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Technical Note

Investigation of coastline change of the Urmia Lake using remote sensing and GIS (1990 - 2012)

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Abstract: The study on water level fluctuation in the Urmia Lake has become of a great importance in recent years. This is due to the importance of the position of this lake as a natural heritage at an international level. The water level decrease at the Urmia Lake during the recent years has made it necessary to address the matter more than before. Investigation and assessment of changes in the Lake is necessary because it is the largest international wetland and one of the Iranian National Parks. The main purpose of the current study was to investigate changes in the Lake water levels using satellite imagery and GIS technique, preparing and processing multispectral Landsat images in 1990, 1998, 2006 and 2011, classifying the images and extract the land use map for these four time periods. Results of this study indicated that the Urmia Lake has faced significant decrease in water level during the past twenty years, especially in the past decade. Also, the surface area of the Lake decreased by 3052 km^2 and the salt area increased from 1990 to 2011. The present study indicate the incidence and development of environmental crisis in the region. Hence, it is essential to take into account the entire social, economic, and environmental considerations as well as all the macro-environmental issues at a regional scale to save the Urmia Lake

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Introduction

Monitoring of coastal area is a necessary task in sustainable development and costal environment management and protection. For coastal area monitoring, the coastline mapping in different times is a fundamental work. The coastline is determined as the line of contact between the land and the water body (Sugumaran et al., 2004). The coastline is one of the important linear features in the environment, which has a dynamic nature (Rasoli et al., 2007; Winarso et al., 2001). Remote sensing performs an important task for spatial data acquisition from economical perspective (Ozesmi and Bauer, 2002). Satellite images are simple to interpret and easily obtainable. Furthermore, absorption of infrared wavelength region by water and its strong reflectance by vegetation and soil make such images an ideal combination for mapping the spatial distribution of land and water. These characteristics of water, vegetation and soil make the images containing visible and infrared bands being widely used for coastline mapping (DeWitt et al., 2002). Examples of such images are: TM (Thematic Mapper) and ETM+ (Enhanced Thematic Mapper) imagery (Moore, 2000).

Lake Urmia in the northwestern corner of Iran is one of the largest permanent hyper saline lakes in the world and the largest lake in the Middle East (Zarghami, 2011; Hassanzadeh et al., 2011; Karbassi et al., 2010). It extends as much as 140 km from the north to the south and is as wide as 85 km from the east to the west during the high-water periods (Jalili

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et al., 2012). The Lake was recognized as a wetland of international importance by the Ramsar Convention in 1971 and designated a UNESCO Biosphere Reserve in 1976 (Birkett and Mason, 1995). The lake itself is home of a unique brine shrimp species, *Artemia urmiana*. It supports many species of reptiles, amphibians and mammals. Lake Urmia provides a very important seasonal habitat for many species of migratory birds. Around 200 species of birds have been documented on and around the lake including pelicans, egrets, ducks, and flamingos (Ebrahimi, 2010). The watershed of the lake is an important agricultural region with a population of around 6.4 million people. It is estimated that 76 million people is resident within a radius of 500 km. Mapping changes of coastline for the Urmia Lake using TM imagery is the main aim of this paper. Furthermore, a new semiautomatic approach for coastline extraction from TM imagery has been developed and presented.

Material and Methods

Study Area: The Urmia Lake, as the largest water body in Iranian plateau is located between two major provinces of the Eastern Azerbaijan and west Azerbaijan bounded between 37° 5´ - 38° 16´ N and 45° 01´ - 46° E at 1275 m above sea level (Fig. 1). Its surface area ranges from 4750 to 6100 km^2 and the average and greatest depths account for 6 and 16 m, respectively (Azari Takami, 1993). More than 20 permanent and seasonal rivers as well as a few submarine streams and springs feed the lake. The average salinity of the lake ranges between 220-300 mg/l depending on temporal and spatial conditions, in recent years it has reached to more than 380 mg/l. Due to the ecological heritage of the Uremia Lake, it has been recorded as a protected habitat in the world by the United Nations (Eimanifar and Mohebbi, 2007).

Methodology: For this study, 12 predominantly cloud-free Landsat TM images of the Uremia Lake (path 168, row 34; path 169, row 33; path 169, row 34) were selected. The Landsat images covering the entire Lake Urmia coastline were acquired from the

Figure 1. The study area.

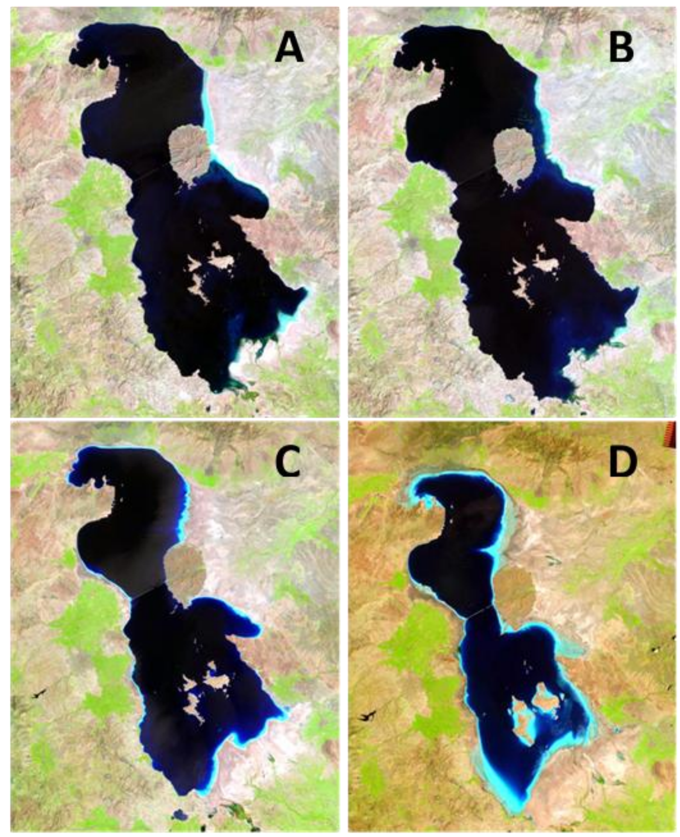

Figure 2. Mosaicked satellite images of 1990 (A), 1998 (B), 2006 (C) and 2012 (D).

US Geological Survey (USGS) website. Data collected within the same year and seasons were best for this kind of study. The satellite images were geometric corrected using 1:25000 topographic maps using maximum neighborhood correction and then radiometric (Chander and Markham, 2003) and atmospheric correction was operated by ENVI 4.5 (Chavez, 1998). For each period of study (1990, 1998, 2006, 2012), three images were mosaicked and final images were prepared (Fig. 2). Then

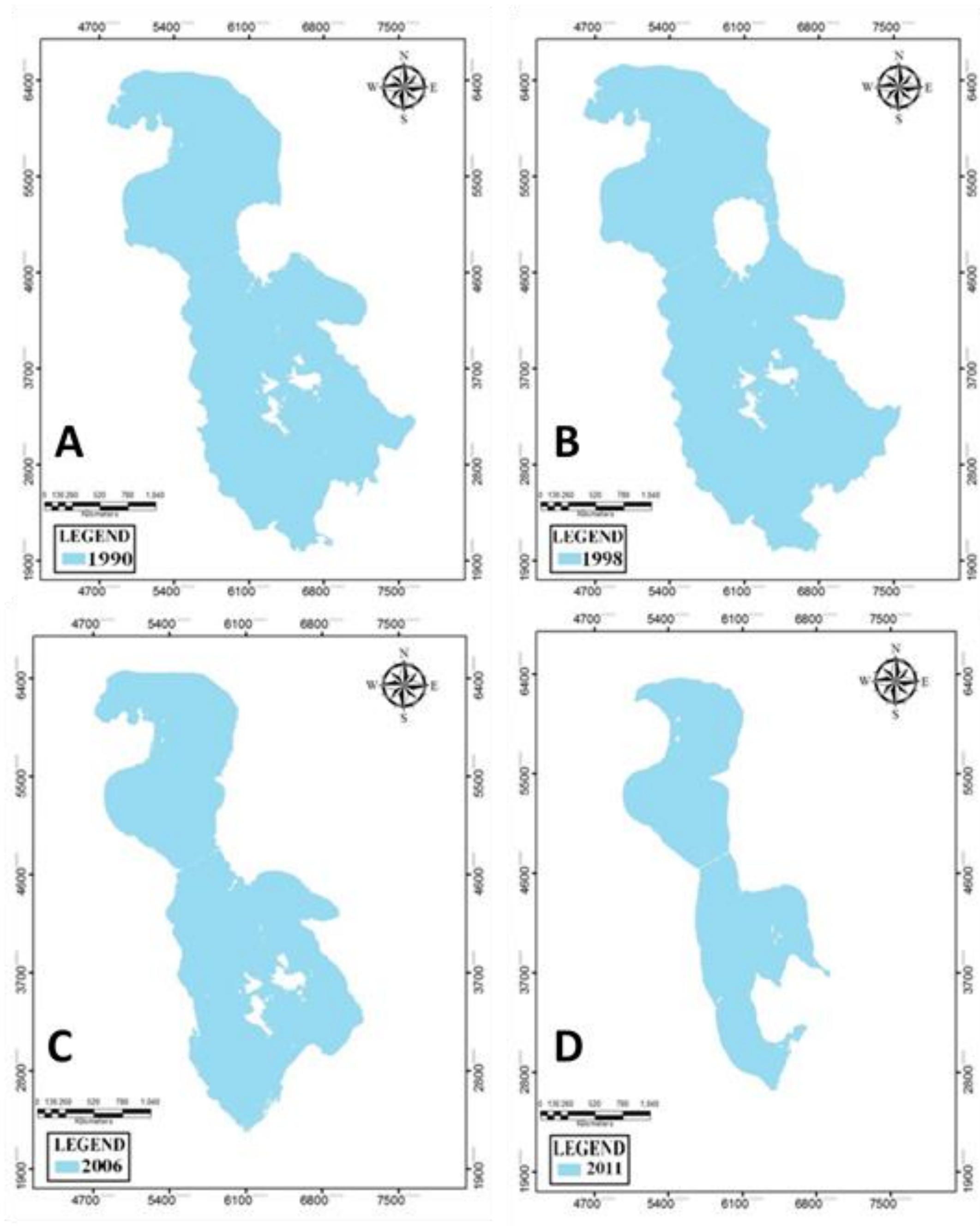

Figure 3. Prepared maps for 1990 (A), 1998 (B), 2006 (C) and 2012 (D).

Table 1. Lake Urmia area in study period.

Year	1990	1998	2006	2012
Area (km^2)	5418	5637	4125	2366

unsupervised classification and K-means were used for image classification. According to the study goals, two land use/cover classes were defined including water body and others (Anderson et al., 1976) in ENVI 4.5. Three bands were used (bands 3, 4 and 5) for Landsat 4/5 TM images. Then the water body of Lake Urmia was separated in ARC GIS 9.3 and finally the layout of maps was prepared.

Results

Image analysis showed significant changes during the study period (Fig. 3). Also the analysis of maps

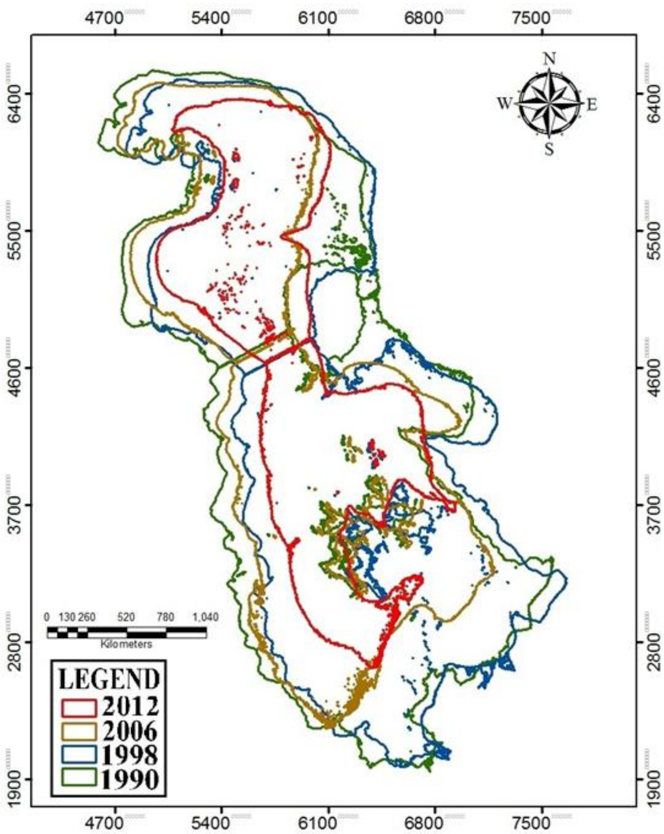

Figure 4. Coastline change detection during 1990 to 2012.

showed that water surface area had increased by 219 km^2 from 1990 to 1998, from 1998 to 2006, decreased by 1512 km^2, and finally from 2006 to 2012 decreased by 1759 km^2. The maximum decrease occurred during 1998 to 2012 (Table 1). Our results indicated that the Urmia Lake lost 56% of the total surface from 1990 to 2012 (Fig. 4).

Discussion

In the present study, coastline changes and water surface were determined using Landsat-TM images and unsupervised classification method, respectively. Whereas Karimi and Mobasheri (2011) in a similar study, used several remote sensing images containing Landsat-MSS, Landsat-TM, Landsat-ETM+ and MODIS sensors. The authors have used supervised classification method to determine water surface. Our results are very close to theirs. We also found a great decrease of coastline changes in 1998 to 2006 which has begun in 1998. In other research Alesheikh et al. (2007) had similar results. Great changes have happened as a result of 3 meters decrease in height of water of the Lake. It seems that the role of human factors and impacts is more than natural factors in the destruction of the lake (Reveshty and Maruyama, 2010).

To investigate the reasons of reduction decrease in depth of the lake, several theories have been brought up. For example, some workers believe that the Shahid Kalantary causeway, which divides the lake, prevents the water circulation and this has caused the salinization of the lake. However, recent study shows that the impact of this causeway on the salt content of the lake is not significant. Construction of dams and diversion of surface water for agriculture, along with reduced precipitation and warmer temperatures over the basin, and to a lesser extent reduced inflow of groundwater are generally among the possible causes (Hassanzadeh et al., 2011; Hoseinpour et al., 2010; Eimanifar and Mohebbi, 2007). Reduced water volume concentrates the salts in the lake making it very saline for the brine shrimp which is near the bottom of the simple food chain support the very diverse bird populations.

Water conservation within the basin might provide some relief. However, finding the volume of water needed to restore the lake, without going outside the watershed, would probably require water from important areas of irrigated agriculture. Water transfer from the Caspian Sea would be very expensive and time consuming and may come too late to avert damage to the ecosystem by the historically low water levels and high salinity that are already occurring. Diverting water from neighboring watersheds would be less costly and time consuming but also has some serious challenges. A comprehensive integrated water management plan would take all the elements of the basin's water budget into account, balancing demands for irrigation, ecosystem preservation, social and human impact and water quality as well as operating within the national and regional political events.

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