Chapter 9
Monitoring and Protection of Egyptian Northern Lakes Using Remote Sensing Technology

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Abstract Coastal lakes in the Mediterranean region constitute a major aquatic resource, yet many in the Egyptian Mediterranean region (EMR) are severely degraded. Despite of the acute problems that sometimes stem from development activities, the lakes aquatic ecosystems are of high or potentially high value for local human populations as well as for regional biodiversity. Northern Egyptian lakes are all impacted by a variety of environmental change processes, but direct human activities have had the greatest effect during the 20th Century. This study is designed to promote these pressing environmental management issues through a variety of tasks that include monitoring, modeling and protecting. Management planning and policies are poorly supported by environmental science in the EMR. Satellite imagery is obtained for the study lakes and was subject to geometric correction and transformations. Ecological classification of satellite images are undertaken to establish the distribution of major ecological zones including distribution of major vegetation communities. For each lake, an array of different remote imagery and topographic maps from different time periods were employed to identify changes in the distribution of open water and aquatic vegetation as well as major changes in the configuration of these lakes. Geographic Information Systems (GIS) are used for all the data for each lake. Hydrodynamic models for some lakes are parameterized using the baseline historical data, bathymetric data, ancillary data, field survey data and monitoring data. The finite element two-dimensional modeling systems MIKE 21 and three-dimensional MIKE 3 were employed. Model results were used to examine ecosystem functioning including, the relative importance of freshwater inflows and exchange to the sea and their influence upon salinity, circulation patterns, and sources and distribution of nutrients. The principal results, achievements, and experience from this study enables to address some recommendations for future actions concerning coastal aquatic environments in the Egyptian Mediterranean Region including; furthering the need for an integrated approach to environmental assessment and management of Northern Egyptian lakes with special attention to harmonizing analytical skills by developing on-line facilities, Establishing continuity in the operation of integrated eco-hydrological investigations including remote sensing, GIS,

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modeling at the coastal lakes that retain links with meaning stakeholders and experts, expanding impact assessment to include social and economic themes that include the societal implications of different scenarios, promoting links between environmental scientists, environmental managers, decision makers and wider society to increase transparency and communication of collected information using online facilities, and building upon the results of lakes studies by raising awareness of issues facing coastal aquatic ecosystems so that their sustainable management can be better integrated into water and land use policy nationally and internationally.

Keywords Northern lakes · Egyptian lakes · Remote sensing · Monitoring · Modeling · Biodiversity

9.1 Introduction

The Northern coastal zone of Egypt, including lakes environment, is of great socioeconomic and environmental significance. In Egypt, the lakes areas along the Mediterranean coast comprise five lakes. Four lakes are deltaic water bodies (Mariut, Edku, Burullus and Manzala) and the other is non-deltaic Lake Bardawil. The deltaic lakes are brackish, shallow (<2 m), with an average depth of ~1.0 m. Among these water bodies, Mariut Lake is artificially enclosed and has been without a major connection to the sea. The other three display typical lake characteristics separated from the Mediterranean by low-lying, long narrow coastal sandbarriers, and connected to the sea by protected inlets. These inlets are vital for a dozen of species of fish that depend on the lakes for at least a part of their life cycles, and they are the only inlet/outlet available for thousands of commercial fishing boats that use the lake. Delta lakes receive much of their freshwater input from irrigation drains that entering the lakes from the southern, eastern, and western margins. The non-deltaic lake is situated away from the delta region at north Sinai, Lake Bardawil. The ecosystem of these lakes has been controlled by the interaction of natural and man-induced factors (Fig. 9.1).

The southern and eastern margins of the Nile Delta lakes are bordered by extensive marshes of aquatic macrophytic plants. Surficial sediments of the delta lake composed of plant- and shell-rich muds and sandy silts, whereas Bardawil Lake is covered by sand-size sediments mixed with evaporates (Levy 1974a, b). The coarsest sediments are found near the inlet where current velocities are maximum, and the finest sediments is in the innermost reaches where current velocities approach zero and where drains are localized. Biological processes contribute significantly to the production of carbonate sediment through the formation of mollusk shells, ostracod and foraminiferal tests (Bernasconi and Stanley 1994).

For better access management of the Nile Delta coastal zone and adjacent coastal lakes, a coastal highway, is nearly completed, extending along the Mediterranean coast of Egypt from El Salum City in the west to Rafah City in the east. The road is more or less parallel to the present shoreline at a minimum distance of about 1 km

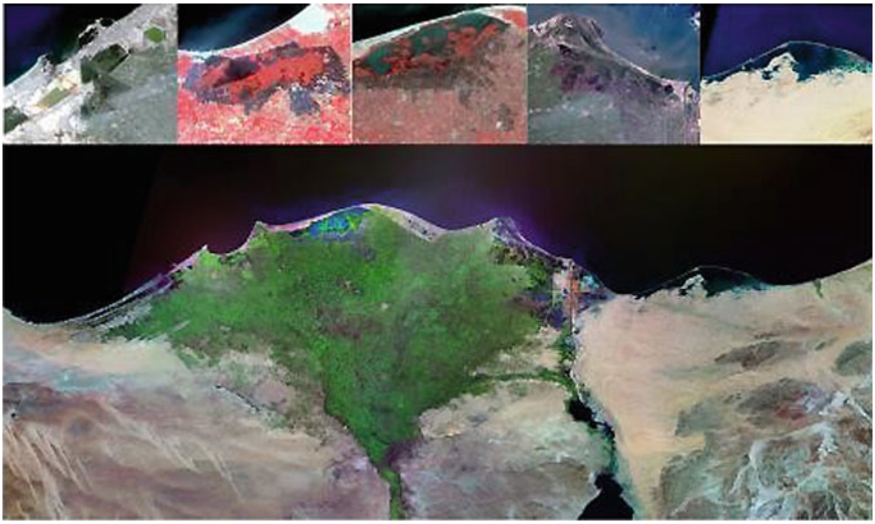

Fig. 9.1 Northern coastal lakes of Egypt (study area). From left to right (top of the figure), the lakes are: (Mariout Lake, Idku Lake, Burullus Lake, Manzala Lake, and Bardawil Lake) (Marine sciences department-NARSS)

from the shore (Mohsen 1992). The coastal road is crossing Burullus inlet by a pill bridge to permit navigation of fishing boats as well as the lake/sea water exchange. This highway will facilitate better access between lakes and other communities, agriculture and industrial centers across the northern coast of Egypt. This means that urban expansion is increasing around the coastal lakes and thus causing more pressure on the lake ecosystem (Ahmed et al. 2000a, b).

The primary objective of this study is to monitor the important problems that exist at the Northern coastal lakes of Egypt. Also, the authors attempt to use the environment of these lakes to be used as a lesson learned for any other lake management processes. The study is based largely on studies that used the satellite data, information technology and consultation of available literature. Most of the existing environmental problems of the Egyptian Northern lakes are derived from anthropogenic and natural influences. In contrast, the other is a hypersaline water body (Bardawil Lake), which is located at the northern coast of Sinai. Using earth observations and information technology (satellite data, GIS, etc.) enhance and update the understanding of the behaviours of lakes ecosystems.

On the other hand, ongoing natural factors have induced substantial changes in the lake environment. These changes include barrier erosion, inlet siltation, land subsidence and rising sea level, subsidence and prevailing sedimentary processes. Monitoring of the these problems of these lakes is discussed herein in view of identifying problems, causes, impacts and proposed actions for protecting and managing the northern Egyptian lakes.

9.2 Objectives

This chapter aims to review the role of satellite remote-sensing imagery to assess and protect the Northern lakes of Egypt; this can be achieved through addressing three major key issues:

(i) Monitoring the present status of the northern lakes of Egypt by providing the origin description and problems identification of the lakes ecosystems. Moreover, consulting the studies and reports that were used the remote sensing technology will be presented.

(ii) Addressing the developed techniques and procedures for using satellite imagery in studying the coastal lakes on a regional scale. These procedures are describing the satellite-based methods for implementation on a routine basis the lake natural resource management. Apply the satellite-based procedures to a series of images that span several decades to evaluate how lakes changed over time and space in relation to land-use and land-cover conditions. This issue is to assemble the necessary GIS databases and develop modeling procedures applicable at the small watershed scale to predict pollutant loadings and water quality responses in lakes based on size, drainage patterns, land-use/cover, and other related watershed information available in GIS format.

(iii) Protecting and conservations of lakes resources as well the management activities will discuss in the light of utilization of information technology in previous lakes studies.

9.3 State-of-the-Art Review

Although previous investigations have demonstrated reliable empirical relationships between satellite data and nearly contemporaneous ground observations, satellite imagery has not been incorporated into routine lake-monitoring programs conducted by institutes and agencies (Kloiber et al. 2002). This study examined the key issues involved in using satellite imagery in the regional assessment of lake, developed a procedure for the use of satellite imagery to assess lake water clarity and applied the procedure to a series of images of lakes taken during last four decades (Ahmed et al. 2000a, b, 2009).

The basic requirement for remote sensing environmental monitoring is the availability of different dates of imagery upon which the same area of land can be observed. Monitoring global, regional and local areas can be performed by restricting the analysis to a single sensor series or by using different satellite data. New multi-source satellites are creating data at higher spatial and temporal resolution than have been collected at any other time on earth. The selection of low cloud cover imagery with careful attention to selecting the dates through the year(s) is very important.

The unique characteristics of the Landsat data make it an ideal data source for monitoring. Its sensor (Thematic Mapper TM) covers a wide range in the electromagnetic wave spectrum with a ground (spatial) resolution of 30 m, which enable precision mapping. Its spectral range starts from the visible range (0.45–0.69 μm), to near Infrared (IR) (0.76–0.90 μm) and mid IR (1.55–2.35 μm), up to the thermal IR band (10.4–12.5 μm). Moreover, its temporal resolution (the ability to obtain repeated coverage of a specific geographic area) is 16 days, which is a considerably short period that permits continuous monitoring and environmental developments over time.

Remotely sensed data could be used as a tool to detect, monitor and evaluate changes in ecosystems to develop management strategies for ecosystem resources, satellite and airborne systems offer a plausible monitoring system for large-scale, earth surface viewing and provide a usable database for change detection studies. Remote sensing data can be used to span temporal and spatial scales ranging from local systems to aggregated global systems (Graetz 1990).

Milne (1988) noted that common types of detectable change in remotely sensed data are associated with the clearing of natural vegetation, increased cultivation, urban expansion, changing surface water levels, post-fire vegetation regeneration, and soil disturbances resulting from mining, landslides and animal overgrazing.

Milton and Mouat (1989), found that the use of remote sensing techniques allows ecologists and resource managers the opportunity to monitor vegetation condition, patterns, and trends in arid regions where rugged terrain, poor access, and extreme climate conditions make field investigations difficult. The use of satellite data is very suitable for inventorying the kind, quality, distribution, and condition of natural vegetation found on the range and forest lands (El-Kafrawy et al. 2017). Observations made by the Advanced Very High-Resolution Radiometer (AVHRR) on board the NOAA-7 platform, assisted in monitoring desertification in Africa (Choudhury 1990).

Dewidar and Khedr (2005), used Landsat Thematic Mapper TM data combined with surface measurements for mapping water quality parameters of Burullus Lake. They indicated that some of the water quality parameters were significantly correlated with TM radiance data.

Subsequently, multiple linear regression models were used to prepare digital cartographic products depicting the water quality over the entire study area (Kloiber et al. 2002).

Temporal pattern mapping of vegetation may further provide clues as to the causes of certain ecosystem changes. Briggs and Nellis (1991) developed a satellite-based textural gontrim which quantifies the temporal changes resulting from the influence of seasonal fires. It has also been demonstrated that it is possible to assess accumulated biomass (Fung 1990; Ringrose and Matheson 1987; Milne and O'Neill 1990; Franklin 1991), the degree of use and changes in the dominant species composition (Hall et al. 1991; Hobbs 1990), land use (Ambrose and Shah 1990; Teng 1990; Wharton 1987; Ramdani et al. 2009; Thompson et al. 2009; Ahmed and Donia 2007) and hydrological differences (Howman, 1988; Christensen et al. 1988; Jensen 1986) in various ecosystems using satellite and/or airborne data.

Recording land cover change over time is perhaps one of the most important applications of digital remote sensing data (Christensen et al. 1988). For example, the conversion of rural to urban land use can be detected using a temporal comparison of spatial change determined from satellite and airborne data. The value of utilizing remotely sensed data for change detection studies is limited only by the imagination of the investigators and potential users.

Satellite remote sensing using Landsat Thematic Mapper (TM) has been explored in several studies as a method of reducing the cost and labor of sampling water clarity in the field (Khorram and Cheshire 1985; Lathrop 1992; Dewider and Khedr 2001; Kloiber et al. 2002). An advantage of using remote sensing is that data for multiple lakes within a single image can be collected quickly and relatively inexpensively.

Remote sensing technology has been used for several decades in oceanography to measure chlorophyll, water-color, and suspended sediments over large areas, but has only recently been explored in lake studies in Egypt. Although sensors such as Landsat TM were primarily designed for detecting land features, recent improvements now provide better spatial and spectral resolutions for aquatic studies than previously available (Zilioli 2001; Kloiber et al. 2002). Recently, remote sensing has been shown to correlate well with Lake Secchi disk transparency (SDT) values (Khorram and Cheshire 1985; Lathrop 1992). However, to effectively implement remote sensing into a state monitoring program for inland lakes, there remain many unanswered questions.

Barale and Folving (1996) demonstrated the use of satellite images and remote sensing in studying the coastal interactions in the Mediterranean region. They showed that several interactions had occurred within the area in front of the Nile Delta during the last 50 years which led to detectable changes in the coastal area.

Ahmed et al. (2006) studied the case of eutrophication assessment of Lake Manzalah using the GIS technique. Their results indicated that the eutrophication index value could be calculated in combination with GIS overlay technique to give a relatively accurate prediction of the status of eutrophication of the lake. They also concluded that the water quality spatial distribution map could also produce using the same technique.

El-Raey et al. (2006), have applied change analyses techniques to TM images for identifying changes inside and outside Lake Burullus. Analysis of the results reveals the occurrence of erosion and accretion along both sides of the lake inlet. During the period (1995–2000), the lake area decreased by an average rate of 1.34 km^2 per year mainly due to illegal drying for land use.

9.4 Origin and Description of the Northern Egyptian Lakes

The Nile and other Mediterranean deltas contain a widespread and generally consistent late Pleistocene to Holocene stratigraphic succession. In respect to the Nile Delta, Stanley and Warne (1993) divided this section into three main sequences. Generally, this section consists of late Pleistocene to Holocene stratigraphic succession of a basal sequence I of late Pleistocene fluvial deposits; an overlying sequence II of late Pleistocene to early Holocene shallow marine transgressive sandy deposits; and an upper sequence III of Holocene deltaic of variable lithologies. Of importance of this study is sequence III which acquires the lake facies. This sequence was mostly formed by a change in sea level rather than by regional climate factors. The rate of sea-level rise decelerated markedly from about 7000–5000 BC to ~1 mm/yr. As sea level slowly was elevated and the gradient decreased to 1:5800. During this period, the rate of sediment accumulation matched or exceeded sea-level rise, shoreline position became relatively stable, and formation of the modern Nile Delta began (sequence III), locally included lake facies. With a slow rise of sea level, a series of smaller individualized lakes and marshes were developed in the northern delta, landward of coastal barrier beaches or dune ridges (Ahmed et al. 2000a, b). The other is hypersaline Lake Bardawil, probably have been developed in a process similar to the delta lakes combined with neotectonic land subsidence. The following is a brief description of these lakes (Ahmed et al. 2000a, b).

9.4.1 Lake Mariut

Lake Mariut has a strategic importance at the regional and local level. It plays an important role in the water balance of the Delta western region. Without it and with the direct drainage to the sea, the level of water would continue to rise, which would eventually flood wide areas of land. Also, due to the scarcity of land for new development in Alexandria, Lake Mariut and the surrounding area are now viewed as prime land for urban expansion as well as a significant economic resource for the city. Accordingly, Lake Mariut represents a vital economic resource to the governorate of Alexandria (Fig. 9.2) (World Bank 2005; Ahmed 2003; Ahmed and Elaa 2003).

Fishing is one of the major activities in the Mariut Lake and was characterized in the past by large fish harvest rates with reputed quality. According to available estimated statistics, there are over 2000 fishing boats owned and employed by about 5000 fishermen representing an estimated community of about 25,000 individual. This community relies solely on fishing as the only profession they know and practices for many years. Their adaptability and willingness to explore and engage in new earning venues are very remote. The current total estimated fish catch is about 4000 tons annually and are declining steadily due to the deterioration of water quality and the drying of vast areas for land acquisition (GAFRD 2008).

Around the lake, there is a wide area of reclaimed land which includes various residential, industrial, commercial, recreational, and other settlements activities such as the Mubarak sports city with a projected total area of 500 acres of which 130 have been already utilized, International garden, Mega market Carrefour. A variety of industrial activities also exist around Lake Mariut comprising a host of activities and including oil refining. The discharges of the combined activities, human and industrial, are the main culprit for Lake Mariut‟s current and future vitality (Ahmed

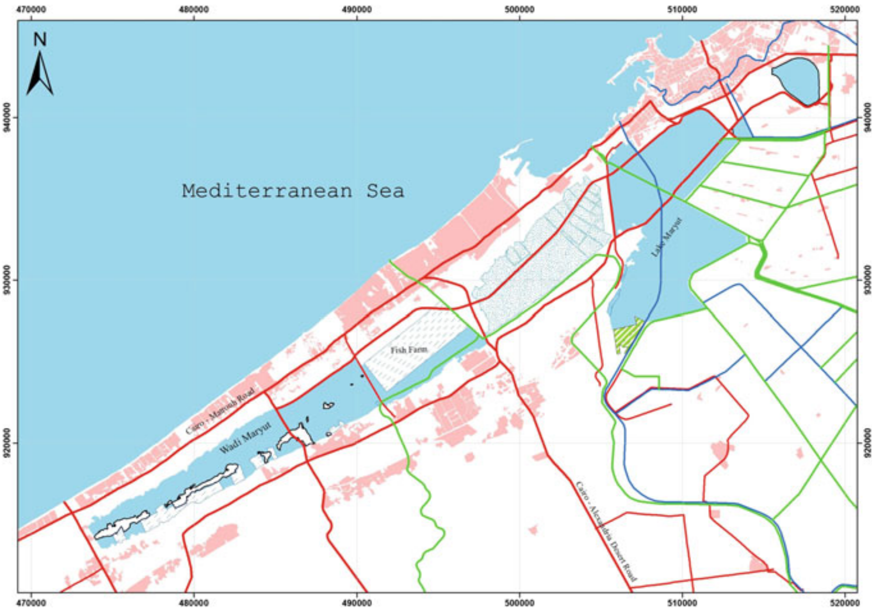

Fig. 9.2 Topographic map of Lake Mariut (Marine sciences department-NARSS)

and El-Leithy 2008). The assessment of the current concerns and challenges facing the sustainable development of Lake Mariut emphasized the following areas:

- Deterioration of water quality
- Continuous shrinkage of lake's area resulting from drying
- Declining fish production and biodiversity leading to deterioration of livelihood of Fishermen society
- The spread of water reeds and vegetation and emission of foul odours
- Negative impacts on public health and the high cost of medical care
- The spread of uncontrolled (squatter) settlements
- The occurrence of illegal, informal, and socially-threatening groups and racketeers.

Despite the many challenges facing the sustainable development of Lake Mariut however, the issues of Lake Mariut were never absent of the minds of officials, active civil society, the general public, and international development organizations. They all share the common interest in the proper development of this vital natural resource and its surroundings important to Alexandria‟s future development and as part of the larger Mediterranean basin environmental sustainability.

9.4.2 Lake Edku

Lake Edku is a coastal lake in the eastern Mediterranean and is located about 40 km east of Alexandria City and 18 km west of Rosetta branch of the Nile River. It is located west of the Nile Delta between longitudes 30° 08′ 30″ and 30° 23′ E and latitudes 31° 10′ and 31° 18′ N (Montaser et al. 2017). The lake is connected to the adjacent Abu Qir Bay through the inlet channel Boughaz El Maadia. The actual surface area of the lake has decreased since 1964 due to the reclamation of a large area from the eastern side for cultivation purposes. Water depths in the lake vary from 10 to 140 cm, the maximum depths being in the central and eastern parts (Fig. 9.3). The lake receives large quantities of drainage water released from the agricultural lands of the Beheirah Province, through the Barzik, Edku and E1-Bosely drains, where the last two drains meet together before entering the lake and discharge their water through the extension of Edku drain. During the period of high discharge, there is an outflow of fresh water from the lake, and during the other period, seawater influx occurs. The marine water influence is limited to the areas near the Boghaz E1 Maadia.

There are two main drains discharge their wastes into the lake; namely El-Khayry drain and Barsik drain. The first drain is joined to three sources of drainage water coming from El-Bosely, Edku and Damanhour subdrains, which transport domestic, agriculture, and industrial wastewaters as well as the drainage water of more than 300 fish farms. The second drain transports mainly agricultural drainage water to the

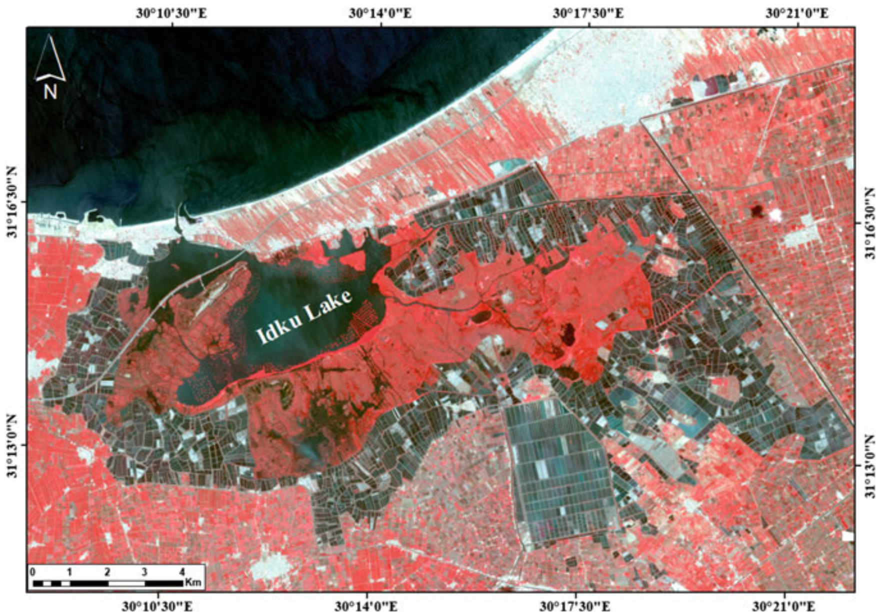

Fig. 9.3 Lake Edku (Marine sciences department-NARSS-LANDSAT8-2018)

lake. This drainage water creates in most time water moves through the lake from both west and south to the north towards the sea (Fig. 9.3).

9.4.3 Lake Burullus

Burullus Lake is the second largest coastal lake in the northern lakes of Egypt and covers an area of about 410 km^2. Its long axis lies parallel to the coastline and separated from the Mediterranean by a sand barrier. The only connection of the lake with the Mediterranean Sea is the Burullus inlet. The lake margin is irregular and bordered by marshes. It is about 54 km long and has a maximum width of 12 km. Water depth ranges from 0.1 to 2.4 m, and salinity from 0.32 to 2.4 g/l (Ahmed et al. 2001; Saad 1976a). The lake receives fresh water from numerous drains along the southern and eastern margins (Fig. 9.4). Burullus Lake receives only agricultural runoff water not contaminated by industrial wastes. The southern margin is bordered by marshes. Lake water is brackish, salinity up to 3.51 g/l (Saad 1990). The lake is divided into several subbasins by natural and artificial barriers. Annual freshwater influx into the lake through drains is about 2.1×10^9 m^3 (Saad 1976b). The input runoff contains mainly agriculture waste and completely free from industrial wastes.

A huge amount of drainage water enters the Lake at the southern coast through several drains, causing dilution of water and rise in the Lake level above sea level. The Lake current towards the sea at certain seasons of the year is weak leading to accumulation of deposits at the Lake–sea connection area. To sustain fish life in the Lake, these deposits have to be removed periodically.

Burullus Lake receives 2.46×10^9 m^3/day of brackish water through drains. Compared with the present total size of the Lake, the residence time of water should be 2.5 months. This contrasts with the measured amount of water leaving the Lake annually, i.e. 446×10^6 m^3/year through Boughaz Al-Burg. This leaves about 2 ×

Fig. 9.4 Lake Burullus (Marine sciences department-NARSS, lANDSAT8, 2018)

10^9 m^3 in excess that has to find another pathway to leave the Lake. Part of this amount is lost through evaporation estimated to be about 0.71×10^9 m^3/y (Maiyza et al. 1991) and possibly the rest through the bottom and consumption by aquatic plants (Fig. 9.4).

Numerous islands characterize Lake Burullus. Most of these islands are elongated from south to north. Others are oriented either parallel or normal to the present coast. These islands consist mostly of mud; however, others are formed of sand (e.g. El Koom El Akhder). These islands are important paleo-geographic indicators of relict deltaic features such as beach ridges, dunes and riverbanks of former distributes (Ahmed et al. 2001).

The bottom sediments in Lake Burullus have a specific textural composition. Shells and shell fragments constitute a significant part of the sediments. Mostly shells, shell fragments, quartz, feldspar, Ostracoda and Foraminifera dominated sand. The fine fraction of the sediments is composed of silt and clay together with fine carbonate particles. Calcium carbonate content of the sediments is less than 30%. In the central and western region of the Lake, the carbonate contents reach higher values (up to 75%) due to the dominance of mollusca. The sediments in the eastern part of the Lake have the lowest carbonate content. The organic matter content of the sediments of Lake Burullus varies between 1 and 2% with an average of 1.8%. The organic matter content becomes higher near the southern eastern and western parts of the Lake (Fig. 9.4).

Several water plants like reeds (Phragmites, Typha, etc.) spreads all over the Lake affecting the movement of water. These plants play an important role to keep the internal coasts of the Lake from immolation. The decrease of the area of Elodea in Lake Brullus indicates the increase of the salinity in the Lake.

9.4.4 Lake Manzala

Manzala Lake is the largest of the northern coastal lakes. It is an important and valuable natural resource area for the fish caught, wildlife, the hydrologic and biologic regime and table salt production. It produces about 50% of the fish catch of the northern lakes and freshwater fisheries (Kriem et al. 2009).

Lake Manzala is not only the biggest one among the Egyptian lakes (area = 0.3 km^2) but also serves five provinces of Nile Delta, Namely Port Said, Ismailia, Sharkiya, Dakahliya and Damietta. It has been recognized as the most productive fishery ground of the country's lakes, since it contributed nearly 50% of the total country yield during early 1970s and about 35% during 1980s (Khalil 1990) (Fig. 9.5).

The lake is the largest brackish water body (~1000 km^2), and is located in the northeastern shoreline of the Nile Delta. The lake is about 50 km long and has a maximum width of 30 km. The lake is shallow (<2 m, with an average depth of ~1.0 m, and salinity varies from 0.77 to 11.67 g/l (Saad 1990). The western and southern sectors are supplied by drainage water from seven main sources. As in Edku and Burullus lakes, emergent and submerging marshes border the southern

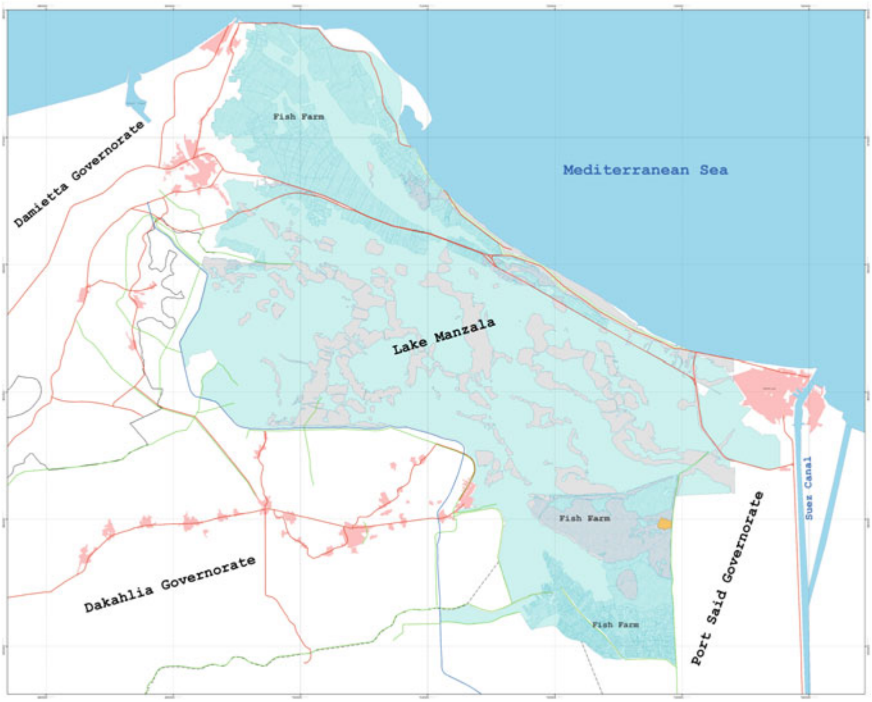

Fig. 9.5 Topographic map of Lake Manzala (Marine sciences department-NARSS)

margin. The sand barrier which separates the lake from the sea suffers from erosion. As a result of this erosion, the coastal road between Damietta and Port Said had been replaced by a new road farther inland connecting the lake islands. Manzala Lake supplies about 50% of the total Egyptian fish catch. El Gamil inlet is the only inlet for release of marine water inflow into the lake. Two jetties were constructed to protect this inlet from siltation and longshore migration (Donia and Ahmed 2006) (Fig. 9.5).

It is divided into sub-basins by natural and artificial barriers. These sub-basins are the sites of aquaculture development. The Ginka sub-basin in the southeast sector of the lake is identified as "black spot". This subbasin is heavily polluted by heavy metals and high nutrient discharging from Bar El Baqar drain (Global Environmental Facility 1992). This subbasin receives a discharge of municipal sewage, industrial effluent, and agricultural runoff. High concentrations for metal pollutants are recorded in the upper 20 cm of the Ginka subbasin, probably from industrial sources. High values for Hg (822 ppb), Pb (110 ppm), Zn (635 ppm), Cu (325 ppm) were recorded in bottom sediments of Ginka subbasin (Siegel et al. 1994; El-Kafrawy et al. 2006).

9.4.5 Lake Bardawil

Bardawil Lake is situated along the northern coast of Sinai, from a point about 45 km east of Port Said and extending to a point 20 km west of El-Arish. Its geographical boundaries extend from 32° 40′ to 33° 30′ east longitude and from 31° 03′ to 31° 14 north latitude. Lake Bardawil is mainly a flat low lying plain, bordered from the north by Sinai Mediterranean coast, from the south by a sand dune belt which extends inland to the region of fold and anticlinal hills, from the west by the Tineh Sabkha flat constituting eastern margin of the Nile Delta plain and from the east by Arish-Rafah sector. Its elliptical shape represents a major morphological feature in north Sinai coast (Fig. 9.6). This lake has an area of about 164,000 feddan (685 km^2), extends for a distance of about 80 km, with a maximum width of about 20 km and a maximum depth of about 3 m. It is separated from the Mediterranean by a long convex sand bar; the main water body of the lake lies towards the east occupying a section along the coast of about 30 km long ending with Zaranik Pond in the east (has an area of about 243.68 km^2), of which Zaranik Pond occupies about 42.02 km^2. The latter is now exploited for salt production (it is locally called Malahat Sebikah). The western part of the lake extends as a long narrow arm of about 50 km length (it has an area of about 445.36 km^2).

Historically, Bardawil Lake (also called Sabkhat El Bardawil or the Sirbonian Lake) is named after King Baldwin I, who took part in the Crusades and according to tradition was killed at El-Arish (Ben-Tuvia 1979). During the Roman period, the lake was called Port Sirbon. Many historians and archaeologists speculate that the Exodus of the tribes of Israel from Egypt passed through this area and the biblical

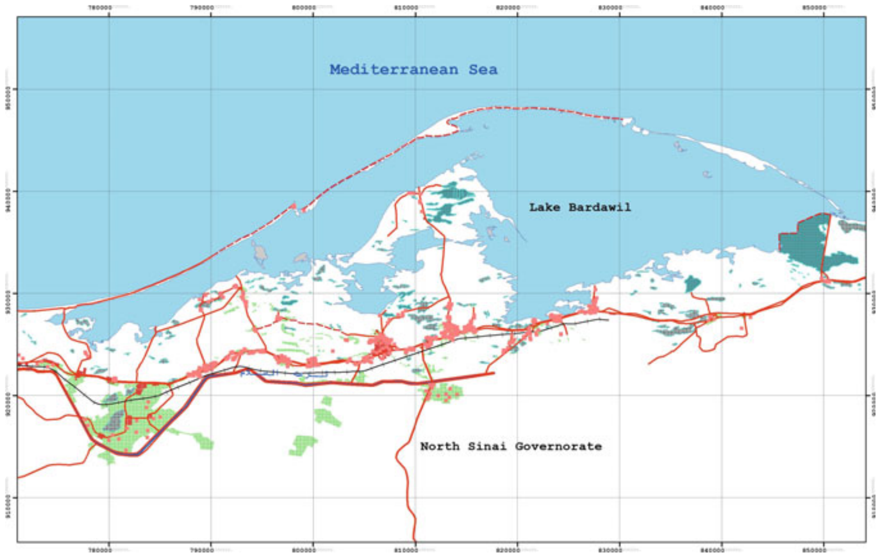

Fig. 9.6 Lake Bardawil (Marine sciences department-NARSS)

«Red Sea» or «Sea of Reeds» is the Bardawil Lake. Some recent excavations on the wide part of the sandy bar (Kals or Mount Cassius) have been reported and found evidence of settlements from the period of the Early Iron Age and a town, evidently Cassius, from the Hellenistic-Roman Period (El-Malky et al. 2003).

Seawater enters the lake at present through three inlets: two artificial tidal inlets (270 and 300 m wide and 4–7 m deep), they are maintained open by periodic dredging, and a natural eastern inlet of Zaranik which is now occasionally closed by silting (Fig. 9.6). Fish production of Bardawil Lake depends on the water exchange between the lake and sea, which regulates lake salinity. Joined to Bardawil Lake, are a number of bays (e.g. El-Telul and Misfiq) and a few restricted shallow water ponds (e.g. El-Rowaq and El-Marqab to the south) in which water depth is only a few centimetres. In the southern areas of the lake, extensive salt pans-sabkha complex occur mostly interrupted by a series of sand dunes (ridges) running mostly parallel to the coast and extending southwards. Thus sabkha of Bardawil may be coastal flat sabkha fringing the lake particularly at the extreme eastern margins or dunal sabkha south the lake (Shaheen 1998).

The bar separating the lake from the sea is arc-shaped, 300–1000 m wide. Its highest point is El-Kals (Mount Cassius), a 60 m high dune located about midway. The western part of the bar is an extension of a dune-covered higher ground which starts at Qantara on the Suez Canal. This ridge is part of the Pelusium Line, a compressional zone dividing the thin Mediterranean crust on the east from the oceanic-type crust on the west. However, there is little evidence that the lake was the estuary of the Pelusiac branch of the Nile. Pelusiac branch debouched at a site situated to the west of the above mentioned ridge (Neev and Friedman 1978), but undoubtedly the Nile supplied the quantities of sand that formed of the bar separating the depression from the sea.

The existence of Lake Bardawil depends upon its connective with the Mediterranean Sea. The low sand bar which separates the lake from sea is often covered by sea water. Lake El-Zaranik is joined to the sea by a narrow inlet; thus its water is constantly being replenished. In 1955, two inlets (i.e. Boughaze) were dug to connect the lake with the Mediterranean, one at the western end and the other at the eastern end of the lake. Each canal is one kilometer long and 150 m wide. Lake Bardawil is the most saline of the northern Egyptian lakes, for it is connected only with the sea. Salinity increases with distance from the inlet canals.

Bardawil Lake is characterized by approximately 51 islets, some of which are elongated, oriented subparallel or normal to the present coast and of few kilometers in diameter. They comprise a total area of about 13.31 km^2 which approximates 1.9% of the lake area. These small islands include El-Mahasnah in the north eastern part of the Bardawil Lake, El-Watawite in the north central part, El-Gouz El-Ashhab in the south and El-Romaia in the western arm of the lake. These islands are mostly made of muddy sand, covered by vegetation. A mud surface layer with dense vegetation occurs in El-Mahasnah Island. El-Romaia Island is about 2 m above sea level and covered with sand sheet and scattered vegetation (Fig. 9.6).

The productivity (kg/km^2) of Bardawil Lake ranged between 9.7 kg/km^2 in 1994, 24.38 kg/km^2 in 1999 and 21.4 kg/km^2 in 2006. It is clear that the productivity per feddan fluctuated over the years, based on the change in gross production of fish and the water area of the lake. Fishing gained significance for the Lake Bardawil. Although it is considered to be one of the best quality fishing areas in Egypt, its production was accounting to about 3534 tons and 0.7% of the national fish production in 2005.

9.5 Problems of Identification

There are some ecological problems invaded and impacted the northern lakes ecosystem due to the continuing and increasing water discharge, either domestic, agricultural or industrial. These problems are eutrophication, excessive growth of aquatic vegetation and the heavy metal pollution, reclamation, illegal fishing, etc.

9.5.1 Eutrophication

The increase of agricultural and domestic discharge into the lakes leads to increase of external nutrient load into the water body and finally eutrophication. This, in turn, changes the characteristics of the aquatic ecosystem. Ahmed et al. (2006) investigated the phytoplankton in the lake and reported that it is considered to be eutrophic as the levels of nutrient are significantly high. Accordingly, this lowered the diversity of phytoplankton population and affected the species composition that was dominated by species considered as indicator for water pollution such as *Euglina* spp. and *Phacus* spp. Ramdani et al. (2001) studied the seasonal chemical composition of Lake Edku water and reported that the lake receives high amounts of nutrient salts (nitrogen salts, phosphates and silicates) through the drainage water and became eutrophic (Ahmed et al. 2006).

9.5.2 Aquatic Vegetations

Aquatic vegetations represent all types of plants that grow in the aquatic ecosystems either rooted, floating or submerged. The undesired growth of aquatic vegetations takes place due to the increased nutrients, which stimulate and support plant growth. Samaan (1974) and Guerguess (1979) studied the primary production and hydrophytes of Lake Edku and found an inverse relationship between increased densities of the macrophytes and standing crops of epiphytes phytoplankton (El Nahry et al. 2006).

Table 9.1 Detection of size change of Lake Burullus during last 30 years using satellite images

Lake name	Year	Size (km^2)	Difference 1984–1997 (km^2)	Difference 1997–2000 (km^2)	Difference 2000–2003 (km^2)	Difference 2003–2006 (km^2)	Difference 2006–2008 (km^2)
Lake Burullus	1984	701.7	52.2	7.1	177.7	5.0	3.8
	1997	649.5					
	2000	642.4					
	2003	464.7					
	2006	459.7					
	2008	456.9					

9.5.3 *Pollution*

The delta lakes are influenced by fresh water runoff from the land via drains and canals. This water enriched the lakes with nutrients including phosphate, nitrate and silicate. Also, some of these drains discharging considerable amounts of sewage and industrial wastes directly into the lakes (Saad 1990; Mitwally 1982; Siegel et al. 1994). The high concentrations of phosphorus, nitrogen in the organic waste, pesticides as well as heavy metals in water and sediments have altered the ecosystem of these lakes. The lake areas adjacent to these drains have been deteriorated and subsequently eutrophicated (Ahmed and Elaa 2003).

Human activities were found to be the main source of ecosystem pollution such as untreated water discharge and sewage. Lake Edku received large amount of domestic sewage, agricultural and industrial effluents; hence, it is highly polluted with humic substances and dissolved organic carbon (DOC) (El-Sayed 1993; Aboul-Ezz and Soliman 2000). Nafea (2005) reported that high concentrations of heavy metals were detected in macrophytes of Lake Edku. Some other studies were carried out on the metal concentration of Lake Edku such as those of Abdel-Moati and El-Sammak (1997), Adham et al. (1999), Appleby et al. (2001).

Coastal lakes are generally a region of high biophysical and human activities. Given the socio- economic importance of the Mediterranean coastal zone of Egypt, diverse activities have increased pressure on the uses of the contiguous lakes. These activates include fishing, aquaculture (fish farm), dumping liquid and solid wastes, land reclamation, urbanization, and recreational uses. Common activities and their magnitudes in each of the study lakes are listed in Table 9.1 and discussed here after.

9.5.4 *Fisheries and Aquaculture*

Fish landing in Egypt (including aquaculture) reached 407,000 tons in 1995 (GAFRD 2008). Lakes fishing accounts for 33% of the Egyptian fish catch (33,000 tons) Manzala and Burullus lakes producing 119,000 tons (59,500 tons each) versus 27%

from fresh water resources, namely Lake Nasser produced 109,000 tons while the production of Mediterranean and Red seas reached 91,000 tons (22%). Fishing fleet consists of 46,269 ships and boats, 2897 of them were engine vessels, the rest were manual boats. Fishing activities sustain a large number of people: 35,000–40,000 fishermen in Manzala and about 47,000 in Burullus (Sestini 1992). Common fish species are tilapias, catfish (fresh water), mullets, seabream, seabass, grouper, pagrus, sardines (sea water). At Bardawil Lake the fish caught are mainly migratory; the main species are Sparus aurata, Dicentrarchus labrax and Mugil cephalus (Meininger and Atta 1994; Zakaria et al. 2007).

Aquaculture is concentrated around the southern margin of Edku and Manzala lakes and Mariut Valley. Aquaculture production accounted for about 15% (62,000 tons) of total fish production in 1995. Tilapia represents about 38% (129,000 tons) of total fish production in 1994 (CAPMS 1994). In the meantime, illegal harvesting of fish fry in Burullus and Manzala lakes will disturb the fish habitat and reduce the natural fish stocks. Moreover, over fishing in Burullus and Manzala lakes have an adverse effect on both fish and larval stocks (Ramadan and Ibrahim 1995).

The total areas of Northern lakes have recently been decreased from 2222.60 to 1936.90 km^2. This is due to land reclamation. The reclaimed lands are used mainly for aquaculture and urban activities. Euryhaline fish fry used for aquaculture especially Mullet, sea bream, sea bass and eel are collected from collection centers scattered along the discharge canals (lakes inlets) connected to the Mediterranean Sea. However, fresh water fish fry especially tilapia and carp are produced artificially.

9.5.5 Lakes Inlets

Lake inlets are capable of changing their cross-sectional dimensions (depth/width) quickly, migrating rapidly along the shore, and even closing completely (Leatherman 1991). In Egypt, siltation problems of the lake inlets generally taken place as a result of the combination of sand transport in the longshore and cross-shore directions characterize most of the coastal lakes (Fanos et al. 1993). Siltation causes shoaling or closing the lake inlets resulting in navigation hazards, decreasing water flow in and out in the inlet channel, as well as negative implications on fishing activities. Keeping the inlet open is important for the fishery to keep the salinity down and to allow migratory movements. The sand barriers of study lakes (Burullus, Manzala, Bardawil lakes) are being subjected to severe beach erosion. This erosion is mainly due to the effect of prevailing dynamic processes of waves and currents, and the absence of the sediment supply resulted from the construction of the High Aswan Dam in 1964. This problem causes shoreline retreat of the lake barrier and hence reducing its function as nature protective line from sea invasion (Fanos et al. 1993).

9.5.6 Reclamation

Large parts of the delta lakes have dried up due to land reclamation. Reclamation activities are due to gain new land for cultivation, aquaculture and also for building illegal houses. These activities have increased the pollution of the delta lakes. In this study, published data obtained from different sources are used to estimate the average rate of lake areas dried. These results show that some of the delta lakes have been intensively reclaimed being at present less than 50% of their former size. Among the Delta lakes, Manzala has been reclaimed rapidly at an average rate of 6.12 km^2/year. The others Edku and Burullus are being reclaimed at a lower rates being 3.42 and 1.99 km^2/year, respectively.

9.5.7 Sea-Lake Interactions

Low-lying littoral deltaic regions are highly vulnerable to even minor changes in sea level, particularly because most deltas are actively subsiding. Moreover, predicted global warming might accelerate sea-level rise, which would have a pronounced impact on low-lying deltas all over the world. In particular, the Egyptian Nile delta coast is expected to be severely affected by sea-level rise (El Fishawi and Fanos 1989; Frihy 1992). Sea level rise could have a serious impact on the lake ecosystem and the fertile land that has been reclaimed from the lakes. Sea-level rise might affect the ecosystem of the coastal lakes by eroding the lake barriers that protect the lakes from the sea and hence altering the water quality of the lake.

9.5.8 Man-Made Interference

Coastal lakes have been recently planned to attract investors to implement large-scale developing projects. Presently, a large-scale project has been implemented to modify coastal lakes to be used development area through construction of artificial inlets associated with long jetties, to connect the large lake with the Mediterranean Sea. These protruded jetties have created local erosion along adjacent beaches on the down drift side. Also, a large urban expansion was built around the lakes. These are presently undergoing extensive investment development. Experiencing, at the time being-potential problems resulting from increasing human pressure and man-made interventions. Bad management of the remarkable white calcareous sand beach has created some serious erosion environmental problems. As a consequence, rapid and uncontrolled development has created many human infringements on the coastal zone and subsequently impact on the coastal development projects (Rasmussen et al. 2006). This impact has changed the shoreline stability and expected to alter the water quality of the sea. Studies have shown that, in addition to the natural phenomena, man has affected physiographic and ecological transformations of the northern lake of Egypt. Anthropogenic alterations include pollution, land reclamation, agriculture, aquaculture, irrigation and industrial projects. Coastal lakes are undergoing very rapid change as a result of increased human activities resulting in pollution problem. Industrial, sewage and agriculture wastes are dumped into the Nile drain system which discharges locally into delta lakes (Mariut and Manzala) (Ahmed et al. 2009). The degree of pollution of these lakes varies from high in the eastern part of Mariut and in the southern, eastern part of Manzala lakes to very minor in the Burullus Lake. In view of increasing pressure in the coastal zone, a great amount of pesticides, insecticides, fertilizer are used for agricultural fields around the delta lakes. Pollutants are washed out from these fields to the canals and drains and then directly to the lakes. These runoff has been badly affected the water quality of the lakes.

9.6 Information Technology Challenge

Remote sensing of the environment is one of the subfields that has materialized in the past three decades as a foundational element in Egyptian lakes monitoring and in informing investigations into global environmental change and environmental resource management.

The use of remote sensing in Northern lakes studies in Egypt is not recent. Despite the commendable progress made in the field of using remote sensing in northern lakes, the adoption of a "scientific" view in the analysis of remote sensing images is quite limited. Little work has been carried out on automated estimation and mapping of lake variables, quantitative modeling and analysis of uncertainties and errors associated with estimated variables, or utilized remotely sensed measures in physical dynamic models of environmental phenomena. Several factors contributing to this limitation are documented below. It should be noted however that these factors are not exclusive to the Egyptian remote sensing community.

The first factor concerns the current-state-of-art in remote sensing analysis. Most remote sensing scholars in Egypt, still rely on tools that mix a variety of qualitative techniques of visual image interpretation with traditional computerized classification methods developed in the formative years of remote sensing when the quality and options of satellite imagery were limited. There are obvious restrictions to this mode of remote sensing practice that make it inefficient for environmental applications (Gong 2006). The most obvious is a great deal of human subjectivity that renders the results inconsistent and incomparable across spatial and temporal scales, and the inability of such techniques to handle large volumes of data or to produce useful inputs for quantitative models and/or simulations.

The second limiting factor relates to the nature of landscapes in which human/lakes interaction take place. Egyptian northern lakes are diverse and composed of a mosaic of many anthropogenic and natural surface materials interwoven with one another in irregular patch sizes and arrangements, and in varying densities that do not fit the idealized representation of image pixels (Fisher 1997; Forster 1985). Experiments have shown that even a 1-m spatial resolution image is likely to include mixed pixels that may produce misclassification errors due to the spectral "noise" from small features that become noticeable at this fine scale (Aplin 2003; Mesev 2003). Various methods of fuzzy classification (Foody 1999; Zhang 2001) and spectral mixture analysis (Phinn 1998; Rogan and Chen 2004; Ward et al. 2000) have been used to perform the sub-pixel mapping. However, studies have documented considerable degrees of uncertainty in the final results (Herold and Roberts 2006; Rashed et al. 2003; Small 2001a).

A third factor complicating quantitative remote sensing and the automatic identification of earth surface features relates to design tradeoffs between the spectral and spatial resolutions of a satellite sensor due to the cost/power/transmission considerations of data acquisition (Aplin 2003; Price 2001). Higher spatial resolution satellite sensors generally have a coarse spectral resolution (broad bandwidths) chosen to provide an optimal contrast between generalized land cover classes (e.g., urban versus vegetated) (Jensen and Cowen 1999). This imposes a considerable limitation on the extraction of features. Although experiments have shown that the majority of Built Surface Materials (BSM) are in fact spectrally separable (Chen and Hepner 2001; Herold and Roberts 2005, 2010; Small 2001b), the majority of operational satellite sensors are "blind" to the spectral regions at which BSM can be differentiated from one another, simply because they were not designed to detect subtle spectral differences in BSM reflectance.

A fourth factor limiting the wider application of quantitative remote sensing analysis in Egypt stems from the general lack of knowledge about the spectral properties of environmental materials. The near future project at National Authority of Remote Sensing and Space Sciences (NARSS) carried out to develop an understanding of the spectral response patterns of native materials in Egypt, i.e. Northern Egyptian Lakes. Contributing to this lack of knowledge is the limited availability of trained personnel as well as the sensors that can be used to provide a quantitative and qualitative characterization of environmental features for lake ecosystem. This situation has changed recently with the launch of the Earth Observing-1 (EO-1) satellite, carrying an onboard hyperspectral instrument, Hyperion, thus opening new horizons in the automated identification and mapping of feature spectra on a global basis.

This and other recent improvements, such as a large number of available and better-calibrated sensors and their higher measurement precision, has made room for the extensive use of quantitative algorithms for measuring and estimating biophysical variables from remotely sensed images, radiative modeling of the atmosphere, etc., and state-of-the-art techniques for sensor calibration and modeling. The potential of these developments will not be fully realized in Egypt, however, without developing a priori knowledge about the spectral response patterns of earth surface materials and improving upon quantitative techniques for utilizing such spectral measurements in image analysis.

It is in this capacity that remote sensing can be effectively used to generate information for use in the assessment, management, and monitoring of environmental risks in Egyptian northern lakes and to remedy environmental problems at various scales.

9.6.1 Lake Satellite Specifications

Five types of satellite data products are used in northern lakes studies: QuickBird, Aster, Landsat, Hyperion, and EgyptSat1. These sets of images acquired for every site. Aside from Landsat data, and their full potential, in terms of the automated mapping of lakes parameters or their utility for quantitative models of the lake environment, has not been assessed yet.

The first sensor, QuickBird, has a limited spectral range but produces the type of data typically welcomed in the remote sensing community due to its fine spatial resolution. The second, ASTER sensor, has a medium spatial resolution comparable to Landsat but its spectral range is considerably extended regarding shortwave infrared radiation. ASTER's spectral library has been limited to a generalized list of environmental materials, the majority of which are vegetative materials.

The third sensor, Hyperion, has a spatial resolution that is slightly coarser than ASTER (30 m) but provides 220 unique spectral bands with a 10-nm bandwidth. Recent studies have reported difficulties in applying spaceborne hyperspectral data, especially to lakes ecosystem, and highlighted the need for more investigation (Rogan and Chen 2004). To date, the literature provides little information about the utility of Hyperion data in automatic mapping and reliable quantitative estimation of environmental features (Ahmed et al. 2009).

Finally, EgyptSat1 is Egypt's first remote sensing that was successfully launched earlier this year (jointly built by NARSS and Yuzhnoye Design Bureau in Ukraine). The sensor produces "SPOT-like" data with a 50 day revisit cycle in the visible (Green and Red bands) and near infra-red with 7.8 m spatial resolution. A fourth band is produced in the mid-infrared but at a coarser spatial resolution (~40 m). EgyptSat1 is the first of a series of satellite sensors NARSS has planned to build before 2015. In this study, lakes ecosystems were monitored and examined the utility of EgyptSat1 in quantitative remote sensing analyses and provide spectral measurements for sensor calibrating, mentoring of sensor performance, and informing the design and implementation of the future sensors in Egypt. In addition to remote sensing data used in this study, several geospatial ancillary data layers (e.g., DEM, land use map, urban streets, geological maps, housing census, native vegetation species, crop yields, population) are used in the applied lakes studies and in guiding the fieldwork and sampling, and validating the results.

9.6.2 Spectral Analyses

This is the most critical and vital task in remote sensing studies. Field spectroscopy is a technique used to study the spectral response of features on the lakes components based on their emitted or reflected energy. Field spectrometry is produced using portable spectroradiometer (or spectrometers) to collect quantitative measurements of radiance, irradiance, reflectance and transmission of ground targets in the field. The quality of collected spectra depends on a variety of factors including the suitability of the field spectroradiometer for the materials of interest (e.g., spectral range, signal-to-noise ratio), the time of year/day for collecting spectra, spatial scale of the field measurement, target viewing, and illumination geometry (Goetz 1992; Rollin et al. 1997).

Using this spectroradiometer ensure that the spectra acquisition follow pre-defined standards that will be applied uniformly across all study lakes to ensure sufficient quality and comparability of the images Processing results. This spectrometer instrument represents state of the art in the technology with a fine spectral resolution of 3 nm possible spectral sampling interval and 10 spectra per second. Its light weight and ability to stay operational under severe weather condition will help ensure repeatability of results and thus better discrimination and analysis of spectra.

In addition to relying on the stratified spatial sampling procedures for spectra acquisition, imaging spectrometry data compiled in other contexts (such as those developed by ASTER images) will be examined to guide and complement the field surveys for some lakes and the help scaling between in-situ and satellite observations. All spectra and metadata are described and stored in a standard spectral database format.

9.7 Methodology

9.7.1 Image Processing (IP)

Image processing is a branch of computer graphics based on image data, which are pieces that make up a picture. In essence, image processing is a special form of two-dimensional (and sometimes three-dimensional) signal processing. Image processing is a powerful technique for uncovering information. The principle idea behind image processing is to make an image more informative. Computer system treats images as arrays or series of elements. The size of elements in an array determines the resolution of the image, and the number of bits available to any element of the array determines the number of colors that each element can have.

Images occur in various forms. Some visible and others not, some abstract and other physical, some suitable for computer analysis and others not, It is thus important to have an awareness of different types of images. A lake of this awareness can lead to considerable confusion, particularly when people are communicating ideas about images when they have different concepts of what an image is. An image is: “a representation, likeness, or imitation of an object or thing, a vivid or graphic description, something introduced to represent something else”. A picture is a restricted type of image, it may be defined as “a representation made by painting, drawing or photography, a vivid or graphics, accurate description of an object or thing to suggest a mental image or give all an accurate of the thing itself”. For our purposes, we take the word picture to mean a distribution of matter that is visible when properly illuminated. So the word picture is sometimes used as an equivalent to the word image.

Now digital image processing is subjecting a numerical representation of an object to a series of operations to obtain the desired result. Digital image processing starts with one image and produces a modified version of that image; it is, therefore, a process that takes an image into an image. Digital image analysis is taken to mean a process that takes a digital image into something other than digital images, such as a set of measurement data or a decision. The following are the steps used in the analysis of the satellite image.

9.7.2 Geo-referencing

It is the process of assigning map coordinates to image data. The image data may already be projected onto the desired plane, but not yet referenced to a proper coordinate system. Rectification involves geo-referencing as all map projection is associated with map coordinates. Image-to-image registration involves georeferencing only if the reference image is already georeferenced. Georeferencing, by itself, involves changing only the map coordinate information in the image file, the grid of the image does not change. Geocoded data are images that have been rectified to a particular map projection and pixel size, and usually have radiometric correction applied.

9.7.3 Image Registration (Rectification)

The problem with using imagery from different dates, or from different sensors, is that, in order to be useful and to be able to compare separate images pixel by pixel, the pixel grid of each image must conform to the other images in the database, they have to be registered to a common coordinate system. This coordinate system can be one of the images or can be a map projection. The selection of appropriate map projection and the coordinate system is based upon the primary use of the data.

Any conversion to another coordinate system not only implies a loss in radiometric accuracy through resampling but is extremely time-consuming and error prone. Usually, it is done through the manual identification of ground control points “GCPs” of the same object in both coordinate systems. Control point identification is difficult, the difficulty increase with decreasing spatial resolution, and it is time-consuming, as it requires a matrix of a sufficient number of suitably spaced control points.

A transformation matrix is computed from the GCPs; the matrix consists of coefficients that are used in the polynomial equation to convert the coordinates. The size of the matrix depends on the order of transformation; linear transformation or first order transformation is used to drive the polynomial equations with the least error to be used to transform the reference coordinate of the GCPs to the UTM coordinates. Control points, which have large errors concerning the polynomial, are described, and a new fit is carried out. This procedure is repeated until an acceptable error is reached. After the polynomial is defined, it is used to transform the image into the desired coordinate system. To reduce the time taken, remove subjective human intervention, while achieving the highest accuracies, an automatic procedure has been developed. This procedure is to automatically register the imagery to a sub-pixel level of accuracy. It is assumed that gross distortions, rotations, and scale changes will not be encountered. The registration is carried out on the shapes of significant objects in the imagery.

9.7.4 Image Resampling

After completing the registration process, create the output file. Since the grid of pixels in the source image rarely matches the grid for the reference image, the pixels are resampled so that new data file values for the output file can be calculated (Fig. 9.7). The nearest neighbor is one method of resampling which uses the value of the closest pixel to assign the output pixel value. This method is the easiest one of all resampling methods, and it has a great advantage as it transfers original data values without averaging them as the other methods do; therefore, the extremes of the data values are not lost.

9.7.5 Image Mosaicking

After rectification and resampling of the desired images, mosaicking of every two images to obtain the area under study took place. Now the images multi-used are ready for the purpose applications.

9.7.6 Image Classifications

The classification process is described as the identification of the pattern associated with each pixel position in an image regarding characteristics of the objects or materials at the corresponding point on the Earth's surface (Mather 1978). The large area covered, the range of cover types and the paucity of ground data of TM series required the use of the classification method based on an interactive ISODATA (iterative self-organizing data algorithm) approach (ERDAS 2000). The ISODATA algorithm attempts to cluster the spectral (feature) space into a number of groups specified by the user. From an examination of the image data along with available ancillary data, both spectral and spatial, were separated initially. Statistics from the clustering were then used as input to the maximum likelihood classifier. With this classifier, it is assumed that the statistics of each class in each band are normally

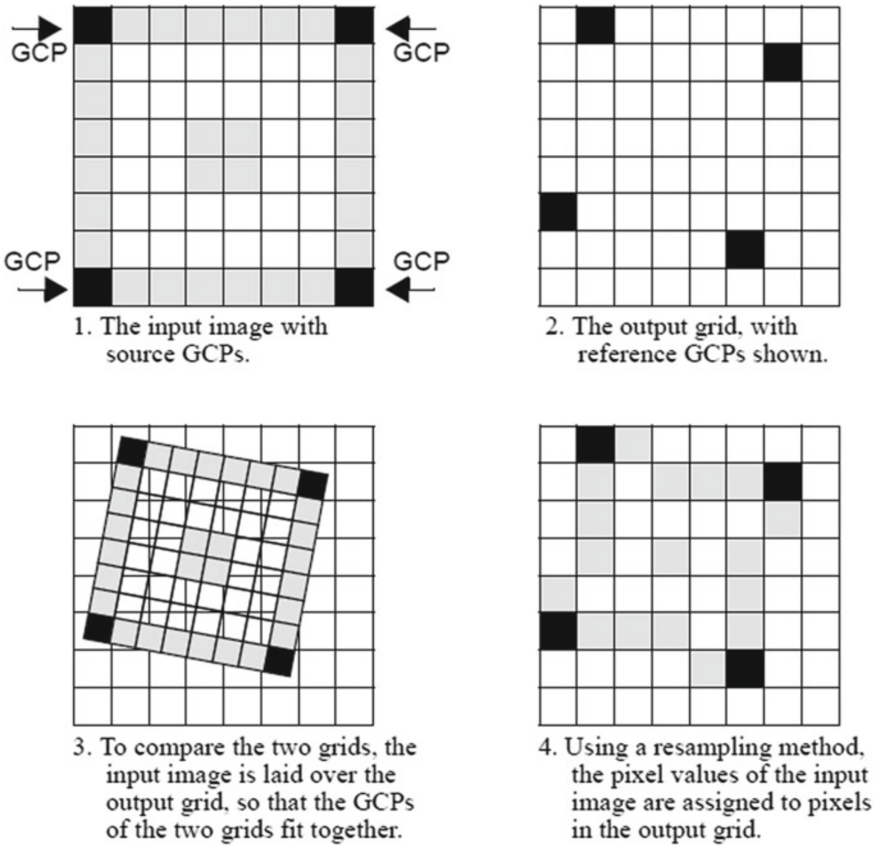

Fig. 9.7 Resampling methods

distributed, and that given pixel belongs to the class in which it has the highest probability (based on this distribution) of occurring. The results from the classification were interpreted with supporting data from topographic maps, aerial photography, local knowledge and the spectral and temporal properties of the classes themselves. Ten Classes were identified covering the lake and neighboring areas, which were too big or covered many types were further divided by clustering and reinterpreted.

9.8 Utilization of Remote Sensing in Monitoring the Egyptian Northern Lakes

9.8.1 Lake Mariut

Monitoring the change in the border area and docks in Lake Mariut basins using satellite images in different dates covering past three decade and assess the impact of natural variability and man-interfered with the lake ecosystem. Lake Mariut are composed of four important basins, these basins are; Fishery Basin, Main basin (six thousand acres), the northwest basin of the lake and the south-western borders of the basin of the lake.

MSS, Landsat-TM, Spot, and EgyptSat-1satellite images are used in different years (1972, 1985, 1999, 2007), these images analyzed to identify possible changes in Lake Mariut basins. Using multi dates satellite and GIS techniques, to monitor land uses/human activities in Lake Mariut, to assess environmental factors caused such changes, define most probable causes for the Lake's resources quality deterioration and explore possible means of mitigation of side effects or rehabilitation of destroyed ecosystems. The results indicated that the area of the Lake Mariut was exposed to multiple stages of drying to create economic development activities. The impact of sewage disposal on parts of the Lake basin was quite obvious too (Fig. 9.8).

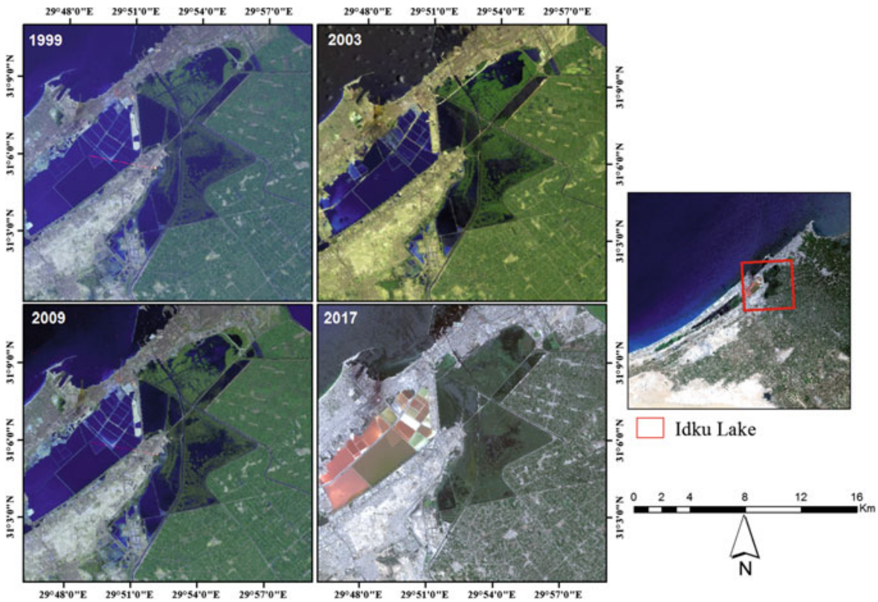

Fig. 9.8 Size change measurements from satellite images of Lake Mariut (Marine sciences department-NARSS)

The use of multidates satellite images of different sensors make the identification of historical changes of Lake Mariut available. This technology makes the quantitative and qualitative assessment for the Egyptian lakes is important to manage and take the correct decision. The monitoring and protecting of lakes ecosystems are considered as a priority for assessment and sustainability of Egyptian lakes.

The study environmental situation of Lake Mariut since Lake Mariut suffered during the past forty years to various types of pollution, whether the exchange polluter and ill-treatment resulted in the end to the pollution and the deterioration of their situation.

Most suffered from the pollution of the lake is dumping huge quantities and persistent remnants of industry, agricultural waste, sewage, and large areas were drying them randomly decreasing area from 248 to 61,414 km^2) (Figs. 9.9 and 9.10).

Monitoring the environmental situation of Lake Mariut indicated that the lake is complaining various types of pollution and anthropogenic inputs to the lake body; however, it is necessary to understand the potential actions lead to reduce negatively the change of environmental development of the lake using information technology. The use of such advanced techniques are useful in the identification of evolution incident lake area with large scale and lead to the availability of much information on the lake historical evolution since long periods up to now. Monitoring and assessment these changes in Lake Mariut basins using multidates images assist the decision makers to estimate the causes and rate of change, drying in the lake basins; to propose the solutions of identified problems, i.e. dynamic changes of vegetation covering percentage in the lake basins.

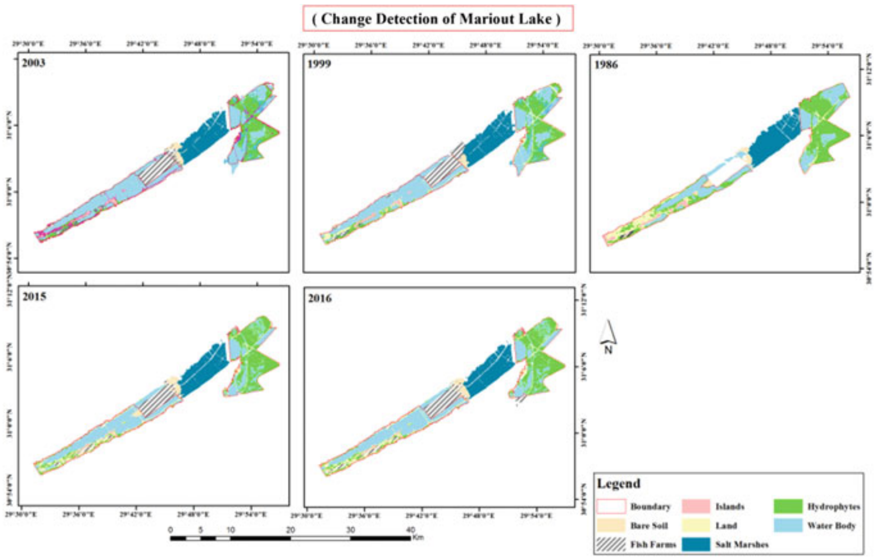

Fig. 9.9 Change detection of Mariut Lake

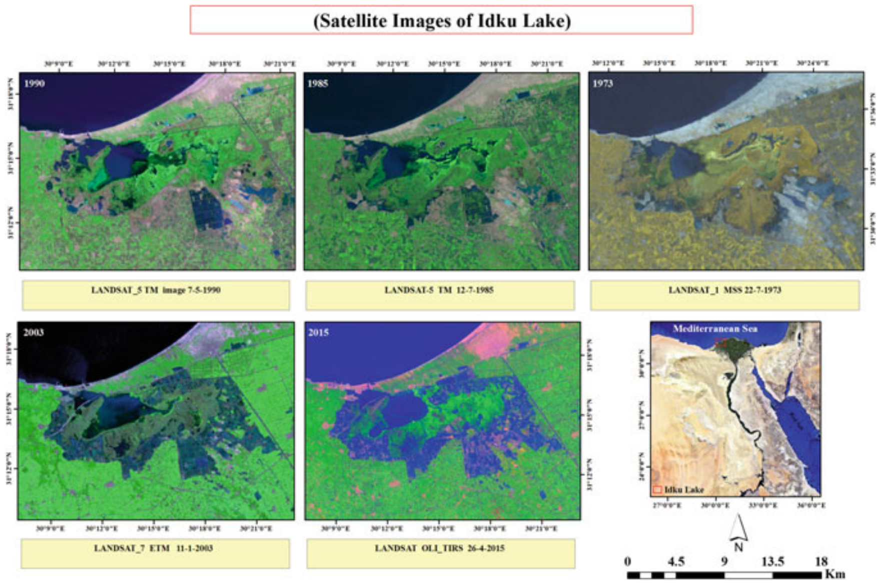

Fig. 9.10 Satellite images of Lake Edku (Marine sciences department-NARSS)

9.8.2 Lake Edku

This lake was considered as a marine lake after closing its connection to the Nile; where the water of the Mediterranean Sea passes in it through Boughaz El-Maadia therefore, it was a marine environment containing marine fish until 1920. Boughaz El-Maadia is a short, shallow channel, 300 m in length and 2.5–6 m in depth, connecting between the sea embayment, Abu Qir Bay; and the brackish lake, Lake Edku. After the formation of the irrigation and drainage system, the lake was receiving the drained water from about 1214.05 km^2. As the lake is higher than the sea level about 16 cm, this facilitates the passage of its water to the sea. Thus, it became a freshwater body. The seawater enters the lake only during the high tide.

In general, the water in the lake Edku could be considered as eutrophic waters during the four seasons of the year as mentioned in Siam and Ghobrial (1999) following the trophic state index is given by Carlson (1977). The agricultural discharge represents about 90% while the seawater is about 10% of the lake water so that the salinity of the water may reach 2 g/l. Some factories discharge their sewage into the Mediterranean Sea, which in turn pass to the lake with the seawater during the high tide through the lake-sea connection.

There are large quantities of the floating, aerial and submerged plants or hydrophytes covering about 50% of the lake surface area. These macrophytes are considered as an important component of the food cycle in the aquatic habitats. Also, this vegetation resists the movement of the fishing boats causes many problems for the fishermen and decreasing the surface area of the lake. The fish production of Lake

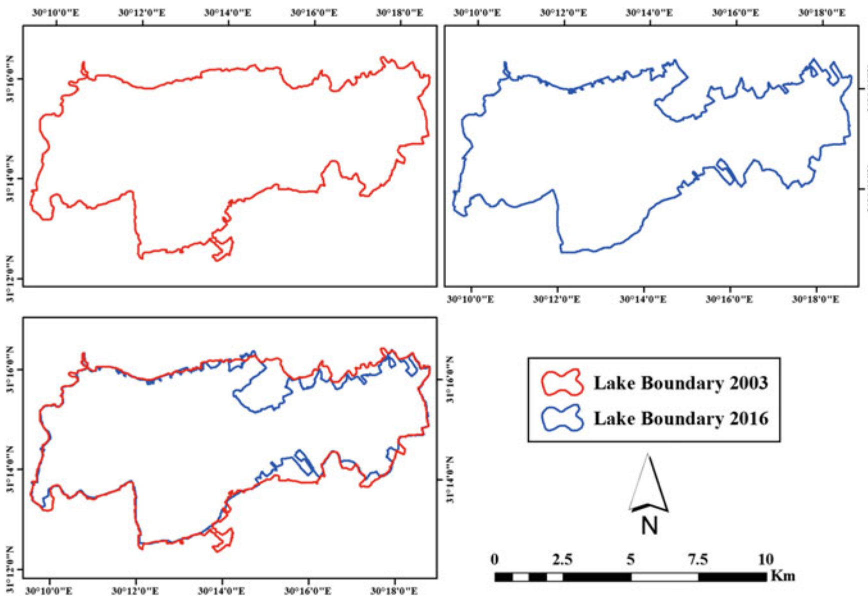

Fig. 9.11 Lake Edku area changes between 2003 and 2016. Explain better what is shown on every picture

Edku may reach 19,000 tons, which is approximately a value added to the Egyptian economy.

Lake Edku has complained dramatic changes in its boundary. The size of the lake recorded about 62 km^2 in 2003 while the area of the lake decreases to 55.88 km^2 in 2016. This difference reveals to the abuse of the lake management and drying of the lake (Fig. 9.11). The fish farm is increased from 61.43 to 67.79 km^2 (Fig. 9.12). This interprets the loss parts of the lake area replaced by the fish farm activities.

The Lake Edku vegetation is covering more than 70% of the lake area. This dynamic movement of the vegetation reflects the lake water interaction with the saline water (Fig. 9.13).

9.8.3 *Lake Burullus*

Multi-dates Images "Landsat TM" are used to monitor the characteristic of both water and land and determine the long-term changes taking place along the lake system and peripheries. The dates of the images are 1984, 1997 and 2000 with a resolution of 25 m/pixel. The multi- date images are also used for Burullus inlet change detection with time (Fig. 9.14).

The merging of multi-sensor image data is becoming a widely used procedure because of the complementary nature of many data sets. Merging information from

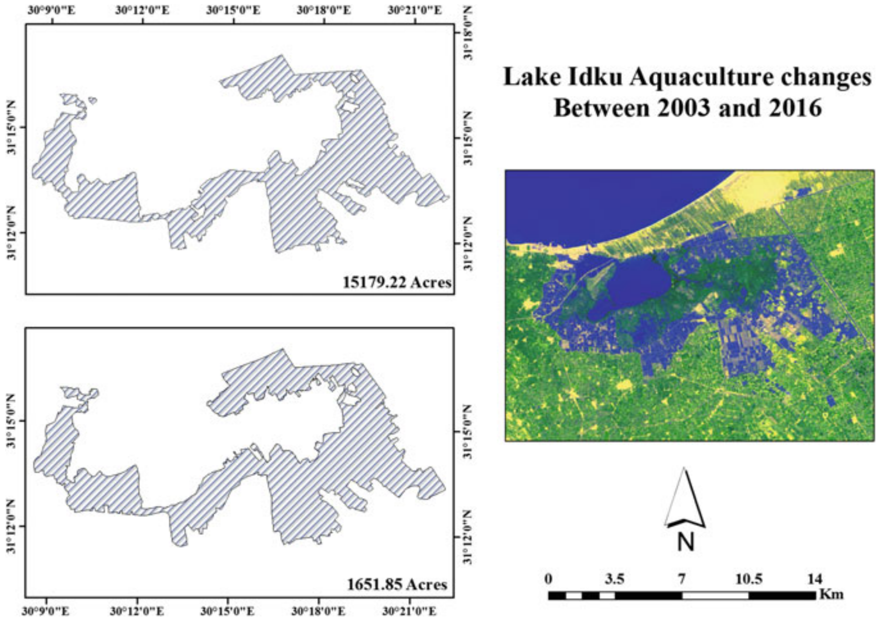

Fig. 9.12 Lake Edku fish farm changes between 2003 and 2016

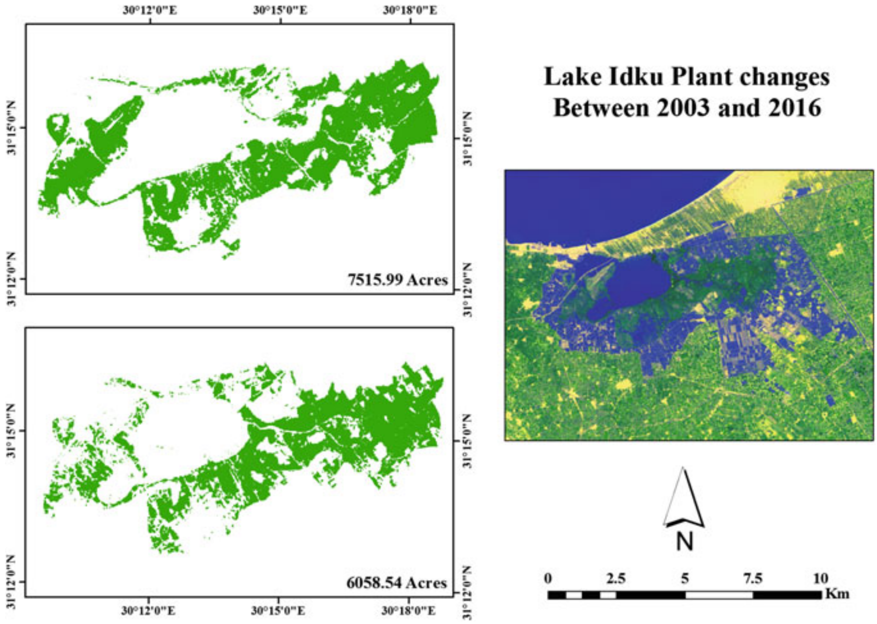

Fig. 9.13 Lake Edku vegetation changes between 2003 and 2009

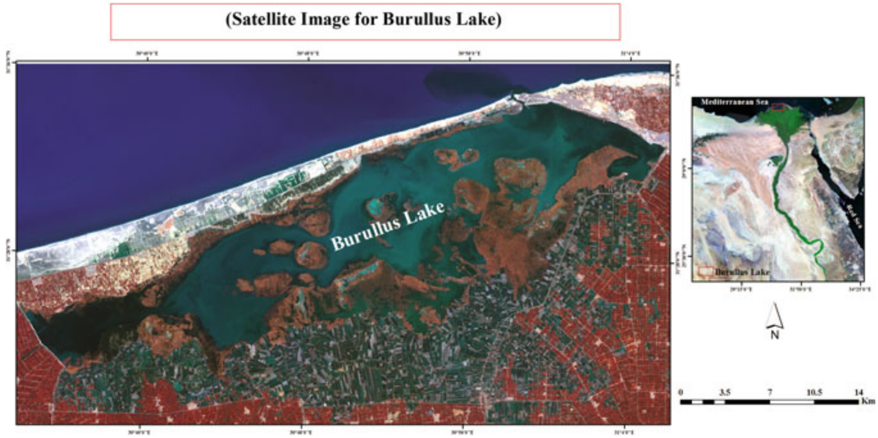

Fig. 9.14 Processed satellite image of Lake Burullus shows the vegetation and water of the lake

different imaging sensors involves two distinct steps. First, the digital images from both sensors are geometrically registered to one another. Next, the spectral and spatial information contents are mixed to generate a single data set by using various transformations such as Hue-Intensity-Saturation (HIS) transformation (Carper et al. 1990).

Reclamation projects in the southern and eastern margins have substantially decreased the size of the lake. To protect the lake inlet from siltation and beach erosion, two jetties were constructed on the western and eastern sides of the inlet. In order to combat siltation problem in the inlet channel, a new jetty was constructed in 1991 between the two jetties to reduce the equilibrium cross section. The identification classes of Lake Brullus are lake water, seawater, plants, marshes, islands, cultivated areas, urban areas, sand dunes and shallow water areas (Fig. 9.15).

The results reveal that the lake has been increasingly subjected to intensive and diverse human activities including fishing, aquaculture industry, dumping wastes, land reclamation, urbanization, saltpan, and recreational uses. Some of these activities have resulted in several environmental problems at a time when the population is expanding exponentially. Pollution, reclamation, fragmentation, over-fishing and illegal harvesting of fry fish are the major environmental issues threatening the fragile ecosystem of the lake. Also, ongoing natural factors have induced substantial changes in the lake environment. These changes include barrier erosion, inlet siltation and rising sea level as well as prevailing sedimentary processes (Table 9.1).

The outputs gained from this study can be considered as a practical lesson learned in future planning and management of Burullus Lake. Moreover, the information presented here is important for managing, improving and conservation of other coastal lakes of Egypt.

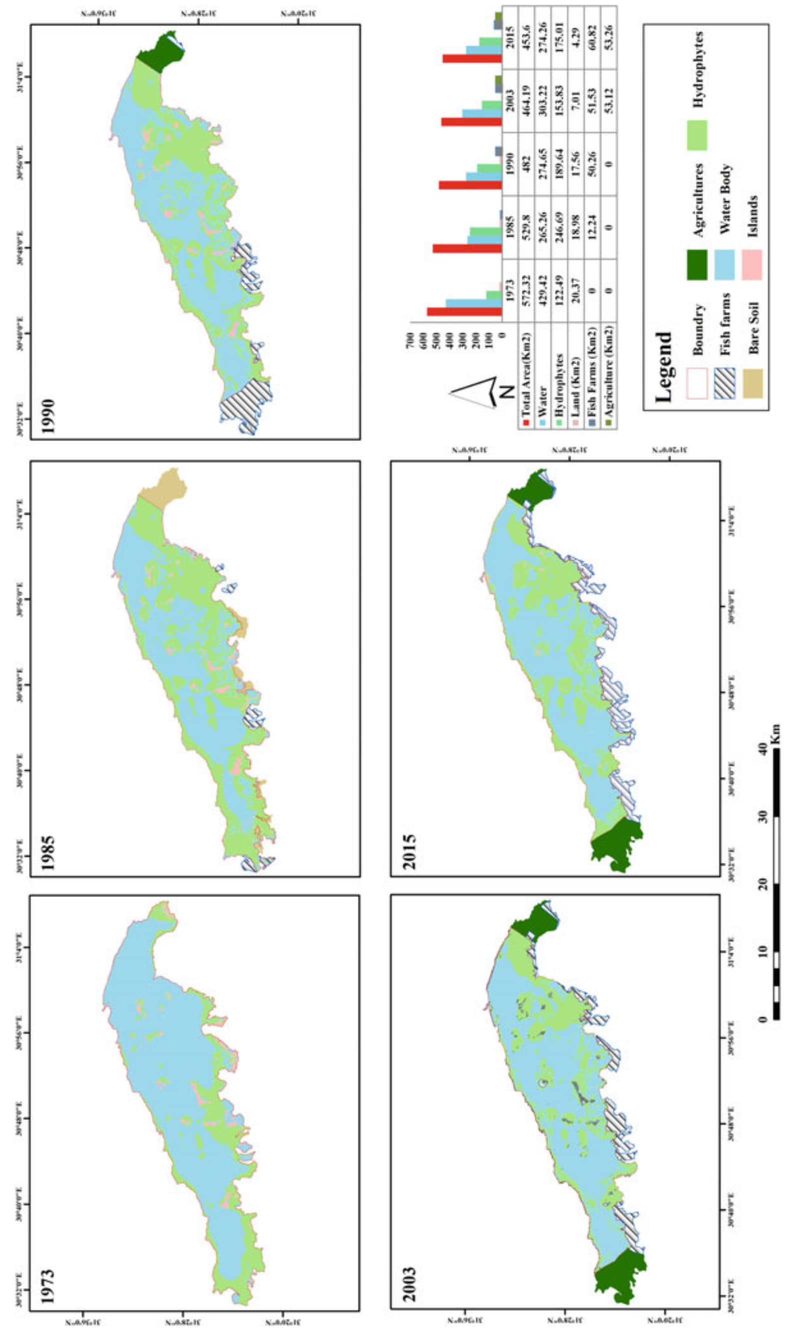

Fig. 9.15 Images classification of Lake Burullus between 1973 and 2015

9.8.4 Lake Manzala

Multidates satellite images have been used to detect the trends of environmental changes in Lake Manzala, during the past three decades. The results represent the way in which ecosystem degradation processes, affecting Lake Manzala, are increased due to external factors (human-induced). A study of ecological changes in the Lake Manzala over the period 1973–2003 has been undertaken to evaluate the effects of the human activities of drying and reclaiming some areas to establish development projects and urban settlements, and to estimate the consequential effects on the lake (Fig. 9.16). A combination of Landsat MSS, TM and ETM+ data were used to analyze temporal changes in the lake ecosystem. Different image processing techniques such as unsupervised classification and enhancement were used to determine the proportions of major ecological features within the lake. An arbitrary number of classes were assigned to represent all types of features. Classes were grouped into three Major classes (water, vegetation and land) within the lake boundary. Each feature class was identified spectrally, and consequently, the area of each major feature was calculated.

The change detection algorithm used is based upon the unsupervised classification technique. Details are provided by Olmanson et al. (2001). The basic premise in multi- spectral computer classification is that terrestrial objects manifest sufficiently

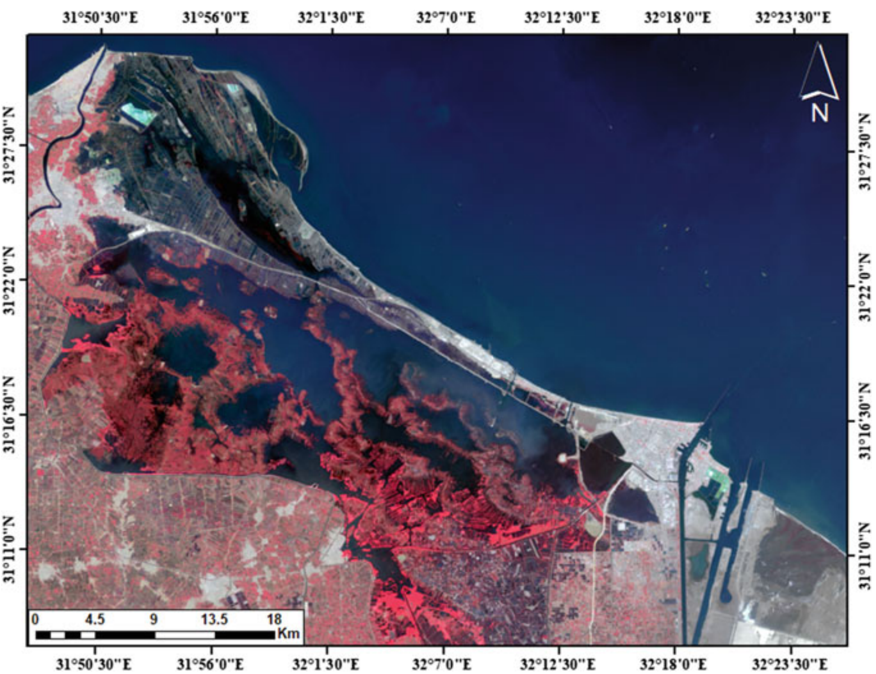

Fig. 9.16 Satellite image of Lake Manzala (Marine sciences department-NARSS)

different reflectance properties (digital values commonly known as spectral signatures) in different regions of the electromagnetic spectrum. Based on these spectral signatures, natural and cultural surface features can be discriminated and a new output image could be created having a specific number of classes or categories.

The results of the classification process revealed that five classes of vegetation showed different spectral patterns. Also, eleven water classes and five different land classes were identified. Changes that are analyzed and calculated from the extracted information explain how agricultural land-use practices interact with the characteristics of the study area. The results of the analysis indicate that Manzala Lake has been subjected to various physical and biological changes mainly due to the different human activities that have serious impacts on its quality and a subsequent deterioration in its ecological parameters.

This project is a research project designed to explore the application of a coastal lake changes based on satellite remote sensing and ground truth data (Fig. 9.17 and Table 9.2).

9.8.4.1 Vegetation of Lake Manzala

The aquatic plant classification methods consist of two major procedures: separation of image features into discrete units and classification of the pixels in each unit as described by Olmanson et al. (2002b). This was accomplished by performing an unsupervised classification. Vegetation classes were spectrally analyzed presenting 7 different species (plants). The different plants were identified/named according to the field survey information. The amount and percentage of each plant were identified. Manzala has clear water and an abundance of aquatic vegetation. Therefore, we assumed that aquatic vegetation was present throughout the lake. The next step thus was to stratify the lake into emergent and submergent vegetation features.

Terrestrial Change

The ecological change along the past two decades was investigated by qualitative and quantitative comparison between the historical images of the lake. The size of the lake was calculated, and as shown in Fig. 9.6, the overall size of the lake decreased about 50% from 1973 until 2003. Also, the water percentage area is decreasing whereas the vegetation and land percentage of areas overall the lake are increasing from 1973 until 2003 ass shown in Table 9.3. The decrease of the area is about 24% from 1978 comparing to 1973. The decrease of the area is changing in the next 5 years to 6%. Then, in the next 3 years the decrease in area is increasing to about 20%. In the next 3 years, the decrease in area is 7%. In the next decade, the area of the lake is decreasing about 8%. Finally, the decrease of the area in 2003 compared to 2000 is about 3%.

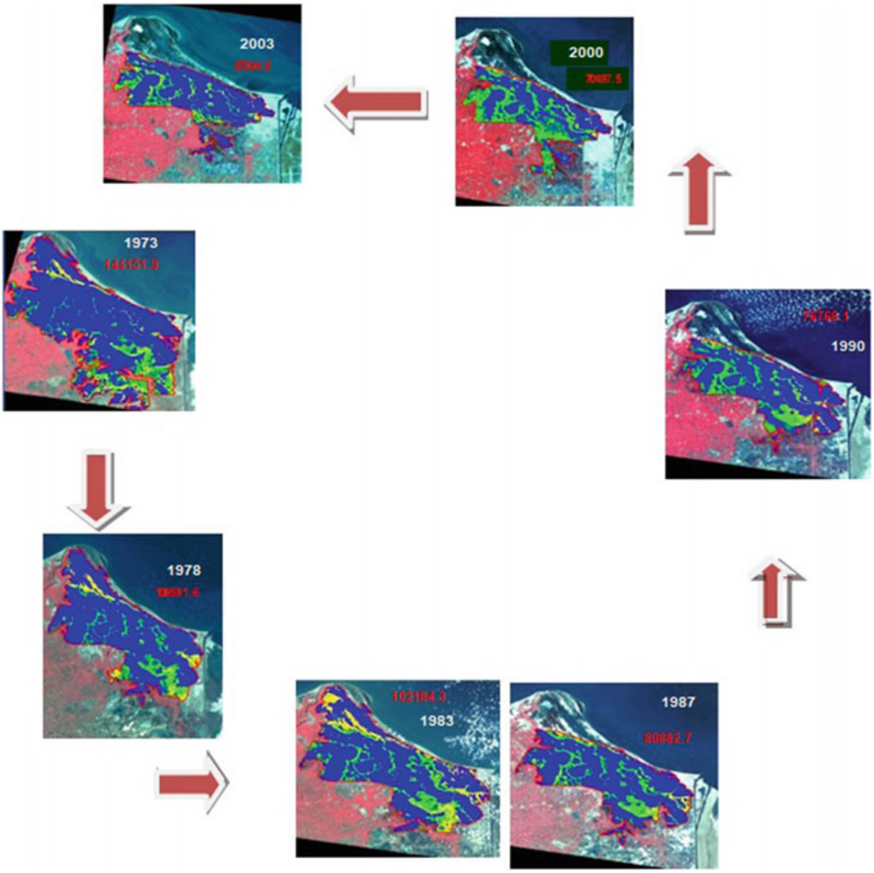

Fig. 9.17 Changes of water, vegetations and terrestrial components of Lake Manzala derived from satellite imagery during the last three decades (Marine sciences department-NARSS)

Table 9.2 Changes of water, vegetations and terrestrial components of Lake Manzala

Date	Water (%)	Land (%)	Vegetation (%)
03/07/1973	74.25	8.89	16.86
10/05/1978	74.68	7.85	17.46
16/05/1983	68.21	15.81	15.98
07/11/1987	71.68	8.01	20.31
04/08/1990	67.57	7.86	24.57
22/07/2000	55.35	6.46	38.19
05/02/2003	72.33	9.30	18.37

Table 9.3 Identifying Lake Manzala habitat types by using NDVI techniques between 1973 and 2017

Habitat type	NDVI Color index	1973 Area/Acres	2017 Area/Acres	changes in Area/Acres
1		0.872822	0.024	−0.849
2		709.917445	6677.489	5967.572
3		709.917445	19226.091	18516.174
4		8692.309893	18344.178	9651.868
5		32372.78213	15969.545	−16403.237
6		42264.24249	9095.747	−33168.496
7		10020.64646	3813.622	−6207.024
8		1463.91501	2488.836	1024.921
9		134.071722	1173.140	1039.068
	Habitat Total	96368.67541	76788.672	−19580.003

Water Classes

The first step is to make a "water-only" image by performing an unsupervised classification using Imagine. Because water features have very different spectral characteristics from terrestrial features, water is put into one or a few distinct classes that can be easily identified. Terrestrial features then are masked, creating a water-only image. Second unsupervised classification is performed on the water-only image. Average brightness values from the unsupervised classification are graphed to show spectral signatures of each class. These signatures, along with the location where the pixels occur, are used to differentiate classes containing clear, turbid, or shallow water (where sediment and/or macrophytes affect spectral response) (Olmanson et al. 2001). Based on this information, classes are re-colored so that vegetation, bottom and terrestrial effects can be avoided when selecting lake sample locations or areas of interest. All seven Landsat bands were used for the classification, and six classes were specified. Because the spectral-radiometric response from water is significantly different from terrestrial features, it should be given its own, easily identifiable class Olmanson et al. (2002a).

NDVI Classification of Lake Manzala Habitat

The Normalized Difference of Vegetation Index (NDVI) is a measure of the amount and vigor of vegetation at the surface. The magnitude of NDVI is related to the level of photosynthetic in the observed vegetation. In general, higher values of NDVI indicate greater vigor and amounts of vegetation. The NDVI was calculated from TM images 1973, and 2017 indicated that eight types of vegetative habitat could be recognized. Each of these habitats is recognized by certain colour index (Fig. 9.18). During the current study, two images were selected to perform this analysis belonging to the years 1973 and 2017, collecting of these two dates is due to the greening coverage on the surface of Lake body have to be detected at the same time. The data obtained from the two images were subjected to analysis including spatial vegetation patterns and assessment of vegetation dynamics. Furthermore, this biophysical parameter is a key remote sensing observation related to several important biospheric properties including the proportion of photosynthetically absorbed radiation and leaf area index were also used.

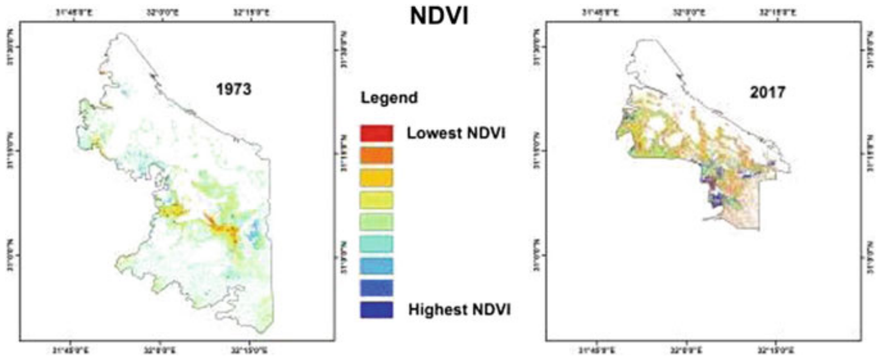

Fig. 9.18 Different types of vegetative habitat in Lake Manzala (Marine sciences department-NARSS)

The data calculated from both images indicated changes in the size of the different habitat within the lake between the two years. Table 9.3 listed the area of different habitat as obtained from the images and the value of changes between 1973 and 2017. The examining of these results showed that some of the lake habitats suffer a considerable decrease in area while others showed an increase in area, i.e. the decreasing percentage in greening habitat area ranged from −1.5% in habitat type 5 to −48.5 in habitat type 8, while the increasing percentage in the habitat area ranged from 10.03 in habitat type 4 to 28.95 in habitat type 2.

The data in Table 9.3 indicated that the Lake habitat which decreased in area has a total of 66% while those increased in area are represented by 55% in total. These means that a certain area of the habitat, with almost 11% value, was lost completely from the lake. However, it is safe to say that the change of certain habitat area is most probably connected to the faunal and floral composition of these habitats and the current rate of habitat loss will affect the biodiversity in the lake in the near future.

Detecting of Landfilling

EL Bashteer area is one of the fast developing areas in Lake Manzala. One of the most alarming practices in this area is land filling. In the current study images of 1973 and 2017 were analyzed for indicating the area lost from the lake due to landfilling. The results of quantitative analyses of Bashteer area are indicated the human interventions in the Lake ecosystem. These results for the Bahr El-Bshteer recorded the 100.726 km cutoff (dryed) the Lake area during 13 years. This is indicating that the developments of Lake are affected on the land reclamation with the rate of 7.75 km a year (Fig. 9.18).

Detection of Anthropogenic Effects

El Jenka area is one of those area in the lake subjected to different sorts of land filling for the establishment of a small fish farm named Hosha. The examination of the images at 1993 and 2017 proved that the human interventions "cultivated the land". This Hosha is used for fish fry catches which is illegal behavior inside the Lake. Results of such this illegal behavior are a loss of areas from the lake. Quantitative

Fig. 9.19 Change detection at El-Jenka area, south east of Lake Manzala between 1993 (left) and 2017 (right). *Source* Satellite, date?

analysis for El Genka area (black spot area) recorded about 8.45 km cutoff (drayed) the Lake area during 13 years, Fig. 9.19.

Detection of Pollutants Outflow

The out flow of Lake Manzala water into the Mediterranean Sea may cause certain problems connected to the water quality in the area. The analysis of the satellite images taken during the opening and the closing of the Lake outlet showed that a considerable amount of organic matters and phytoplankton bloom to be discharged into the Mediterranean waters. The extend of these blooms may reach a few kilometers then directed towards the east with the current. Such alarming situation may result in dramatic changes in the water quality to as far as El-Arish area (Fig. 9.20).

Detection of Lake Islands Change

Lake Manzala is famous for the presence of a large number of small Island, which represents part of the natural habitat of the lake. Due to the development of certain unsustainable activity within the lake, a large number of these islands disappeared

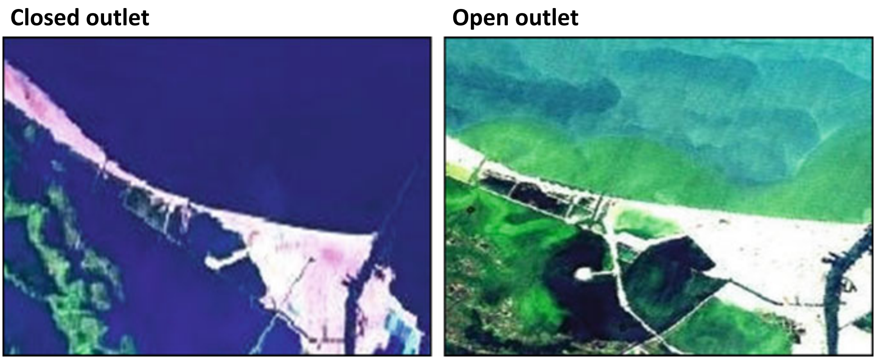

Fig. 9.20 Blooms of polluted water flowing from Manzala tidal inlet and dispersed by the eastern longshore current, during the opening of the outlet (Marine sciences department-NARSS)

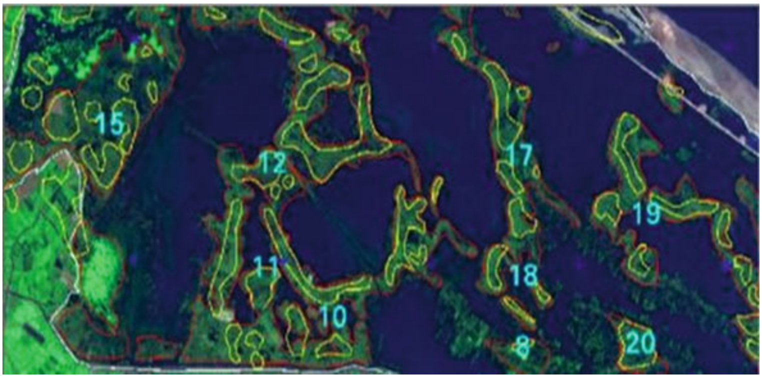

Fig. 9.21 Islands in 1987 and it dynamic change in 2000 (red) situation of the island in Lake Manzala (Marine sciences department-NARSS)

and/or replaced by another for of activity (fish bound, cultivated land, etc.). By comparing the 1987 and 2000 satellite images marking the boundary of these island detection of the amount of drifting islands that were occurred during this period (Fig. 9.21).

9.8.5 Lake Bardawil

The Lake is sustained by one natural strait called Zaranik and two artificial sea inlets. These inlets, locally called Boughaze, are silting up considerably; keeping them open is essential to keep Lake Salinities down and for fish recruitment from the sea. A salt plant has recently been established at Zaranik, with extensive evaporation ponds for salt harvesting.

Bardawil Lake is the greatest hypersaline lake in Egypt, Situated in the north of Sinai Peninsula. The 0.6 km^2 of Lake Bardawil yield some 1500–2500 tons of fish yearly; fisheries management and some in-lake aquaculture development could raise this production to a sustainable 3000 tons. The significance of Bardawil Lake fisheries is not only in the supply of fish for regional domestic consumption but especially in employment and export earnings.

Multi-date Images "Landsat TM" are used to monitor the characteristic of both water and land. The dates of the images are 1993 and 2000 with pixel resolution 25 m (Fig. 9.23). A Landsat TM image dated 1996 is used as geo-reference to correct the satellite data. The multi-date images are used for detecting the changes in the lake size as well as the inlet and barrier changes.

The accurate special registration of the two images is essential for all change detection methods. This necessitates the use of geometric rectification algorithms that register the images to each other or a standard map projection. Also, most of the methods require a decision as where to place the threshold boundaries to separate areas of change from those of non-change as it was done to identify the barrier change between the Bardawil Lake and the Mediterranean Sea (El-Asmar et al. 2015). The technique for change detection is briefly described:

If an image contains light objects, change, on a dark background, no change, then these light objects may be extracted by a simple thresholding

$$\begin{aligned} I(x, y) &= 1 \; I(x, y) > T \\ I(x, y) &= 0 \; I(x, y) <= T \end{aligned}$$

where,

I (x, y)	represent the intensity value of the pixel at x, y.
T	is the threshold value supplied empirically or statistically by the analyst.
1	is the code of the pixel, which belongs to the object change.
0	is the code of the pixel, which belong to the no-change object “background”.

This is exactly our case to define the changes in both inlets of Bardawil Lake where rationing is the technique of change detection used; this technique is considered a relatively rapid mean of identifying the areas of change. In rationing, two registered images from different dates (1993 and 2000) are radioed; the data is compared on a pixel-by-pixel basis. Figure 9.24 shows the areas subjected to deposition or accumulation and that subject to erosion or inundation in 1993 and 2000. The barrier is eroded in 2000 than that in 1993, and this is an indication that the lake is decreasing in size. Several dredging operations have been carried out since 1927, and the most recent one took place in 1987. To systematically investigate this siltation problem, the CRI conducted a comprehensive field monitoring program during the years 1985 and 1986 which was re-evaluated and updated in 1990, 1991, 1992 (Khafagy et al. 1988, 1990; Khafagy and Fanos 1990, 1992). Figure 9.22 shows the shoreline changes for both inlets (1986–1996).

Results of using the change detection techniques reveal that the size of Bardawil lake is decreasing with a rate of 0.71 km^2/year; (0.89% negative change in the size of the lake). The decrease in size of Bardawil Lake can be calculated by combination of the remote sensing results derived from present chapter with other results (see Hasan 2001; Ahmed et al. 2000a, b). The dataset of the yearly size changes indicated that the long-term size changes of Bardawil Lake decreased dramatically from 1922 to 2000 with a rate of 0.98 km^2/year whereas it decreases from 1935 to 2000 with a rate of 2.21 km^2/year, this is listed in Table 9.4. This means that the lake complains

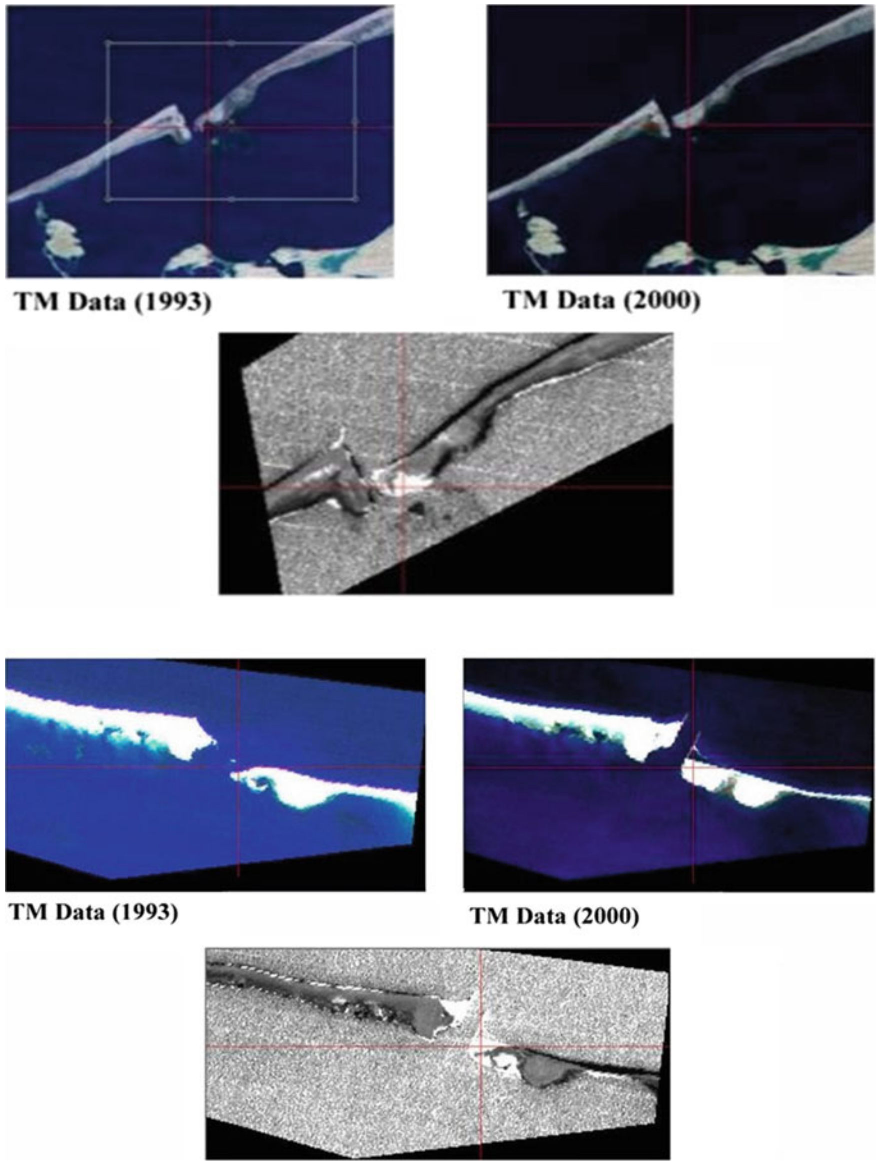

Fig. 9.22 The shoreline changes for both inlets (1986–1996)

of continuous natural and anthropogenic impacts affecting the lake development; therefore, the lake deterioration is becoming a national problem for the Egyptian Governorate.

Table 9.4 The size change in Bardawil Lake (1922–2000)

Year	Area (km^2)	References
1922	634.0	Ahmed et al. (2000a, b)
1935	701.15	Hasan (2001)
1955	663.23	Hasan (2001)
1969	685.9	Hasan (2001)
1984	598.89	Hasan (2001)
1993	562.0	Present study
1994	558.6	Hasan (2001)
2000	557.0	Present study

9.9 GIS-Based Lakes

Since the satellite image processing has been provided with information and data, field check was carried out to check the consistency of the image results in the field. To build the GIS system for the lakes, the following steps are followed to construct the GIS for northern Egyptian lakes. Selected samples are planned as fixed stations for sampling the lake water, sediments, and plants; these sites cover the whole geographical lake area.

Two GPSs were used in each site investigation on some of the sites specified by the used satellite images. The GPS was used for accurate determination of the geographical place and instrument calibration. Collecting the earth observations found in the study area help in recognition of the different classes of unsupervised images that reflect the types of Lake Ecosystem to supervised classification image for the study area.

Complete scanning of the surrounding lake features adjacent to Mediterranean Sea water, to investigate the different types, determine how to manage them, and how finally evaluate their environmental status. Consulting the study area exerts to know the different human activities in the area, as well the dynamic changes could happen and notice by the in-suite observer. Specify the places and the development activities along the coast by following up the erosion and sedimentation sites on the north barrier especially the border between the Mediterranean and the lake.

Urban diffuse-source pollution is a significant contributor to water quality degradation. Watershed planners need to be able to estimate the loads arising from diffuse sources to plan effective management strategies. As part of the effort to develop a GIS-based model for watersheds and lakes, we assembled a database of urban/suburban runoff data from field works on lakes drainage areas conducted over the past 40 years. Relationships between runoff variables and drainage characteristics were monitored and surveyed. The best regression equation to predict runoff volume for rain events was based on rainfall amount, drainage canals, and percent impervious area.

As an essential step in the development of the GIS of the lakes, i.e. GIS water quality, image processing procedure, a database consisting of growing-season measurements of water quality, these measurements were analyzed to determine the nature and consistency of seasonal patterns among lakes in the region.

Therefore, the following are the GIS of different northern coastal lakes and how it can help in understanding the lake behaviours and interaction between the lake and the sea. Figures 9.23, 9.24, 9.25 and 9.26 are demonstrate the Northern lakes GIS-based resources.

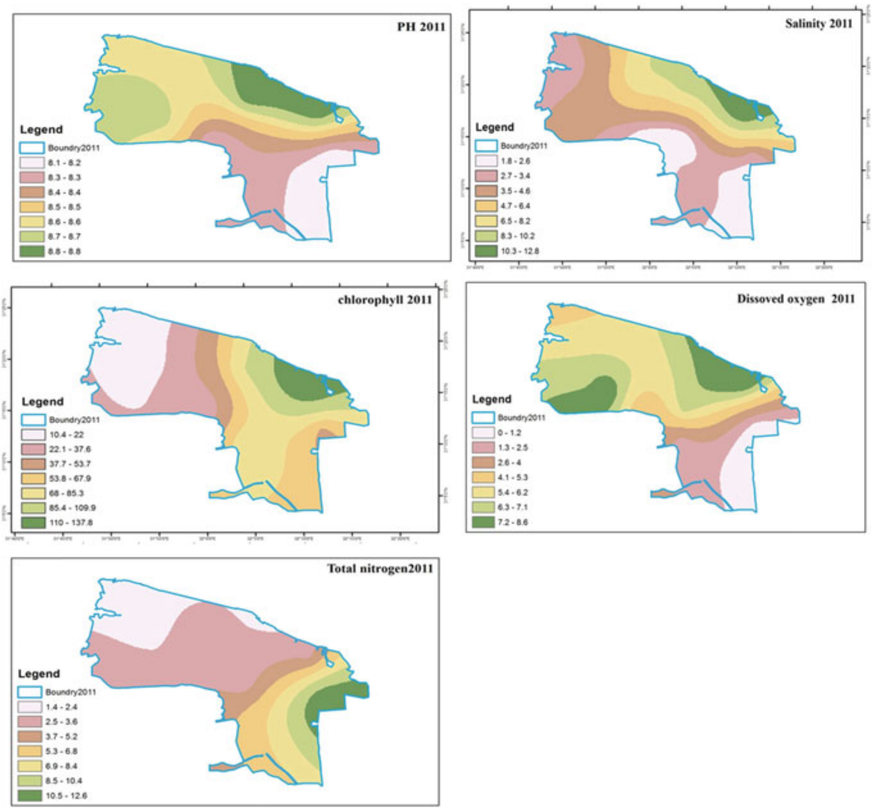

Fig. 9.23 Water quality parameters distribution using GIS software (Marine sciences department-NARSS)

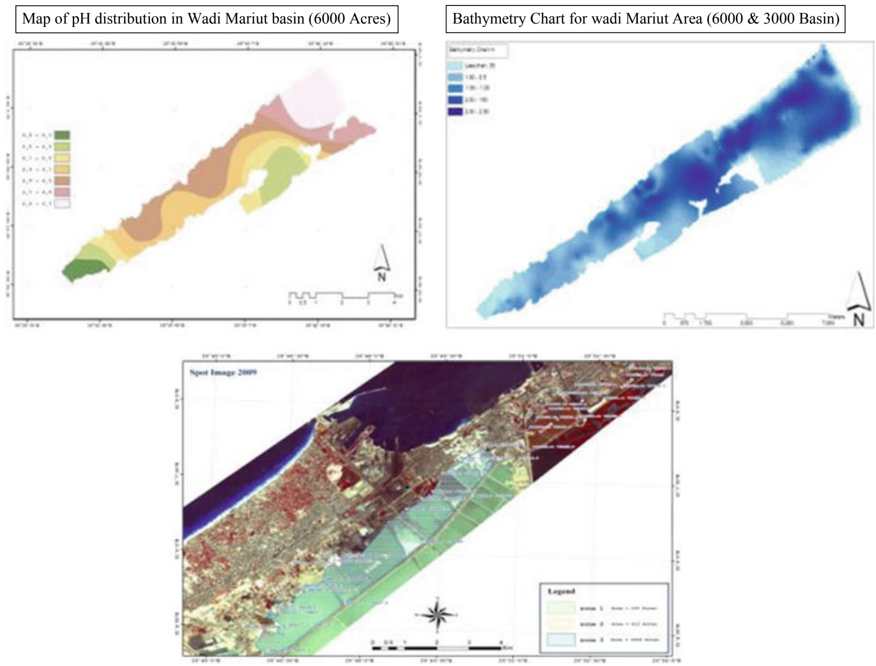

Fig. 9.24 Bathymetry and landuse of Lake Maruit using GIS software (Marine sciences department-NARSS)

9.10 Proposed Actions for Protecting the Lakes

Most of the worldwide coastal lakes are undergoing very rapid changes as a result of accelerated anthropogenic activities combined with natural influences. To better develop an integrated plan for improvement, conservation of the examined lakes and their future management, the main key issues are identified. The existing environmental problems of the Egyptian lakes are mainly related to natural and anthropogenic influences.

To protect the coastal lakes and sustain its resources based on the results extracted from this review study. The following are the main long-term tasks arranged in a descending order of priority to achieve this lakes sustainability:

- Maintain and enhance the ecological values of the lake,
- Conserve available resources through proper environmental management tools, i.e. Remote sensing technology, etc.
- Improve the socio-economic opportunities of the local population of the lake,
- Develop public awareness and participation in monitoring programs and nature conservation of the lake resources,
- Resolve existing legal conflicts, especially those of land ownership, and responsibilities.

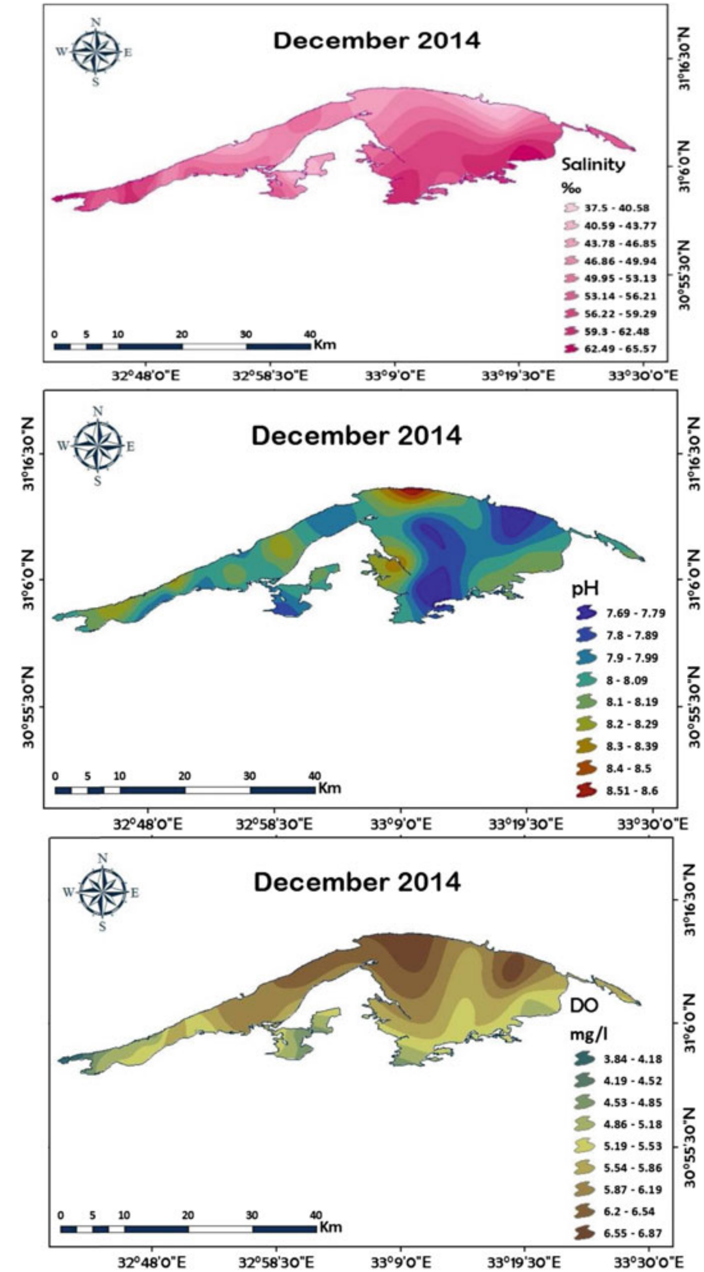

Fig. 9.25 Water quality parameters distribution of Lake Bardawil using GIS software (Marine sciences department-NARSS)

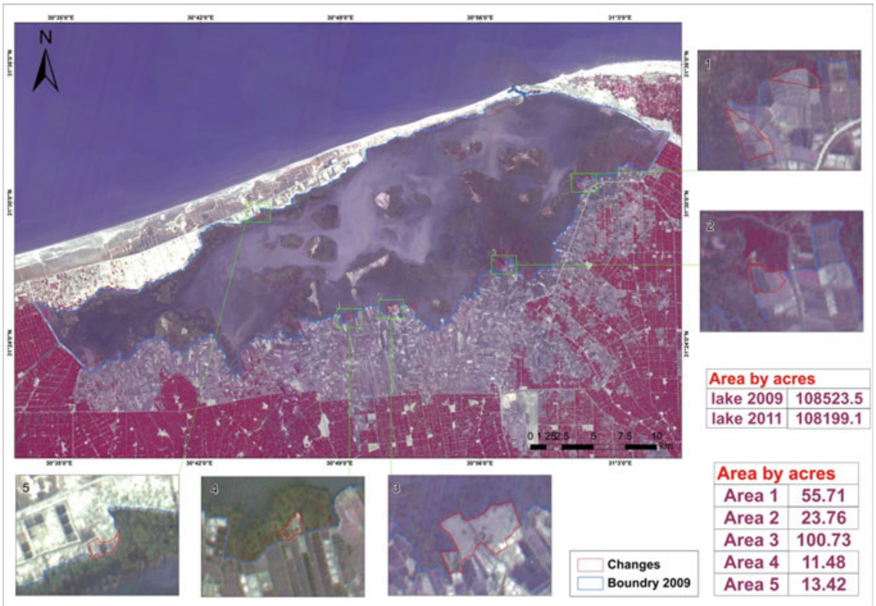

Fig. 9.26 Using GIS for change detection of Burullus lake fish farms

- Expand the protectorate to include the totality of Lake and its immediate terrestrial surroundings.
- Apply the legislations, rules and law for lakes conservations.

Meanwhile, the current situation with all humans impacts on the northern lakes is without any control or treatment. After discussions the main environmental problems facing these Lakes, some proposed solutions for solving those problems based on the information derived from using Remote Sensing techniques and applications. In following, each proposed solution for problems would discuss separately.

An artificial circulation system is designed such as to include nine positions inside the lakes. Each one has two positions upper and lower of the selected lake island. i.e. in Lake Manzala, three main islands in the east, middle and west sectors of the lake have been chosen. Any device (such as a fan) could be placed in each cell to push water. This device must be in contact with the meteorological device to define wind speed and direction. This also can be applicable on Lake Mariut.

The system is designed to remove most of these plants from many places inside the lakes. Dividing the rooted plant area into small areas, isolate these areas and dry them. Dredge these areas until plants root is reached. Leaving the soil of the dredged area some time to completely dry. After that, let the lake water to release to the cleaning area.

The harvesters units are paddle wheel propelled and have a large frame extending down into the water ahead of the bow. This frame is made up of vertical sickles on the sides and a sickle across the bottom connecting the two sides. A conveyer belt extends up from this frame to the boat and carries the cut macrophyte to the surface where they are collected (Klein 1997).

Duckweeds such as Lemna gibba have been utilized to treat municipal wastewater and removal of very high Biochemical Oxygen Demand (BOD). These plants must be removed from the lake (manually) with the timetable (depends on the season of growth).

The present situation of Lake Bardawil is rather precarious, vulnerable and could deteriorate in the future. Ill-advised management of the Lake plus the detrimental impact of major development projects (land reclamation for agricultural purposes, El-Salam Canal, new and expanding urban centers, the international highway, the new railway line, the fast proliferation of large-scale seaside resorts, etc.) will undoubtedly impact the current pristine status of the site, possibly beyond repair. All of these projects are in various stages of implementation, and it will not be long before their undesirable impact on Zaranik is felt.

Therefore, in order to keep the changes in the lakes under control and to minimize their impact on the lake ecosystem, the ideal concept envisaged for protectorate area inside the lake is that it should become a core conservation area for the totality, i.e. Lake Bardawil. In other words, the boundaries of the Protectorate should be expanded to include the entire Bardawil region. The newly added areas (aquatic and terrestrial) will become an associated zone, and the enlarged protectorate will be managed on the basis of sustainable development (i.e. environmental management).

The management plan of the protected areas located with the northern lakes should be a legal and technical instrument which helps to achieve the main long-term objectives as well as to maintain the delicate balance between the interests of the local population and the sustainable conservation and development of the lake's resources.

9.11 Conclusions

Results of this study indicated that these lakes had been increasingly subjected to intensive and diverse development activities including fishing, aquaculture industry, dumping wastes, land reclamation, lakes drying, urbanization, saltpan, and recreational uses. Some of these activities have derived to several environmental problems as well; the population is expanding exponentially. These problems are pollution, eutrophication, reclamation, fragmentation, over-fishing, illegal harvesting of fry fish, is considered as major environmental issues threatening the fragile ecosystem of these lakes.

The experiences gained from this study can be considered as a practical lesson learned in future planning and management of coastal lakes at the northern Egyptian lakes of the Mediterranean region. On a local scale, monitoring of such these ecosystems using Multidates satellite images presented here are important for managing, improving and conservation of the Northern coastal lakes of Egypt.

Remote sensing proves to be very successful in monitoring the water quality, vegetation types, and ecological changes along the Manzala Lake. Manzala Lake is characterized by special sensitive environments. However human activities including the discharge of sewage and industrial waste and the impact of canal and road networks have a serious impact on the Lake. Image processing techniques as enhancements were applied to help the identification and discrimination of the different features and classes in and around the Lake.

The ultimate goal of this remote sensing research is to provide resource managers with a useful tool to monitor natural resources such as Coastal Lakes and make better-informed decisions about their use and conservation. For example, fishermen need accurate forecasts of locations of good fishing waters, and for fish areas, managers need to monitor the water quality. Remote sensing is a valuable tool for studying Water Quality of the Manzala Lake. Integrating all available data into an easily accessible data system further improves remote sensing images potential as a tool for resource managers.

Steps which could facilitate improvement in the Lake Manzala ecosystem through reductions in nutrient loads include:

- (i) treatment at source of the domestic and industrial wastewater which is at present responsible for the high BOD and nutrient loads within the Bahr El-Baqar drain;
- (ii) treatment of wastewater from lakeside communities so that the use of the lake as a secondary and tertiary wastewater treatment unit declines and eventually ceases;
- (iii) diversion of nutrient-rich wastewater from the Port Said wastewater treatment plant away from the lake and instead out to sea using a deep-water delivery system; and
- (iv) improved control and regulation of fish farms within the lake.

These steps will require that Lake Manzala is managed sustainably as a large shallow lake ecosystem which supplies important goods and services. Restoration of Lake Manzala will undoubtedly bring about major ecosystem improvements that will benefit both people and biodiversity. Nevertheless, such changes will require political will, considerable financial resources and careful environmental planning.

The present-day coastal lakes host the Mediterranean coast of Egypt are mainly differ in shape, dimension, depositional environment, water quality, runoff of tributary streams, and inlet stabilization. The delta lakes (Mariut, Edku, Burullus, and Manzala) are brackishly influenced by freshwater runoff from drains and irregular canals. In contrast, the other lake is hypersaline and not connected to any freshwater flow (Bardawil). Like other Mediterranean lakes, they were generally originated as a result of changes in sea level combined with neotectonic land subsidence. These lakes are socially and economically important for the coastal population. The quality of these lakes is influenced to a large degree by various types of human activities and human habitats. Human activities differ throughout these lakes including fishing, wastewater through drains, lake reclamation, recreation, salt paning, hunting of water birds and engineering works at inlets.

Some of these lakes are presently experiencing environmental problems resulted from natural and human activities. Because these lakes are very valuable regarding natural resources and related economic activities, these problems have caused serious implication on the lake ecosystem, resources, fauna, flora, and human beings as well. Moreover, the lacks of effective and consolidated earlier management of these lakes have accelerated such implications.

Within the present task of finding practical solutions for the environmental problems of the lake, this study integrates the existing scientific knowledge in order to obtain an ecological understanding of the lake. It also implements a systematic decision support procedure in such a way that final judgments can be as objective as possible.

An enhanced model requires discharge time series measured daily or weekly (according to the type of study). These measurements should be carried out at the same points where the boundary conditions are placed. Ideally, a gauging station would be established at each known inflow to the lake. For an appropriate calibration and validation of the model, water levels referred to standard reference level are needed. At least one water level measurement point is needed in each basin. Water level and discharge measurements should be carried out simultaneously. Openings through the embankments of the drains should be surveyed as they define the interaction between canals and basins. In the presence of culverts connecting basins and drains, it is also necessary to model their hydraulics properly.

9.12 Recommendations

Based on this comprehensive study for the most important characteristics, problems and future development options of northern Lakes have been carried out. It is recommended that an integrated management program be implemented for the development of the lake and adjacent area taking into account the capability of recent remote sensing techniques in identifying and assessing changes and law enforcement.

Lake management is a dynamic process, the rules keep on changing, the problems keep on changing, and approaches of management also keep on changing. It is necessary to be able to make decisions at the proper time.

Periodic monitoring and assessment are therefore necessary. In the absence of main tools for management, (legal frame, corrective actions, technical and socioeconomic), conditions of the coastal zone will deteriorate without control. A decentralized remote sensing and geographic information system (GIS) capability must be developed to collect and upgrade available data and to help decision makers on local and national scales.

A sensitivity analysis must be carried out for all coastal lakes in Egypt to assess vulnerabilities to various problems including pollution, lake reclamation, erosion of Lake Barrier, illegal fish fry, etc. A contingency plan for protection and emergency measures must be developed.

The model built for some lakes is only indicative, and its results are only approximations of the flow pattern, water levels and velocities in the lake. Moreover, for an enhanced model that would permit a detailed analysis of the lake hydrodynamics, further detailed topographic and bathymetric data could be required, e.g. openings and interaction between drains and basins. Besides, the input data should be provided as time series instead of constant average values. Furthermore, it is essential to calibrate and validate the model to have reliable results.

The use of the ecological models to calculate the water flow velocities may give better results and understanding of the lake's ecosystem than using the increased roughness values for the vegetated areas, as done in this study. Therefore, it is recommended to do further research in this respect.

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