period from 1945 to 1983. The largest ranges of accretion are distributed to the west and east from Rashid promontory, sand spit of Damietta and Gamasa Bay area.

As for sabkhas changes of the study area, it was revealed by comparing the data of the satellite images from 1984 to 2003 that the area of the sabkhas on Manzala Lake barrier decreased by 1.9 km^2 (15.7%). Where sand deposits and fish ponds covered large areas of sabkhas. During the same period, the areas covered by sand dunes were significantly reduced. Only a quarter of the area of Gamasa

(*)Lecturer of Physical geography, Faculty of Arts, Mansoura University.

sand dunes was left in 1984, and the remaining area (76.31%) was converted to other uses. Manzala Lake lost 297 km^2 (43%) during the period 1984- 2003. Burullus Lake was also affected by the decline in the area of the water body, similar to the trend in the lakes of study area. This is linked to the expansion of the fish ponds located south of the lake towards the water body to the north.

Keywords: Satellite Images, Change Detection, Erosion, accretion, Shoreline, Sabkhas, Sand dunes, Coastal lakes.

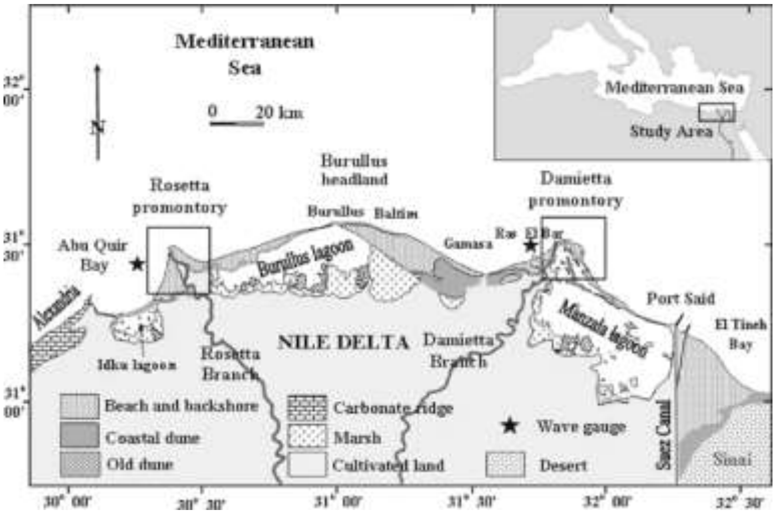
1. Introduction

The importance of geographical information system and remote sensing in studying the changes detection of geomorphological features in the study area is being a modern source through which access to the nearest picture of the current reality in light of the rapid changes experienced by the features . The availability of more than one generation of Satellite Images in monitoring the changes of features is particularly accurate, especially those features (eg, sabkhas, shoreline, sand dunes and coastal lakes) that are difficult to detect from other sources with the same precision.

The objectives of this study are to assess the changes in the geomorphological features of the Nile Delta coastal plain by integrating RS/GIS capabilities. Topographic maps of 1945, 1983 and 1991 and LANDSAT Images for the date of 1984 and 2003 were considered.

2.Study Area

The study area extends from the plain of clay in the east to Edko Lake in the West for a distance of up to more than 220 km. It is confined to the Mediterranean coast in the north and a point of branching sub-Damietta and Rosetta in the south, which means that it extends between latitudes 30ْ 10َ & 31ْ 37َ to the north and longitudes 29 ْ 45َ & 32 ْ 30 َ (Figure 1).



Source : (Frihy & Lawrence , 2004)

Figure (1) Location of study area

3. Previous Studies

- Frihy, O. E., 1988, Nile Delta Shore Line changes aerial photographic study of a 28 year period, journal of Coastal Research, vol. 4, p.p. 597-606.
- Frihy, O.E., El Fishawy, N. M. & El Askary, M. A. 1988, Geomorphological Features of the Nile Delta Coastal Plain: A review, Acta Adriata, Vol. 29, p.p. 51-65.
- Nafaa, M. G. & Frihy,O. E. 1993, Beach and Nearshore Features along the dissipative Coastline of The Nile Delta, Egypt, Journal of Coastal Research, Vol. 9, p.p. 423 - 433.
- Sadek, A. S., Abdel Rahman, S. I. & Ghabour,T. K. 1993, Multitempotal analysis of Landsat images for studying coastal changes along the shore line of the Nile Delta, Egypt. Journal. Soil, Vol. 33, p.p. 85-96.

- Sharaf El-Din, S. H. & Mahar, A. M. 1997, Evaluation of Sediment Transport Along the Nile Delta Coast, Egypt, Journal of Coastal Research, Vol. 13, p.p. 23-26.
- Stanley, D. J. & Warne, A. G. 1998, Nile Delta in its destruction phase, journal of Coastal Research, vol. 14. p.p. 794-825.
- El-Raey, M., Sharaf El-Din, S. H. Khafagy A. A. & Abo-Zed, A. I. 1999, Remote sensing of beach erosion/accretion patterns along Damietta – Portsaid shoreline, Egypt, International Journal of remote sensing, Vol. 20, p.p. 1087-1106.
- Frihy, O. E., Fanos, A. M. Khafagy, A. A. & Komar, P. D. 1999, pattetns of nearshore sediment transport along the Nile Delta, Egypt, Coastal Engineering, Vol. 15, p.p. 409-429.
- White, K. & El Asmar, H. 1999, Monitoring Changing position of coastline using Thematic Mapper Imagery, an example from the Nile Delta, Geomorphology, Vol. 29, p.p. 93-105.
- Ahmed, M. H., 2002, Multi-temporal conflict of the Nile Delta coastal changes, Egypt, the changing coast, p.p. 317-323.
- Frihy, O. E., Debes, E. A. & El Sayed, W.R. 2003, Processes reshaping the Nile Delta Promontories of Egypt: Pre-and Post Protection, Geomorphology, vol. 53, p.p. 263-279.
- El Sayed, M. A., Younan, N. A. Fanos, A. M. & Baghdady, K. H. 2005, Accretion and Erosion patterns along Rosetta promontory, Nile Delta Coast, Journal of Coastal research, Vol. 21, p.p. 412-420.

4. Materials /Software

4.1. Materials

4.1.1 Topographic maps of 1945, 1983 and 1991.

4.1.2. ETM (Enhancement LANDSAT Images)1984,2003.

4.1.3. Shuttle Radar Topographic Mission (SRTM) Path 176 and row 38 date 2001.

4.2. Software

Arc GIS 10.1 , IDRISI Taiga 16 and ERDAS Imagine 9.1.

5.Methodology

5.1. Image Restoration

Grounds Trusting: During an initial field visit, field GPS controlled points were collected in order to re-examine the geo-referencing of the ETM 1984-2003.

Geometric Restoration : Resample module was used. Map projection and coordinate system of the ETM 1984 - 2004 was considered to rectify all images using Image to Map and Image to Image techniques. UTM_Zone_36 N. and X, Y Resolution =30 m. were considered.

5.2. Visual Interpretation

Principal Compounded Analysis (PCA) was carried out to assign informative bands. False Color Composites were developed. Screen digitizing was carried out to assign Manzala Lake, Burullus, Edko areas and for sea shorelines, Google Earth image was considered to assign urban settlements.

5.3. Digital image processing

5.3.1.. Vegetation Indices

Normalized difference vegetation index (NDVI).

5.3.2. Unsupervised Classification

ISOCLUST in IDRISI was applied. ISOCLUST uses a procedure known as Selt-Organizing Cluster Analysis to classify up to 7 raw bands with the user specifying the number of clusters to process.

5.3.3. Land Cover Change Analysis

5.3.3.1 Difference Image

Vegetation Index Images were considered. The difference image can be calculated for this equation: later–earlier. Significant vegetation/Biomass change should be more than the mean +/- 2 Standard Deviation.

5.3.3.2 Percentage of Change

Land cover maps were considered. The percentage of change = (later–earlier)/earlier * 100.

6.Results and Discussion

6.1.Shoreline changes

Erosion and accretion are the main drivers of recent shoreline changes over a long period of time. Hence, it is necessary to monitor and follow the patterns of erosion and accretion in the study area through following the shoreline positions of topographic maps and satellite images. Shoreline changes over a long period of time over 50 years have been studied, based on topographic maps of 1945, 1983 and 1991, as well as the 2003 satellite image.

The general trend of shoreline changes between Edko Lake and the entrance of Suez Canal has been studied (Figure 2) where the following points are observed:

- The feature of erosion and the corresponding accretion can be inferred during the study periods in the light of the patterns of distribution of adjacent erosion and accretion cells and the direction of sediment transport. Accretion cells often drive their deposits from nearby erosion cells, especially after the supply of river sediments that has been disrupted (**Crowell, 2003, p 254**).

- Figure (2-a) shows the distribution of erosion / accretion cells in the first stage (1945-1983), where erosion predominantly prevails at the sites of Delta promontories and Burullus Lake barrier except the Eastern side of the barrier. The total area exposed to erosion from Delta promontories was 19.6 km^2 with a percentage of 62% of total area of erosion cells at that stage. The largest accretion cells are distributed to the west and east from Rashid promontory and sand spit of Damietta (East Damietta promontory) and Gamasa Bay area. The exchange between erosion and accretion in Manzala Lake barrier sector is evident.
- Figure (2-b) shows the distribution of erosion / accretion cells in the second stage (1983-1991). It is noted that the same pattern prevails in the second stage in the areas of Damietta, Rashid promontory and Manzala barrier. The most important changes in erosion / accretion patterns were the presence of a clear exchange of erosion / accretion cells at the apex of Burullus promontory and Burullus Lake barrier sector.
- Figure (2-c) shows the distribution of erosion / accretion cells in the third stage (1983-2003), where the prevalence of erosion continued at the apex of Rashid promontory and the eastern side of Damietta promontory by 60% of the total area of erosion cells, with a clear shift towards accretion at the apex of Burullus promontory and the continued exchange of erosion / accretion in other sectors.

It is clear from the foregoing that the regions of delta promontories are the most active areas that are subjected to change (specifically regarding the decline) throughout the study period. This is largely related to the form of promontories and shoreline trends, as well as the promontories increase the energy of the waves and thus their ability to erosion through the process of convergence of the lines of progress of the waves (**Woodrofe, 2002, p 110**).

6.2.Sabkhas changes

Sabkhas are characterized by different nature of changes from other features because they are the most stable features in their positions. These changes are linked to external movement, whether due to human intervention or natural factors. Sabkhas changes entail many hazards to different patterns of land use.

6.2.1.Case studies of sabkhas changes from satellite images

6.2.1.1.Sabkhas changes in Manzala Lake barrier

Table (1) shows the results of quantitative analysis of sabkhas changes on Manzala barrier and inferred by comparing satellite images data for 1984 and 2003 where following results were concluded:

- The area of sabkhas on Manzala barrier was reduced by 1.9 km^2 with a percentage of 15.7% of the total area of sabkhas at the beginning of study period (1984).
- At the beginning of study period, 58% of sabkhas area was transformed into features (other categories of use) by the end of the study period. The sand deposits covered a large area of sabkhas east of the barrier (Figure 3). Water bodies covered 11.6% of sabkhas area in 1984 due to their exposure to erosion from the sea, as well as the establishment of fish farms from the side of the lake.

		1984		
		Sabkhas		Total area (km^2)
		area (km^2)	%	
2003	Agricultural lands	1.05	8.7	13.7
	Sand deposits	4.65	38.5	12.2
	Sabkhas	4.96	41.1	10.1
	Water bodies	1.4	11.6	39.3
	Total area (km^2)	12.06	100	
	The difference between the two satellite images	− 1.9	15.7	

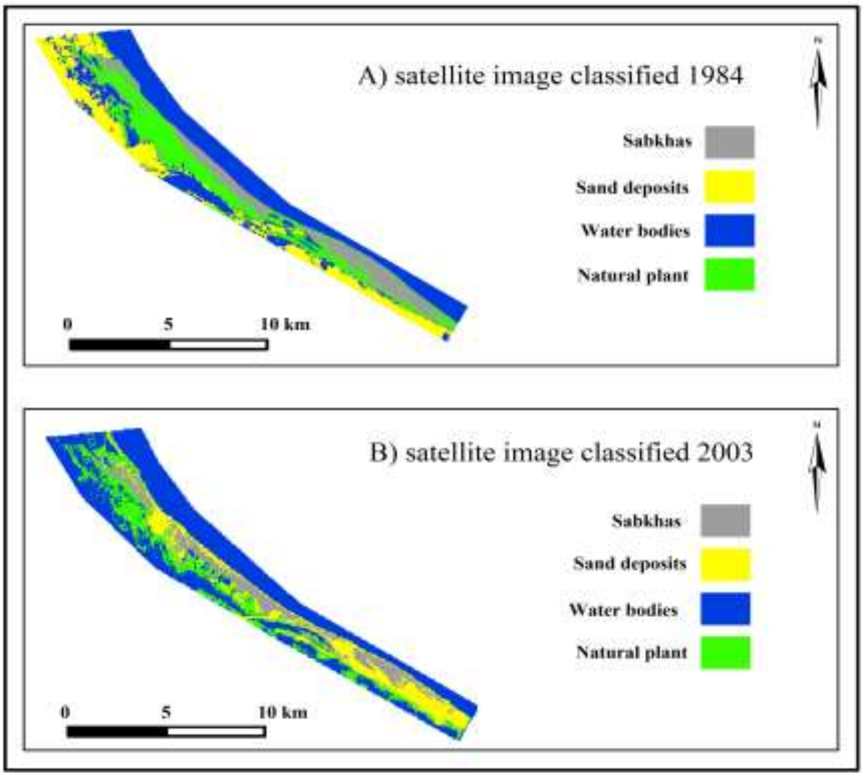


Figure (3) Sabkhas changes in Manzala Lake barrier

6.2.1.2.Sabkhas changes in New Damietta area

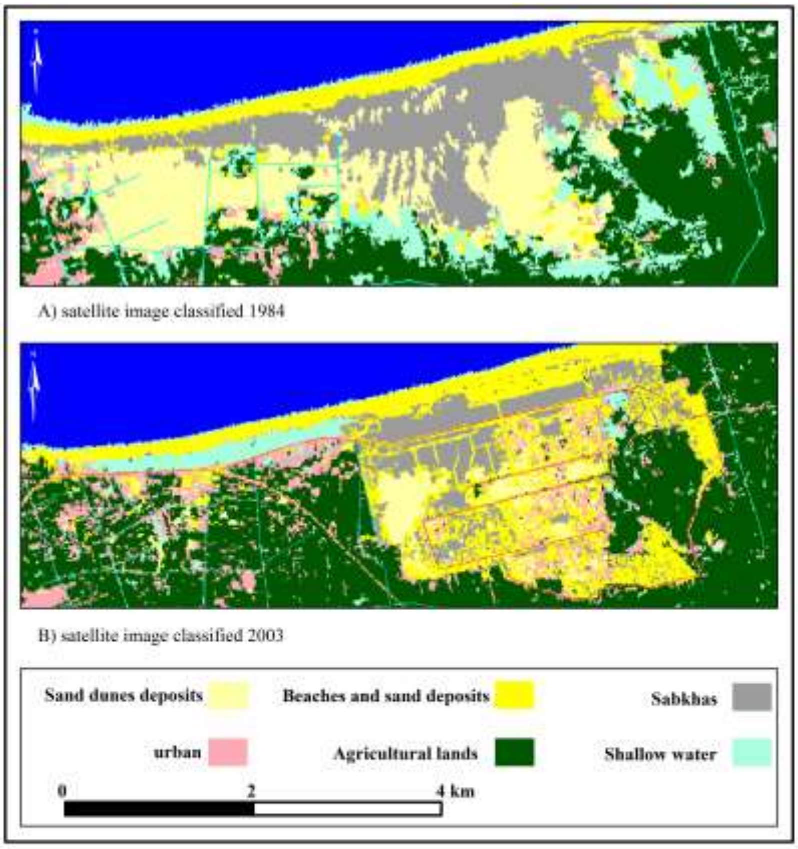
Table (2) shows the results of the quantitative analysis of sabkhas changes in New Damietta area using the same previous technique and the following results were observed:

- The area of sabkhas in New Damietta area decreased by 6.2 km^2 or 45.4% of the total sabkhas area at the beginning of the study period.

- In 1984, 12.1% of the sabkhas area was transformed into urban and roads by 2003. This is largely related to the continued urban growth of the New Damietta city and the extension of the international coastal road (Figure 4).

Table (2) Sabkhas changes in New Damietta area (1984 – 2003)

		1984		
		Sabkhas		Total area (km^2)
		area (km^2)	%	
2003	Agricultural lands	0.73	5.3	49.1
	Urban	1.53	11.1	10.2
	Roads	0.13	0.95	0.55
	Irrigation and drainage	0.04	0.29	0,76
	The sea	0	0	32.9
	Sabkhas	4.8	35.7	7.4
	Beaches	4.03	29.4	17.5
	Sand dunes	0.82	6	4.6
	Sandy land	1.51	11.05	4.8
	Total area (km^2)	13.6	100	
	The difference between the two satellite images	− 6.2	− 45.4	



A) satellite image classified 1984

B) satellite image classified 2003

Figure (4) Sabkhas changes in New Damietta area

6.3.Sand dunes changes

The study of sand dunes changes requires the availability of spatial data that can reflect the status of sand dunes on multiple observation dates; the case studies relied mainly on follow-up of sand dunes at several locations using aerial images and satellite images data. In addition, there is an important role for the field follow-up process of sand dune situation. These studies are presented below:

6.3.1.Sand dunes of Damietta bend

The old aerial photos of 1955 show a clear concentration of a group of barchan dunes in northwest area of the last major bend of Damietta branch (Figure 5-a), The 1985 aerial photos show that the area covered by sand dunes shrunk due to the encroachment of agricultural land (Figure 5-b) with clear geometric limitations by engineers.

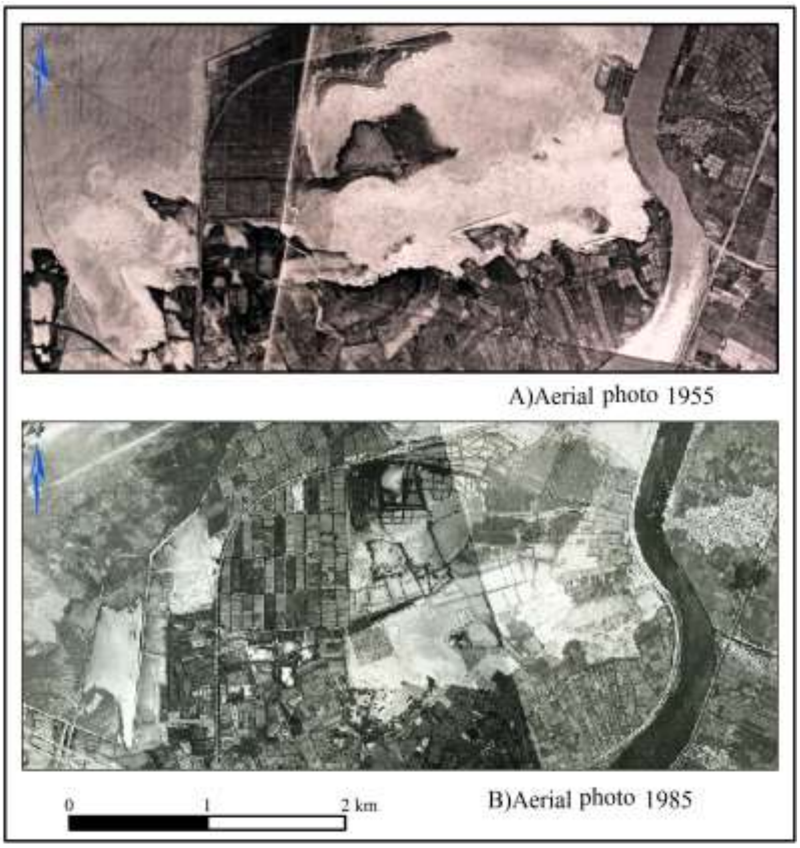


Figure (5) Changes of sand dunes in Damietta bend

During the field study of the site, it was observed that sand dunes disappeared completely and that a dense cover of agricultural land and palms prevailed. Sand dunes can be traced by the presence of a single sand dune at the entrance to the road leading to Damietta port sandy patches appear to represent the remnants of one sand dune that was removed.

6.3.2. Gamasa sand dunes

Sand dunes variations in Gamasa field were estimated through comparing the 1984 and 2003 satellite images data. The area covered by sand dunes was clearly decreased between the beginning and the end of the study period. Only about a quarter of the area of sand dunes was left in 1984 by 2003 and the rest of the dunes (76.31%) had been diverted to other uses, (for example, in 1984, 68.9% of the area of sand dunes was converted into agricultural land, waterways and ponds by 2003).

The quantitative estimation of Gamasa sand dunes changes is consistent with the nature of the changes as they appear visually in (Figure 6) and (Figure 7) where sand dunes may be stretched by waterways. Large areas have been exploited to grow crops and establish fish farms.

The previous case studies show that there are two images of sand dunes degradation in the study area. The first is the total degradation and complete removal of sand dunes such as Damietta bend sand dunes. The second is the partial and gradual degradation of sand dune fields such as Gamasa sand dunes.

Images of sand dunes degradation have been largely associated with the morphological characteristics of the sand dunes. Smaller and denser sand dunes were less adapted to human intervention and further degraded. Consideration should be given to the location and accessibility of sand dunes. The international coastal road has made many sand dunes sites accessible to man. The current picture seems to indicate continued human pressure on the sand dunes. In the absence of sand dune maintenance management, the sand dunes will be further degraded and disappeared regardless of their dimensions and characteristics.

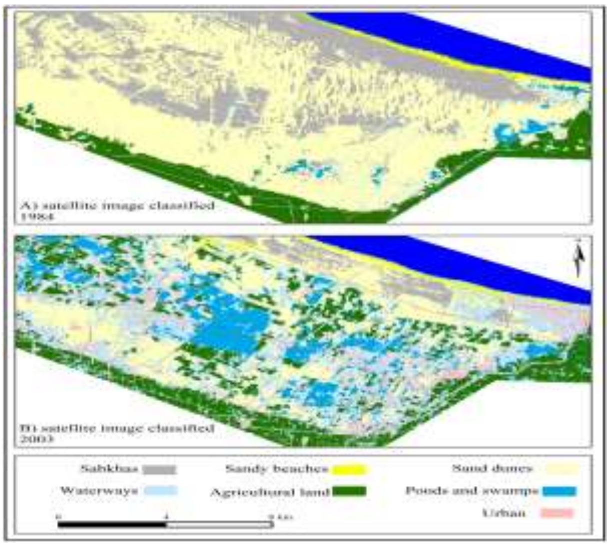


Figure (6) Sand dunes changes in Gamasa field

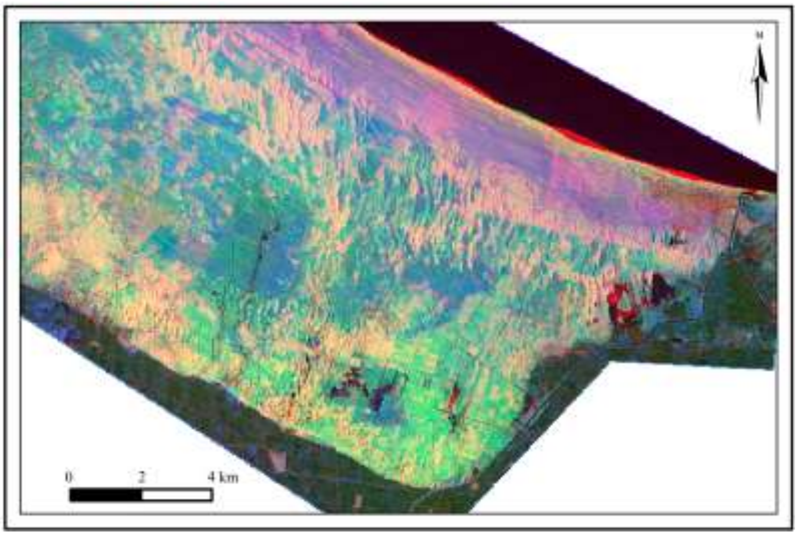


Figure (7) Sand dunes Gamasa field
(Satellite Image 1984-2003)

6.4.Coastal lakes changes

Lakes changes are those of contemporary changes that are primarily related to human intervention. Topographic maps and satellite images are among the most important means used to monitor and interpret lakes changes in the study area. It is necessary to note the different method of study and the nature of the results obtained depending on the method used to study changes in the feature.

6.4.1.Changes in lakes from topographic maps (1945-1991)

Maps represent an important source for examining changes in lakes in the study area over a long period of time, especially during some early periods during which there were no alternative means through which to monitor the feature. Water bodies and islands are the most specific features on topographic maps that can be separated and digitized.

Table (3) shows some of the characteristics of the water body and islands of the study area lakes based on the data obtained from topographic maps of the years 1945, 1983 and 1991, where the following can be concluded:

Table (3) Characteristics of the water body and islands of the study area lakes

Characteristics	Water body	Number of	Islands area	Numerical density of	Area density of

Date of monitoring		area (km^2)	islands	(km^2)	islands (Island per 1 km^2 of water)	islands (km^2 per 1 km^2 of water)
Manzala Lake	**1945**	1236.5	672	128.2	0.5	0.1
	1983	723.9	294	201.4	0.4	0.2
	1991	585.4	205	151.3	0.3	0.2
Burullus Lake	**1945**	562.4	55	11	0.09	0.01
	1983	415.8	10			
	1991	436.3	32	16.9	0.07	0.03
Edko Lake	**1945**	147.2	72	5.6	0.4	0.03
	1991	14.4	2	0.4	0.1	0.002

- There is a clear trend towards decreasing water body area in all lakes, although the amount of change varies from one lake to another. Edko Lake is the most shrunken lake with 90% of the total water area lost between the beginning and end of the study period (1945-1991), while the same proportions reached 52.6% and 22.4% in both Manzala and Burullus, respectively.
- The increase in rate of decrease of water body of the lakes between the periods of the first study (1945-1983) and the second (1983-1991) indicates the extent to which the water body is exposed to the lakes over time, and the increase is evident in Manzala and Burullus Lakes Table (4).

Table (4) Changes in the water body of study area lakes

Values of change / Study periods		Total water loss in km^2	Rate of change water body (km^2 / year)
Manzala Lake	**1945-1983**	512.6	13.4
	1983-1991	138.5	17.3
Burullus Lake	**1945-1983**	96.6	2.5
	1983-1991	29.5	3.6
Edko Lake	**1945-1991**	132.8	1.3

- There is a clear trend towards the numerical decline of lakes islands. Edko is the most lost island between the beginning and end of the study period as a whole. Burullus departed from the constant trend of declining numbers of islands. The number of islands decreased between 1945 and 1983 and then increased between 1983 and 1991. This result cannot be recognized as an indication of an increase in the number of islands during the second period without reference to another source. The 1984 satellite image review reveals that the actual number of islands is higher than in maps and therefore reliance on maps is only a misleading criterion.

- The direction of change in the area of the islands may be consistent with the trend of changing numbers and may vary, This consistency appears to be the case in Edko Lake, which shows a significant decrease in the number of islands, followed by a decrease in the total area of the islands to the same degree. Although the number of islands in Manzala and Burullus decreased, the total area of the islands in both lakes tended to increase between the beginning and end of the study period (1945-1991).
- The changes in islands are very much related to changes in the body of water because water represents the medium in which islands grow. This relationship appears by following the changes in the numerical and cadastral density of the islands Table (3), which reflects the direction and nature of the change of water body and islands in each lake.
- It is clear from the previous data that the process of analyzing the changes of water body and the islands based on topographic maps may not be high accuracy. This is due to the fact that the accuracy of the representation of lake features on topographic maps varies from one topographic survey project to another (especially for islands). The picture may be further illustrated by the spatial follow-up process of changes.

6.4.2.Changes in lakes from satellite images (1984-2003)

The importance of using satellite images in examining changes in lakes of the study area is a recent source through which we can reach the nearest picture of the current reality in light of the rapid changes witnessed by the feature. According to the availability of more than one generation of satellite images in the monitoring of changes in the features lakes with high accuracy, especially those features that are difficult to monitor from other sources with the same accuracy. The changes in lakes have been monitored through comparing the 1984 and 2003 satellite images data (Table 5) with reference to improved satellite images and sometimes visually comparing them.

Table (5) Lakes changes in satellite images

Dimensions / Year	Water body area (KM^2)	Plant body area (KM^2)	Fish ponds area (KM^2)

Lakes	1984	2003	1984	2003	1984	2003
Manzala	688.9	391.8	---	385	95.1	132
Burullus	328.9	229.7	261	202	44	59.1
Edko	25.8	28.2	77.6	42.2	1.8	29.6

The following are the most important changes in each lake in the study area:

6.4.2.1.Manzala Lake

Manzala Lake is one of the most exposed lakes in the water body area. The lake lost about 297 km^2 during the study period (1984-2003) by 43% of the water body area in 1984. This change is related to many processes, the most important of which are:

- Deduction of large areas of the water body for the establishment of fish ponds, especially in the north-west and south-eastern sectors of the lake (Figure 8) and (Figure 9). This result is consistent with the apparent increase in the area of fish ponds during the study period (Table 5).
- Some marginal areas of the water body were subjected to truncation and drying, especially the area south Port Said Plain to the east of the main stream of the Bahr El-Baqar Bank (Figure 10). It is noticeable that some water basins are isolated from the main water body of the lake. This feature is clearly south of Port Said due to the extension of the international coastal road and the identification of some industrial drainage basins. This feature may help further shrink the area of water body.

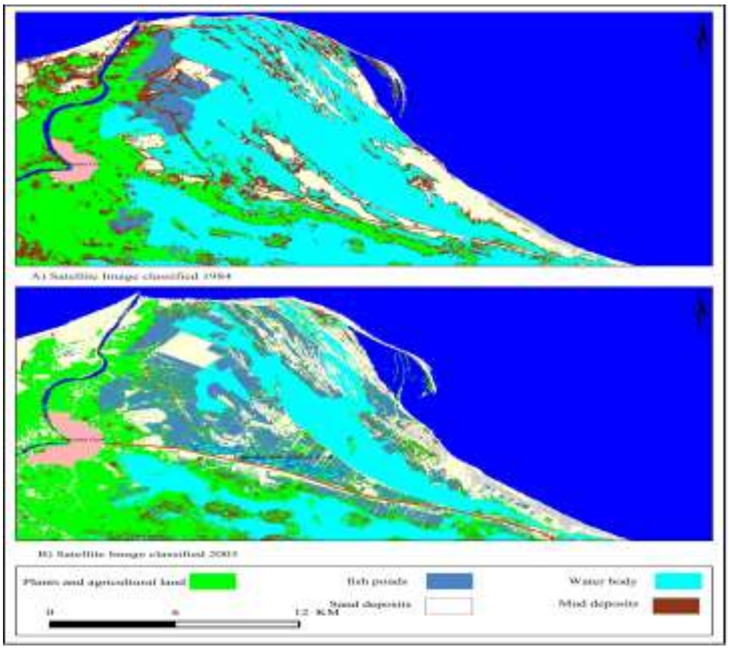
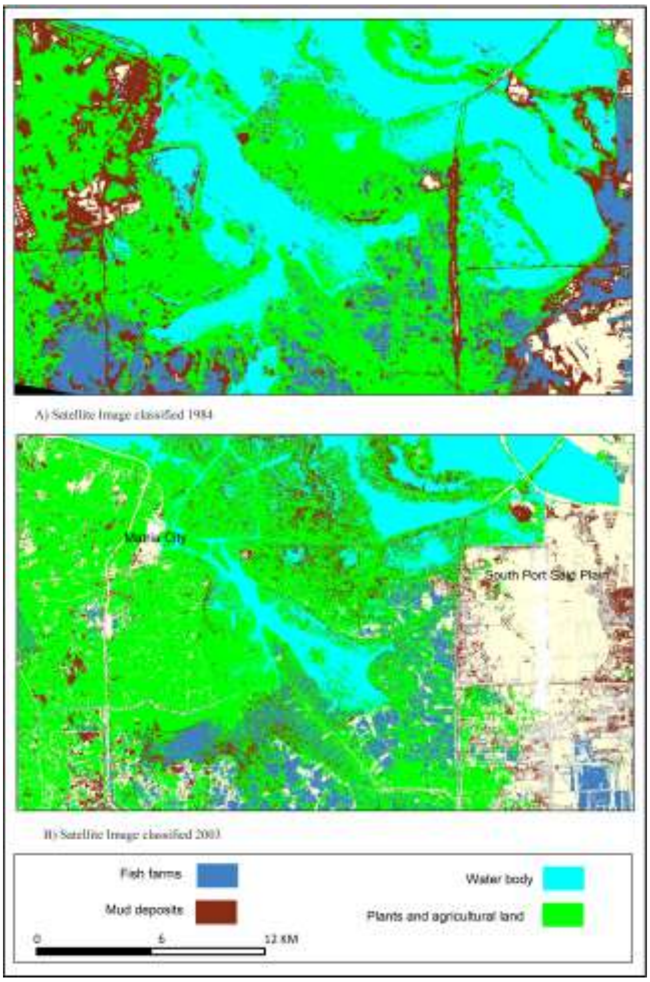


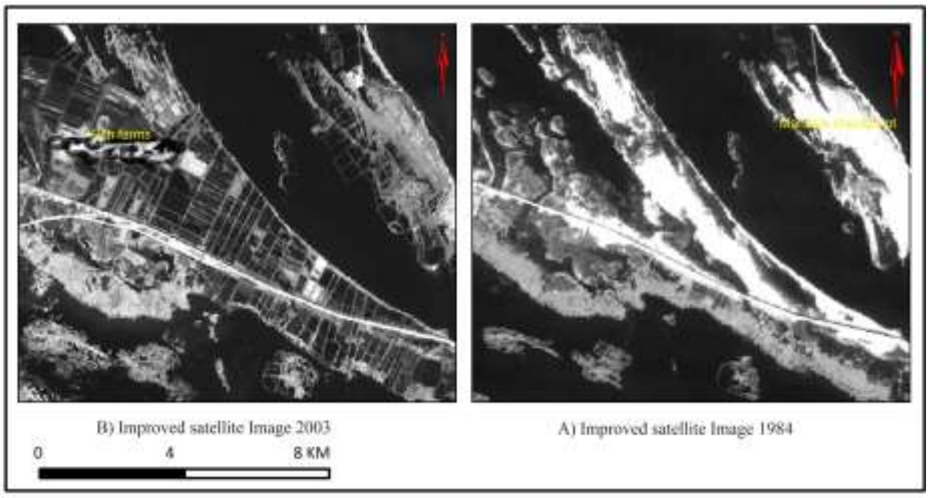
Figure (8) Manzala Lake changes (North West Sector)



A) Satellite Image classified 1984

B) Satellite Image classified 2003

Figure (9) Manzala Lake changes (South East Sector)



B) Improved satellite Image 2003

A) Improved satellite Image 1984

Figure (10) Deterioration of Tawellat islands (Manzala Lake)

- The growth of plants of lake at the expense of water body where there is a clear trend of plant growth both on the margins of lake or around the islands. This feature is concentrated in some locations in front of the main drains exits due to the availability of water with relatively low salinity content with increasing organic content (Figure 11).

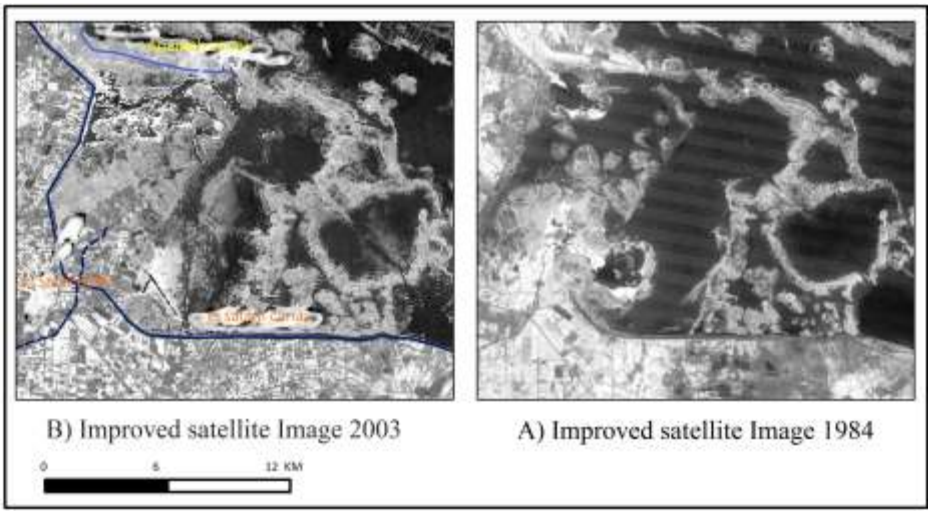


Figure (11) Plant and islands changes in Manzala Lake

Location: West Central Sector

6.4.2.2.Burullus Lake

Burullus Lake was subjected to a decrease in the area of water body, similar to the trend in the lakes of study area even if the extent is small compared to Manzala as it is estimated that the percentage of loss in the area of water body at 30% of the total area at the beginning of study. This is largely related to the encroachment of the range of fish ponds located south of lake towards the water body in the north. It is noticed that the total area of plant body decreases during the study period. This is linked to the deduction of some areas directly in the far southwest of lake in order to reclaim land for agriculture or because of the extension of fish ponds. In spite of this decrease, another trend towards high-density plant growth appears in the central and eastern sectors of lake, which resulted in the emergence of the feature fusion of carrot plants and the margin of the lake (Figure 12).

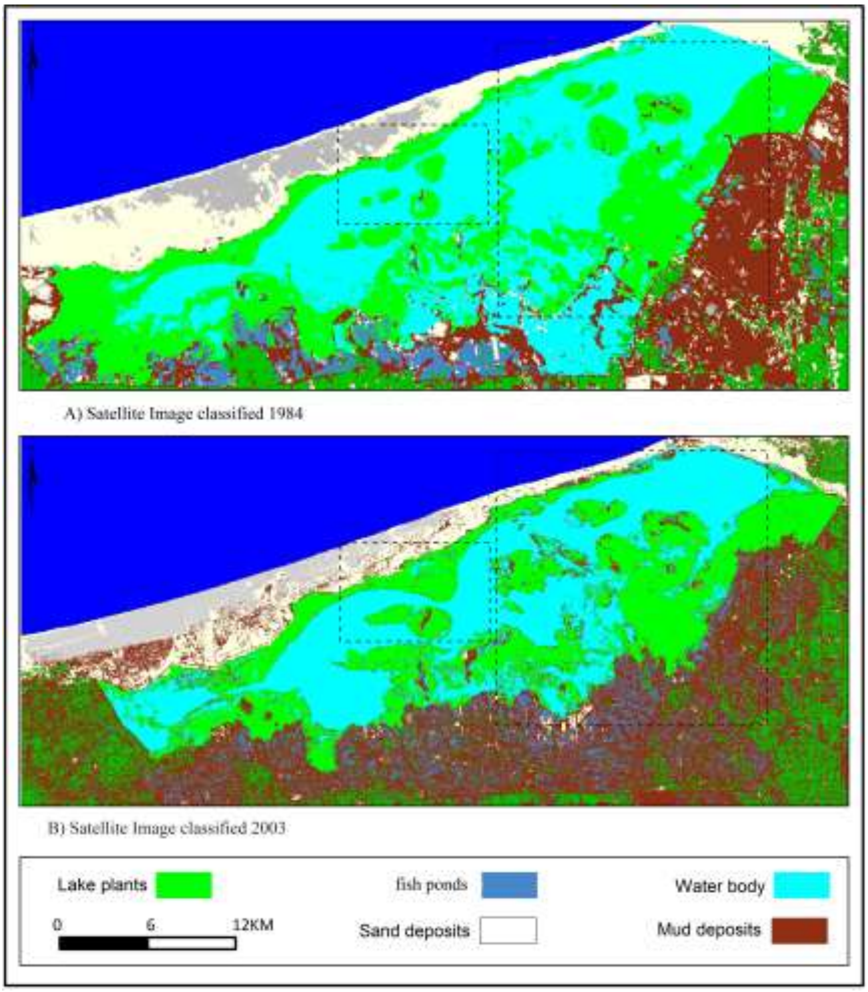


Figure (12) Burullus Lake Changes

6.4.2.3.Edko Lake

Decreased water body area of Edko Lake is associated with the transformation of a group of scattered aquariums towards other uses (especially the establishment of fish ponds). In addition, other areas of drought, such as in the water arm extending from southern basin to the east. The shrinkage of vegetation is a characteristic feature where the lake lost nearly half of its vegetation during the study period. This is linked to the huge increase in the area of fish ponds at the expense of plant body (Figure 13).

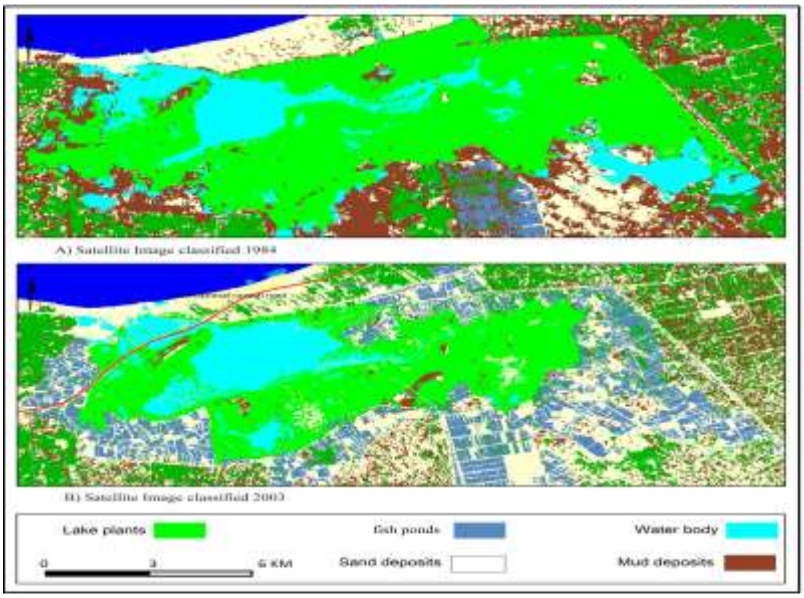


Figure (13) Edko Lake Changes

Summary

The objectives of this study are to assess the change detection in the geomorphological features of the Nile Delta coastal plain by integrating Remote Sensing (RS) and Geographic Information System (GIS) methodologies. Topographic maps of 1945, 1983 and 1991 and Enhanced LANDSAT images for different dates were used. Vegetation cover and unsupervised image classification layers were processed. The results indicated that :

1. The total area exposed to erosion from Delta promontories was 19.6 km^2 with a percentage of 62% of total area of erosion cells at that stage. The largest accretion cells are distributed to the west and east from Rashid promontory and sand spit of Damietta (East Damietta promontory) and Gamasa Bay area.
2. Sabkhas changes on Manzala barrier by comparing satellite images data for 1984 and 2003 where following can be concluded: sabkhas on Manzala barrier was reduced by 1.9 km^2 with a percentage of 15.7% of the total area of sabkhas at the beginning of study period (1984), and 58% of sabkhas area was transformed into features (other categories of use).
3. During the field study of the site, it was observed that sand dunes disappeared completely and a dense cover of agricultural land and palms prevailed.
4. Edko Lake is the most shrunken lake with 90% of the total water area lost between the beginning and end of the study period (1945-1991), while the same proportions reached 52.6% and 22.4% in both Manzala and Burullus, respectively.
5. There is a clear trend towards the numerical decline of lakes islands, Edko is the most lost island of the islands between the beginning and end of the study period as a whole, Burullus departed from the constant trend of declining numbers of islands. The number of islands decreased between 1945 and 1983 and then increased between 1983 and 1991.
6. Manzala Lake is one of the most exposed lakes in the water body area. The lake lost about 297 km^2 during the study period (1984-2003) by 43% of the water body area in 1984.

References

1. Ahmed, M. H., (2002), Multi-temporal conflict of the Nile Delta coastal changes, Egypt, the changing coast, p.p. 317-323.

2. Clark Labs. (2006), IDRISI Tiaga 16. User's Guide, Clark University. Worecester ,MA,USA.

3. Crowell, M., S. Leatherman & M. Buckley, (2003), Shoreline changes rate analysis: long term versus short term data, Shore and Beach, Vol. 61, p. 13-20.

4. El-Raey, M., Sharaf El-Din, S. H. Khafagy A. A. & Abo-Zed, A. I. (1999), Remote sensing of beach erosion/accretion patterns along Damietta – Portsaid shoreline, Egypt, International Journal of remote sensing, Vol. 20, p.p. 1087-1106.

5. El Sayed, M. A., Younan, N. A. Fanos, A. M. & Baghdady, K. H. (2005), Accretion and Erosion patterns along Rosetta promontory, Nile Delta Coast, Journal of Coastal research, Vol. 21, p.p. 412-420.

6. ERDAS, Inc., (2003), ERDAS Imagine version 9.1, Field Guide, Fourth Edition ERDAS, Inc., Atlanta, Georgia. USA.

7. ESRI. (2003). ArcGIS software. Environmental Systems Research Institute, Inv. Redlands, CA.Sensing23:1741–1748.

8. Frihy, O. E., (1988), Nile Delta Shore Line changes aerial photographic study of a 28 year period, journal of Coastal Research, vol. 4, p.p. 597-606.

9. Frihy, O.E., El Fishawy, N. M. & El Askary, M. A. (1988), Geomorphological Features of the Nile Delta Coastal Plain: A review, Acta Adriata, Vol. 29, p.p. 51-65.

10. Frihy, O. E., Fanos, A. M. Khafagy, A. A. & Komar, P. D. (1999), pattetns of nearshore sediment transport along the Nile Delta, Egypt, Coastal Engineering, Vol. 15, p.p. 409-429.

11. Frihy, O. E., Debes, E. A. & El Sayed, W.R. (2003), Processes reshaping the Nile Delta Promontories of Egypt: Pre-and Post Protection, Geomorphology, vol. 53, p.p. 263-279.

12. Frihy, O.E. & Lawrence, D. (2004), Evaluation of the Modern Nile Delta Promontories , Development of Accretional features during shoreline retreat , Environmental Geology, Vol. 46, P.P. 914-931.

13. ILWIS 3.3, (2003), "The integrated land and watershed management system (ILWIS): User's Guide", ITC, Enschede, The Netherlands.

14. Jensen, V., Lunetta ,K. & Elvidage , T., (2018), Comprehensive remote sensing , Elsevier ltd , Vol. 34 , Issue.8, USA.

15. MWRI. (1995), Ministry of Water Resources and Irrigation, Egypt. www.nwrc-egypt.org.

16. Nafaa, M. G. & Frihy,O. E. (1993), Beach and Nearshore Features along the dissipative Coastline of The Nile Delta, Egypt, Journal of Coastal Research, Vol. 9, p.p. 423 - 433.

17. Sadek, A. S., Abdel Rahman, S. I. & Ghabour,T. K. (1993), Multitempotal analysis of Landsat images for studying coastal changes along the shore line of the Nile Delta, Egypt. Journal. Soil, Vol. 33, p.p. 85-96.

18. Sharaf El-Din, S. H. & Mahar, A. M. (1997), Evaluation of Sediment Transport Along the Nile Delta Coast, Egypt, Journal of Coastal Research, Vol. 13, p.p. 23-26.

19. Stanley, D. J. & Warne, A. G. (1998), Nile Delta in its destruction phase, journal of Coastal Research, vol. 14. p.p. 794-825.

20. White, K. & El Asmar, H. (1999), Monitoring Changing position of coastline using Thematic Mapper Imagery, an example from the Nile Delta, Geomorphology, Vol. 29, p.p. 93-105.

21. Woodroffe, C.D., (2002), Coasts form, process and evolution, Cambridge University, U.K.

الملخص العربي

يتميز رصد التغيرات تحليل سلسلة زمنية من الصور ذات تواريخ مختلفة ، وتعد الدراسات المرتبطة بالموارد المائية وتغير الغطاء النباتي من الظاهرات الشائعة في هذا المجال . وقد تكون هذه التغيرات قصيرة الأمد مثل حدوث الفيضانات أو ذوبان الغطاء الثلجي ، وطويلة الأمد مثل إزالة الغابات أو التوسع في المناطق الحضرية .

ومن هذا المنطلق يتناول هذا البحث دراسة لرصد التغيرات في بعض الظواهر الجيومورفولوجية بالسهل الساحلي لدلتا النيل باستخدام نظم المعلومات الجغرافية والاستشعار من البعد ، وذلك من خلال رصد التغيرات بخط الشاطئ ، والسبخات ، والكثبان الرملية ، وأخيراً تغيرات البحيرات الساحلية . حيث أتضح من دراسة تغيرات خط الشاطئ سيادة النحت في مواضع النتوءات الدلتاوية وحاجز بحيرة المنزلة ، فقد بلغت المساحات المعرضة للنحت بها ١٩.٦كم^{٢} بنسبة ٦٢% خلال الفترة من ١٩٤٥ – ١٩٨٣ ، وتتوزع أكبر نطاقات الإرساب إلي الغرب والشرق من نتوء رشيد ولسان دمياط الرملي ومنطقة خليج جمصة .

أما عن تغيرات سبخات منطقة الدراسة فقد أتضح من خلال مقارنة بيانات المرئيات الفضائية لعامي ١٩٨٤ و٢٠٠٣ تعرض مساحة السبخات علي حاجز المنزلة للتناقص بمقدار ١.٩كم^{٢} بنسبة ١٥.٧% ، حيث غطت الرواسب الرملية والمزارع السمكية مساحات واسعة من السبخات . وخلال نفس الفترة تعرضت المساحات التي تغطيها الكثبان الرملية للتناقص بشكل واضح ، فلم يتبق من مساحة كثبان جمصة عام ١٩٨٤ إلا ربع المساحة عام ٢٠٠٣وتحولت باقي المساحة (٧٦.٣١%) إلي استخدامات أخرى . علي الجانب الآخر وجد أن بحيرة المنزلة أكثر البحيرات التي تعرضت لانكماش واضح في مساحة الجسم المائي حيث فقدت البحيرة حوالي ٢٩٧كم^{٢} بنسبة ٤٣% خلال فترة الدراسة (١٩٨٤ – ٢٠٠٣) ، كما تعرضت بحيرة البرلس لتناقص مساحة الجسم المائي علي غرار الاتجاه السائد في بحيرات منطقة الدراسة ، ويرتبط ذلك بزحف نطاق المزارع السمكية المتمركز جنوب البحيرة باتجاه الجسم المائي شمالاً .