International Journal of Geographical Information System Applications and Remote Sensing

"المجلة الدولية لتطبيقات نظام المعلومات الجغرافي والاستشعار عن بعد"

Vol. 2, No. 1, May 2011
ISSN 2077-771X; Copyright © ICSRS Publication, 2011
www.i-csrs.org

Shoreline Change Detection of Qadisiya Reservoir

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Abstract

To improve management of the main water resource in Iraq, the Euphrates River, the Qadisiya Dam was constructed and fully operated in 1984-1985 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, Qadisiya reservoir, 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, was carried using remote sensing images from 1992 to 2009. Landsat5 TM 1992, Landsat7 ETM+ 2002, 2003 and EO-1 ALI 2008, 2009 multi-spectral sensor systems were used. Surface area and wetted perimeter were calculated and two steps of software facilities delineated the shoreline as a vector layer for each dataset. The first step used was Lines of Communication (LOC) – Water Technique from ENVI 4.5, and Spatial Analyst Tools from ArcGIS 9.3 was used as the second step. The presented procedure can be used as a comprehensive algorithm to extract effectively and accurately reservoir shoreline.

***Keywords**: Landsat, EO-1, Shoreline, remote sensing, ENVI, ArcGIS.*

1. Introduction

Reservoirs are sensitive ecosystems vulnerable to environmental pollution and very attractive for human activities. They are not only man-made landscape, recreational areas for tourists, electricity generation, drinking and irrigating water reservoirs, but are also gathering places for migratory birds and habitats for millions of animals and numerous types of plants. (Williamson et al., 2008.)

A shoreline is defined as the line of contact between land and a body of water. Although it is easy to define, the shoreline is difficult to capture because of the natural variability of water levels (Ron et al., 2009). Knowledge of shoreline is the basis for measuring and characterizing land and water resources, such as the surface area of the reservoir, and the wetted perimeter of shoreline. Information about shoreline position, orientation and geometric shape is also essential for autonomous navigation, geographical exploration, shoreline erosion monitoring and modeling, and shoreline resource inventory and management as well as it depicts the relationship between the water elevation and the surface area.

Monitoring the temporal hydrological changes is very difficult with the conventional methods. Using remote sensing data and GIS help find solutions to the potential hydrological and environmental problems on time. Furthermore, accurate, fast and low cost data/ information can be obtained in the studies aimed at determining the potentials in hydrological and environmental changes and updating relevant information.

There are concerns that hydrological boundary conditions and ecology of Qadisiya reservoir had changed in recent years. Possible causes for this change include climatic and land use changes as well as construction of many large dams on Euphrates in Turkey.

Conventionally, shorelines were manually identified and traced by cartographers with a pencil on vellum paper overlaying on aerial photographs. Due to the subjectivity and substantial effort involved in manual delineation, a comprehensive approach to extract effectively and accurately Qadisiya reservoir boundary was done in this research in two stages.

2. Study Area

Qadisiya reservoir lies on the Euphrates River, in Iraq, 8 km north of Haditha city long. $41^o55'$ to $42^o27'$ easting and lat. $34^o13'$ to $34^o40'$ northing as shown in Figure 1. Qadisiya reservoir has a maximum water storage capacity of 8.3 km^3 and a maximum surface area of 500 km^2. Actual capacity is however 7 km^3, at which size the surface area is 415 km^2 (Jones et al., 2008). At maximum capacity, annual evaporation from the lake is estimated at 0.6 km^3 (Kliot et al., 1994). The average reservoir water level changes were shown in Figure 2 (http://www.legos.obs-mip.fr/en/), which can give with geographical of the region an initial depicts about the shoreline.

By means of satellite images, it is possible to display in visual format and express in digital values the changes in shoreline areas, starting from the past up until today. One of the most important problems in management of the shoreline areas is to define how the natural conditions have been in the past. When multi-temporal satellite images are used, development of the impact of the dams on shoreline areas can be ascertained. The remote sensing datasets used were shown in Table 1.

3. Methodology

Changes in the shoreline morphology had been examined using multi-temporal and multi-sensors with multi-spectral satellite images of the study area related to different dates. In addition, ENVI 4.5 and ArcGIS 9.3 had been used in two stages to show temporal changes as shown in Figure 3.

In the first stage, ENVI 4.5 had been used with Lines of Communication (LOC) – Water Tool and supervised spectral processing (Spectral Matching) was done. Applying atmospheric correction, internal average relative reflectance (IARR) had been chosen, which is similar to flat field calibration in that a reference spectrum is divided into each pixel in the image to generate relative reflectance. The reference spectrum for IARR is the mean spectrum of the entire image, rather than that of a user-defined ROI. IARR requires no user input.

Selecting suitable region of interest (ROI) for distinguishing water regions was part of methodology. Normalized Difference Water Index (NDWI) where selected as a spectral processing parameter. NDWI works in the same manner as the common NDVI transform used to map vegetation. NDWI produces a single grayscale image, where water is bright. The NDWI is sensitive to changes in vegetation canopy water content because reflectance at 857 nm and 1241 nm has similar but slightly different liquid water absorption properties. The scattering of light by vegetation canopies enhances the weak liquid water absorption at 1241 nm. Applications include forest canopy stress analysis, leaf area index studies in densely foliated vegetation, plant productivity modeling, and fire susceptibility studies. NDWI is defined by the following equation:

$$NDWI = \frac{\rho_{875} - \rho_{1241}}{\rho_{875} + \rho_{1241}} \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

The value of this index ranges from -1 to 1. The common range for green vegetation is -0.1 to 0.4 (Gao et al., 1994).

In the second stage, ArcGIS 9.3 had been used with condition on NDWI image (after normalized from 0 to 255), such that if a pixel value is greater than or equal to suitable selected threshold value (*T*), the best was found *T=132*, then set pixels equal one and else zero, the new binary raster can be converted easily with Conversion Tools From Raster to Polygon as in Figure 4. The geometric calculations/ (wetted perimeter and surface area) were done to the resulted polygons, as show in Table 2, which gives an indication to the magnitude change in shoreline with its year.

4. Conclusions

The results describe the effort towards shoreline delineation for multi-temporal satellite images from multi-sensors to support management and decision-making in the dynamic shoreline environment. Despite the successful applications of the presented procedure on satellite images, it should be noted that the quality of the image sources remains an important factor for shoreline extraction. The success still depends upon whether considerable contrast exists between water and landmasses.

In the application view, Shorelines geological condition has a direct impact on erosion and according to Iraq Soil Map (1961); the demonstrated soils surrounded by Qadisiya reservoir are sandy and silty soil which are classified within the easily eroded materials. Thus, it is very important to take the effect of sediment and erosion processes in shoreline regions inherent to dynamic shoreline changes in consideration by causing in long term changing in reservoir capacity.

The presented work can be integrated with effect of climatic; annual rainfall and evaporation; for long term and analysis about Digital Elevation Model (DEM) in order to create an equation for shorelines in order to predict the position of shoreline in the future. Accordingly, such a study can help in decision making.

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Table 1: Satellite images used in details.

Satellite	Sensor	Path/ Row	Date
Landsat5	TM	170/ 36	August 1, 1992
Landsat 7	ETM+	170/ 36	May, 24, 2002
Landsat 7	ETM+	170/ 36	May, 18, 2003
EO-1	ALI	170/ 36	March, 5, 2008
EO-1	ALI	170/ 36	April, 14, 2009

Table 2: Area and Wetted Perimeter for the shoreline with its year.

Year / Geometric	August1,1992	May,24, 2002	May,18,2003	March,5,2008	April,14,2009
Wetted Perimeter (m)	290.81	509.62	484.51	409.49	253.38
Area (km^2)	376.748071	340.391831	382.575652	294.378895	136.390335

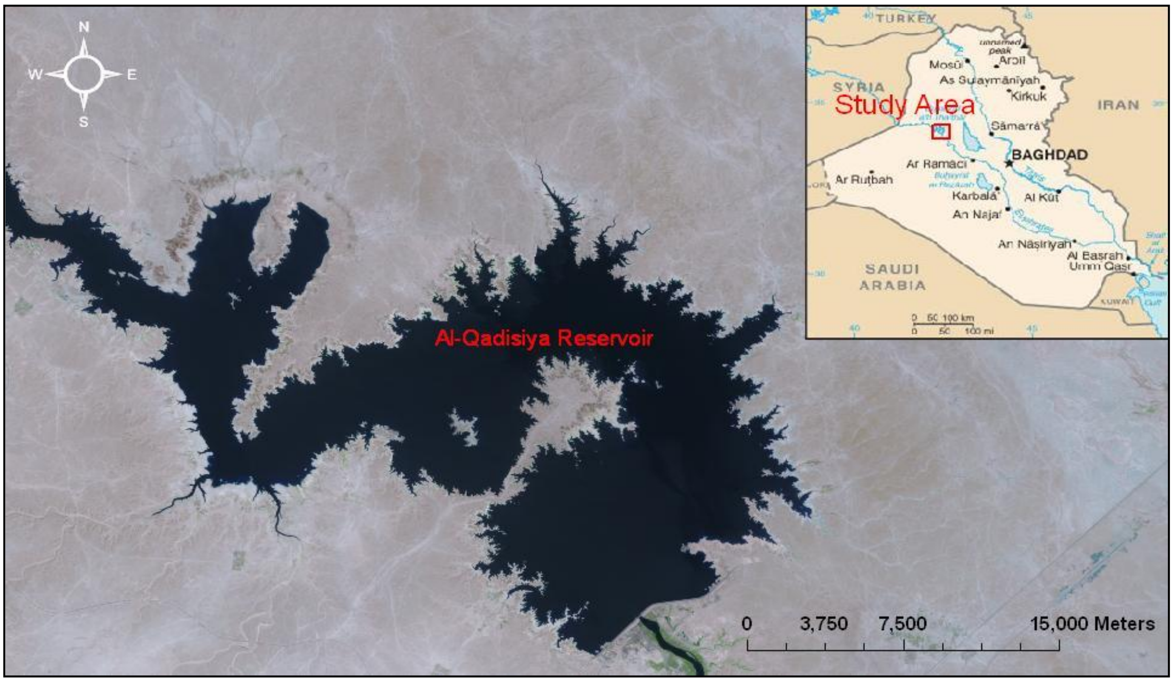

Figure 1: Study Area Location.

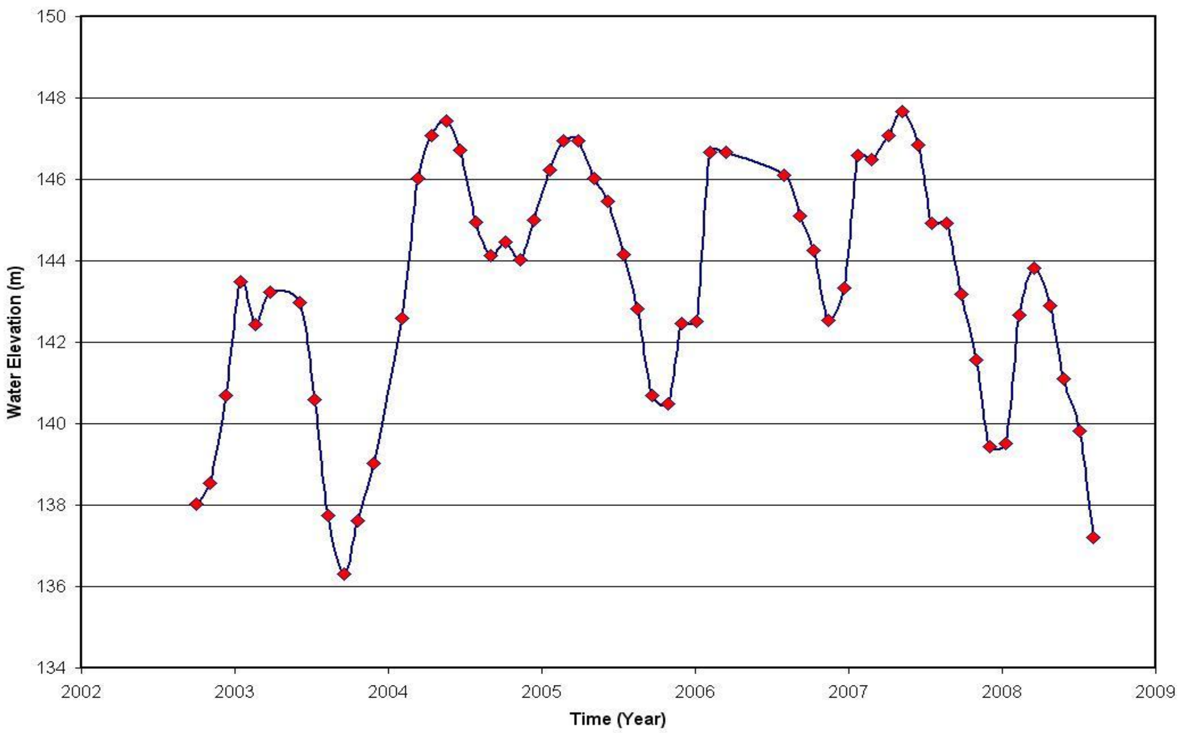

Figure 2: Average Reservoir Water Level Changes.

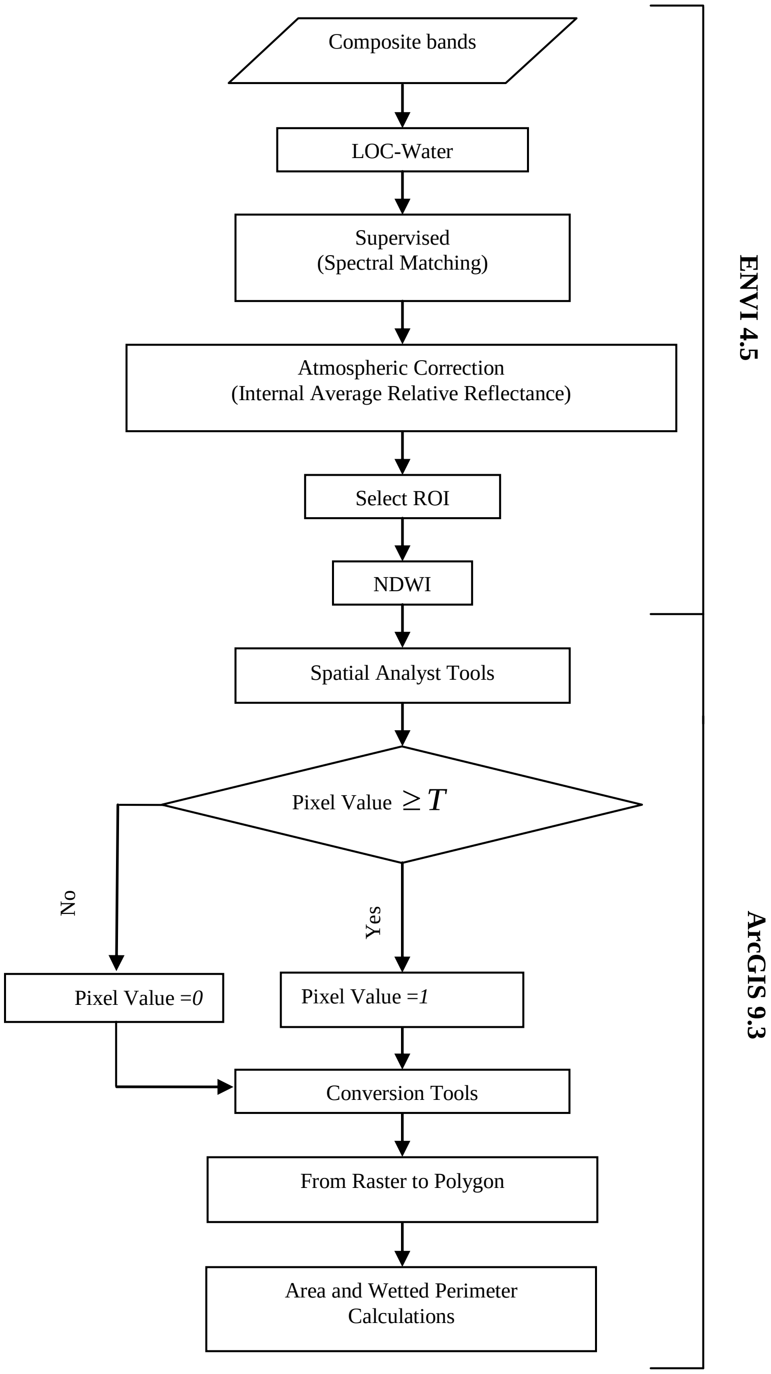

Figure 3: Methodology Flowchart.

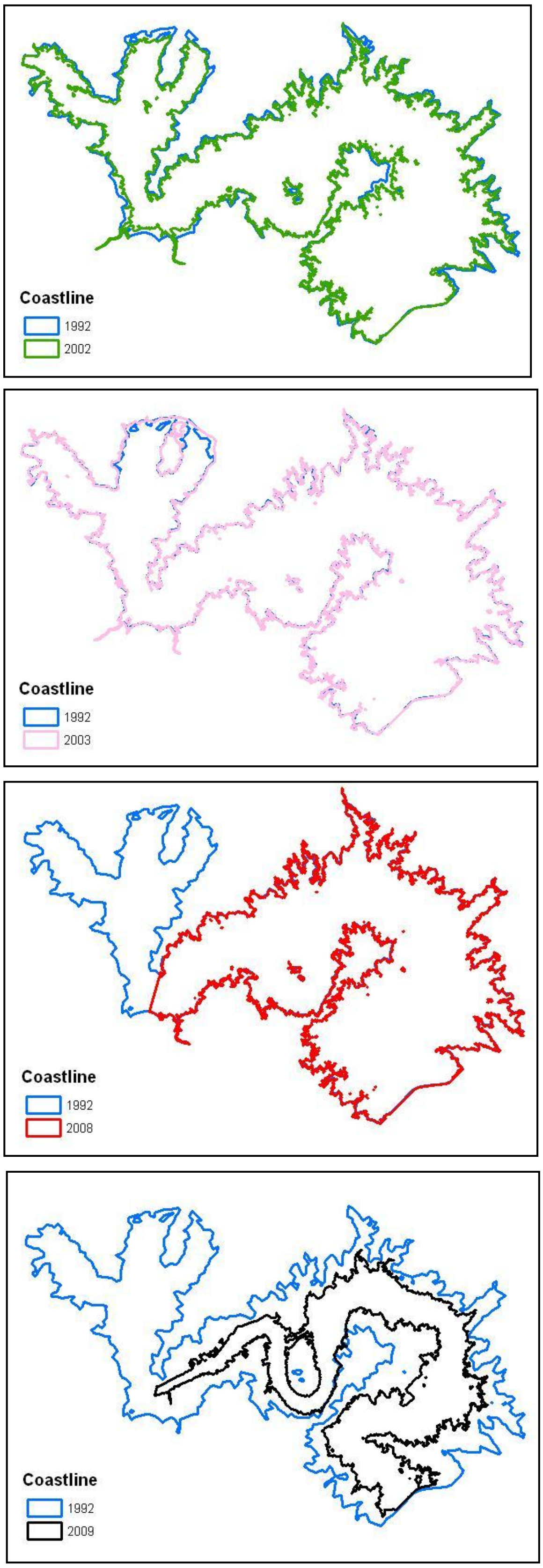

Figure 4: Temporal Coastline Comparison, date 1992 considered as the base date.