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Assessment of the trend of salt and water variation in Urmia Lake using object-oriented processing of Landsat satellite images

Keyvan Mohhamad Zadeh [a*], Maryam Maleki [b] Ali Akbar Rasouli [c]

M.Sc. student of remote sensing and GIS- University of Tabriz [a]
M.Sc. student of remote sensing and GIS- University of Tabriz[b]
Professor of Geography and Planning faculty - University of Tabriz[c]

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Abstract

Over the past years, lake water levels have decreased considerably by various factors and the subsequent emergence of salt plain has brought disastrous consequences that need an essential action. Therefore, this study aimed to investigate the effects of drying up and increasing lake water salt and Landsat satellite images were used during different time periods in 12 years. To identify the new and old salt, and also the rate of water regression, Object-oriented processing method was used. In this type of classification in addition to spectral data, texture and content information is also used. After the segment, the different types of indicators, salinity, light and vegetation were applied on images. The results show that annual changes in lake water levels, as well as new and old salt changes in annual terms were significant. Finally, classification accuracy assessment parameters were calculated 96.0 and kappa coefficient 92.0. Which implies the ability of object oriented classification process phenomena in the Earth's surface.

*Corresponding author. Tel.:+989148440791
E-mail address: km_rs1990@yahoo.com

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INTRODUCTION

Urmia Lake with an area of 4500-6000 square kilometers is the largest inland lake in Iran and twentieth lake in the world and has a special importance and is one of the most important pillars of environmental sustainability in North West of Iran (Rasouli et al, 2005). Today, the lake has been experiencing a massive environmental crisis and is in the danger of complete drying up. Drying up of Urmia Lake due to the huge salt storage in its heart has many environmental consequences that destruction and salinization of soils around the lake is one of them (Khademi et al, 2012). Soils in these areas due to incorrect operation of environmental capabilities in recent decades, is at the risk of increasing soil salinity that is one of the most important factors in reducing soil fertility in these areas. Soil salinity is one of the environmental and agricultural acute problems in many arid and semi-arid earths due to the parent material originating from passion, intense irrigation, shallow underground water and poor drainage which prevents leaching soluble salts. Coastal areas, especially the inland lakes as ecological environment is taken into consideration. Under these conditions, monitoring and evaluation of such areas can be considered as an important issue in the development and management of natural resources (Dieter Kltat, 2002: 23). Bobby (2015) used Landsat remote sensing data in the period from 1972 to 2012 to Nowadays, remote sensing and multispectral images from Landsat satellites in the activities of many organizations are used for mapping and monitoring of salinity, soil salinity. Differences in different images bands reflect can be used to detect land cover types (translated Alavi Panah et al., 2014). It is an effective method to obtain the required data. This procedure avoids the usual constraints of time and place (Al-Sheikh, et al., 2003). Remote sensing tools in the form of satellite images and thematic maps production of these images with remote sensing and geographic information system techniques, is among the most important and effective tools in terms of the cost, speed and accuracy for monitoring and controlling of this phenomenon. (Sharifi Kia et al., 2012).

Since 1972, remote sensing satellite such as Landsat provides users with the digital images of the infrared spectral. The differentiation of land and water is carried out easily. The images of remote sensing and image processing technologies can reduce problems above (Winarso, et, 2001). With the advancement of science, the use of new technologies such as monitor changes in Kuwait country land use and cover coastal areas. His study result pointed to transgression of the sea to the coast and the negative effects of humans on the coastal territory.

Too much salinity, have a negative impact on crop production and finally destructs the earth. So assess the extent and progression of soil salinity in order to select the proper operation of agriculture, irrigation and drainage management helps to reduce the salinity is important (translated Alavi Panah et al., 2014). All soils contain some soluble salts, but soil salinity cause land destruction when salt accumulation reaches a higher degree and affect crops (Rngsmay, 2006). Average salt dissolved in lake water ranges between 220 to 300 milligrams per liter and differs based on the circumstances of time and place. Some studies also show that the salinity of the lake since 2001 reached more than 300 milligrams per liter (Esmaeili, et al and 2010). Due to these reasons, the analyses of preventive strategies to minimize the environmental damages are very important. However, continuous monitoring of such areas can be an important issue in national development and natural resource management to be considered. For this reason, in recent decades the uses of emerging technologies such as remote sensing and GIS have greatly increased (Hussein Sanaee Nejad et al, 2010).

receiving and processing data via satellite and using software and information processing systems play an important role in the management of water resources and soil. (Daem Panah, et al., 2011). Including new techniques that are of high accuracy object-based methods can be mentioned. Class classification methods in satellite images have limited ability to separate the classes that have similar spectral information and are merged, there. And this would reduce the accuracy of the based pixel classification techniques (Gao Yan, 2003). That is why in recent years with advances in computer processing technology, new methods such as object-based methods have been developed. Including studies on classification methods can be referred to the studies of Kamagata et al. (2014), using high-resolution images, pixel-based classification and object-based in urban areas can be compared and showed that the pixel-based method classification error is high while object-based classification accuracy is better than the pixel-based classification. It also showed that object-oriented approach can be an effective tool for the analysis of vegetation in semi-urban and suburban landscapes in big cities. White site and

Ahmad, (2005), compared the pixel-based and object-oriented classification methods and showed

that object-based classification accuracy is greater than pixel-based classification. Object-based method gives results with acceptable accuracy and they also showed that object-oriented analysis has great potential for land cover data derived from satellite images obtained by Australia. Rasouli et al., (2007) studied lake water level fluctuations by using multi-sensor and multi-temporal satellite images from 1976 to 2005 and showed that there are wide fluctuations and significant seasonal changes in the geometric parameters of the lake. The most changes caused by low water is especially in the south east and the east coast of Urmia Lake. And the fluctuations caused significant reduction of 23% of the lake's water levels during the study. Al Sheikh et al (2004), studied shore lines of Urmia lake from 1989 to 2001 by using remote sensing and GIS and showed that the lake area of 1040 square kilometers has decreased over the period in question. Changes in water level during this period were estimated to be 3 meters. Valizadeh et al (2013), examined the Lake of physical changes in the period of 22 years using Landsat images and showed that during this period temperature and evaporation were increased which led to lower lake level. They also showed that the eastern and southeastern areas of the lake in terms of depth and high temperature have the maximum potential of damage caused by dehydration

Study Area:

Urmia Lake and a portion of the land around, because of its special importance, were selected as the case study. The region covers an area of approximately 15375.11 square kilometers and is located between latitudes of 37° and 38.5° N and longitudes of 45° and 46.5° E in the north west of Iran. Average salinity of lake water is between 220 to 300 grams per liter that varies over time and place. Urmia Lake due to certain ecological environment has been registered as a protected environment by UNESCO. This park includes a rare collection of ecosystems with its diverse plant and animal life, topography structure of 102 islands and also hordes of marshes, wetlands, forests and finally the tamarisk shrubs and fourteen permanent and seasonal river deltas around. Aqueous environment with chemical properties and life cycle of Artemia, algae and large number of rare birds, distinguishes it in Iran and even in world parks (Nassiri et al., 1996).

Unfortunately in recent years by increasing the drying process, the lake has become a serious threat to the inhabitants of the region and its neighbors. And quires serious attention must be pay.

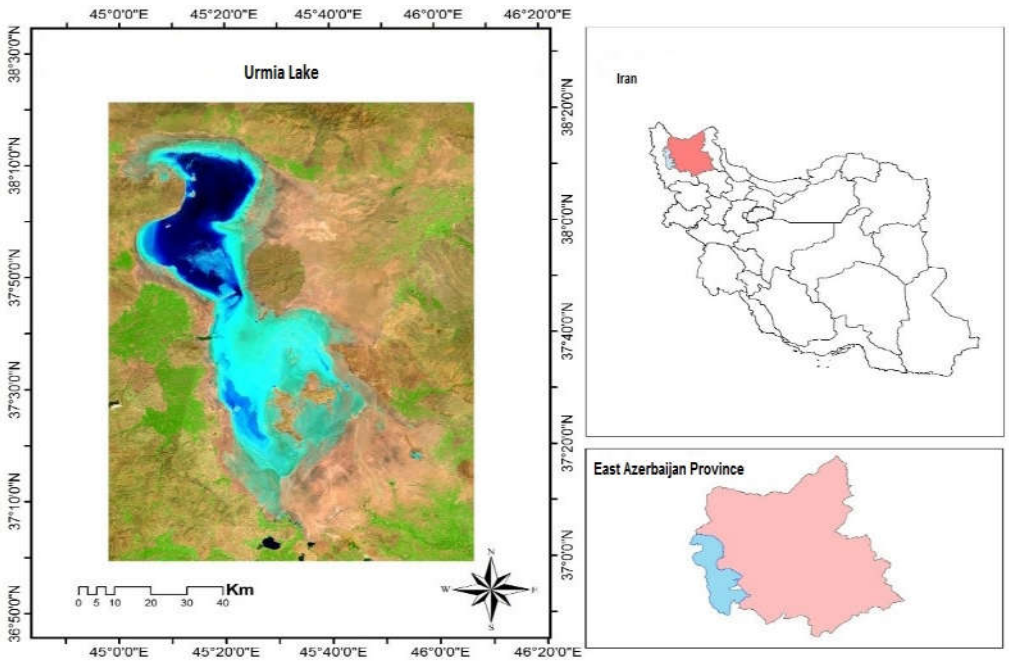

Fig 1. Location of the study area

MATERIALS AND METHODS

In this research, study area is covered by three Landsat images with 34-169 and 33-169 and 34-168 rows and path. This study was conducted during the period of 2003-2015 every fourth year, that the north of Landsat 7 images (ETM sensor) is for 2003 and 2011, Landsat 5 image (TM sensor) is for 2007 (due to cloudiness the Landsat 5 image was used) and Landsat 8 image (OLI sensor) is for 2015. In addition, data derived from earthly incarnations with GPS used to verify the results.

In this study, ENVI 5.1 software was used to pre-processing and preparing image for processing, in eCoginition 9.1 software and the Arc Gis 10.3 was used for post-processing and preparation of necessary Outputs. It is noteworthy that all the images were georeferenced by default. In image pre-processing stage to perform image processing, functions such as images stack, wavelength range, Landsat, images mosaic definition and cutting the target range ... Were prepared. The main objective of this phase is to resolve the systematic and unsystematic errors in the raw images and enhance the accuracy and reliability of the Classification of digital information. Then for processing operations, images entered to eCoginition 9.1 software environment. In eCoginition 9.1 environment different algorithms were applied for classification of saline areas and finally the algorithm which has the best outcome for classification was applied to other images and so, the images were zoned regarding the salinity.

Object-oriented processing

Object-oriented classification method is a process in which each image objects allocates to one of new salt water classes, old salt or another use. This type of classification unlike pixel-based classification, based on fuzzy logic and convert feature value to the value of the phase (between zero and one) with a certain degree of membership for each class. In this method, pixels with different membership degree can be classified in more than one class. The definition of appropriate conditions for each class forms the basis for classification. The classification process is repeatable, and continues till achieve the highest degree of membership for each of the classes. Compared with the theory of binary (base pixel) that has a value of zero and one, fuzzy theory is more flexible and allows you to set a pixel based on certain membership degree that attributes to several classes (Feyzi Zadeh et al., 2009). Benefit of object oriented classification than pixel-based classification is that image objects contain more information than a single pixel. Because object-base classification, in addition to texture information, uses content and texture information for classification (James, 2006).

Fuzzy classification

In object-oriented processing method each class has its own definitions and descriptions and descriptions of each class consists of a set of conditions that is determined based on fuzzy operators. This method converts to phase value (between zero and one) with a certain degree of membership for each class. These conditions can be defined individually for each class that is very important in object-oriented classification in eCognition software and forms the basis of fuzzy classification. In eCognition, the definition of appropriate conditions for each class will form the basis of fuzzy classification. By determining the characteristics of spectral data and geometric characteristics of land use classes during the process of image processing, fuzzy logic can be used and the conditions for classification can be defined. (Fayzi Zadeh et al. 2009).

Segmentation

Segment means a group of neighboring pixels within an area which similarity is the (such as numerical value and texture) is the most common criterion. In object-oriented processing of images, objects of pixel groups form with the homogeneous and heterogeneous criteria that are the most important processes in object-oriented images. Segmentation separates image elements according to the texture, tone and shape. (Fayzi Zadeh and Mir Rahimi, 2007). In this study, first suitable bands were created and then the segmentation operations with multi-resolution segmentation algorithm were applied. Among the different scales, scale 50 was chosen as the appropriate scale and the form factor and compression factor were chosen 5.0 respectively for each one. In addition, during segmentation, the weight of near Infrared band was chosen 2 and the weight of other bands was chosen 1.

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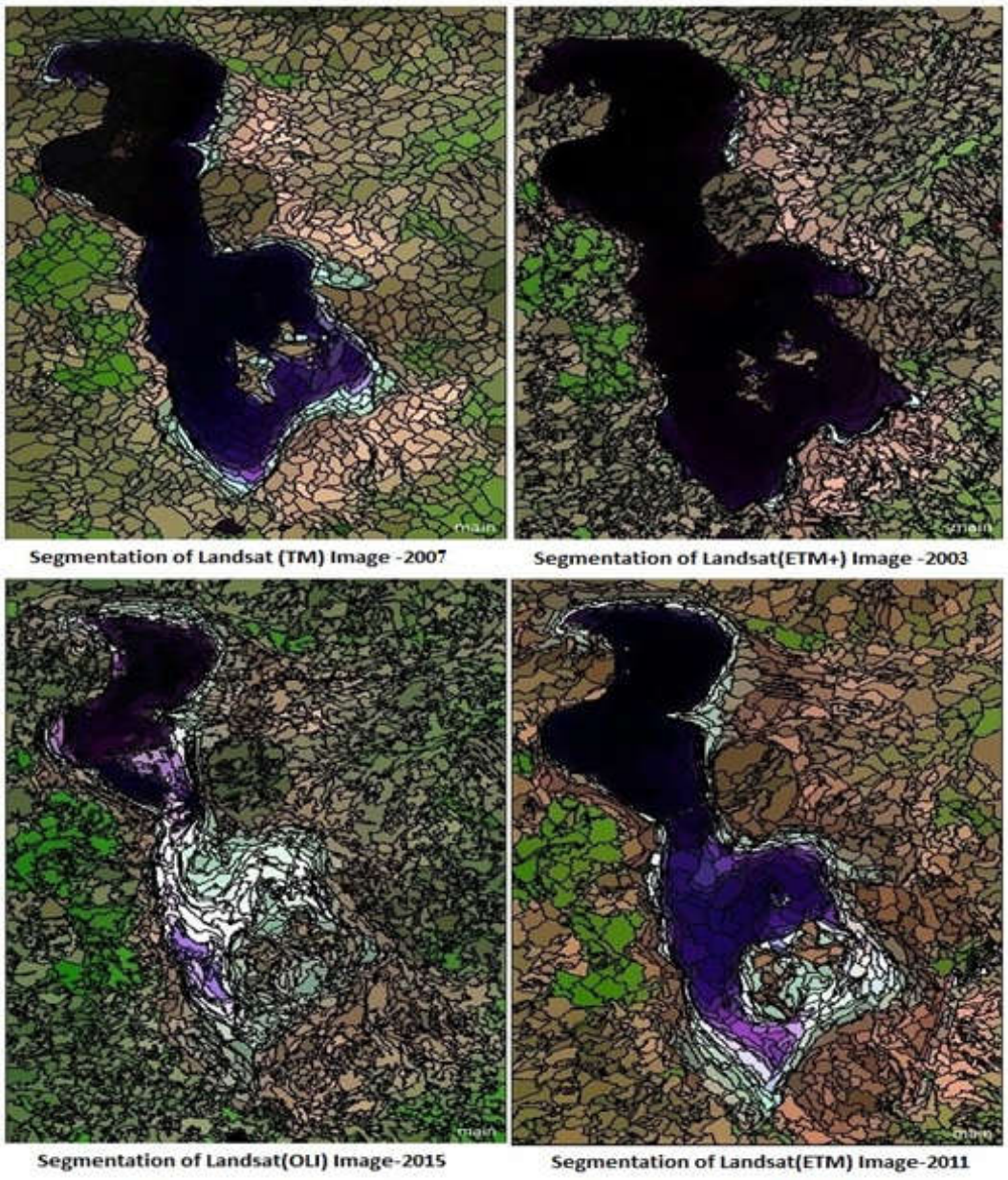

Fig 2: Segment results in different periods of Landsat images

Afterr segmentation Different types of salinity indices, lighting index, as well as vegetation index and indices listed in Table (1) entered to software environment for object-oriented classification and most suitable indices were selected among them. Then by considering the optimum parameters Assign class algorithm was used for object-oriented classification. Results entered to Arc Gis 10.2 application environment for appropriate cartography as well as calculate the area of each of the classes. Results are as follows.

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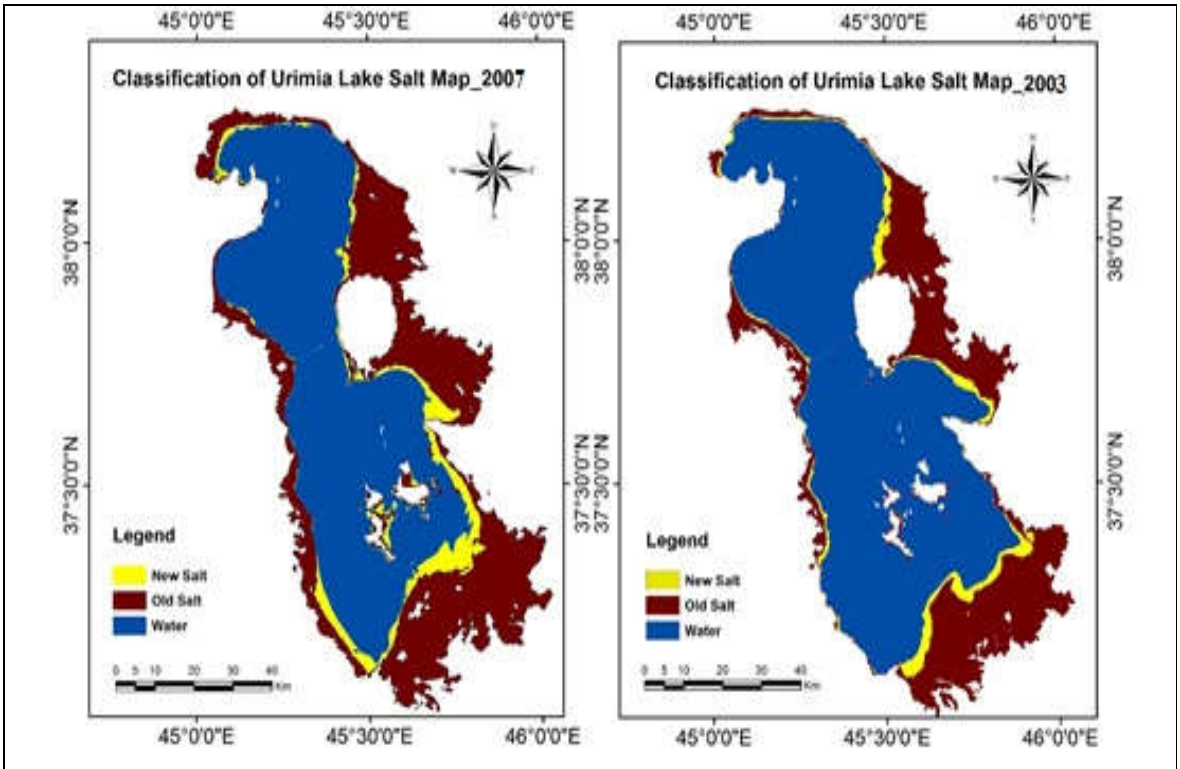
Table 1: Common indicators to assess the salinity

index	Formulation	Reference
Soil-Adjusted Vegetation Index(SAVI)	(NIR-R)(NIR+R+L)(1+L)	(Huete , 1988)
Salinity index(Si-T)	(R/NIR)*100	(Tripathi et al.,1997)
Brightness Index (BI)	$\sqrt{R^2 + \mathrm{NIR}^2}$	
Normalized Differential Salinity Index (NDSI)	(R-NIR)/(R+NIR)	(Khan et al.,2005)
Salinity Index (SI)	$\sqrt{B * R}$	
Salinity Index 1 (SI1)	$\sqrt{G * R}$	
Salinity Index 2 (SI2)	$\sqrt{G^2 + \mathrm{R}^2 + \mathrm{NIR}^2}$	(Douaoui et al., 2006)
Salinity Index 3 (SI3)	$\sqrt{G^2 + \mathrm{R}^2}$	
Salinity Index (S_1)	B/R	
Salinity Index (S_2)	(B-R)/(B+R)	(Abbas and Khan.,2007)
Salinity Index (S_3)	(G*R)/B	
Salinity Index (S_5)	(B*R)/G	
Salinity Index (S_6)	(R*NIR)/G	



Figu 3: Lake salt and water classification map in 2003 and 2007

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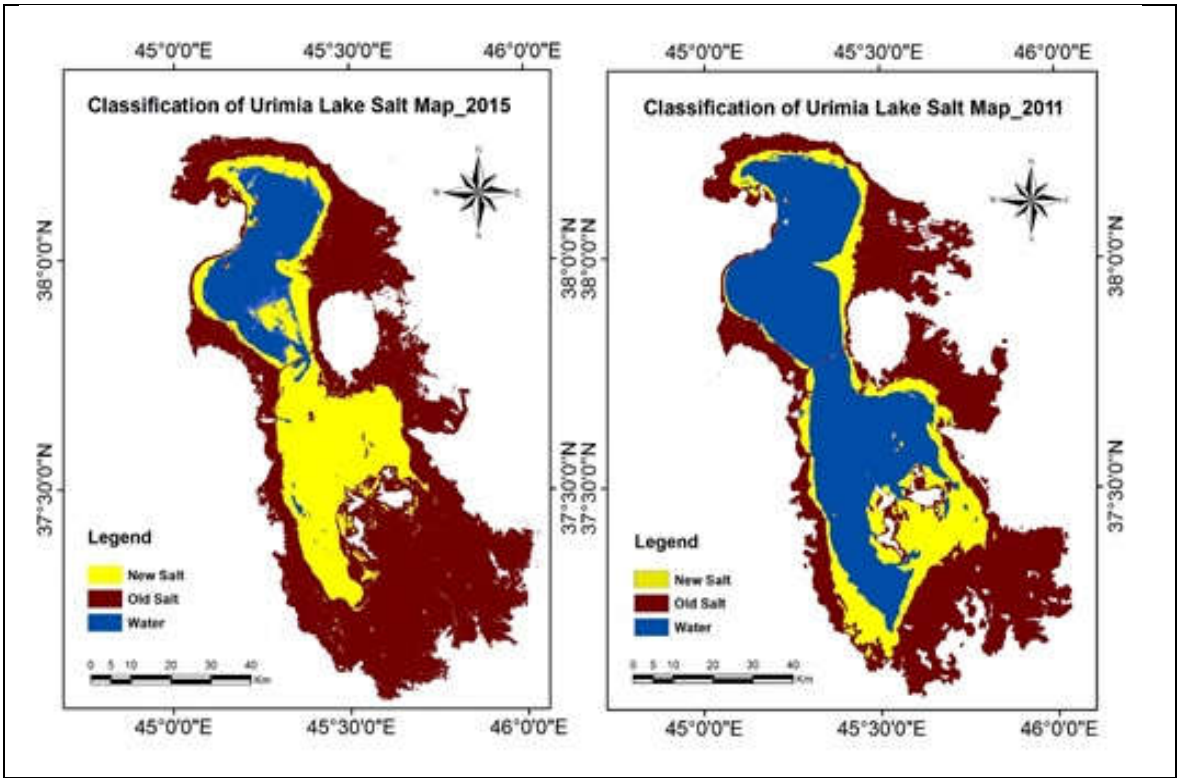

Fig 4: Lake salt and water classification map in 2012 and 2015

The classification accuracy

Classification accuracy Indicates the level of trust to the extracted map, the land use maps accuracy derived from remote sensing images should be at least 85%. The classification accuracy is a level of assurance that is obtained from the ratio between the assessed pixels for classification and a collection of ground data collected by the interpreter (Rasouli and Mohammad Zadeh, 2010). At this stage of research, to ensure the accuracy of classification, we evaluate the classification accuracy and during field operations randomly determine control points with GPS from our area and classification accuracy assessment parameters include error matrix, manufacturing accuracy, user accuracy, kappa statistics coefficient as well as overall classification accuracy was obtained. The total classification accuracy equivalent to 96.0 percent and Kappa coefficient was estimated to be equivalent to 92.0 percent. This high accuracy is largely because in this method in addition to use spectral data, the information about the content, form, texture and tone is used for classification. So, using the information other than numerical values in classification of images, thereby increasing the classification accuracy is made (Fayzi Zadeh, 2007).

eCognation provides the accuracy evaluation method using the error matrix based on the ground facts. By definition of ground fact, the software automatically generates error matrix. In addition to the classification error matrix parameters related to the accuracy of the manufacturer, the user accuracy and kappa coefficient for each class is obtained from the classification error matrix. In Table (3) the statistical parameters are provided. Also Table (2) shows a classification error matrix with nearest neighbor.

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Table (2): Matrix classification error

Total	Other uses	Old salt	New salt	Water	Error Matrix 2015
9929	79	0	240	9610	Water
7300	0	180	7140	0	New salt
8175	49	8125	0	0	Old salt
11270	11270	0	0	0	Other uses
	11398	8305	7380	9610	Total

* Numbers located on the diagonal of the error matrix indicates the number of pixels that were correctly classified.

Table 3: Manufacturer accuracy, user accuracy, accuracy and kappa coefficient

Other uses	Old salt	New salt	Water	Accuracy 2015
0.986	0.8236	0.947	1	Manufacturer
1	0.995	0.893	0.967	user
0.983	0.865	0.948	1	kappa coefficient
0.942				Overall Accuracy
0.9245				kappa coefficient

Conclusion

Given that satellite images are be prepared in time series, they can be used to assess land cover and land use. In this study, after necessary corrections and pre-processing of images, was attempting to classify data into object-oriented approach, in other words, images quality were reviewed and revised for the presence of geometric and radiometric errors. The images were entered to eCognition software environment and all conventional indices have been tested for salinity assessment and appropriate indicators for classification were used and results were obtained as follows:

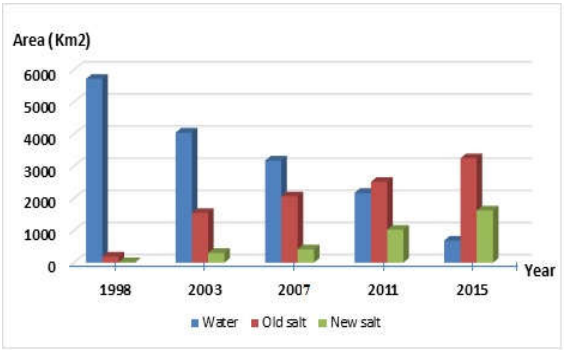

Fig (5): changes in each of the classes

Table (4): Classification of the each area of the classes per square kilometers unit

2015		2011		2007		2003		1998*		User type
Percent	Area (Km^2)	Percent	Area (Km^2)	Percent	Area (Km^2)	Percent	Area (Km^2)	Percent	Area (Km^2)	
4.47	687.718	14.14	2175.53	20.68	3179.71	26.32	4048.13	37.22	5722.83	Water
10.58	1627.14	6.67	1025.76	2.72	419.343	1.98	305.803	0.107	16.502	New salt
21.16	3253.64	16.36	2515.94	13.42	2063.55	10.08	1550.94	1.25	192.69	Old salt
63.78	9806.55	62.81	9657.88	63.17	9712.5	61.59	9470.24	61.41	9443.08	Other uses

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* Image 1998 is the year of full water lake. And just is to compare the current situation with the earlier situation that the lake has been in high water state and is clearly visible in Fig (7). So that the light blue that is covered broader range is lake overhydration state in 1998. And middle parts that are shown with dark blue are Lake dehydration in the 2015. Water and salt changes in 1998 and 2015 years in Fig 8 clearly shows that during this period the water level had dropped dramatically and subsequently the amount of new and old salt have increased.

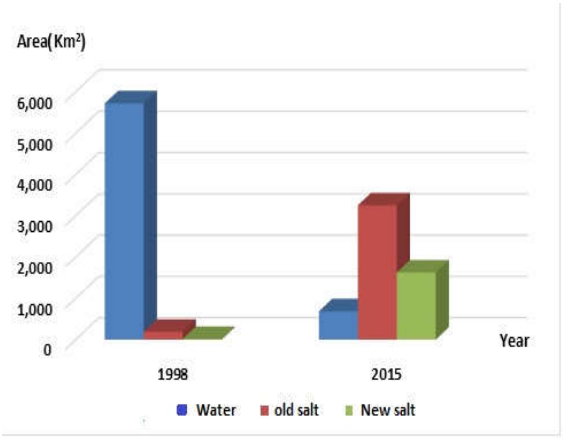

Fig (6). Comparison Chart of water between the two high-water and low-water

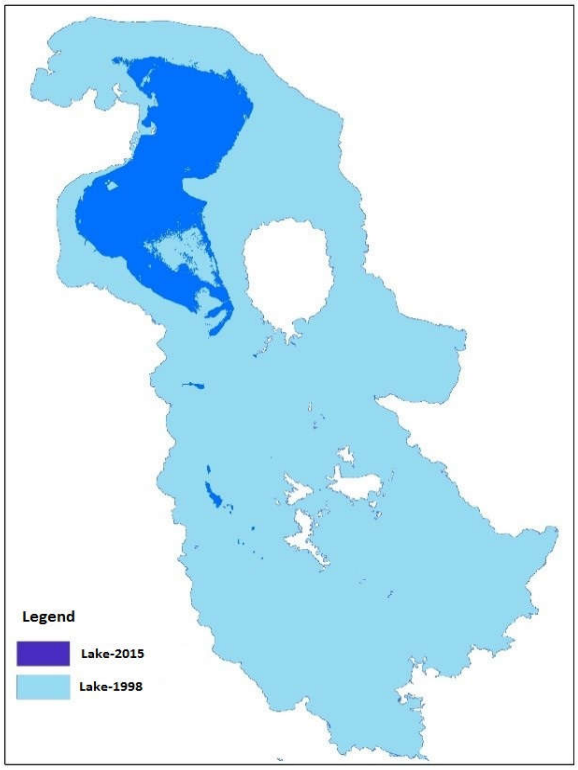

Fig (7). Comparison of lake water in 1998-2015

Today, images obtained from remote sensing are known as the newest information to study land cover and land use (Rasouli, 2005). In this study, Landsat imagery to achieve higher classification accuracy, object-oriented method in eCognition software environment were processed and water classes, new salt, the old salt and also other uses identified. Knowing the percentage of each use, review of land use changes for the time, natural resource management, evaluation of the environmental pressures caused by industrial development and management of agricultural production, especially gardens in each geographical area can be determined (Rasouli and Mahmood Zadeh, 2010). To determine the accuracy of the maps, action was taken to assess the accuracy of classification. And by determining ground control points the accuracy was re-evaluated. Looking at the table (2) and (3) it can be seen that object-oriented classification method with overall accuracy is 94.0 and Kappa coefficient is 92.0, and it shows that Landsat images have relatively high accuracy for classification. The highest amount of Kappa coefficient is 1 for water class, and the lowest is 86.0 for old salt. They also determined by analyzing the results of the annual changes in water level as well as new and old salt changes in annual terms were significant. Changes related to the area of classes in the study area Table (4) as well as the diagram in Fig (6) are shown. They are observed in both cases that during the 12 years, the lake water has become lower and the amount of new and old salt have increased. However, the process of dehydration in the last three years has taken a relatively steep and in contrast new and old salt have increased and day-to-day salt zones around the lake area are added. And this requires concerned authorities serious attention.

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