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Investigating Trend of Water Level Changes in Urmia Lake (1984-2017)

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Abstract

The decrease in the level of Lake Urmia is evidence of climate change and anthropogenicity. This decrease in level has led to an increase in salt area, salt storms and salinization of groundwater. It is one of the major environmental challenges in northwestern Iran. Fluctuations in lake level, decrease in water level of plains and decrease in river discharge are evidences of hydrological changes in Urmia Lake basin. The present study tries to provide a clear picture of the water changes of Urmia Lake during the last three decades. Hydrological data and images of Landsat satellite for Urmia Lake basin in the period 1984-2017 were studied using remote sensing and statistical methods. The classification of satellite images was performed using the maximum likelihood method. According to the results, the highest decrease in the area of the lake between 2001 and 2013 happened. Also, the analysis of the results showed that along with the very important role of global warming on the water volume of Lake Urmia, humans have been able to be one of the most important regional factors in creating the challenge of Urmia Lake. In fact, the water problems of Urmia Lake, especially after 2001, are a combination of climatic and anthropogenic factors.

***Keywords**:* Planning, Trend, Ecological Level, Urmia Lake

1. Introduction

Water is a key element of land management and sustainable development. Recognition and analysis of water resources capacity is a prerequisite for land use planning (Kazemi et al., 2020). Urmia Lake (UL), as the largest inland lake in Iran, since the mid-1990s, due to changes in level, water volume and area, has received much attention (Eslami et al., 2015; Asghari Zamani., 2013; Rasouli., 2008; Fathi et al., 2015). The water level of UL has decreased rapidly since 1995 (Bagheri et al.,2017) and since 2001 it is lower than the ecological level (1274.1 meters). Due to the shallow depth of the lake, this level

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drop has led to a significant percentage of dryness of the lake (ULRP*., 2017). Continuation of the drying process of UL can affect the health of human communities, climate and water resources, socio-economic status, biodiversity and natural environment of the lake more than before (SCCULRP†., 2015). Any planning to strike a balance between the human and natural environments requires a detailed understanding of the past and the present. The research tries to provide a clear illustration of the water changes of UL during the last three decades.

2. Materials and Methods

The study area of this research is Urmia Lake Basin (ULB) from 1984 to 2017. In each decade, a year is examined which Landsat images cover the entire region and have sufficient resolution. In selecting images, a cloud cover filter below 10% has also been applied. Landsat images 5, 7, 8 related to years: 1984, 1992, 2001, 2013 and 2017 were downloaded from the site (https://earthexplorer.usgs.gov/). The maximum likelihood method was used to classify satellite images. To measure the validity of the drawn maps, user accuracy, overall accuracy and kappa coefficient were used. Data related to the hydrology of the region have been received from the Water Resources Research Organization (TAMAB) and statistical yearbooks.

2.1. Evaluate the Accuracy of Satellite Image Classification

In order to use maps prepared through the classification of satellite images, the accuracy of the map and its error rate must be clear and acceptable. Otherwise, the quality of the map information is not clear and the interpretations and decisions made from it may be accompanied by complete uncertainty and become problematic. There are several ways to evaluate maps. User accuracy, overall accuracy and kappa coefficient are the most usable. To perform these validations, an error matrix must first be formed. The error matrix includes tabulated results of accuracy assessments for a thematic classification such as land use map. The elements on the main diameter of this matrix show the number of samples that have matched to reality (Rosenfield & Fitzpatrick-Lins., 1986). User accuracy is obtained by dividing the numbers of the error matrix's the original diameter on the sum of each row. This shows the total number of samples that are correctly placed in each user. The sum of the elements on the main diameter divided by the total number of samples also gives the overall accuracy of the classification. In both methods mentioned, the acceptable result should be more than 85% (Lunetta & Lyon., 2004).

Kappa coefficient is a discrete multivariate technique in evaluating the validity of maps. The kappa value can be between +1 to -1. Landis and Koch (Landis & Koch.,1977) have divided the results of the kappa coefficient into three groups: values greater than 0.8 (80% and above), high accuracy, values between 0.4 and 0.8 (between 40 and 80%) Medium accuracy and less than 0.4 (less than 40%) indicate low accuracy (Congalton & Green., 2009).

2.2. Study Area

The area of ULB is 52,000 Km2, the area of UL has changed a lot, fed by the main three rivers of Aji chai, Zarrineh Roud and Simina Roud (IME‡., 2012; Malekian & Kazemzadeh., 2016 and SMWRAULB§., 2013), (Fig.1). UL is a national park and a unique habitat of Artemia, safe shelter for

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* - Urmia Lake Restoration Program
† - Socio-Cultural Committee of Urmia Lake Restoration Program
‡ - Water Research Institute
§ - Sustainable Management of Water Resources and Agriculture Urmia Lake Basin

Flamenco and Pelican species. It is registered as the biosphere reserves by UNESCO. The annual precipitation is 329 mm and annual temperature is11.7°C (IRIMO* and IME†., 2017; Bashirian et al., 2020).

UL is recognized as a biosphere reserve by UNESCO. it is one of the international wetlands under the Ramsar Agreement (SMWRAULB., 2012). In the ecological area of the lake, there are 17 important sites including the lake, the islands inside the lake and the surrounding wetlands. Many of these wetlands are not properly managed and destroyed (IEPO‡., 2010; Sima & Tajrishy., 2013). Under normal hydrological conditions, the average depth of Lake Urmia is about 4.5 meters. Its maximum depth is about 15 meters, which is located in the northern parts of the lake. When UL is in ecological condition; The water level is 1274.1 meters, the lake area is 4333.3 square kilometers and the water volume of the lake is 13.7 billion cubic meters. At maximum, the value of each of these components will be 1278.4 meters, 5724.4 km 2 and 30.7 BCM respectively (WRI., 2017).

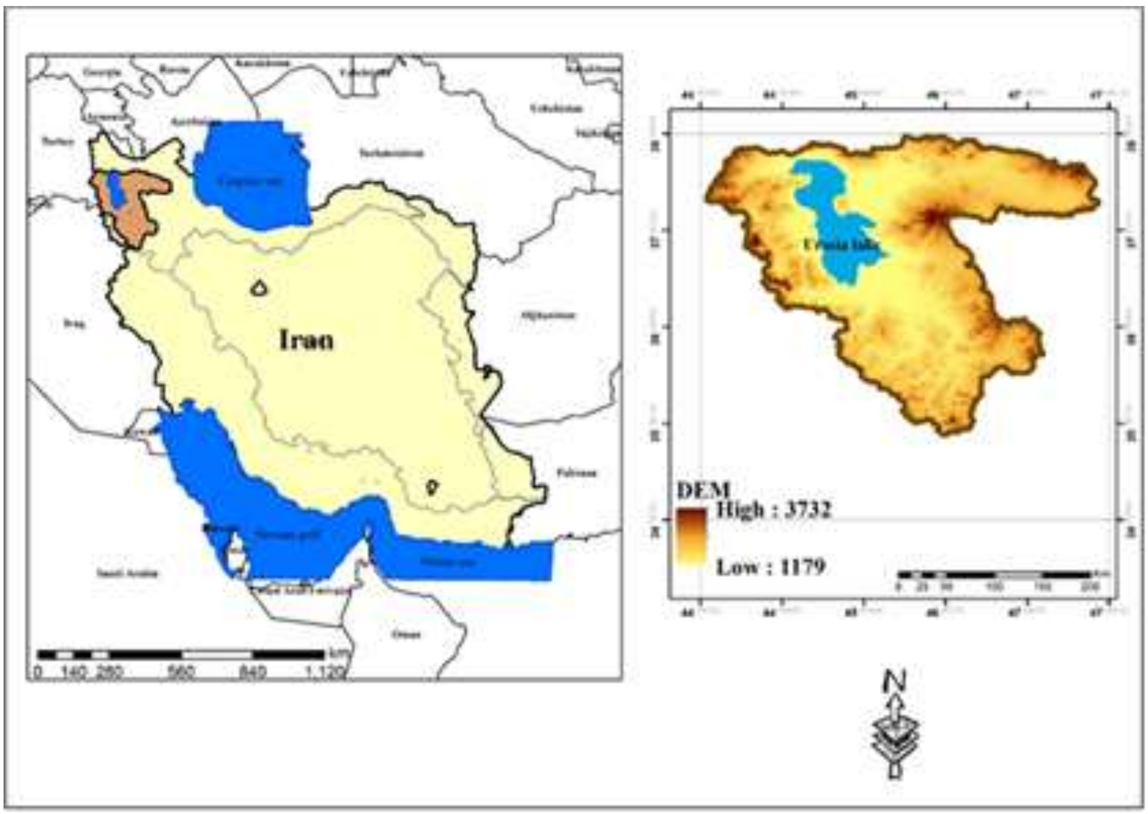

Figure 1. Location map of the ULB in Iran

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* - Iran's Meteorological Organization

† - Iran’s Ministry of Energy

‡ - Iran’s Environmental Protection Organization

3. Results and Discussions

3.1. Changes of UL

The maps drawn using Landsat images show that the area of the lake has been decreasing since 2001. So that its area has increased from 4981 Km2 in 1992 as the wettest year of the study period to 1938.5 Km2 in 2017. Therefore, the lake in 2017 compared to 1992 has decreased by about 3061 square km2, that's mean 61%. These changes are more evident in the southern parts, especially in the southeast of the lake (Figure 2 - 3).

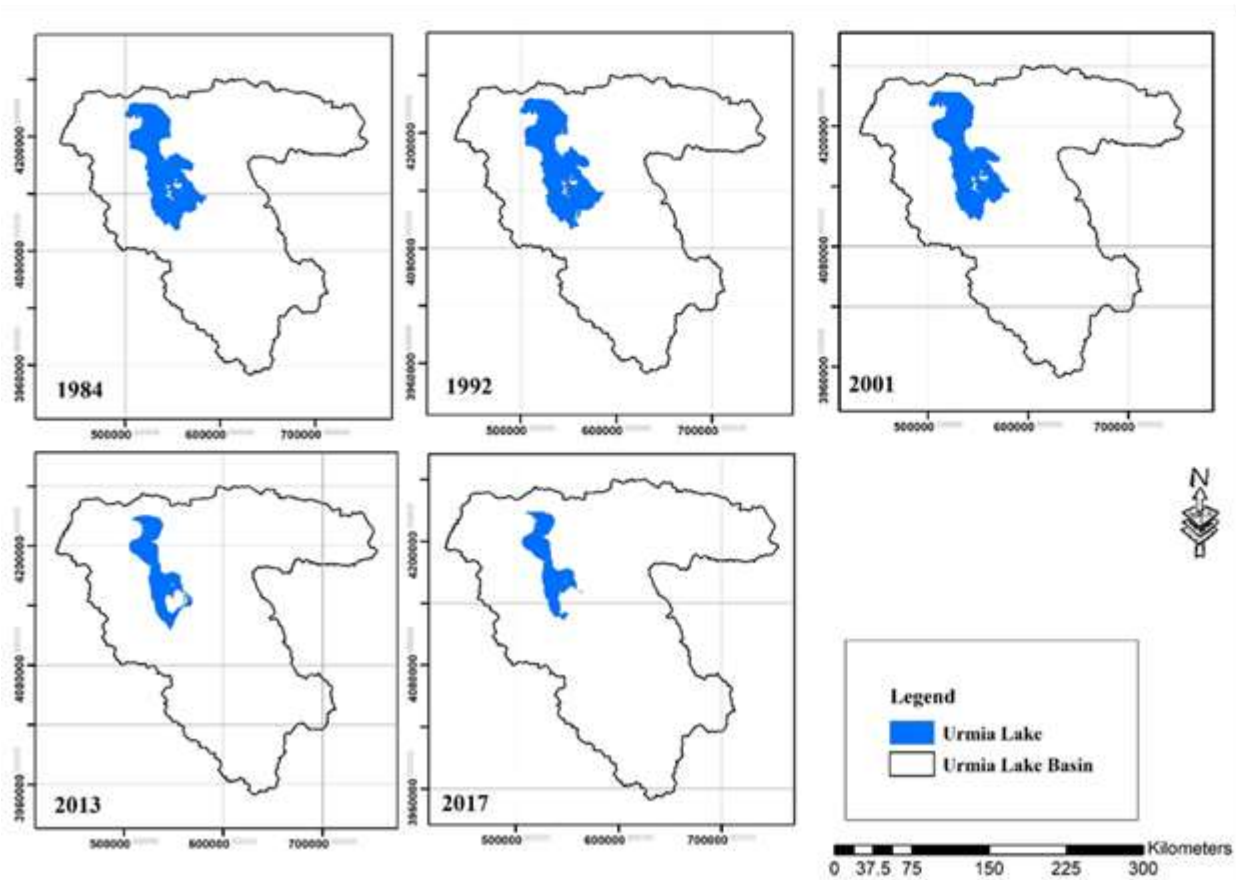


Figure 2. Map of UL in the ULB

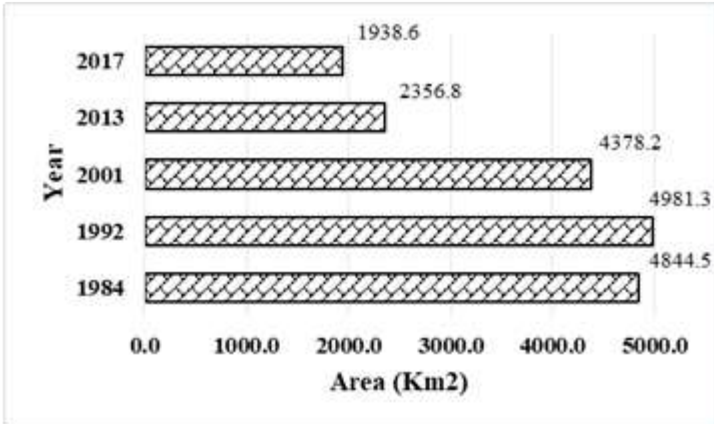


Figure 3. UL Area Changes 1984-2017

The results of validation showed that the drawn maps have high validity (Table 1).

Table 1. Accuracy of the classification, overall accuracy and kappa coefficient

	1984	**1992**	**2001**	**2013**	**2017**
UL	100	100	100	100	100
Over All Accuracy	0.99	0.97	0.97	0.97	0.96
Kappa	0.99	0.96	0.97	0.96	0.96

3.2. Changes in the Water Level of UL

In order to study the ecological level of Lake Urmia, the level of the lake was studied in March (high level) and September (low level). Figure (4) shows that the long-term trend of lake water level in both months is decreasing and significant (Z = -5.52, Z = -5.76). Also, the water level has decreased sharply and significantly since 1995. From 2001 upwards, the lake level is lower than the ecological level (1274.1m). This situation indicates the critical condition of the UL.

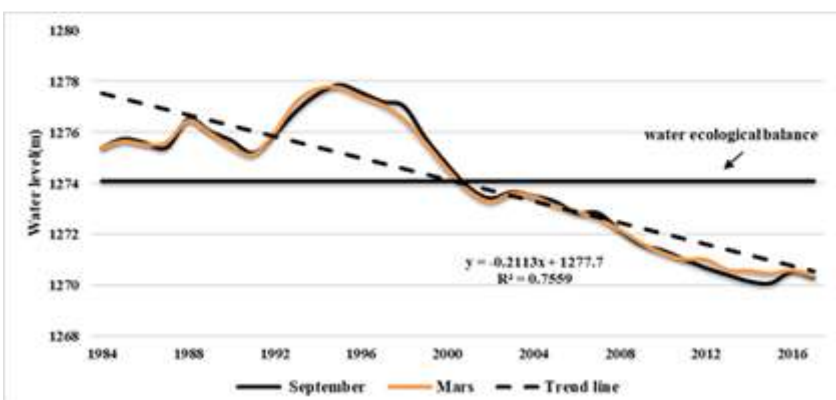


Figure 4. Monthly trend of changes in the water level compared to the water ecological balance of UL

3.3. Changes in the Water Volume of UL

Statistical analysis of the inflow of water to UL shows that during the study period, the inflow of the lake has fluctuated consumedly. So that it has fluctuated from 11.4BCM in 1987-88 to 1.27 BCM in 2000-2001. According to Figure (5), from 2001 onwards, the volume of water in UL is lower than the volume of ecological water in the lake (13.4 BCM). In this period, the coefficient of determination between the volume of water entering the lake and the volume of rainwater in the basin is 48%. While before 2001, these two had a high coefficient of determination of about 80%. This indicates that before 2001, changes in the water volume of the lake were completely influenced by the behavior of climatic elements but from that year onwards, in addition to these elements, anthropogenic regional factors are effective (Figure 6).

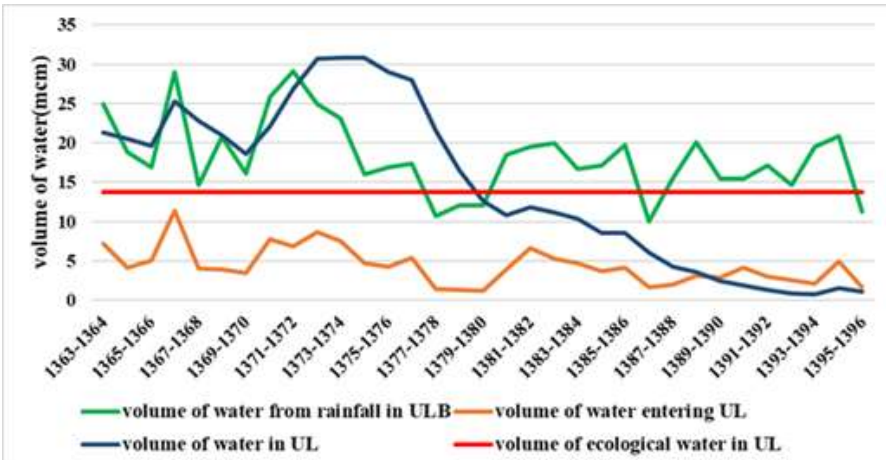
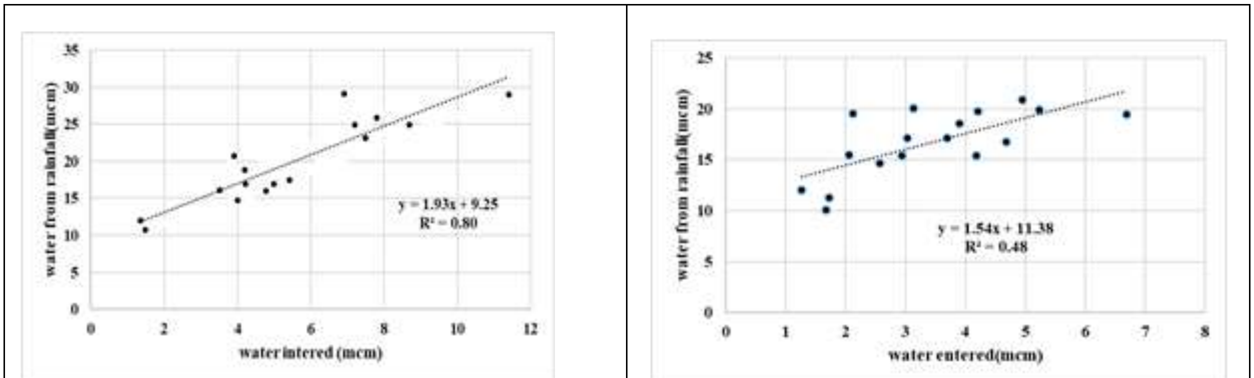


Figure 5. Trend of changes in the volume of water from rainfall in ULB and volume of water available and entry in UL



(a) (b)

Figure 6. (a) Correlation between the volume of water entering UL and the volume of water resulting from the rainfall of the ULB before 2001. **(b),** Correlation between the volume of water entering UL and the volume of water resulting from the rainfall of ULB after 2001.

4. Conclusion

Lake Urmia, the largest inland water area of Iran, has faced the challenge of drying up during the last two decades (2001-2017). So that the area of the lake has decreased from 4378 to 1938.5 Km2 and the level of the lake has reached from 1274.9 to 1270.3 m (about 3 meters less than the ecological level). The highest decrease in the area of Lake Urmia occurred between 2001 and 2013. Also, the analysis of changes in the volume of the lake showed that since 2001, the volume of water in the lake has been lower than the volume of ecological water; The coefficient of determination between the volume of water entering the lake and the volume of precipitation in the basin decreased from 80% to 48%. This indicates that before 2001, changes in the water volume of the lake have been completely influenced by the behavior of climatic elements, but since then, along with these elements, anthropogenic regional factors are also effective.

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