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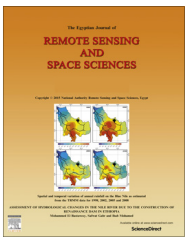

RESEARCH PAPER

Change detection and restoration alternatives for the Egyptian Lake Maryut

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Abstract This paper analyzes all changes that occurred to the Egyptian Lake Maryut in order to identify the best strategy for restoring it. Four scenes were used for change detection; three LANDSAT images (dated 15th of March 1991, 2nd of May 2004, and 22nd of May 2013), and the fourth scene was a SPOT-HRV image dated 16th of August 1995. Maximum likelihood classification (MLC) algorithm was used to classify the images. The next step used was to focus on land cover changes by using change detection comparison (pixel by pixel) and the cross tabulation technique to analyze changes for the four supervised classification images. The results indicated that severe land cover changes occurred in different land covers especially in the last few years that may be due to political and socio-economic problems. Finally, a modern method based on the Delphi technique was used to select the best restoration alternative for restoring the Lake Maryut. Results indicate that severe land cover changes have occurred. In addition, the most suitable restoration alternatives are pollution control for the eastern part of the lake and reopening closed parts in its western part.

1. Introduction

In Egypt, the pressure of population on land and its limited resources for producing more food, fodder, and fuel represent a major factor affecting sustainable development. During the last few years, and due to political changes and the absence of tight monitoring procedures, land use/land cover changes are taking place at high rates that make this environment prone to degradation. Planners, resource managers, and decision-makers need a reliable mechanism to evaluate the problem and give alternatives for land restoration including lakes' rehabilitation.

The Governorate of Alexandria hosts about 40% of the Egyptian industrial activities. Most of these activities are dependent on using Lake Maryut, which is located to the south of Alexandria City, either in the cooling process or as a liquid waste dumpsite. In addition, agricultural drainage water (at least six million m^3/day), carrying agro-chemicals and trace metals together with industrial wastes and untreated domestic waste were discharged into the lake (Sestini, 1993). Due to this strong human impact on the lake, many changes occurred to this environment both physical (i.e. changes in land cover/land use and water quality) and biological (i.e. changes in fish catch from 7767 tons in 1962, to 3847 in 1972, to less than 1000 tons in the 808 s) as reported by Halim, 1983. Increased eutrophication and emission of H_2S gas from the lake and salinity have

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also exacerbated the problem. These negative effects together with socioeconomic changes facing the country have put a tremendous pressure on Lake Maryut.

The objective of this study is to identify and assess the changes that occurred in the lake's ecosystem over the past two decades. All the different impacts on the lake are also listed and categorized, and results are used to identify options for restoration and sustainable development of the lake.

2. Study area

The present Lake Maryut represents a small portion of a larger lake that was known during the Roman era by Lake Mariutus. It extended for 80 km parallel to the north coast and 30 km south of Alexandria city, as shown in Fig. 1.

3. Data

The data used in this study could be classified into two groups. The first data group is the remote sensing images. Four scenes were used; LANDSAT-TM dated 15th of March 1991; SPOT-HRV dated 16th of August 1995, LANDSAT ETM + dated 2nd of May 2004; and LANDSAT ETM + Dated 22nd of May 2013. Fig. 2 represents the most recent image taken, as an example of those images.

The second data group used in this study is the GIS information with the field surveys' data used in building the geographic information system, like topographic maps, field survey databases, classified satellite images, and statistical data.

4. Image classification

The hybrid classification technique done through the ERDAS software was carried out for all available satellite images using MLC algorithm (Paola and Schowengerdt, 1995). Only 14 themes were found separable, as shown in Fig. 3. These are:

- Deep, shallow, and turbid water classes (representing 3 water bodies classes);
- Wet vegetation class (representing water hyacinths in the lake);
- Vegetation (two classes; annual crops and complex vegetation);
- Barren land (represents those agricultural areas with no vegetation cover);
- Wet land (on the margin of the lake and some logged areas);
- Orchards (mainly fig trees and some palm trees);
- Bare soil, Calcareous bare soil (two classes);
- Urban and Build up areas (one class includes roads and tracks);
- Calcareous sediments (represent those unconsolidated, high calcium carbonate content soil); and
- Limestone (and highly calcareous consolidated soils).

4.1. Post-classification (accuracy assessment)

An equal number of random points was chosen for each class in the supervised classification images for accuracy assessment. This is equal to $(n + 1)$, where "n" is the number of obtained classes (i.e. equal to 15 points). Then, around each created random point, a polygon of size 9×9 pixels was created for testing. Thus, the total number of points used for each class is equal to 1215 $(9 \times 9 \times 15)$ points. Results obtained indicated that the overall classification accuracy for LANDSAT TM scene taken in 1991 was 98.0%; for SPOT–HRV scene taken in 1995 was 98.6%. On the other hand, the accuracy percentage was 96.7% for the LANDSAT–ETM image taken in 2004, while it was 98.9% for the LANDSAT–ETM scene for the year 2013.

Figure 1 Location of the study area.