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Signifying of the Urmia Lake Changes using Objected- Oriented Image Processing Techniques

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Abstract:

The main aim of the present study was to map of Urmia Lake water surface diminishing rates over a long-term period, and demonstrating the most recent surface of emerged salty alluvial plains. For this purpose, Landsat TM, ETM+ and OLI imageries, observing from 1984 to 2015, were progressively processed to generate most of the thematic models in tempo-spatial context. All multi-date satellite data were subset and progressively preprocessed by ERDAS software based on the accurate topographical maps and the precise referenced Ground Control Points. Two classification projects were then implemented in this research based on preprocessed satellite imageries. Primary, by applying an ISOData function all Urmia Lake time series images have been classified to extract water surface classes. Subsequently, the 2015 year images have been segmented to derive remaining water surfaces and other landcover maps, particularly salty surfaces, by applying an object-oriented method in eCognition software. Revealed models demonstrate several long-term meaningful persuaded fluctuations and considerable periodical changes on the Urmia Lake water surfaces, mostly observed during the last decade. These great variations have occurred as the result of 15 meters decrease in height of water in the lake and about at least 70 percent deceasing on water capacity.

Keywords: Landsat Images, Object-Oriented Image Processing, Urmia Lake, Water Level Changes.

1. Introduction

Natural and artificial land features are very dynamic, changing somewhat rapidly in our lifetime (Lunetta and Elvidge, 1999). It is important that such changes could be inventoried accurately so that the physical and human processes at work can be more fully understood. During the last decade, change detection has been regarded as a technique in remote sensing to determine the changes in a particular object of study between two or more time-periods (Singh, 1989) and (Donnay et al., 2001). Water surface is accordingly regarded as unique environment and its monitoring could be an important task in national development and resources management (Jensen , 1996). For coastal zone monitoring, water surface extraction in various times is considered a fundamental work because coastlines have a dynamic nature. Moreover, coastal zone management requires the information about coastline changes over time intervals (Jupp, 1988). Currently remote sensing technology plays a unique role for data acquisition as an economical method and optical images have advantages such as easier interpretation and easier availability (Lillesand and Kiefer, 1994; Mas, 1999). It has been previously known that absorption of infrared by water and its strong reflectance by vegetation and soil make an ideal combination for mapping of the spatial distribution of water surfaces (Tucker, 1979).

Accordingly, it can be reviewed as an important process for monitoring of the Urmia Lake fluctuations and its existent and very fast water surface diminishing, because it provides quantitative analysis of the spatial variation of water resources in the area of interest (Rasuly, 2000). Consequently, Landsat data such as TM, ETM+, and OLI images have been simultaneously processed for visualizing and mapping Urmia Lake water surface and its coastline changes (UNEP, 2012). In the present study, an attempt is made first to estimate the Urmia Lake water surface variations in the past 30 years using some available multi-date satellite data. Then, long-term coastline changes were mapped during the time considered. Finally to identify the most recent appeared landuse changes an object-oriented process was applied. To be certain, all available satellite data have been processed to map of historical water surface changes as well as the latest development of coastlines. Most recent years researches indicated that around the Urmia Lake there are actual and considerable variations of water surfaces and coastline changes which are distinguishable on periodical scales (Rasuly, 2008a). Visual comparison of dynamic maps demonstrates some dramatic changes, especially in the east and southeast of Urmia Lake. Such fast water surface diminishing and coastlines changes could be corresponded with the rapid development of more than 20 dam construction projects, and the last two decades drought phases which occurred in the country.

By the current research, the importance of remote sensing in monitoring of water sources is also positively emphasized (Mather, 1987). There are at least two advantages of using multi-temporal remotely sensed data in this study. First, used methodology provides researchers with a new way in which the temporal-spatial changes could be detected by means of comparing different sorts of data provided by a dissimilar sensors. Second, in this study the longest time series change maps were overlaid not only to analyze the processes with a complex nature, but also to identify the conditions and factors that cause such dramatic changes. There are two disadvantages by referring to the methodology applied for different types of data in the current study (Duda and Hart, 1973) and (Wickware and Howarth, 1981). Mainly, in many regions of Iran, historic and landcover data are either poor or nonexistent. Next, the dynamic and complex land-water interaction in coastal Urmia Lake wetlands makes the discrimination of land-water features less certain, especially in marsh environments. In current research, it was nevertheless realistically possible also to separate directly water from land by applying two of different classic and modern image processing methods; namely an ISO-DATA and Object-oriented approaches (Winarso and Budhiman, 2001). Therefore, at this stage, an initial analysis in regions such as the Urmia Lake has focused on the mapping of water surface variations and estimating the last landcover changes (Rasuly, 2005).

2. Materials and methods

2.1. Study area

The Urmia Lake is located in the north-west of Iran; as a second largest salty lake in the world. The last decade droughts based on climate change episodes, water consumption in agricultural fields, artificial coastal changes (roads building operations) and importantly dam construction programs have simultaneously caused more evaporation of the lake water and thus considerable variations of water surface levels. These circumstances have been accompanied with a hyper-saline condition in the lake and appearing various the most recent coastal hydro-morphological features. This lake as the largest habitat for Artemia and the largest water body in Iranian plateau is located between two major provinces of East and West Azerbaijan provinces (Eimanifar and Mohebbi, 2007). The lake is bounded between 37 4 - 38 17 latitudes and 45 13 - 46 longitudes and covers an area between 4000-6000 km2 averaging around 5000 km2. About 20 permanent and seasonal rivers as well as a few underwater streams and springs feed the lake (Alesheikh et al., 2005). Average salinity of the lake ranges between 220- 300 mg/lit depending upon temporal and spatial conditions. Due to the ecological heritage of Urmia Lake it is recorded as a protected habitat in the world by the United Nations.

It is worth to identify that Urmia Lake is the 20th largest lake and the second hyper-saline lake in the world and its basin is covered about 3.15 percent of the whole country (Kelts and Shahrabi, 1986). The maximum depth and average depth of this lake respectively are 20 and 5 meters. The lake with 103 islands was listed as a biosphere reserve by UNESCO and also it is recognized as a national park in the national level (UNESCO, 2012). Most importantly, the Urmia Artemia is one of the seven polygamy species (male and female) yet recognized in the world.

Mostly, northwest of Iran can be accounted for being interesting in the fields of topography and so to speak the relief of the land. Sahand Mountain with 3780 meter elevation is the highest peak in the region, which lies in the east of Urmia Lake. Low-lying areas are unevenly speared out among mountains or just about other summits and heights located in the region. Generally, northwest of the country enjoys a cold and semi-dry climate, being affected by mountains seriously. Figure 1 indicates the geographical location of the study area within Iran as well as the position of Urmia Lake in the region.

Figure 1: Study area – location of Urmia Lake in the Northwest of Iran and Middle East

To achieve the main aims of the current study, some different sorts of multi-sensor satellite remote sensing data of Urmia Lake region were obtained from USGS site. The earliest one was Landsat-TM data with the spatial resolution of nearly 28.5 meters taken on August 1984. Based on accessible time intervals and the image quality, other Landsat (ETM+ and OLI) images were provided and have been taken on different image processing procedures respectively. Table 1 indicates all Landsat images sources, which have been processed in current study.

Table 1: Sources of Landsat Images

Data Type	Sensor Name	Selected Data
Landsat 5	TM	August 1984
Landsat 5	TM	September 1990
Landsat 5	TM	October 1995
Landsat 5	TM	October 1998
Landsat 5	TM	August 2000
Landsat 7	ETM+	September 2002
Landsat 7	ETM+	September 2004
Landsat 7	ETM+	September 2006
Landsat 7	ETM+	September 2009
Landsat 8	ETM+	September 2012
Landsat 8	OLI	October 2014

2.2. Research methods

On the processing of accessible satellite images three main phases were taken. In the pre-processing stage, by applying of satellite digital images in detection of landuse changes of Urmia Lake, several procedures such as: radiometric correction, geometric correction and image enhancement techniques were introduced (Rasuly, 2008b). The goal of this phase was to increase both the accuracy and the interpretability of dissimilar sort of digital data. All satellite images were re-projected to UTM zone 38 map projections and each image scene was co-registered by image to image registration. The geometric and radiometric corrections of all images were successively done in an image processing data software of ERDAS 2014. It should be further noted that the survey of Iranian topographical maps on 1: 50000 scales formed the baseline data for assessing the variations of water surface as well as a base map for the preparation of a Digital Elevation Model (DEM). Each time series of lake imageries was united by mosaic of three other Landsat images with 169-33; 168-34 and 169-34 path and row ID numbers. To reduce the time and quantity of image processing all data were presently sub-set for Urmia Lake with its surrounding area.

At the processing phase, several image bands ratio methods were applied in introducing a Iterative Self-Organizing Data Analysis (ISO-Data clustering technique) as an unsupervised classification method, was introduced in extracting of Urmia Lake water surface spatial surroundings (Birkett, 1994). It is iterative in that it repeatedly performs an entire classification (outputting a thematic raster layer) and recalculates statistics. Self-Organizing refers to the way in which it locates the clusters that are inherent in the data (Dalton and Kite, 1995). The ISOData clustering method uses the minimum spectral distance formula to form clusters; as lake water surface maps (Table 2).

Table 2: Image processing techniques used for extracting of water surface on Urmia Lake

Sensor Type	Band Ration	Classification	Algorithm
Landsat TM	2/5	Unsupervised Clustering	ISO-Data
Landsat ETM+	4/5	Unsupervised Clustering	ISO-Data
Landsat OLI	6/7	Unsupervised Clustering	ISO-Data

The composed data are interpreted cell-by-cell in the image processing system, and the water and non-water areas have been distinguished from each other (Richards, 1999). The results of this stage were maps that show water surface with constant pixel values.

In the second stage of image classification procedure, an object-oriented image processing function was introduced in eCognition software setting (Lewinski and Zaremski, 2004). Object-oriented image analysis is different from conventional pixel base image analysis e.g. Maximum Likelihood Classification, which analyses the image based on image objects rather than pixel values (Liu and Xia, 2010). As an example to Object-oriented image classifier, eCognition is one of the software to implement this concept (eCognition Developer, 2013). It is a powerful and versatile technology for multi-scale analysis of earth observation data, particularly suited for the analysis of Urmia Lake imageries. In fact, object-oriented image such as eCognition is based on the concept that important semantic information necessary to interpret an image is not represented in single pixels, but rather in meaningful image objects and their mutual relations (Rasuly, 2006). In software setting, the image classification is based on attributes of image objects rather than on the attributes of individual pixels. Therefore, Object-oriented classifier found to deliver results noticeably better than conventional methods. It leads to better semantic differentiation and higher classification accuracy (Rasuly and Mahmoudzadeh, 2010b).

In recent years, in remote sensing technology the image processing procedure has been considered one of the best available techniques to extract landuse maps which with lowest price within a short period of time permits to access to valuable information. Among the image processing methods, object-oriented image processing - due to the use of spectral information and information related to the context and content in classification process - has higher accuracy normally in eCognition 8.7 software setting. In object-oriented analysis the main units of the image processing are segments (Yan, 2003). In a software setting, the segment-making stage is the first and most important step in thumbnail image classification to separate landcover class units (Huang and Ni, 2008). In fact, segment means a group of neighboring pixels within an area that their most important common criteria; such as numerical value and structure, is similar. In current research, a multi-resolution segmentation algorithm was used to segment the Urmia Lake images captured in 2015. Accordingly 3 factors including scale, form coefficient and compression coefficient are regarded to be the most important effective parameters in segment-making process. The segmentation procedure works according the following rules, representing a mutual-best-fitting approach:

The segmentation procedure starts with single image objects of one pixel and repeatedly merges them in several loops in pairs to larger units as long as an upper threshold of homogeneity is not exceeded locally. This homogeneity criterion is defined as a combination of spectral homogeneity and shape homogeneity. Higher values for the scale parameter result in larger image objects, smaller values in smaller image objects.

As the first step of the procedure, the seed looks for its best-fitting neighbor for a potential merger.

If best fitting is not mutual, the best candidate image object becomes the new seed image object and finds its best fitting partner. When best fitting is mutual, image objects are merged. In each loop, every image object in the image object level will be handled once. The loops continue until no further merger is possible.

In final stage, classification algorithm is run in different stages. First, all classes of the image demined objects were specified by the use class parameter. Then, the membership value for each assigned class is set to 1 for all objects independent of the class description and the second and third-best classification results are set to 0. Remembering that, in multi-resolution segmentation stage; scale parameter is set to 100, shape parameter is set to 0.2 and compactness was regarded to be 0.4 in the 8 classes by assigning class algorithms in two main landuse and salty area categories respectively as it is indicated in Figure 2.

3. Results and Discussion

Undertaken study has reached to following results related to the different sort data of Urmia Lake based on the processing of available remotely-sensed images. Temporal-Spatial changes of Urmia Lake level at least on an annual scale were found to be certain from 1984 to 2014. Maximum outline of the Urmia Lake are graphically given in Figure 3.

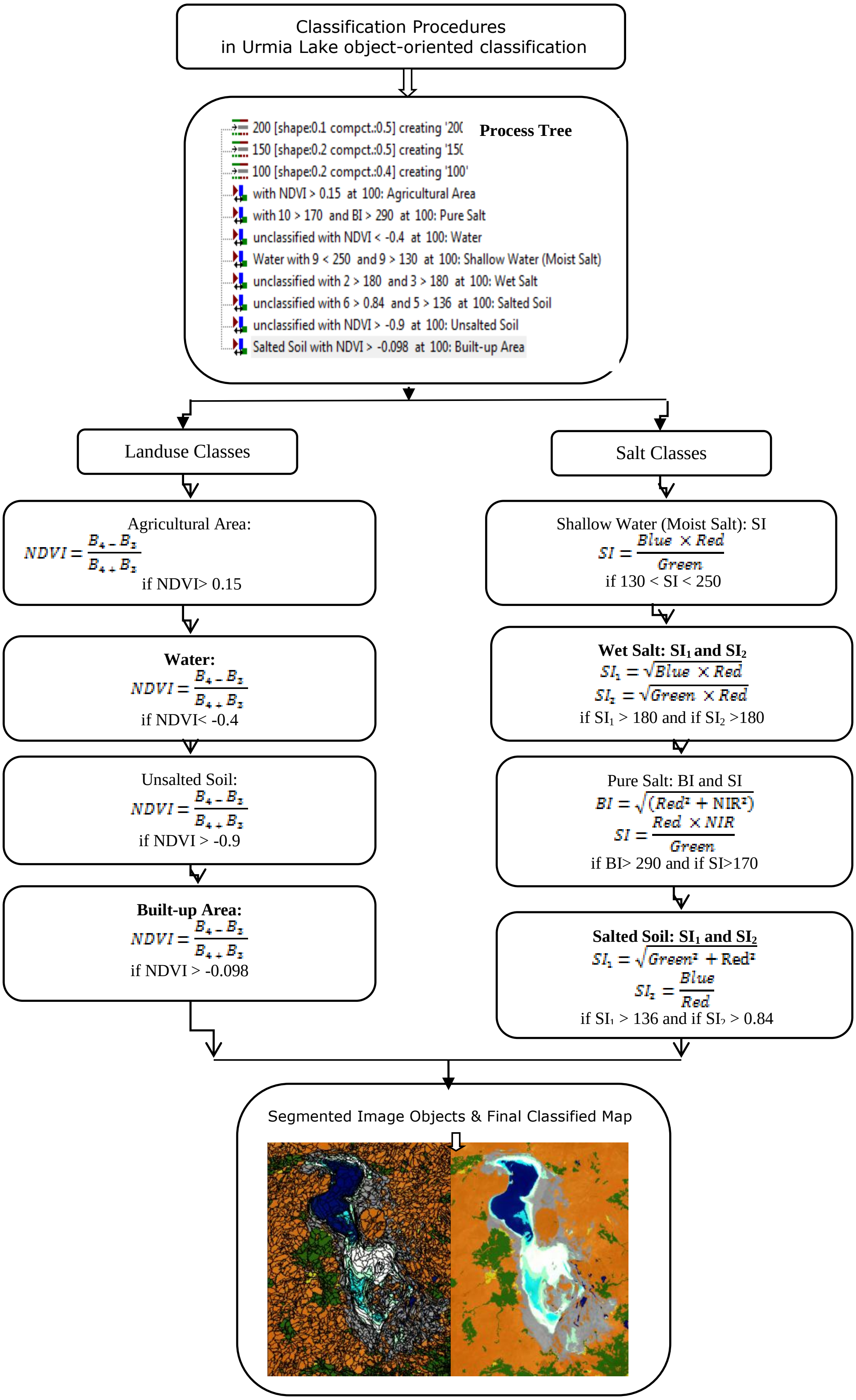

Figure 2: Classification procedures for Urmia Lake image

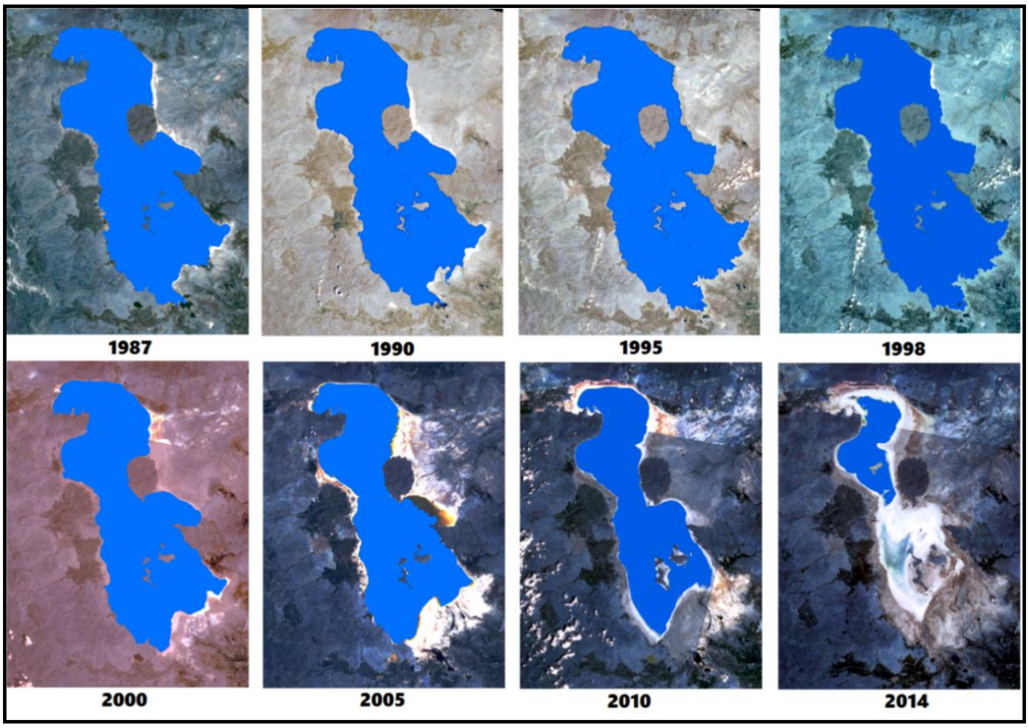

Figure 3: Temporal-spatial changes of Urmia Lake level at least on an annual scale

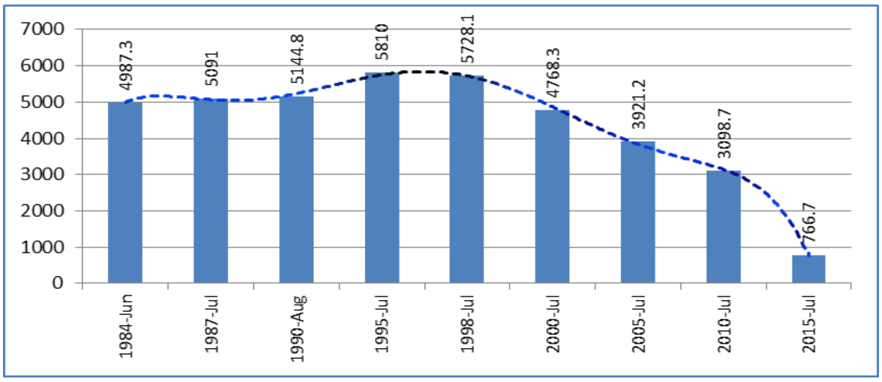

Figure 4: Area variations on Urmia Lake water surfaces during the time

Distinction of Urmia Lake water surfaces was detailed in Figure 4. It can be identified that there are various significant variations on increasing or decreasing of water areas during the last 30 years. To model some realistic variations of Urmia Lake landuse changes and due to mentioned nature of classical methods, an object-oriented image analysis of eCognition software has been applied for 2015 Landsat images. It is based on the concept that important semantic information (necessary to interpret an image) not only could be represented in individual pixels but also in meaningful image objects and their contextual relations. In other words, object-oriented approach takes the form; textures and spectral information of Urmia Lake landcover into account simultaneously. Its classification phase starts with the crucial initial step of grouping neighboring pixels into meaningful landuse areas. As it is indicated in Figure 5, the study area landuse classes such as, water, salty water, agricultural area and salt in different phase of formation have been recognized.

All image objects were imported into ArcGIS environment and vector base coastlines and landuse classes have been edited and produced. This was done for the purpose of calculating the changes during the time period which is considered in the current study. Applying bi-spectral technique, the sampling areas were selected and error matrix and kappa coefficient performed using TTA MASK in eCognition software. The obtained kappa coefficient was equal of 0.92 and the overall accuracy has been estimated about 0.95 that confirms classification accuracy is significantly high (Volker, 2003). Final classification landuse and salt classes for Urmia Lake in year 2015 is illustrated by Figure 6.

The Landsat image for year 2015 is over imposed on a DEM model (Figure 7). By visual interpretation of the latest situation of Urmia Lake it could be distinguished that enormous areas, located on the east and southeast of the region, has severely changed to a saline or barren landcover types. The Latest situation of Urmia Lake accelerates various recent anomalies emerged in river networks.

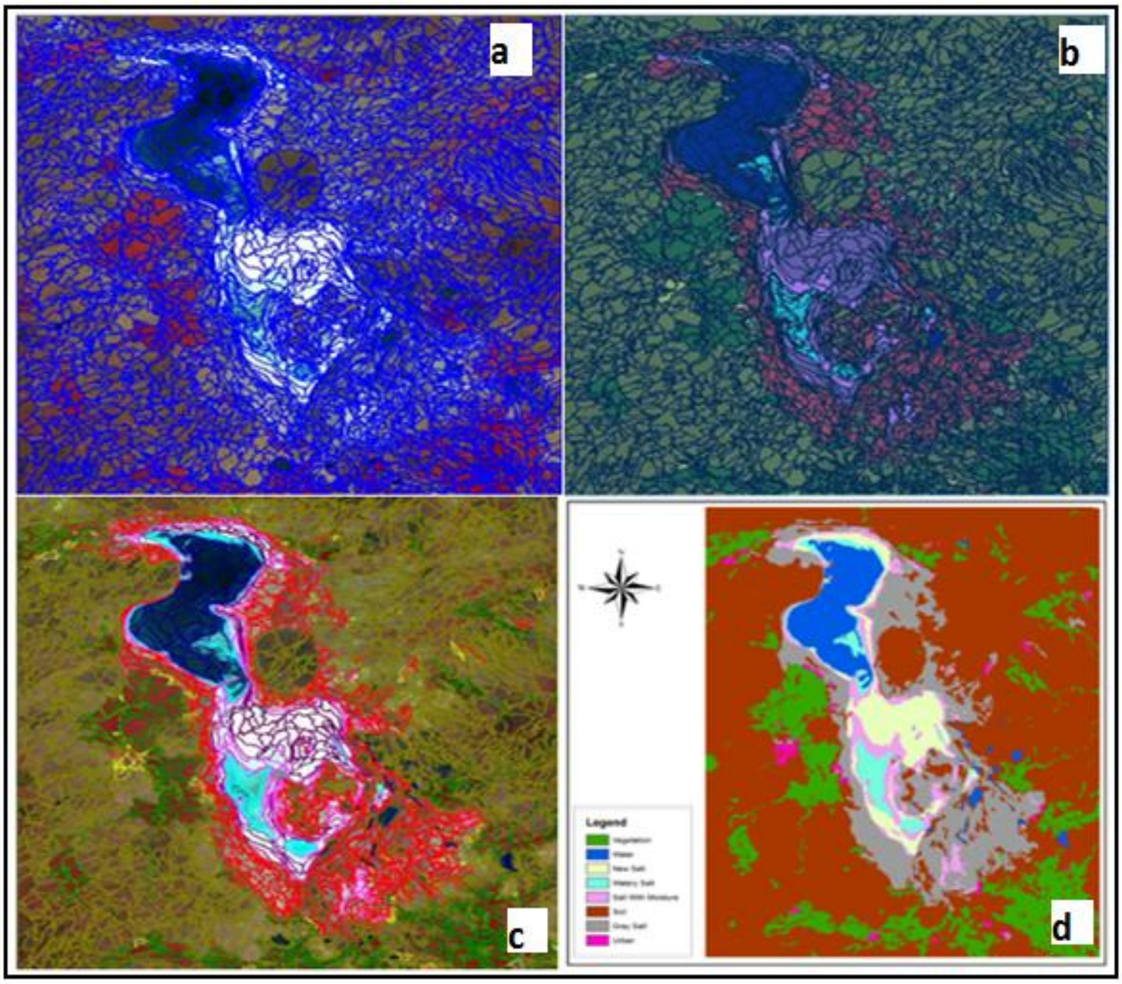

Figure 5: Object-oriented classification results for Landsat image 2015; (a) initial image segments, (b) multi-threshold segmentation, (c) recognized image objects with outlines and (d) final classification landuse classes

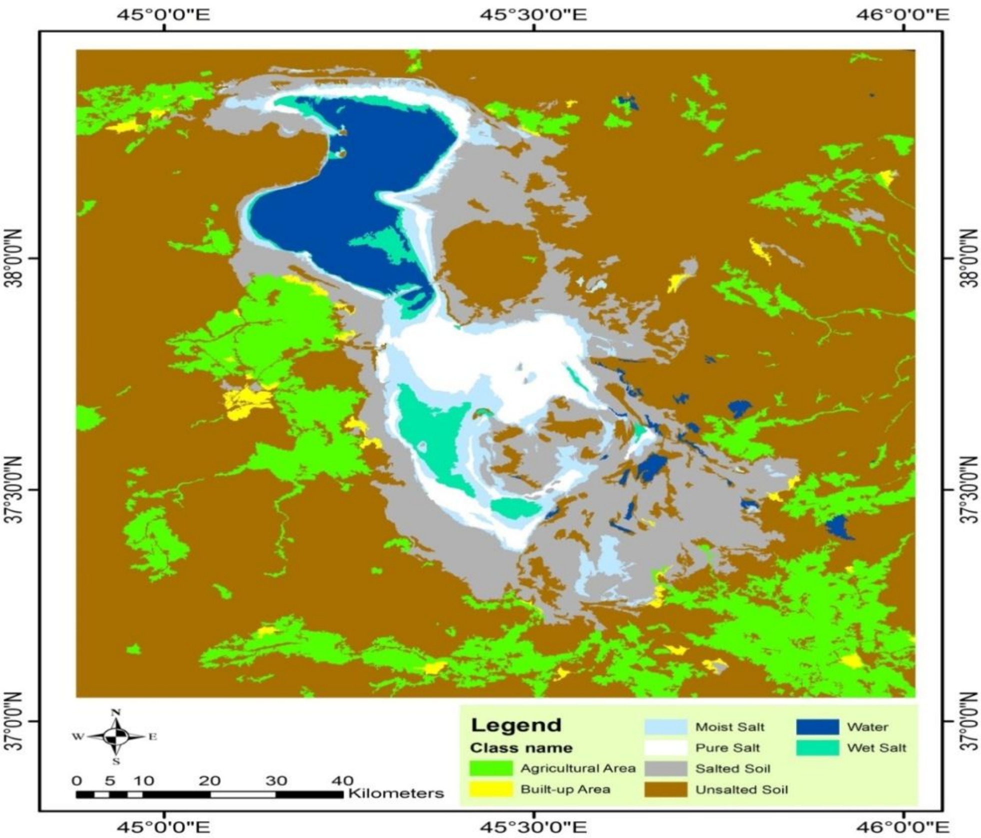

Figure 6: Final classification landuse and salt classes for Urmia Lake in year 2015

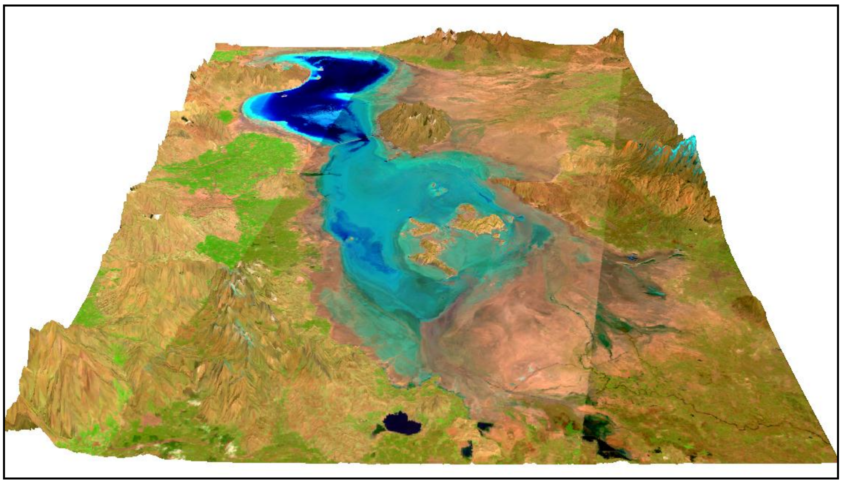

Figure 7: The latest situation of Urmia Lake (June 2015) overlapped on a DEM

4. Conclusions

The main purpose of this study was to monitoring of Urmia Lake tempo-spatial changes during the period from 1984 to 2015. For this reason, several remote sensing image processing techniques were applied in detecting water level and coastline declining by means of all available imageries (Macleod and Congalton, 1998). Preliminary results indicate that water surface and sounding landuse are changing severely and in consequence, nearly about 70 % of water level has been decreased during the last 30 years. Such large changes around the Urmia Lake happened as the result of 15 meters decrease in height of water, which consecutively caused approximately 1600 square kilometers decrease from the averaged area (4137 km^2) of the lake.

Based on some investigations, it was suggested that the climate change is really occurring mainly with decreasing on rainfall amounts and increasing of yearly temperature measured nearly 1.7 degrees. In addition it was found that water consumption in agricultural fields, artificial coastal changes (roads building operations) and importantly dam construction programs have simultaneously caused more evaporation of the lake water and thus considerable variations on water surface levels.

These circumstances have been accompanied with a hyper-saline condition in the lake and appearing various the most recent coastal hydro-morphological features. Performing analyses on different images allowed for the monitoring of spatial revolutionize of the Urmia Lake's water level over the time considered from 1984 to 2015 (see Fig. 3). Final models provide beneficial insight into the extent nature of all water level changes that have taken place in the study area (see Figure 4). The quantified object-oriented procedure results indicate that the rate of water level changes is significant during the past thirty years, accompanying by a critical hyper-saline condition around the lake (notice Figure 5). The current research leaves the foundation for further research to be conducted, encountering development and landuse changes by illustrating the importance of satellite imagery. In future research to exploit image information more intelligently, an integrated remote sensing with a knowledge engineer expert approach could be applied. In exact evaluating of Urmia Lake changes over time and space a real-time monitoring system is needed.

References

A. A. Alesheikh, A. Ghorbanali and A. Talebzadeh, Generation the coastline change map for Urmia Lake by TM and ETM+ imagery, 2005, http://www.gisdevelopment.net.

A. A. Rasuly, An analytic approach to GIS technology (Tabriz University Press, 2005).

A. A. Rasuly, Forecasting of climate elements using ARIMA and SARIMA methods, Faculty of Literature and Humanities, Journal, 21, 2000, 12-25.

A. Eimanifar and F. Mohebbi, Urmia Lake (Northwest Iran): a brief review, 2007, 3:5 1746-1448.

A. Singh, Digital change detection techniques using remotely sensed data, Int. J. R. S, 10(6), 1989, 989-1003.

A.A. Rasuly and H. Mahmoudzadeh, Fundamental of knowledge based remote sensing. (ElmIran Press, Tabriz, 2010b).

A.A. Rasuly, Modeling of Urmia Lake coastal changes by applying an integrated RS/GIS approach. The 7th International Symposium on GIS and Computer Cartography for Coastal Zone Management. Sydney, Australia, 2006.

A.A. Rasuly, Monitoring the Water-Level Fluctuations of Urmia Lake through Satellite Images Analysis. Proceedings of 3th Conference of Water Resources Management in Iran, Tabriz University, 2008a, 137-165.

A.A. Rasuly, Principle of Applied Remote Sensing: Satellite Image Processing. Tabriz University Press, 2008b).

C.J. Tucker, Red and photographic infrared linear combinations for monitoring vegetation, Remote Sensing of Environment, 8, 1979, 127-150.

C.M. Birkett, Radar altimetry - a new concept in monitoring global lake level changes. Eos Trans. AGU 75 (24), 1994, 273–275.

D. Liu and F. Xia, Object-based Classification: advantages and limitations, Remote Sensing Letters, 1:4, 2010, 187 – 194.

D.L.B. Jupp, Background and extensions to depth of penetration (DOP) mapping in shallow coastal waters, Proceeding of the symposium on remote sensing of coastal zone, Gold Coast, Queensland, September 1988, IV.2.1-IV.2.19.

eCognition Developer 8.7, Reference Book, (Trimble Documentation, München, Germany, 2013).

G. Winarso and S. Budhiman, The potential application remote sensing data for coastal study, 22nd Asian Conference on Remote Sensing, 5-9 November 2001, Singapore, 2001.

G. Yan, Pixel based and objects oriented image analysis for coal fire research, ITC, the Netherlands. 2003, 15-97.

G.M. Wickware, and P.J. Howarth, Change detection in the Peace – Athabasca Delta using digital Landsat data, Remote Sensing of Environment,11, 1981, 9-25.

J.A. Richards, Remote sensing digital image analysis, (Springer-Verlag, Berlin, 1999, 240).

J.F. Mas, Monitoring land-cover changes: a comparison of change detection techniques, Int. J. Remote Sensing. 20, 1999, 139-152.

J.P. Donnay, M.J. Barnsley and P.A. Longley, Remote sensing and urban analysis, (Taylor & Francis Inc., London, UK, 2001).

J.R. Jensen, Introductory digital image processing a remote sensing perspective (Second Edition, Prentice-Hall, Upper Saddle River, New Jersey 1996).

JA. Dalton and GW. Kite, A first look at using the TOPEX/Poseidon satellite radar altimeter for measuring lake levels. Proceedings of the International Workshop on the Application of Remote Sensing in Hydrology, Saskatoon, Canada, 1995, 105–112.

K. Kelts and M. Shahrabi, Holocene sedimentalogy of hypersaline Lake Urmia, Northwestern of Iran. Paleogeography, Paleoclimatology and Paleoecology. 54, 1986, 105–130.

L. Huang and L. Ni, Object-oriented classification of high resolution satellite image for better accuracy, Proceedings of the 8th International Symposium on Spatial Accuracy Assessment in Natural Resources and Environmental Sciences, Shanghai, P. R. China, June 25-27, 2008, 211-218.

P.M. Mather, Computer processing of remotely-sensed image: an introduction (John Wiley, New York, USA, 1987).

R.D. Duda and P.E. Hart, Pattern classification and scene analysis (John Wiley, New York, USA, 1973).

R.S Macleod, and R.G. Congalton, A quantitative comparison of change detection algorithms for monitoring Eelegrass from remotely sensed data, Photogrametric and Remote Sensing of Environment. 8, 1998, 127-150.

R.S. Lunetta, and C.D. Elvidge, Remote sensing change detection: environmental monitoring methods and application , Taylor & Francis Inc. London, UK, 1999.

S. Lewinski and K. Zaremski, Examples of object-oriented classification performed on high resolution satellite images, miscellanea Geographica, Warszawa, 11, 2004.

T. M. Lillesand, and P.W. Kiefer, Remote sensing and image interpretation (John Wiley & Sons, Inc. USA, 1994).

UNEP, GEAS, The drying of Iran's Lake Urmia and its environmental consequences. J. Environ. Dev. 2, 2012, 128–137.

UNESCO, UNESCO-MAB Biosphere Reserves Directory. 24 January 24, 2012 at: http://www.unesco.org.

W. Volker, Object-based classification of remote sensing data for change detection, ISPRS Journal of Photogrammetry & Remote Sensing, 58, 2003, 225– 238.