MONITORING OF LAKE NASSER USING REMOTE SENSING AND GIS TECHNIQUES

M. M. Mostafa\textsuperscript{a} and H. K. Soussa\textsuperscript{b}

\textsuperscript{a} Information Technology Institute, GIS department - mostafam@mcit.gov.eg
\textsuperscript{b} Ain Shams University, Faculty of Engineering, Irrigation and Hydraulics Dep. - hoda@nbcbn.com


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 Km\textsuperscript{2} with a maximum capacity of 165 km\textsuperscript{3} 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.

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,
especially, 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
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
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.

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.
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.
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 temperatures range from 140°C with relative humidity of 45% in January to 450°C 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 RESULTS

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. CONCLUSIONS 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.

References

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