Detection of Shoreline Change in AL-Thirthar Lake using Remotely Sensed Imagery and Topography Map

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Abstract

This research introduces an efficient method to deduce shoreline changes of AL-Thirthar Lake using time series, satellite TM data dated 1990 and topography map in scale metric 1:100 000, dated 2003 covering the same geographical area. This research utilized the experience-conditions/ (thresholds) of different bands to recognize the total region of AL-Thirthar Lake. Taking DNs less than or equal to (45) in band 4, and DNs less than or equal to (36) in band 5. These conditions extract lake body from other image features. Various shorelines should be used to detect lake levels change. The area of the lake has been decreased approximately (444.16) km^2 from 1990 to 2003. These results have been verified through TOPEX/Posidon satellite information that indicate a height variation of approximately 21 m. This study was performed using ArcGIS9.3, ENVI4.5 software, and MATLAB7.8a language.

Introduction

Shoreline is defined as the line of contact between land and the water body. It is one of the most important linear features on the earth’s surface, which displays a dynamic nature. It could be regarded as the most unique feature on the earth's surface. The location and attributes of shorelines are highly valued by a diverse user community; because they have never been stable in either their long-term or short-term positions.

The monitoring of the processes that occur along the shoreline rapid reliable techniques are required to monitor and update shoreline maps of these areas to explore rates of environmental retreats. Fluctuations of the lake level cause significant changes in the nature of its shores [1, 2].

The delineation, extraction of shorelines and water bodies, (e.g. rivers and lakes), is an important task useful for various application fields such as shoreline erosion monitoring, shore region management, watershed definition, flood prediction, and the evaluation of water resources. This task is difficult, time consuming, and sometimes impossible for a large region, when using traditional ground survey techniques, due to several reasons such as: water bodies can be fast moving like in floods, shore movement because of erosion and deposition, presence of inter-tidal mudflats and marshy areas along the shore most of which are misclassified as parts of water, water level changing and storm surges or may be inaccessible.

Tracing the shoreline manually, although easy along relatively simple stretches of shore, is not practical where the shoreline becomes very complex. Pixels quite often represent the mixture of different spatial classes especially in relatively coarse spatial resolution like Landsat imageries. Intermixing pixels of water-saturated land that represent shallow water bodies in satellite imagery may affect the discrimination of accurate shoreline boundary [3, 4].

Approaches to detect shoreline changes can be roughly divided into four categories, all of which have both advantages and disadvantages: (1) conventional ground surveying can achieve high accuracy of measurement, but it is labor intensive and time consuming; (2) modern altimetry technology uses radar altimeters or laser altimeters. It has a great potential, but the detectors are currently less available; (3) airborne imagery measurement provides sufficient pictorial information, but the frequency of data acquisition is low, and the photogrammetric procedure including data acquisition and image mapping is costly as well as time consuming [6]. (4) Multispectral remote sensing satellites provide digital imageries in infrared spectral bands where the land-water interface is well defined. Furthermore this method has advantages: not time consuming, inexpensive executed cost and large ground coverage monitoring [5, 1].

This paper examines the current method of shoreline change detection using time series satellite image and topography map. Based on the experience-condition for discrimination of land/water boundary, and only based on pixel values to acquire the better results in the shoreline investigations. Changes in the shape of shoreline may fundamentally affect the environment of the shore region. The shoreline in this area is very sensitive to external conditions, causing by natural processes such as sedimentation, erosion from storm impact, tides, topography, accretion and human activities. [6, 7].

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (multi-temporal datasets). Timely and accurate change detection of Earth’s surface features provides the foundation for better understanding relationships and interactions between human and natural phenomena to better manage and use resources [8, 9].

A few NASA satellites designed to study heights of Earth's ocean surfaces are now also coming in handy for tracking water levels of inland lakes and reservoirs. NASA/CNES satellites fly over 350 of the world's largest lakes. The records begin with archived data from TOPEX/Poseidon satellite, launched in 1992. This satellite is in orbit at a height of 1330 km, and sends back information that measures the average ocean height very accurately, and gives you a good indication of whether there is going to be a systematic or major problem in water supply. If water is low, there may be problems for agricultural production. AL-Thirthar Lake in central Iraq provides irrigation water to areas downstream. It is also linked to the Tigris and Euphrates rivers. A drought that is carried over many years severely cuts grain output between 1999 and 2002. But since then, rainfall has increased, allowing grain production to recover and even surpass pre-drought levels [10, 1].

Study Area

The available studied scene is AL-Thirthar Lake, which is located in Al-Anbar province of Iraq. Geographic location of AL-Thirthar Lake is shown in Fig. (1), 120 km^2 north of Baghdad between the Tigris and the Euphrates rivers.

The available image and the test scene topographic map were TM exposure at 1990, and designer at 2003, respectively illustrated in Fig. (2). The satellite image band combination was (R: 5, G: 4, and B: 3), and the upper left corner is lat. 34°38'23.02"N, long. 42°53'18.32"E and the lower right corner is lat. 33°38'35.34"N, long. 43°39'44.32"E. It covers (2059.42 km^2), average Lake level is (52.32 m). It is the largest lake in Iraq.

Methodology

There are different characteristics for light scattering from all kinds of objects, which exhibit different intensity information in remote sensed images. Intensity experience-conditions utilize the water's intensity information to delineate shoreline feature. Shoreline feature extracting by experience-conditions technique need to be defined based on bands: TM3, TM4, and TM5, with band combination of 5, 4, and 3 as RGB. The algorithm for delineating the shoreline for the satellite image is:

(i) Applied the condition, which is explained in the following equation:

$$TM4 \leq 45 \text{ and } TM5 \leq 36, \ldots\ldots.(1)$$

(ii) Generated the binary image using MATLAB7.8a language, by setting the pixel value equals (1) for lake, otherwise equals (0).

(iii) Exported the binary image to ArcGIS9.3 software, and used Spatial Analyst Tools to delineate the lake as a shape file and calculate its surface area and length.

For the topography map, the algorithm is:

(i) Used ArcGIS9.3 Editor to delineate the boundary of the lake as a shape file.

(ii) Used Spatial Analyst Tools to calculate the surface area and the length of the lake.

In order to assess the accuracy of these results and analysis of the shoreline change of AL-Thirthar Lake, they had been compared with ground truth observations, as shown in Fig. (3) which illustrates the relative lake elevation variations computed from TOPEX/POSEIDON satellite data [11].

Experimental Results and Discussions

The area and length of the shoreline of AL-Thirthar Lake for the satellite image were: 2059.42 km^2 and 944.396 km respectively and for the topography map were: 1615.26 km^2 and 532.112 km respectively. The outcomes of shorelines were shown in Fig. (4).

The total height variation of AL-Thirthar Lake is approximately (21 m) as illustrated in Fig. (3), where in April 1993 was (63.51 m), and in September 2001 was (42.98 m).

The regression and transgression for changing the shoreline was affected by many factors such as climatic changes, the neglect policy, operating large dams in Turkey, and the natural of soil surrounded by AL-Thirthar Lake, which are classified within the eroded materials.

Conclusions and Suggestions

The research presents a new procedure to delineate the shoreline from satellite image and topographic map depends on TM4, TM5 using Matlab 7.8a and ArcGIS9.3

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

The presented work can be integrated with effect of climatic; annual rainfall and evaporation; for long term and information about Digital Elevation Model (DEM) in order to create equation for the shoreline to predict the position of shoreline in the future. Accordingly, they will be able to make reasonable decisions. For a large shoreline, such that it can't contain in a single scene, mosaic must be done for images in different dates, in such case the converting from digital number (DN) of the image to reflectance is very important since this conversion provides a basis for standardized comparison.

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Fig. (1): Location of Study Area.

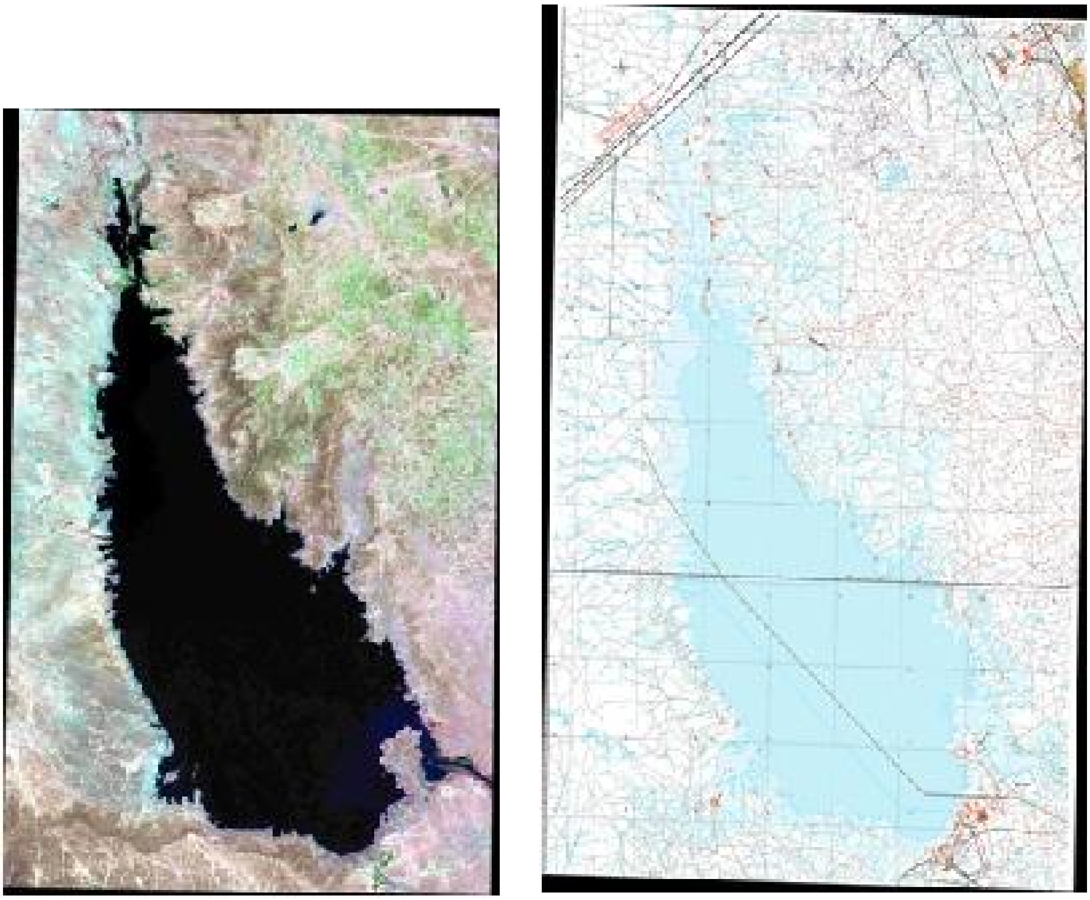

Fig. (2): Tharthar Lake, (2756× 3623) pixels with band combination (R: 5, G: 4, and B: 3), and Topographic Map, scale 1:100,000 Zone 38 North, Projection UTM, Datum WGS84

Fig. (3) Water Levels of AL-Thirthar Lake (1992-2008)

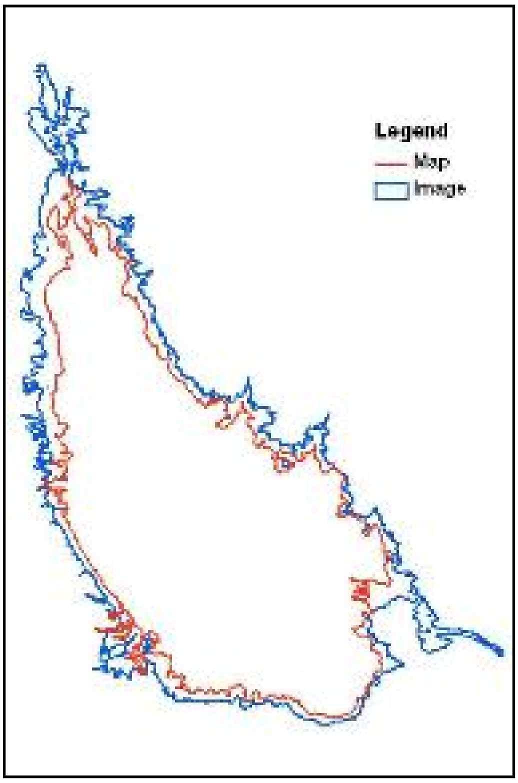

Fig. (4) Comparison of Map and Image Shorelines

كشف تغييرِ خَطِّ الشاطئ لبحيرة الثرثارِ باستعمال الصور المتحسسة عن بعد والخريطة الطوبوغرافية

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الخلاصة

يُقدّمُ هذا البحثِ طريقةَ كفوءةَ لمُرَاقَبَة تغييرات خَطّ شاطئِ بحيرةِ الثرثار، باستعمال الصورة الفضائية للقمر الصناعي TM بتاريخ 1990نفسه و خريطة العراق الطوبوغرافية بمقياس متري يعادل000 1:100, بتاريخ 2003 تغطيان الموقع الجغرافي. تم في هذا البحث استعمال شروط تجريبية \ (محددات) لحزم مختلفة لتمييز المنطقةِ الكلّيةِ لبحيرةِ الثرثار . بأخذ القيم الرقمية للحزمة الرابعة أقل من أو يساوي (45) والقيم الرقمية للحزمة الخامسة أقل من أو يساوي (36). تعطي هذه الشروطِ وصفاً لمستويات البحيرةِ لهذه المدد الزمنية المختلفةِ. تكشف خطوط الشاطئ المختلفة التغير بمستويات البحيرةِ. نُقِصتْ مساحة البحيرة تقريباً (444.16) كيلومتر مربع مِنْ 1990 إلى 2003. تم التحقق من النتائج من خلال معلومات القمر الصناعي (TOPEX/Posidon) التي تشير إلى اختلاف ألارتفاع تقريباً (21) مترِا". الدراسة تمت باستعمال برامج ENVI4.5,ArcGIS9.3 ولغة MATLAB7.8a.