MONITORING OF LAKE NASSER USING REMOTE SENSING AND GIS TECHNIQUES

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ABSTRACT:

To improve management of the main water resource in Egypt, the River Nile, the Aswan High Dam was constructed and fully operated between 1964 and 1971 aiming to control the floods and fluctuation in water provisioning levels, regulating the water releases (and store extra water) and generating hydroelectric power. Since that date, Lake Nasser, the water storage body behind the dam, was born, and it was subjected to many studies covering the quantity and quality of stored water and environmental resources. In this research, the environmental impacts, including morphological aspects, and sedimentation in the lake, was carried using remote sensing images. Spectral reflectance characteristics of the water were correlated with in-site data measurements to analyze spatial and temporal changes of characteristics. The fluctuation in water depths leading to changes in the surface area as well as different geometric features of the lake were estimated by classification of the imagery data in spectral reflectance. The lake sediments were studied using digital image processing techniques and detected by the field data for an accurate assessment. Remote sensing techniques demonstrates a reliable environmental and water monitoring efficient methodology to the biggest artificial lake, Lake Nasser.

1. INTRODUCTION

Lake Nasser is a reservoir in the course of the Nile river formed as a result of the construction of the Aswan High Dam. It is located at the border between Egypt and Sudan between latitudes 21.8 to 24.0°N and Longitudes 31.3 to 33.1°E. Its surface area is about 5200 Km2 with a maximum capacity of 165 km3 and mean depth of 25m, its surface elevation is 175m. The lake is circa 550 km long (more than 350 km in Egypt and the rest in Sudan) and 35 km across at its widest point. It plays a main role in the local and national economy. That is reason why the water levels are accurately controlled.

Remote sensing has become an important and major source of geographic information on current land cover and land use needed for rational development and sustainable management of agricultural and forestry resources and for environmental protection. These techniques were also found to be complementary and useful tools to get time series of lake level height that are often difficult to obtain from field measurements. The role of remote sensing as a potential data source, and of GIS as an analytical tool, in developing a management system based on studying the environmental impacts of Lake Nasser showed promising to replace current manual procedures.

2. STUDY AREA DESCRIPTION

Figure 1 shows a location map of Lake Nasser, which represents the world's largest man-made lakes. It is of vital importance for the country, representing Egypt's main reservoir of fresh water. Lake Nasser and the adjacent region are mainly considered as the future food security for the country. To the east of Lake Nasser are the elevated mountain ranges of the Eastern Desert divided by dry valleys concurrently to the west is the low lying sandy Western Desert. The capital of the Governorate is Aswan city. In the north, the dominant feature is the valley of the River Nile which extends 140 km from Aswan City to the border of the Governorate north of Edfu City. South of Aswan City lies Lake Nasser, which extends 350 km from Aswan City to the international borders with Sudan.

Figure 1. Location map of Lake Nasser

In 2000 it was estimated that 1,063,000 persons were resident in the Governorate of Aswan. Almost 99.3% of the population live in the northern section of the Governorate, while the remainders are in Lake Nasser area. The urban population accounts for 40% of the population. Approximately 29% of the population is engaged in agriculture and fishing, some 28% in personal and social services, 11% in manufacturing industry 7% in construction, trade, transport, storage and communications, and 2% in tourism. In recent years the proportion of the population engaged in agriculture has declined whilst that engaged in all other sectors increased. The greatest increases between 1986 and 1996 occurred in the financial services, manufacturing and tourism sectors (Barber, 2001). Its surface area is about 5200 Km2 with a maximum capacity of 165 km3 and mean depth of 25m, its surface elevation is 175m. The lake is some 550 km long and 35 km across at its widest point.

One of the most concerned features of Lake Nasser is the complex nature of its shoreline, it changes enormously due to any minor change in the water level. One meter increase in the water level could expand the shoreline for six kilometers.

The shoreline is composed of numerous khors, which are, essentially, inundated desert streams. Most are narrow and meander into the desert for long distances, although some are very wide. There are some 85 major khors, 48 on the eastern side of the lake and 37 on the western side. Allaqi, Kalabsha and Tushka are the three largest khors in Lake Nasser, making up a large part of its total area. Khors support the richest habitats in the lake. Their shallow waters support aquatic flora and provide good breeding grounds for fish; and their often gently sloping shores allow vegetation to grow. Much of the rest of the lake’s shores are steep and rocky with little vegetation. A vast number of islands of various sizes, representing the tops of former hills, are scattered throughout the lake. The number, location and size of these varies greatly with fluctuations in lake-level.

3. PROBLEM STATEMENT

The northern sector of Aswan governorate has virtually all the economic means of production. It also has high levels of unemployment, crowding, poor services, decline of agricultural productivity and hence a high level of out-migration. The southern sector (Lake Nasser area) on the other hand with 73% of the Aswan governorate land area, has a wealth of resources including huge tourist potentials, extractive and mineral resources, fishing activities and above all water abundance from the lake that can be used for irrigation and reclamation of land. This sector currently has less than 1% of the population. The irregular and huge fluctuations in water-level of the lake, poor soils, steep shoreline and inaccessibility are some of the factors that have led to the failure of almost all development efforts along the lake shores. Vegetation and fishing varies greatly with fluctuations in lake-level, one meter increase in the water level could expand the shoreline for six kilometers.

Within this paper, the authors are using GIS and Remote sensing techniques to monitor the reasons that resist the development efforts in this potential area, and try to propose a suitability map of the study area based on the different environmental impacts by analyzing the spectral reflectance characteristics of the satellite images in correlation with other field data available.

4. METHODOLOGY

Three satellite (Landsat) images for Nasser Lake was available in a good time series (1984, 1996, and 2001). Topographic maps of scale 1:50,000, which is suitable to the resolution of landsat images, was used for developing the 10 meter interval contour maps and consequently the Digital Elevation Model – DEM, Figure 2, Slope in Figure 3 and Aspect Maps.

The topographic maps were used as well for geometrically correcting the satellite images. ERDAS Imagine, ArcInfo and open-source GRASS packages were applied for data preparation and analysis. Field data for water depths was collected along and across the lake, Figure 4, Figure 5. Then it was compared with the resulting DEM layer for checking and corrections.

Due to the formation of the lake since 1964, the majority of the transported sediments were trapped in the reservoir. It is taken into design, that a dead storage capacity of 31.6 milliard m3 (up to elevation 147m) is used for silt deposition along 500 years. The field data showed that majority of sedimentation through the years and specifically after the date of constructing the high dam is settled in the Sudanese part of the lake.

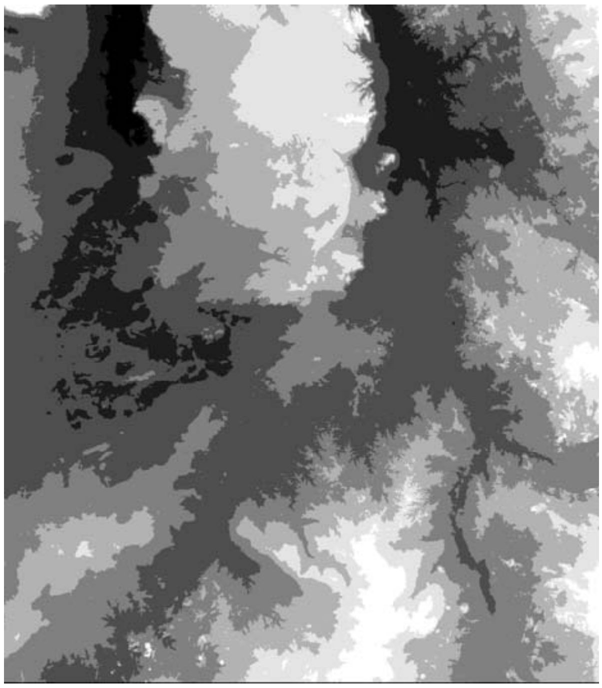

Figure 2. DEM of Nasser Lake area

The sharp decrease in water velocity of the Blue and White Niles when entering the reservoir causes massive deposition of the silt load. As a result the sediment load is filling the reservoir (forming a new delta at its entrance), instead of reaching the downstream of the dam and the coastal delta (Stanley, 1996).

The shoreline of the lake is constantly undergoing wide ranging changes in shape and environment due to natural as well as human development activities. Natural processes such as fluctuated water levels, sand dunes movement, erosion, climatic changes etc., cause long time effect at faster rate; while man made activities, which is very limited, such as settlement, fishing, industrial activities, tourist and recreational activities, waste disposal etc., affect the lake environment at comparatively much slower rate. We have to improve the environment for encouraging the development of this area and to satisfy the basic needs required for their survival.

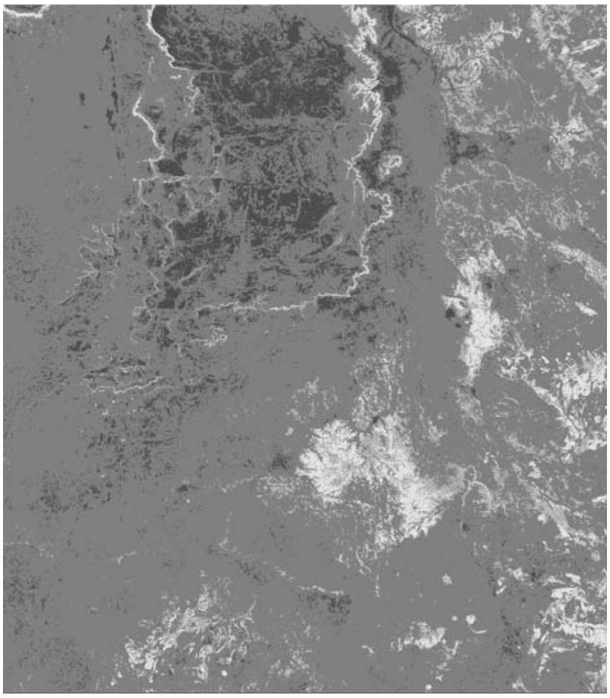

Figure 3. Slope of Nasser Lake area

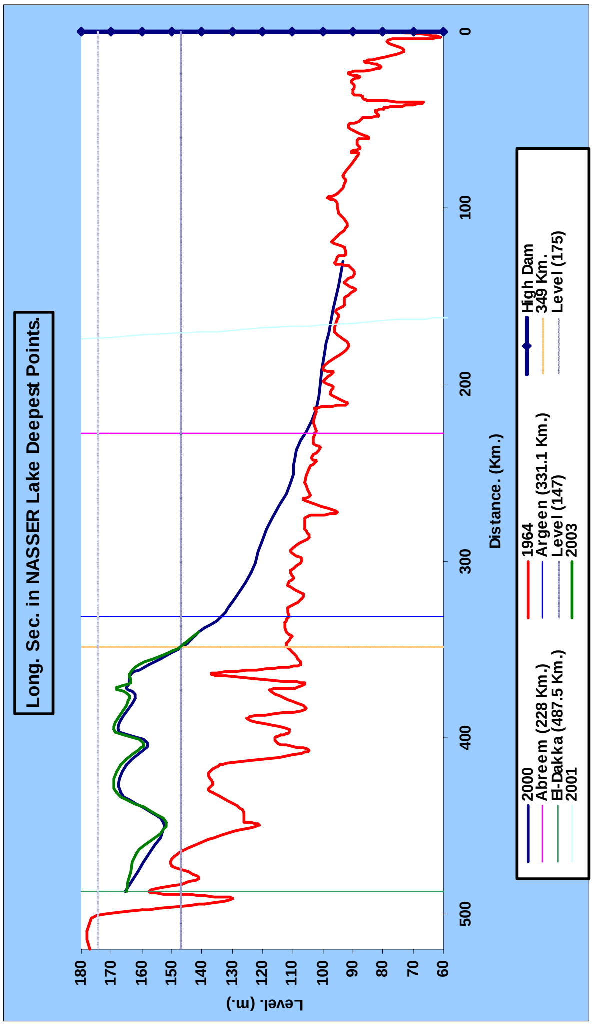

Figure 4. Longitudinal Section in Nasser Lake in different years

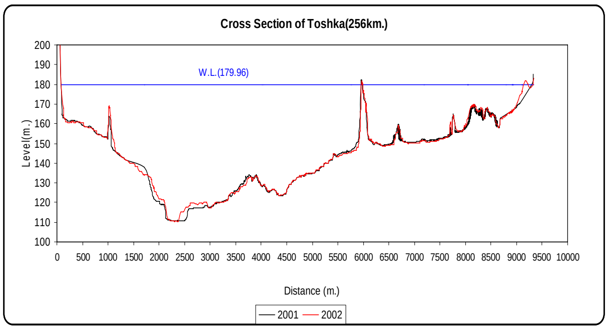

Figure 5. Cross Section at Tushka (256km from the high dam)

The changes in the Lake shape was detected from satellite images in the different years and the edges of water were derived in Figure 6. Figure 7 shows the difference of the Lake shape between years 1984 and 2001 respectively.

Landsat image data are used in studying the shoreline, land-use/land-cover and landform of the Nasser Lake area, which were later integrated in GIS. Change detection analysis are carried out using algorithms developed in GIS environment.

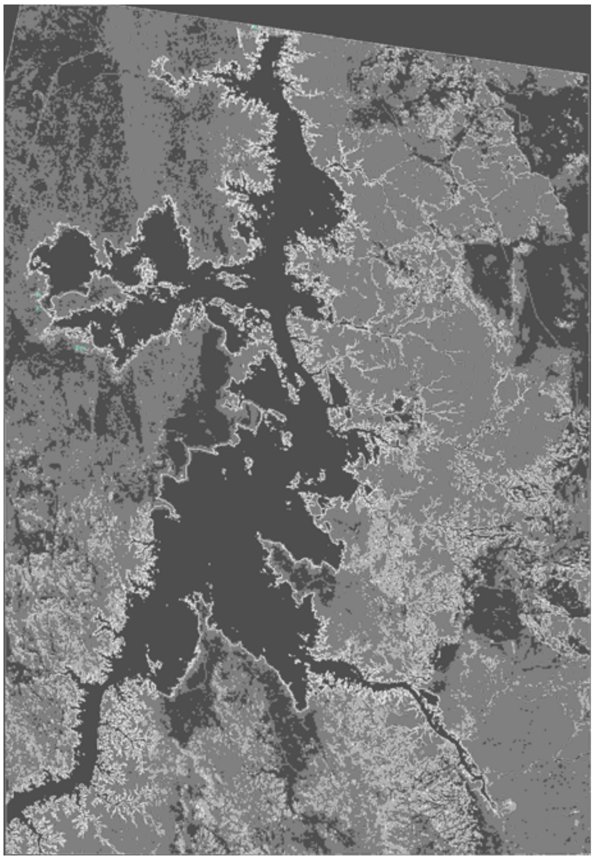

Figure 6. Nasser lake 2001 edge detection

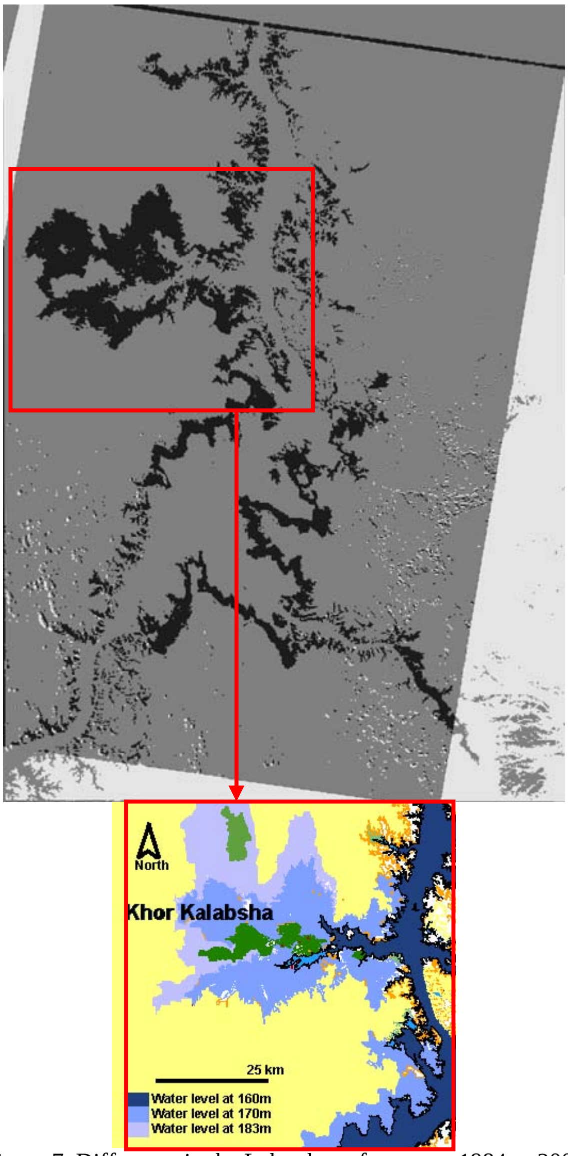

Figure 7. Difference in the Lake shape from year 1984 to 2001

The Land cover map of the lake area, Figure 8, is subdivided into five main classes namely, 1)Water, 2)Sand Sheets, 3)Sand Dunes, 4)Granite Mountains, 5) Basalt Mountains, and 6)vegetation. The classification system focuses on land-cover classes that can be discriminated primarily from satellite remote sensor data, and which is of great influence for any development in this area.

Many cultivation projects in the area was failed due to insufficient information about the nature of the area. From the analysis of the available data, permanent vegetation around the lake would be suitable around contour line of elevation 190m to be away from the flooding which reaches elevation 180m. Suitable slope should not exceed 10% to facilitate irrigation.

The buffering area surrounding the lake is mostly sand which needs to much water to be cultivated. One feddan (about one acre) needs more than 15000 cubic meter of water per year for cultivation.

The climate is typical of a tropical arid region: very dry, with less than 1 mm/yr of rainfall in average. The daily average

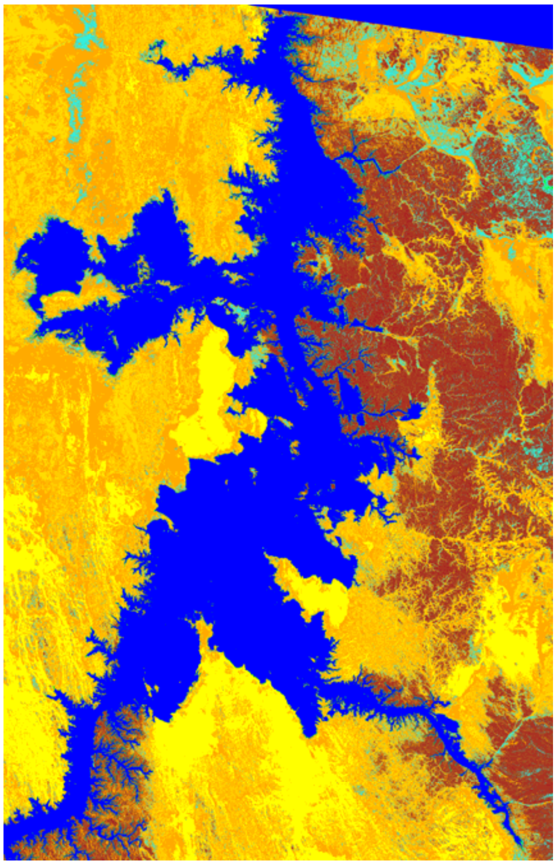

Figure 8. Classified Image of Lake Nasser in 2001

temperatures range from 14oC with relative humidity of 45% in January to 45oC with relative humidity of 19% in July. The average crop evapotranspiration (ET) is around 5 mm/day (equivalent to 21 m3/day/feddans). An agricultural experimental station was established by the Ministry of Agriculture and Land Reclamation (MALR) at Abu Simbel in 1998, with the purpose of developing the area. A Water Research and Studies Complex was established by the NWRC and Ministry of Water Resources and Irrigation in 2000, with the main scope of running the huge infrastructures needed for pumping and delivery of water from Lake Nasser to the Tushka area.

5. ANALYSIS AND RESUTLS

Using remote sensing in a GIS environment combined with the field investigation in Nasser Lake area resulted in several important benefits that can be summarized to outline the importance of developing lake Nasser to embrace a number of different activities in southern Egypt including agriculture, industry, transportation, communications and roads, as well as social aspects and services.

The satellite image helped in detecting the fluctuation in water level and detects the changes in the lake shape. It helps to identify the agricultural areas as well as the natural vegetation areas around the Lake.

The Lake is considered as a fragile ecosystem because of its infant water body formation in the middle of an arid-hot climatic region. Vegetation, animal life, ground water resources, tribal cultures may be easily threatened by large scale-high density development. Already three Nature Reserves have been declared for protection in the study area. Some call for the whole lake to be protected as well and limit any development. The overall concentration of activities means that unlike the Old Valley, development would follow an uneven low-density approach, concentrated in areas of highest resources and spreads with time to areas of fewer resources. This approach is believed to protect the fragile resources of the area and at the same.

Monitoring Lake Nasser through Satellite images and using of GIS techniques is important to the different users involved in the management and operation of the Lake and its relevant projects (like Tushka project). It is considered as a new vision of deploying new technologies in monitoring, operation, and research. Several image processing and spatial query methods could be used to extract information from the maps and satellite images.

6. COINCLUSIONS AND RECOMMENDATIONS

The major part of Egypt is desert (more than 95% of total area). Most of development concentrates in the Nile Valley and Delta which is less than 5% of the area of the country. The discrepancy between the development in the north and south part is not thought to continue for long. The Tushka project is a part of a national scheme to reform this pattern of skewed population; potentials distribution. Twenty four pumps are being installed to raise water to a canal 70km long and provide 25 million m3 per day (290m3/s) to irrigate four areas totaling 540,000 feddans. The works are planned to begin changing the landscape and demographics of the country.

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