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USING GEO-INFORMATION AND REMOTE SENSING DATA ENVIRONMENTAL ASSESSMENT OF BURULLUS LAGOON, EGYPT

By

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ABSTRACT

This paper identifies and evaluates the existing environmental problems for one of the important Egyptian Mediterranean coastal lagoons: Burullus lagoon. These problems are resulting from anthropogenic as well as natural influences. Remote sensing data, topographic charts and hydrographic data were used to monitor the lagoon ecosystem and to suggest appropriate environmental management for the sustainable development of the lagoon. The environmental matrix is used to analyze and evaluate the magnitude of human intervention into the lagoon through the addressing of the main problems and identifying causes, impacts and proposed actions.

The results reveal that the lagoon 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 lagoon. In addition, ongoing natural factors have induced substantial changes in the lagoon environment. These changes include barrier erosion, inlet siltation and rising sea level as well as prevailing sedimentary processes.

through a narrow passage called Al-Burg inlet or Boughaz Al-Burullus (Fig. 1). The lagoon is separated from the sea by a long curving sand barrier. The lagoon covers an area of about 420 Km^2 of which 370 Km^2 are open water. The average length of the Lagoon is 47 Km while the average width is about 14 Km. Lagoon Burullus is shallow with an average depth of 1.25 m. It is very important for fish production and is often inhabited by mixed stands of submerged aquatic vascular plants while the bottom is covered with fine grain sediments. The eastern and southern borders of the lagoon are characterized by their irregularity and are surrounded by agricultural land and fish farms. However, the southern shore of the lagoon is mostly low, flat and marked by some marshes and swamps. The lagoon has considerably changed since 1800 having moved 10-12 Km northwards.

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

Burullus Lagoon receives 2.46 x 10^9 m^3 /day of brackish water through drains. It also receives about 100 x 10^6 cm/year of precipitation. Compared with the present total size of the lagoon, the residence time of water should be 2.5 months. This contrasts with the measured amount of water leaving the lagoon annually i.e. 446 x 10^6 m^3/year through Boughaz Al-Burg. This leaves about 2000 x 10^6 m^3 in excess that has to find another pathway to leave the lagoon. Part of this amount is lost through evaporation estimated to be about 0.71 x 10^9 m^3 /y (Maiyza et al., 1991) and possibly the rest through the bottom and consumption by aquatic plants.

Numerous islands characterize Lagoon 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.

Several water plants like reeds (Phragmites, Typha, etc.) spreads all over the lagoon affecting the movement of water. These plants play an important role to keep the internal coasts of the lagoon from immolation. The decrease of the area of Elodea in Lagoon Burullus indicates the increase of the salinity in the lagoon. Image processing of Burullus lagoon can't determine accurate variation in the areas of floating aquatic plants inside the lagoon. Seasonal images can be used to monitor such variation.

Lagoon Morphometry

The development of the lagoon coastline was connected with the morphological changes occurring at the lagoon area. As a result of its liability to contraction, the lagoon coastline is shrinking either due to increasing bottom level or due to human interference. The application of Soul Arrow equation for the coastline development resulted the following:

Rate of coastline development = length of lagoon coastline ÷ lagoon area at zero line $\times 22/7 = 143.2/71.7 = 1.9$.

Morris (1984) declared that the rate value exceeds 1.5 in the case of lagoons where the contraction processes are the most, and its coasts are liable to withdrawal. At the same time it is between 1-1.5 in the case of delta lagoons. It is less than 1 in the case of volcanic or ice lagoons. As the result of the previous equation, it can be said that the lagoon is liable to withdrawal processes not only by natural factors but also due to human interference.

The lagoon peripheries are affected by the swinging of the water level especially with the difference in the natural factors affecting the lagoon from the beginning of its setting up till now. These are like the vanishing of the old delta branches and the decrease of water quantities flowing inside the lagoon basin. This is in addition to the human factor, which is represented in the control of irrigation and drainage systems.

The northern lagoon coastline changed clearly through the past two centuries as shown in (Fig. 2). During 1800 –1909 the rate of withdrawal was estimated by 600 m. During the period 1909 – 1945 the rate of advancement was about 195 m while from 1945 to 1997 the coastline withdrew by 100 m. From this, it is clear that the rate of advancement of the north coast of the lagoon through the period 1800 – 1997 was about 895 m, with an annual rate 40.22 m.

The southern coast of the lagoon extends near the mouth of drain 7 till the mouth of Brenbal canal (about 55.8 km). This area is also characterized by its extended curvatures as a result of water penetration. The southern coast is surrounded with a group of a small area water basins most of which had decreased in their area during the period from 1984-1997 where 35% of the areas of bays were dried. In less than 20 years, many of the existing bays will disappear like Jonet Dahr Mansour, Bahr Taashish, Bashkhin lagoon, El Fakaah, Ghraket El Sadah and Drain 11 bay. Sestini (1976) has shown that the south coastline has advanced northward with distance of 10-12 m in the period 1954-1976. The inhabitants of these regions use the bays for fish farming. Recently, there were some changes in the morphometric dimensions and areas of these bays due to their exposure to drying and use for agriculture and other activities. These areas decrease from 84.1 km^2 in 1960 to 23.8 km^2 in 1997 (28.36 %). This decrease was connected with the small curvature of the coast and contraction of the lagoon.

Changes of Burullus lagoon Using Remote Sensing

In this study, 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 lagoon system and peripheries. The dates of the images are 1984, 1997 and 2000 with resolution of pixel of 25m. The multi-date images are also used for Burullus inlet change detection with time.

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 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).

Both raw and classified images were geometrically corrected to the national UTM projection system in order to integrate them within the GIS. Correction is based on a coordinate transformation, described by a polynomial, and calculated by applying a least-squares regression analysis to a set of Ground

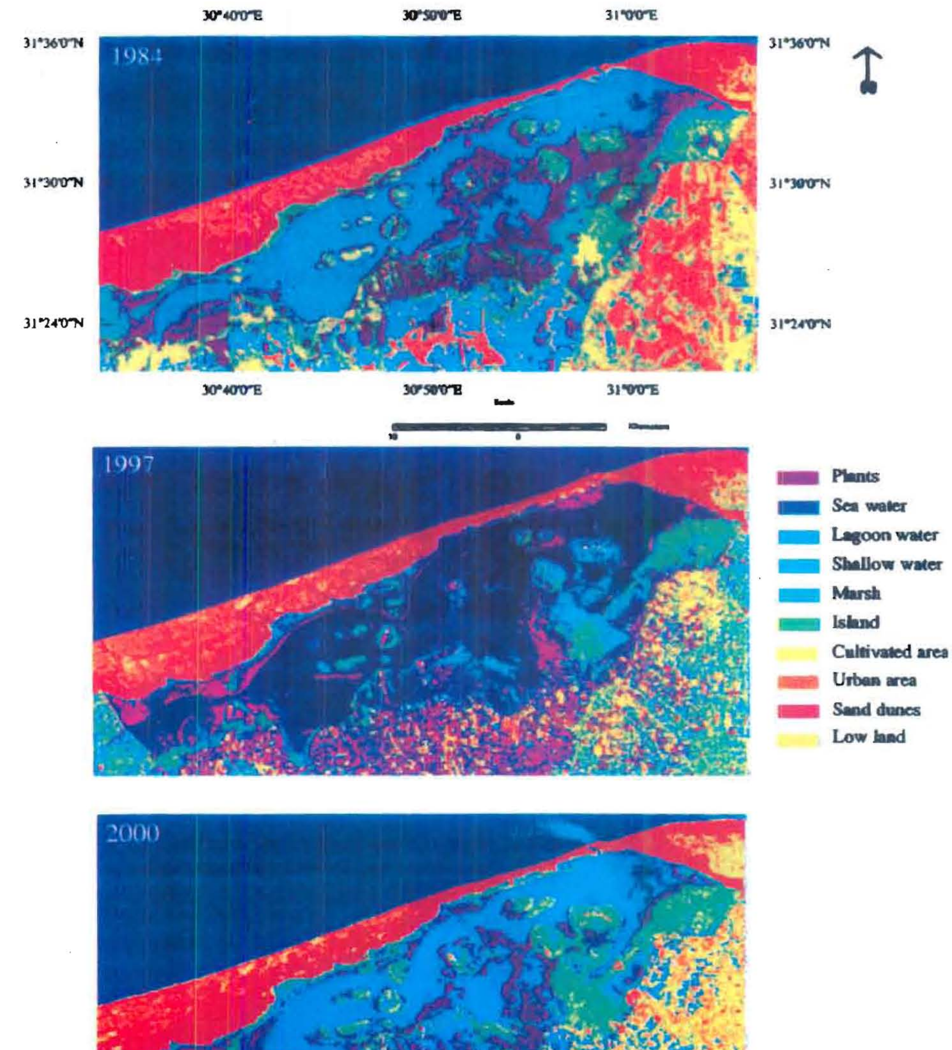

Figure (3): Classification of multidate satellite images TM (1984,1997 and 2000) of Burullus lagoon.

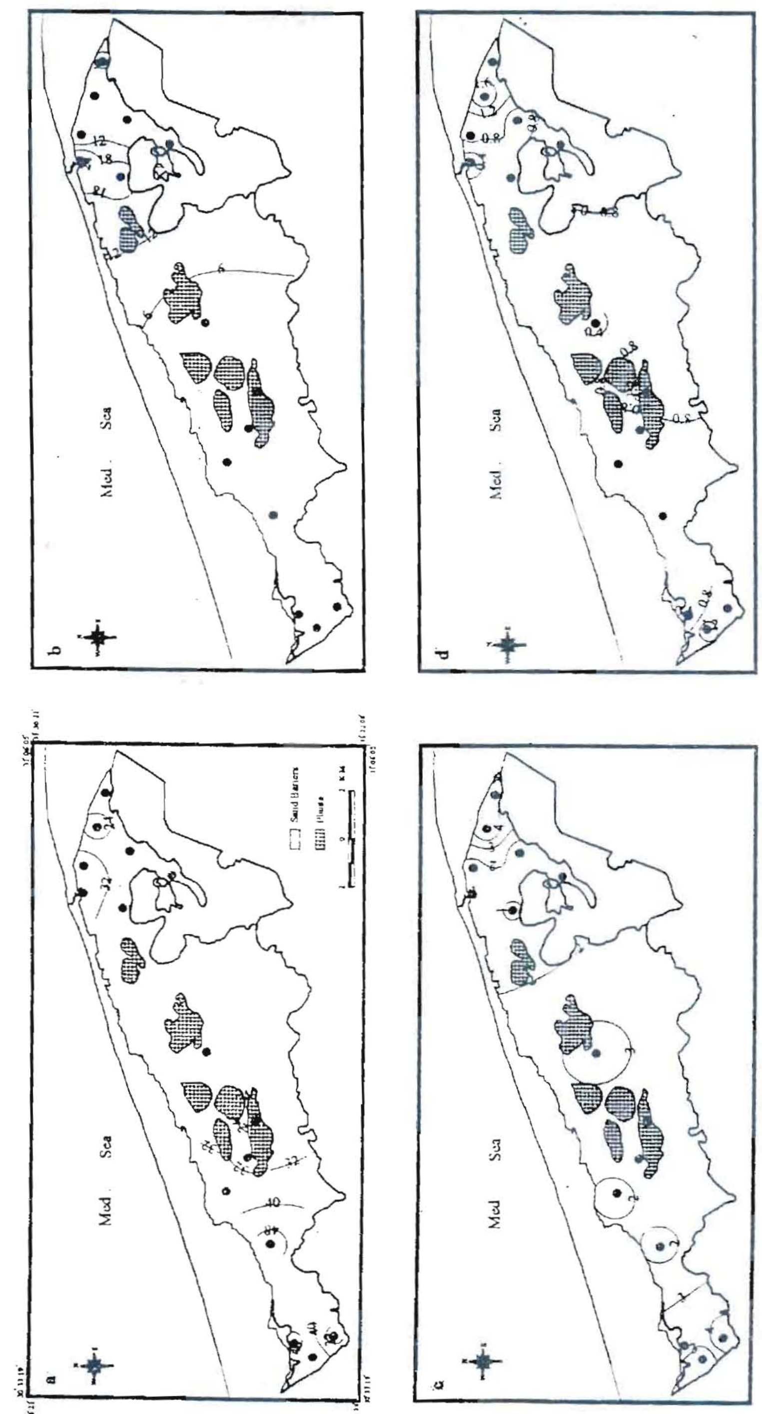

Figure (4) : Spatial distribution of (a)Transparency (Cm), (b) Salinity (psu), (c) Nitrate NO3 (µg/l), (d) Phosphate PO4 (µg/l), in Burullus Lagoon .

industrial discharge source to the lagoon. This may explain the low content of chlorinated pesticides found in the samples. The total concentration of BHC, a-BHC, Heptachlor, d-BHC, Aldrin, o.p- DDE, pp DDE, Dieldrin, o.p. DDD, o.p. DDT, pp DDD and pp DDT was determined. The lagoon water contained between 144×10^{-6} ppm and 1421×10^{-6} ppm, with an average of 825×10^{-6} ppm. Brenbal canal, discharging fresh Nile water has an average of 835×10^{-6} ppm. Individual compounds a-BHC and d-BHC show higher concentrations in Brenbal canal and Al-Boughaz area. Also Drain #11, El-Kodea and Al-Burullus drain show high concentration of pp DDE.

Chemical analysis of Tilapia fish samples [the main fish species in the lagoon] of the lagoon has concentrations of Cu [19.8-69.3 ppb] with an average of 38.9 ppb. It has also high concentrations of Cd ranging between 2.8 and 9.4 ppb with an average of 5.08 ppb. Fishes collected from drain 9 have the highest concentration of Cu, while samples collected from drain 8 have the highest concentration of Cd.

Biological material analyzed for chlorinated pesticides shows that Tilapia collected from the lagoon as well as the drains contained ca. 1000 times the concentrations reported for the lagoon water; however, fishes of different species and from different locations showed different concentration factors. Average concentration of pesticides in fishes of the lagoon ranges between 418 ppb and 10.56 ppb (Abdel-Kader, 1982).

The bottom sediments in Burullus Lagoon 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 lagoon, the carbonate contents reach higher values (up to 75%) due to dominance of mollusca. The sediments in the eastern part of the lagoon have the lowest carbonate content. The organic matter content of the sediments of Lagoon 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 Lagoon.

Steps towards a better Management of Burullus Lagoon

The present work aims to evaluate the important problems that exist at Burullus lagoon for better-integrated management of the lagoon ecosystem. Also; we attempt to carry out an environmental assessment within the lagoon to be used as a lesson learned for any other lagoon management processes. This assessment is based on identifying main problems and key issues, effects and causes as well as possible actions are suggested for further improvement of the lagoon.

Key Issues, Effects and Causes Identification

Most of the world wide coastal lagoons are undergoing very rapid changes as a result of accelerated man-made activities combined with natural influences. To better develop integrated plans for improvement, conservation of the examined lagoons and their future management, main key issues are identified. The existing environmental problems of Burullus lagoon are mainly related to natural and man-made influences.

Natural Factors

Lagoon inlets are capable of changing their cross-sectional dimensions (depth/width) quickly, migrating rapidly along the shore, and even closing completely (Leathrman, 1991). Siltation problems of the Burullus lagoon inlets generally take place as a result of the combination of sand transport in the longshore and cross-shore directions (Fanos *et al.*, 1995). Siltation causes shoaling or closing the lagoon inlets resulting in navigation hazards, decreasing water flow in and out through the inlet channel, as well as negative implications on fishing activities. Keeping the inlet open is important for the fisheries to keep the salinity down and to allow migratory movements.

The sand barriers of Burullus lagoon 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 Aswan High Dam in 1964. This problem causes shoreline retreat of the lagoon barrier and hence reducing its function as a nature protective line from sea invasion (Orlova and Zenkovitch, 1974; Fanos *et al.*, 1995; Ahmed *et al.*, 2000).

Low-lying littoral deltaic regions are highly vulnerable to even minor changes in sea level, particularly because most deltas are actively subsiding.

bream, and sea bass are collected from collection centers scattered along the discharge canals (lagoon inlets) connected to the Mediterranean sea. However fresh water fish fry especially Tilapia and Carp are produced artificially. The number of fry collected is fluctuating between 96×10^6 and 148×10^6 during 1989/90 - 1994/95 (GAFRD, 2001).

Recently, an intensive aquaculture development has been initiated in the Burullus lagoon especially along the northern and southern boarders. This aquaculture and other construction such as roads and canals have subdivided the existing lagoon. Fragmentation of this lagoon will accelerate conversion of natural wetlands to anthropogenic use (Stanley and Warne, 1993). Also, the inhabitants in the coastal zone of the Nile delta have initiated uncontrolled filling activity for land reclamation for gaining agriculture land or new land for constructing housing around the lagoon margin. These activities increasingly reduce the natural size of the lagoon. During the period 1984-2000, the area suitable for fishing activity increased by 18.2% relative to the whole area of the lagoon. This is due to the expanding use of reclaimed land in aquaculture activities particularity in the southern parts of the lagoon (Fig. 5).

Naturally, coastal lagoons have high organic production so they are important nursery environment for juvenile fish fry (Phleger, 1981). The illegal harvesting of the fry fish in Burullus lagoon could also negatively effect the future fish production.

Pollution

Lagoon Burullus is influenced by fresh water runoff from land via drains and canals. This water enrich the lagoon with nutrients including phosphate, nitrate and silicate. The total N and P inflow to the lagoon through drains is 2318 and 558 T/y respectively (Abdel-Moati *et al.*, 1990). However, despite receiving such huge amount, the lagoon is considered mesotrophic due to the precipitation of the nutrients adsorbed on suspended matter opposite to the drainage area. In addition, some of these drains discharge considerable amount of sewage and industrial wastes directly into the lagoon increasing the levels BOD and chlorinated pesticides. The high concentrations of phosphorus nitrogen in the organic wastes, pesticides as well as heavy metals in water and sediments have altered the ecosystem of this lagoon. The lagoon areas adjacent to these drains have been deteriorated and subsequently eutrophicated. The degree of pollution in the lagoon varies from low in the western part to very

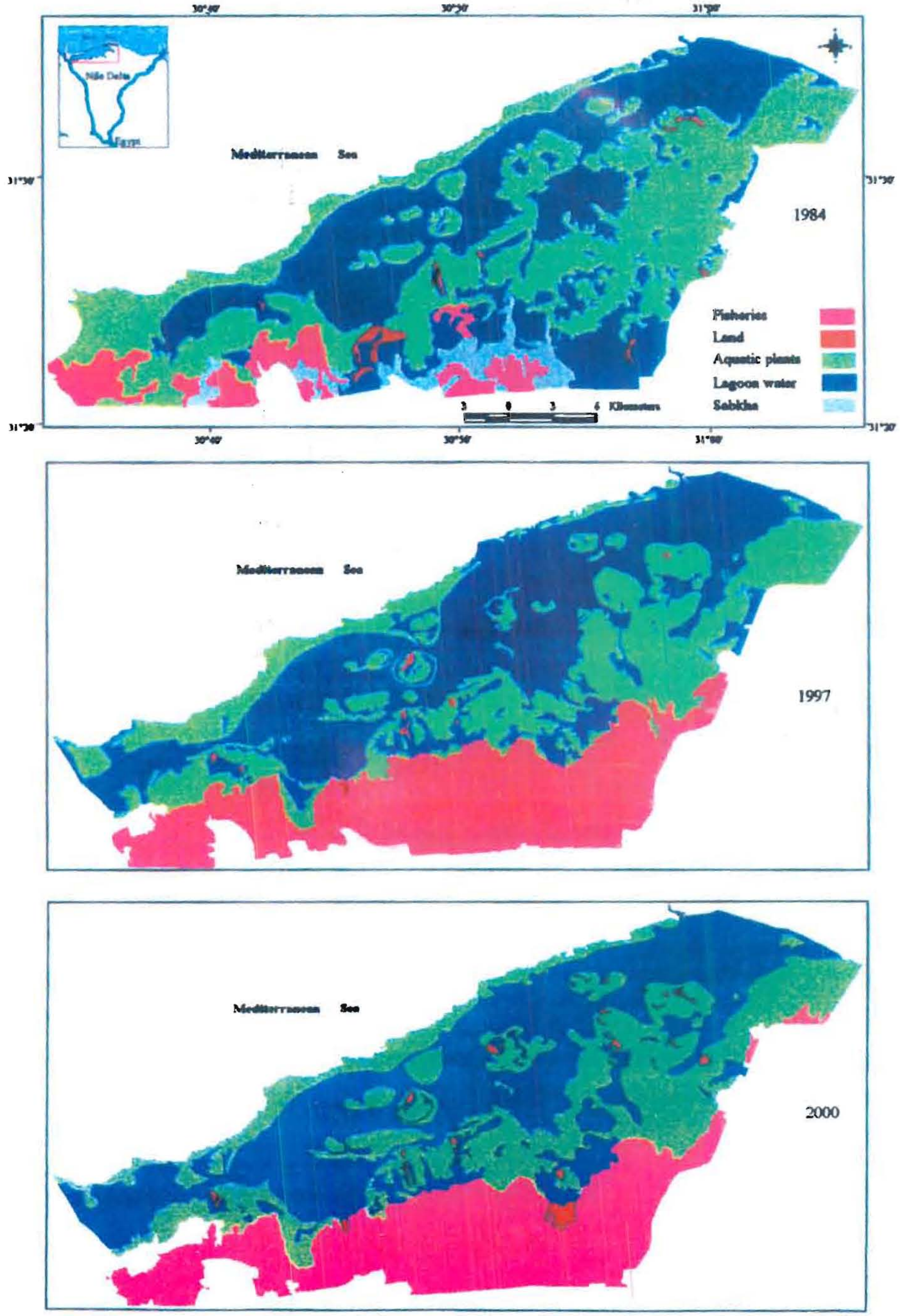

Figure (5) : Environmental Changes of Burullus lagoon during the last two decades using TM-Satelite images

high in the eastern part. In view of increasing pressure in the coastal zone, great amount of pesticides, insecticides and fertilizers are used for agricultural fields around the lagoon. Pollutants are washed out from these fields to the canals and drains and then directly to the lagoon.

Reclamation

Large parts of the lagoon have been dried up due to land reclamation. Reclamation activities aims to gain new land for cultivation, aquaculture and for building illegal houses. The processing of satellite data and some published data were used to estimate average rate of lagoon areas dried. The results show that Burullus lagoon has been intensively reclaimed being at present less than (21%) of its former size. Burullus lagoon has been reclaimed rapidly at an average rate of 4.1 km^2/ year (Ahmed *et al.*, 2000). Results of image classification show that areas recognized as sabkhas are reduced with 2 km^2/year and nearly disappeared by the year 2000 (Fig. 5).

Recreational activities

As a matter of fact, Burullus Lagoon has not been managed for any recreational uses. Two artificial inlets associated with long jetties, 500 m long, were constructed to connect the large lagoon with the Mediterranean. These protruded jetties have created local erosion along adjacent beaches on the down drift side. In addition a large tourist village was built around the lagoon. These activities include: swimming, wind surfing, boating, sunbathing, beach sports, etc. This zone is presently undergoing extensive investment development. The large-scale summer recreational experience, at the time being, exerts potential problems resulting from increasing human pressure and man-made interventions. The improper management of the remarkable white calcareous sand beach has created some serious erosional environmental problems. As a consequence, rapid and uncontrolled tourism development has created many human infringements on the coastal area and subsequently impact on the coastal zone. This impact have changed the shoreline stability and expected to alter the water quality of the sea.

General recommendations

Lagoon management is a dynamic process, the rules keep on changing, and the problems 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 is therefore absolutely necessary. In the absence of main tools

- Develop a decentralized remote sensing and geographic information system (GIS) capability to collect and upgrade available data and to help decision makers on local and national scales.
- Upgrade awareness by providing the public with special training programs on problems of the coastal lagoons with illustrative examples for protection and management
- Develop a contingency plan for protection and emergency measures

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