THE USE OF SPECTRAL SIGNATURES IN EXTRACTING INFORMATION FROM WATER QUALITY PARAMETERS IN THE LAKE URMIA, IRAN

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Abstract

Lake Urmia, the second hyper-saline lake in the world, because of its climatic and economical importance has created a populated region in Iran, and in return its fragile ecosystem has been affected by the presence of this growing population. The economical and social importance of the connection between the population centers in both sides of the lake has encouraged the construction of a causeway; which consequently has been divided the lake into northern and southern parts. Thus, the navigational and hydrological links have been limited to a gap. The aim of this paper is to study the impacts of the division of the lake in water quality parameters such as salinity and sediment concentration and the efficiency of the implemented gap in connecting two parts using remotely sensed data. The multi-temporal Landsat images were used in order to observe the spatial and temporal variations of water quality parameters. The preliminary examinations of the image data have shown that some patterns could be detected through using image composites. To examine the spatial variability of the parameters, certain transects were drawn over reflective and thermal bands and then the spectral signatures were analyzed. Some changes in the spectral behavior of water were studied by the selection of homogenous regions of the lake from both sides of the causeway. The images were closely examined to follow the changes using image processing techniques. The study of spectral signatures of the selected regions of different times revealed a significant difference between two sides of the causeway having increased spatial variability. Thus, it can be concluded that the observed differences of two sections in under-study parameters could be attributed to the blocking effect of the causeway and inefficiency of the gap in preserving the link. The crucial importance of the lake in the region and its endangered ecosystem prompts for continuous study and monitoring of the parameters using remote sensing.

Key words: Lake Urmia causeway, Landsat TM, water quality parameters, salinity, sedimentation

1. Introduction

The economical and social importance of the connection between the population centers in both sides of Lake Urmia (Fig. 2) encouraged the construction of a road over it. In 1979, one of the country's largest national projects was launched to facilitate road and rail transportation. In order to preserve navigational and hydrological link between the north and south parts of the lake an opening was implemented but may not be successful in maintaining proper linkage. The causeway over the lake has caused changes in its natural conditions. These changes affected the sedimentation pattern inside the lake as well as the spatial pattern of surface temperature in the lake.

The lake has been the subject of several studies focusing mainly on the chemistry, geology, limnology, resource assessment and sedimentology of the lake based on field samplings. Kelts and Shahrabi (1986) examined the sedimentary record of the lake and projected the evolutionary steps of the lake. They found evidences of historical water-level fluctuations. Comparing the consequences of the causeway in Lake Urmia with those of earthworks in Great Salt Lake in Utah, USA, Nazariha (2002) concluded that the north part of the lake will become more saline. Ahmadi (2002) studied the Physiochemical characteristics of samples of Lake Urmia water from five stations in the north and south of the causeway. The results showed that the electrical conductivity in the north part is greater than south part. Thus, he concluded that the dissolved salt is greater in the north part. He argued that the north part of the Lake nourishes much from saline waters than the south part which nourishes much from opening. Alipour (2006) has done a systematic study of the geochemistry of the lake Based on regular samples from the lake.

Remote sensing by providing a dense grid of information has been used to aid in-situ point observations of hydrologic variables. Remote sensing has been used to monitor spatial extent, organic/inorganic constituents, depth, and temperature of water in rivers, reservoirs, lakes, seas, and oceans (Jensen, 2000). The total radiance recorded by a remote sensor from a water body is a function of electromagnetic energy from four sources (Fig. 1).

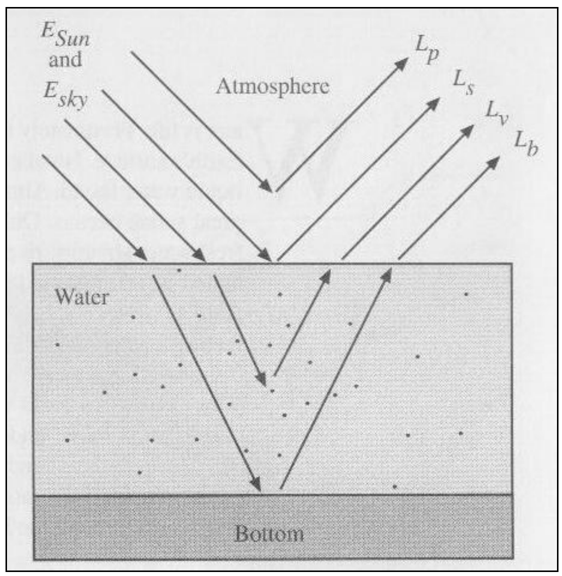

Fig.1. Four sources of electromagnetic energy recorded by remote sensor (After Bukata et al., 1995)

Water bodies receive irradiance from the sun (E_{sun}) and atmosphere (E_{sky}). The total radiance exiting from a water body towards the remote sensor is a function of the radiance form atmosphere scattering (L_p), water-surface radiance (L_v), and radiance from the bottom (L_b) of the water body (Jensen, 2000).

There has been a significant amount of research to develop methods for quantitative measurement of water quality parameters by means of remote sensing technology. Carpenter and Carpenter (1983) used MSS data to study water quality parameters of fresh-water lakes located on south-east Australia. Khorram and Cheshire (1985) investigated the feasibility of providing water salinity map using MSS data. Bhrgava and Mariam (1992) studied the combined effect of water salinity and solid suspended sediments on the spectral reflection of water in a lab and concluded that the reflection level is positively correlated with the density of suspended substances and negative correlation with salinity level. Thus, reflection decrease with suspended minerals decrease and salinity increase. Using Landsat TM data and field observations, Serwan (1993) studied water quality parameters like solid suspended substances, salinity, and temperature and modeled the relationship between TM bands and water quality parameters. The model was used to predict and provide map of water quality parameters.

Remote sensing has not been used widely in the study of Lake Urmia. Barzegar and Sadeghian (1991) used MSS, RBV and SPOT image data to investigate the effect of the causeway on the general circulation of the water body between 1972 and 1986. They concluded that the Highway had caused changes in the natural water circulation and hence the process of sedimentation will lead to possible blocking of the gap by deposition of sediments in the opening.

The purpose of this study is to examine the impact of construction of Kalantary highway over Lake Urmia using remote sensing observations and to provide a background for the constant monitoring of the lake's fragile ecosystem by means of this technology

2. Study Area

Lake Urmia (a protected biosphere reserve) is the second large hyper-saline lake in the world and the largest inland lake in Iran. This sodium-chloride lake has extended between 37 40' 0" N and 45 30' 0" E over an area of about 52000 km2 in the semi-arid region of the North-West of Iran and has created a natural barrier between two populated provinces of East and West Azerbaijan and their bustling capitals, Tabriz and Urmia. Geologically, the lake is known to be of tectonic origin. The lake receives water from 13 rivers of varied length. The water of the lake has been classified as Na-Mg-SO4-CL type (Eugster, 1980). The lake shows an annual fluctuation of about 1 m due to high evaporation during the summer. In the stressed environment of the lake, species are limited to Artemia Salina and Olena. The hydrologic link between northern and southern parts was maintained by the 15 km wide section which has been narrowed down to a 1.5 km opening.

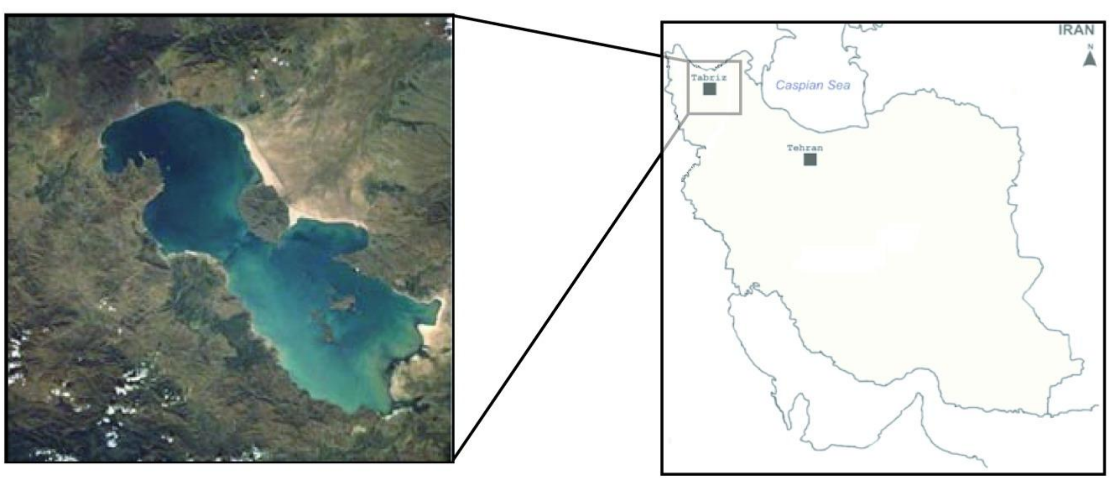

Fig.2. the study area

3. Data Set

Multitemporal Landsat TM image data acquired on August 1990 and May 1998 were used in this study. Landsat TM provides multispectral data in 7 spectral bands in visible, near infrared and thermal regions of electromagnetic spectrum with a resolution of 30 m in VNIR and 120 m in thermal bands.

4. Methods

For investigation of water quality parameters and the impacts of highway construction on the distribution of these parameters, several image processing methods were adopted. False color composites (RGB 3-1-7), contrast stretching, PCA and NDVI were used to detect the suspended load diffusion pattern over the lake. To examine the effect of the causeway in distribution pattern of the suspended substances, spectral profiles were used in the different sections of the Lake. In order to evaluate the information content of different TM spectral bands for recognizing level and distribution of suspended substances and the salinity, some sample image regions from different areas of the lake were taken. These regions were used to extract statistical information in order to compare different bands. Band 3 was selected as the most informative band by calculating the mean value of pixels in each region and as the most sensitive band to the changes in water quality parameters in the lake (Fig. 3). Based on the above results, band 3 was use for determining the proportional salinity distribution and thermal data of band 6 was used to investigate the spatial distribution of the surface temperature in both sides of the causeway by means of spectral profiles.

5. Results and Discussion

5.1. Spectral behavior of solid suspended substances in water and the impact of the causeway on their distribution patterns.

Fig. 3a shows FCC (7-1-3) of 1998 Image. It is obvious that considerable amount of suspended materials is transported to the lake by Adji-Chay River and Shahi Island drainage systems from east and Shahar-Chay and Barandoz-Chay Rivers from the west, which may be evidences of a rain prior to satellite imaging.

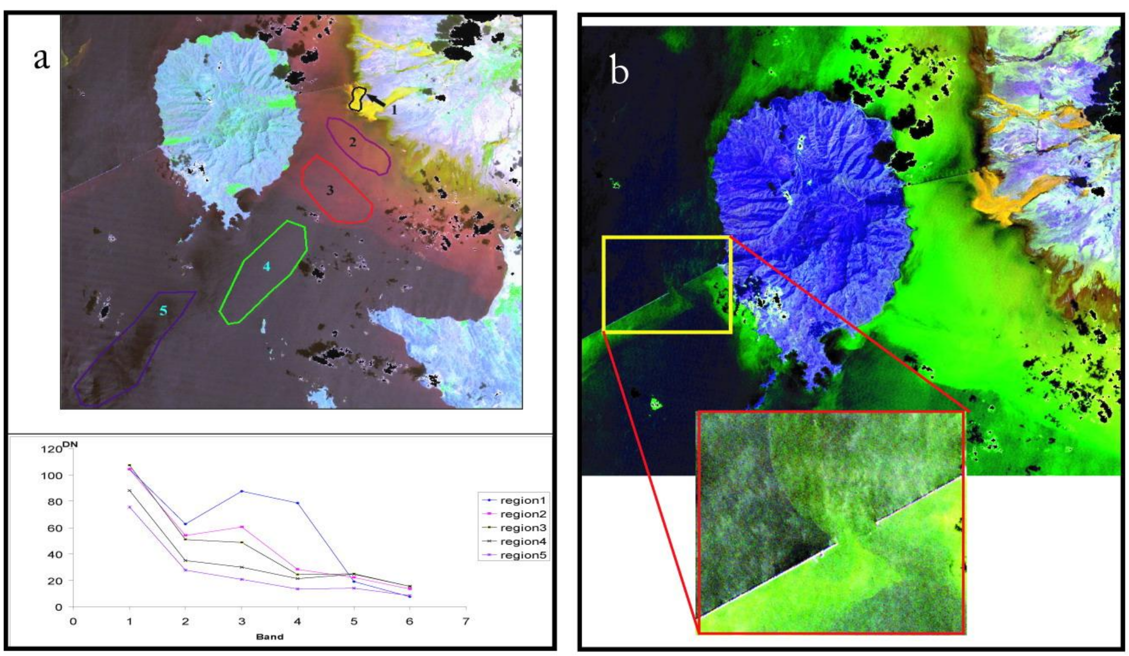

Fig.3. Selected regions for investigating the sensivity of TM bands to water quality parameters (a), the diffusion of suspended load around the causeway gap (b).

Dense water of the lake prevents solid suspended substances from quick deposition which is useful in recognition of causeway impacts on the natural circulation of the water in the lake. Fig. 3 (b) shows that deposition direction in eastern beach is northward and in western beach is eastward parallel to the causeway. Eastward moving materials have been depositing in the southern side of the western section of the causeway and some find their way through the gap to the northern part of the lake. The causeway seems to have a significant role in creating the above mentioned depositing pattern.

A spectral profile was provided crossing the causeway (Fig. 4a). This profile illustrates a clear reflectional distinction between the south and north parts and depicts that the causeway prevents full connection. Fig. 4b shows the spectral profiles parallel to the Tabriz-Saray road. Because of the northward movement of the load it is possible to distinguish the openings in this part of the road.

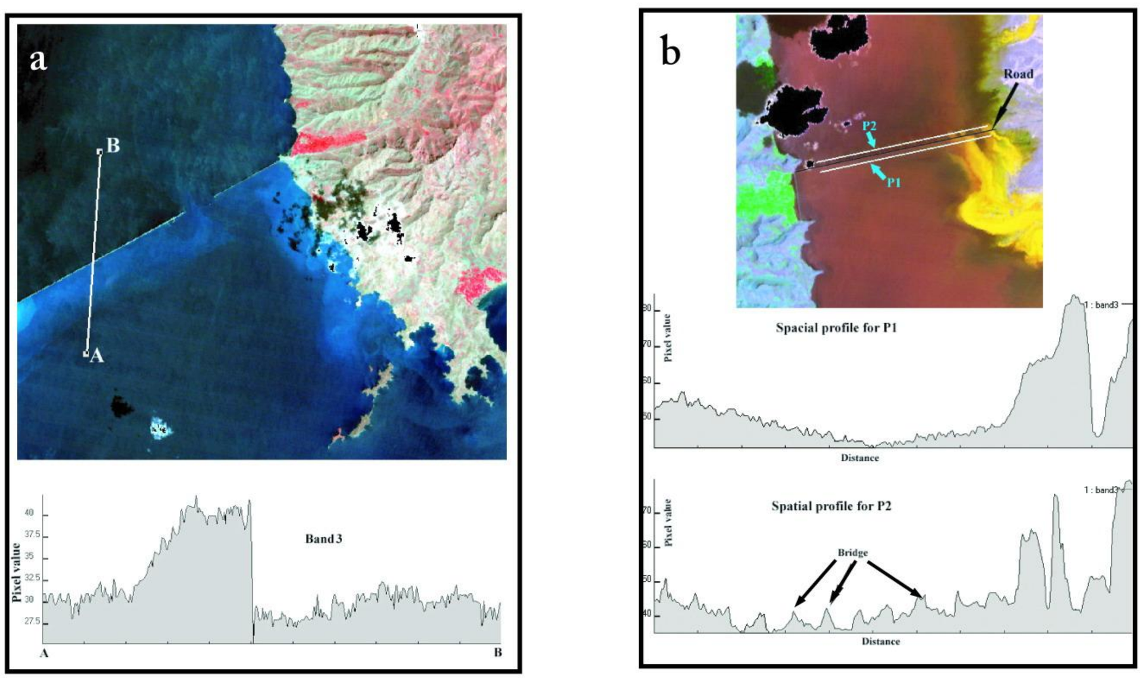

Fig.4. Spectral profile crossing the causeway depicting the different reflection in both sides (a), Spectral profiles along the Tabriz-Saray road from south (P1) and North (P2) parts of the Lake, the number of openings are clear

5.2. Causeway impacts on the distribution of salinity.

TM6 thermal infrared and TM3 spectral profiles was provided along the AB transect (Fig. 5a). Band 6 thermal data also shows remarkable differences in both north and south parts which is another clue for causeway impacts on lake's water circulation and for the deficiency of the gap. The profile depicts a gradual reduction in the reflection of the water body in the south-to-north direction, with abrupt fall and anomalies around the causeway. As a result of water-level decrease the salinity level is high and affected the spectral reflection of the 1990 TM. According to Bhargava and Mariam (1992) the spectral reflection has converse relation with water salinity. South-to-north reduction in the spectral reflection of TM3 can be attributed to the sudden increase in the salinity level which can be due to blocking effect of the causeway. By field sampling from Lake's water and finding relations between TM3 and salinity sample levels, a map of salinity can be provided. However; field sampling is necessary for calibration of satellite data in order to estimate the salinity level and to provide lake's water salinity map.

Fig. 5b shows the provided spectral profile of the bands (5, 4, and 3) along the AB transect. Reflectional difference in the estuary of Adji-Chay River is obvious. The difference of reflected energy from the water body along transect is notable, the low values near the Adji-Chay delta could be related to the shallow water, the reflection form the bottom of the lake and sediment load. As thermal data is different from reflective data in nature (Prakash, 1999), thus; further investigations on both thermal and reflective bands are necessary. Alavipanah (1999a and 1999b) showed that there is a reverse relationship between NDVI values and thermal band data.

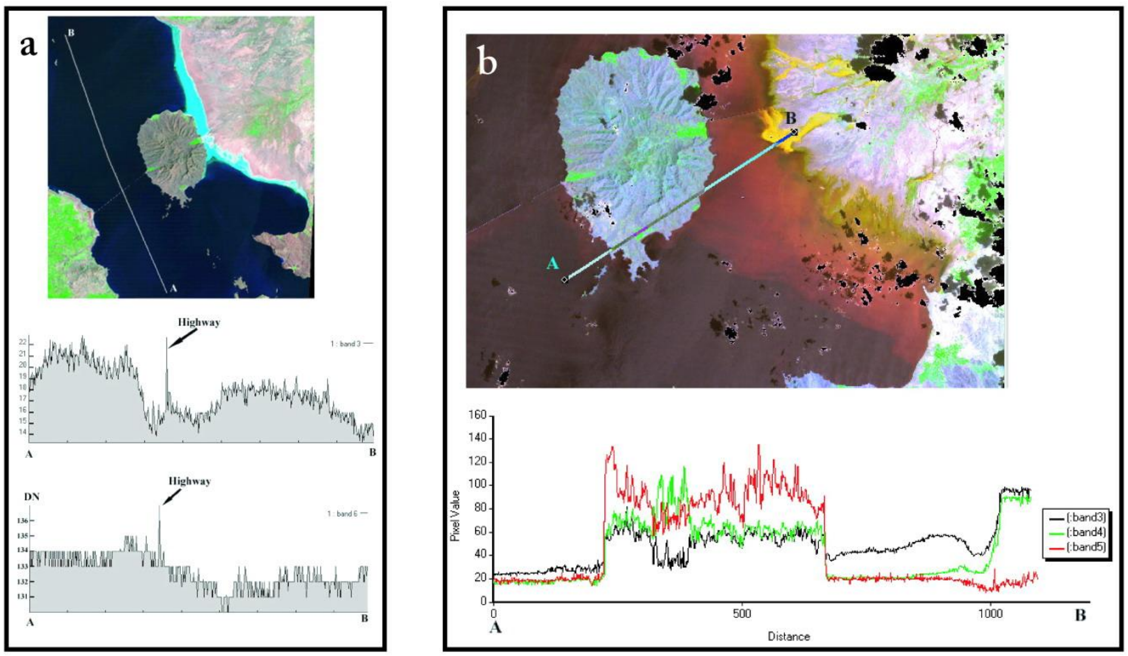

Fig.5. Spectral profile along the AB transect showing the different behavior in the estuary of the Adji-Chay (a), South-to-North spectral profile of TM3 and TM6 showing the difference of the both sides (b)

6. Conclusion

- The causeway had restricted hydraulic connections between north and south parts of the lake.
- Landsat TM data is effective for historical study of water quality parameters of the lake. However; filed sampling is necessary for calibration data for quantitative applications.
- TM3 and TM6 provide better information for the study of suspended materials, salinity and their distribution.
- Transported suspended load is mostly depositing on the south edge of the western section of the causeway.
- The spectral profiles from both reflective and thermal bands depict south-to-north changes, with abrupt changes near the causeway.

According to the attained results from sediment density and salinity level impacts on spectral reflection and the possible future problems related to the causeway impacts on the changes of the lake system, we suggest that:

- The water quality parameters should be continually controlled.
- The water quality parameters should be studied and the human-induced potential impacts on Urmia Lake's system should be identified and,
- The ecosystems of the lake should be studied through recognizing the interactive impacts among biological, chemical and hydrological characteristics.

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