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Statistical Modeling of Future Lake Level under Climatic Conditions, Case study of Urmia Lake (Iran)

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ABSTRACT: The present research focuses on the changes of Urmia Lake level. For this purpose, two time scales have been considered. The trend changes of temperature, precipitation rate and quantitative values of climate type for the observational period from 1968 to 2011 (past scale) and from 2011 to 2100 (future scale) have been analyzed. General Circulation Model (GCM) is considered for simulating the values of the future meteorological components, and statistical models have been used for modeling the lake's level in future decades. One of the most significant results achieved for the future decades is the increase of the lake's temperature for around 1.5 degrees centigrade till 2100 in comparison with the long-term average of 1961 to 1990. Furthermore, the values extracted from precipitation rate and climate type of the zone also indicate a remarkable decrease of quantitative values in the future decades. Accordingly, the climate type extracted for the year 2100 with numeric value of around 17.75 will be entered a new phase called arid climate for the first time in recent decades. The Lake surface area is diminished from 5650 square kilometers in 1998 to about 2005 square kilometers in 2010. According to the results achieved by statistical models and time series, if this trend continues, the Lake level will be reduced around 3 more meters in 2100.

Key words: Simulation, Circulation Models, Desertification, Urmia Lake, Water level dro

INTRODUCTION

Qualitative and quantitative degradation of water resources is one of the major challenges in the way of sustainable development (Baghvand *et al.*, 2010; Nasrabadi *et al.*, 2010a; Nasrabadi *et al.*, 2010b; Rowshan *et al.*, 2007; Serbaji *et al.*, 2012; Guinder *et al.*, 2012; Li *et al.*, 2012; Siddiqui, 2011; Pei *et al.*, 2011; Ying *et al.*, 2011). Features and phenomena in the earth's surface have been changed over time; the lakes as one of these features and due to having a closed environment are not considered as an exception. Due to climatic changes such as reduced rainfall, increased temperature and also uncontrolled use of surface water resources in watershed areas, distinguished changes are exposed (Sadatipour *et al.*, 2012; Sandeep *et al.*, 2012; Madani *et al.*, 2012; Mirbegheri *et al.*, 2012; Arias *et al.*, 2012). Monitoring such changes should be considered as an important issue in the national and regional development and natural resource management. Currently, monitoring the coastal areas and extraction of water at different intervals is regarded as an infrastructural research interest due to the significance of coastal zone management and dynamic nature of such sensitive ecological environments (Reveshty and Maruyama, 2010; Nasrabadi *et al.*, 2009; Pamer *et al.*, 2011; Kavian *et al.*, 2011; Karbassi *et al.*, 2011; Mortazavi and Sharifian, 2011; Lei *et al.*, 2011; Hudak, 2011).

Due to the ever increasing rate of greenhouse gas emissions, climate warming is expected to be more intensive during the next century (Houghton *et al.*, 1996; Ashrafi *et al.*, 2012; Manju *et al.*, 2012). This warming would very much influence natural processes as well as human activities. In general, it is supposed that in low latitudes, like in Iran (25 and 40° N latitude and 44 and 63.5° east longitude), climate change would have some negative influences on the whole society. For example, higher temperatures will increase the energy demand for cooling, reduce the precipitation rate and degrade the water resources (Roshan *et al.*,

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2010; Roshan *et al.*, 2011). Regarding the effect of global warming on lakes depth and surface area fluctuation, lots of studies have been run on simulation and prediction of such changes all around the world (Chelton *et al.*,1982; Fang *et al.*,1998; Cabanes *et al.*,2001; Chen *et al.*,2002; David *et al.*,2002; Bouzinac *et al.*,2003; Michael *et al.*,2009; Mooij *et al.*,2009; Moernaut *et al.*,2010). As lakes respond directly to climate changes, quantifying their sensitivity to possible potentials will provide crucial information for the assessment of water resources quality and aquatic ecosystems in future (IPCC, 1996; Hauser *et al.*, 1997; Magnuson *et al.*, 1997; Mulholland *et al.*, 1997; Rouse *et al.*, 1997; Schindler, 1997; Fang *et al.*, 1999, Komatsu *et al.*, 2007). Any increase in water temperature would change hydrodynamics regime in lakes, expand the thermal stratification period, and consequently deepen the thermocline (e.g. Hassen *et al.*, 1998; Blenckner *et al.*, 2002, Komatsu et al, 2007). Lake level drop is one of the key problems that should be taken into consideration in climate change impact assessments for Urmia Lake (location map on Fig. 1). It will cause desertification of coastal areas, erosion of sandy beaches and destruction of harbor constructions. Covering an approximate area of 483 thousand hectares Urmia lake is the twentieth largest lake of the world and at the same time one of the most unique and invaluable global water ecosystems (Karbassi, *et al.*, 2010; Ahmadi *et al.*, 2011; Ahmadzadeh Kokya *et al.*, 2011; Farzin *et al.*, 2012). The most recent statistics indicate that 250 thousand hectares of this lake which has been registered in the list of Ramsar convention on conservation of wetlands since 1975 has been changed into salt marsh and the water level has dropped to the minimum possible level during the past few decades. Passing the oversaturation limit, the salinity has also reached to 340 grams per liter which has caused Artemia, the most significant organism in this lake, goes toward extinction. All above-mentioned facts indicate the gradual and of course painful death of this great Iranian lake and a bioenvironmental catastrophe in this zone.

Fig. 1.Urmia Lake location (black color) and its catchment boundaries (cross filled)

The main objectives of this study are to derive and analyze future climate projections over the region, to model the lake surface fluctuation regime by linking the observed data to current climate and finally to model future lake behavior due to climatic projections.

MATERIALS & METHODS

Urmia Lake as the largest water body in Iranian plateau is located between two major provinces of East Azerbaijan and west Azerbaijan .The lake is bounded between 37°5´ -38°16´ latitudes and 45°01´ - 46°longitudes at 1275 m above sea level .Its surface area ranges from 4750 to 6100 km2 and the average and greatest depths account for 6 and 16 m, respectively (Azari Takami, 1993). More than twenty permanent and seasonal rivers as well as a few submarine streams and springs feed the lake. Average salinity of the lake ranges between 220-300 mg/lit depending upon temporal and spatial conditions, although in recent years it has reached up to 380 mg/lit. Due to the ecological heritage of Urmia Lake, it is recorded as a protected habitat in the world by the United Nations (Reveshty and Maruyama, 2010).

The catchment was defined as the most appropriate spatial unit to relate hydro-climatic conditions to the lake levels variability. The catchment delineation was based on Hydroshed database (Fig. 1). In order to study the fluctuations of Urmia Lake surface area, multi-temporal Landsat Images (ETM, TM and MSS sensors) over a 34-year period (1976 to 2010) were used (Fig.2). Spectral specifications and spatial resolution of each of the bands of this satellite are presented in Tables 1 and 2.

In the present study, the coastlines extraction for each year was done in two major steps using the ENVI software. Firstly, geometric and radiometric corrections as well as different filters on the selected images were applied to make the spectral difference of objects more clear. Secondly, supervised classification method has been used to extract coastlines. For this purpose, Training Areas where appointed across the lake and more than 25Training Areas have been provided in any of the images. All of these Areas have been provided from the lake's surface area. Selecting a large number of Training Areas goes back to the nature of

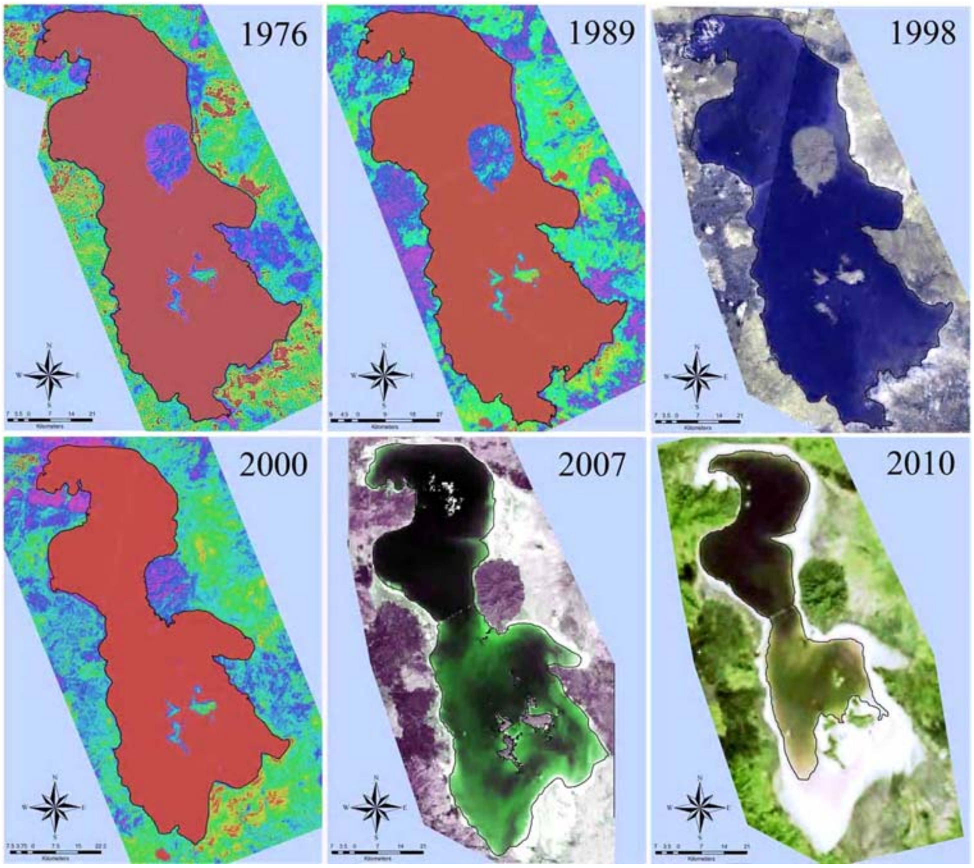

Fig. 2. Satellite Image of Urmia Lake during 1976-2010

Table1. Landsat 7 ETM+ and Landsat %TM spectral and spatial resolution

Band No.	Spectral range(Microns)ETM+/TM	Ground resolution(m) ETM+/TM
1	.45 to .515 /.45 to .52	30
2	.525 to .60 / .52 to .60	30
3	.63 to .69 / .63 to .69	30
4	.75 to .90 / .76 to 90	30
5	1.55 to 1.75 /1.55 to 1.75	30
6(L/H)	10.4 to 12.5 / 10.5 to 12.4	60 / 120
7	2.09 to 2.35 / 2.08 to 2.35	30
Pan	.52 to 90 /Nil	15 Nil

Table 2. Determination of Urmia Lake coastline by the use of different satellite images

Date	Satellite	Sensor	Spatial Resolution
1976	Landsat	MSS	57m
1989		TM	30 m
1990			
1998		ETM	
2000			
2003			
2005			
2007			
2009			
2010			

Urmia water, its depth and sediments. Such a number allows us separate the watery part of the lake easily from its arid and humid parts in which there is no water regardless of the depth and muddiness of the lake's water. Since this study aims merely at determining coastlines _meaning the border line where the land meets the water_ this number of Training Areas has been used. Upon determination of the Training Areas based on images and their analysis, classified images have been obtained for each of the years. These images of high accuracy indicate the border between the lake and the land, or in other words the coastline.

Multi-temporal images of Landsat satellite (Mss, TM, ETM components) for a period of 34 years have been used to examine the changes in Urmia Lake coastline. Spectral features and precision of each component have been given in Table 2. To determine the coastline of Lake Urmia during a 34-year period, supervised classification method has been used. After required corrections such as geometric and radiometric corrections on the images, the detection of coastline was followed. The most important band used in this step was the infrared band of the components, because in this band wave limit, the volume of water of the lake displayed significant differences with other land phenomena.

To use the supervised classification, the preparation of the training area from the lake surface has been carried out. The reflection values in these areas have been generalized to the entire lake surface using the software and thus, the border between the lake and surrounding areas has been set precisely. Finally, through the algorithm for conversion of two vectors, the coastline limits have been drawn for different years. To carry out the analysis of images the ENVI software has been used.

In order to model the lake levels in relation to the averaged climatic conditions over the catchment, the inter-annual monthly time series of precipitation and air temperature were used. Such data were collated from the Climate Research Unit (CRU) dataset (Version 3.2; available at http://www.cru.uea.ac.uk/cru/data/hrg/). Future climatic conditions describing monthly mean temperature and precipitation rate for three periods (2030, 2050 and 2080) were extracted from the FutureClim dataset (FCC; Jones *et al.*, 2009) according to two Global Climate Models (GCMs) namely the MIROC_3-2_MEDRES (National Institute for Environmental Studies, Japan) and MPI_ECHAM5 (Max Planck Institute for Meteorology; Germany). Additionally, scenarios A2, A1B and B1 from Special Report on Emission Scenarios (SRES) were also used in order to account for the variability in future climate conditions and to discuss the mitigated impacts of global climate change on Urmia lake future levels. Based on current and future climate projections for the three distinct periods (2030, 2050 and 2080), an inter-annual time series of monthly climate conditions for the period 2000-2100 was derived. Accounting for a part of stochasticity in the projections related to monthly climate variability, such time series also reflect the temporal trend in future monthly climate variables over the 21th century. The time series were built in three major steps. Firstly, the future inter-annual trend over the 21th century was estimated using Generalized Linear Model (GLM). Each monthly precipitation and temperature data was regressed against the inter-annual variability assuming a gamma and Gaussian distribution of the errors, respectively. Secondly, in order to account for monthly variability in future projections, a stochastic weather generator was developed. The probability distribution function (PDF) of GLM residuals for the period of CRU records (1968-2006) was estimated. For each year of the period 2007-2100, one value from the estimated PDF was randomly picked up and summed to the linear trend to build a complete time series. Finally, the overall two previous steps were repeated ten times in order to account for a part of variability in future climate projections.

The inter-annual variability of lake levels was modeled dynamically using climatic conditions of the year and lake levels of the previous year. To synthesize climatic conditions, a Principal Component Analysis (PCA) was applied to the annual monthly mean temperature and precipitation data. The first three components of the PCA (hereafter, refereed as CLIM1, CLIM2, CLIM3) accounted for more than 70% of the total climate variability. The components were used as predictors in the model. The model was calibrated and validated for the period of lake records by randomly splitting the full dataset into two independent dataset, the first 50% being used for the calibration and the remaining 50% for the validation. Since the model is temporally dynamic in terms of linking lake levels to antecedent conditions, simulation results may depend on initial conditions used to calibrate the model. To account for the variability in simulations due to initial conditions, all possible values in the calibration dataset were used to initialize the model. The overall model calibration and validation was repeated ten times and validation results were averaged per year.

The model was validated over the validation period using the coefficient of determination (R^2).

RESULTS & DISCUSSION

Having determined the coastlines, area of Urmia Lake has been calculated and the results are presented in Table 3. In this table, the maximum extracted surface area was 5650 square kilometer for the studying period 1998 while the minimum area has been estimated to be 2005 square kilometer for 2010. After 1998, the evidences indicate decrease of the lake's surface area. The trend of this decrease has been almost fixed till 2007, but since then the decreasing trend of the lake's area has become quicker, so that it has reached 2005 square kilometer in 2010(Fig. 3). Therefore, what extracted from the total trend of the lake's area fluctuations indicates a decrease of the lake's area with a trend of r=-0.74 using the available data. The results of satellite images processing show that most changes occurred in the southern and eastern parts of the lake where the depth value is smaller compared with other areas. The lowest lake retreat occurred in the north and northwest parts. Despite the relatively remarkable river water discharge into the area, the small depth values have caused a retreat in this section compared with southern parts. During recent years especially in 2008 and 2009, connection of Aspire and Ashk islands in the middle part of Urmia Lake has indicated the salt area intensification (Reveshty and Maruyama, 2010). Based on existing data about water level, the Urmia Lake long-term average water level in the periods 1968- 2006 is estimated to be 1275.6 m above sea level. From 1999 to 2009 the lake water level has fallen to the long-term average of about 4.898 meters. Overall, these changes of water level trends agree with those measured by other researchers, which indicate highest decreases during the recent decade (Reveshty and Maruyama, 2010). In general, according to the long-term average of 1968-2006, the surface level of Urmia Lake is declining (-0.54cm/decade; P = 0.014; r = 0.30). Reducing the lake water level will reduce lake surface area, especially in the southern half and eastern parts of the lake where available evidence shows to be shallower in comparison with other parts.

Table 3. Urmia Lake's surface area in different time periods

Year	Lake Area(Km^2)
1976	5266
1989	5423
1998	5650
2000	4610
2003	4241
2005	4099
2007	3841
2009	3107
2010	2005

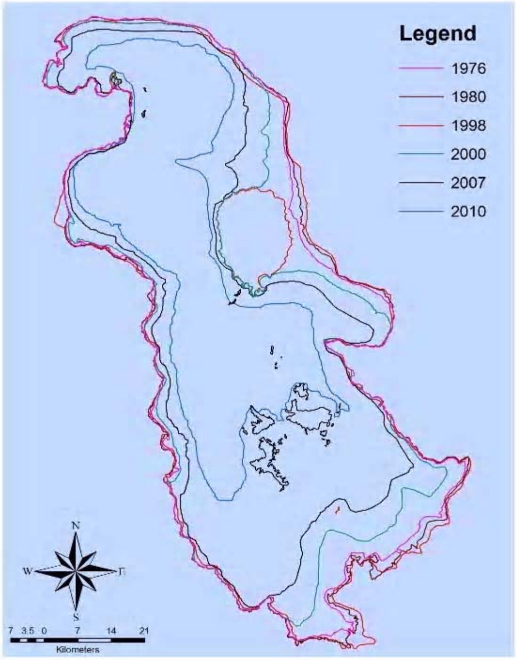

Fig. 3. Coastline Fluctuations of Urmia Lake from 1976 to 2010

To show the trend of changes of the average temperature and precipitation, two time scales of the past and future has been taken into account. To characterize the changes in climate components for time scale of the past and that of future the longitudinal data set between 1968 and 2011 and between 2012 and 2100 have been used, respectively. In an overview of the trend of changes in average temperature between 1968 and 2011, it is indicated that in most months of the year a significant rise has occurred in temperature, with the highest correlation coefficient of r=0.59 for June and the lowest one of r= 0.12 for November. Similarly, such trend of rise in temperature displays a significant level of annual rise (0.59ÚC/decade; r=0.61) (Table 4). Due to the values of correlation coefficient for precipitation, a complete understanding of overall trend of changes in precipitation over the Lake is impossible, because in majority of the months except for May (r=0.22), June (r=0.35), December (r=0.2) and July (r=0.27), which are either significant or close to a significant level, the trends of changes are accidental (Table 4). The changes of annual average of precipitation displays a decreasing trend every decade from 1968 to 2011(-14.83mm/decade; r=-0.21). Having examined the climate type of Lake Urmia by the use of De Martin method, a decreasing trend for January (r=-0.3), May (r=-0.24), June (r=-0.36) and December (r=0.2) and an increasing trend for July (r= 0.25) has been observed. Despite the different monthly trend of changes, annual average indicates a trend of changes in climate towards warmer and more arid climate (-1.29 IA /decade; r=-0.3) (Table 4).

It is important to know that correlation between observed data and fluctuations of the depth of the Lake has been calculated for precipitation(r=0.28). It indicates the fact that the more (or less) the precipitation, the higher (or lower) the water level is (r=-0.67). Regarding temperature, with an increase (or decrease) in temperature, the water level of the Lake has been increased (or decreased). Ultimately, the correlation coefficient between the quantitative values of climate type and fluctuations of the depth of the Lake has been calculated as r=0. 39. This means that with a decrease (or increase) in quantitative values of climate type, which is indicative of more humid (or dryer) conditions, the level of water surface has been increased (or decreased). Therefore, according to the correlation coefficient calculated, the role of changes in climate components can be considered prominent in the fluctuations of the water level of the Lake. Using the overall average according to two models of general atmospheric circulation and three above mentioned scenarios, it has been shown that as with observational data for temperature, the increasing trend of changes in temperature would be expected in the future. The lowest correlation coefficient of r=0.53 in November and the highest one for April with an r=0.93 have been recorded. Also the increasing trend of annual temperature at highest value (0.10 ^{o}C/decade; r=0.98) indicates an increase in temperature of +0.88 degrees centigrade by the year 2100 in the Lake region. Regarding the simulated data for monthly precipitation, it is indicated that apart from three months of May, July and November which display an increasing trend by 2100, in other months there is a significant and reliable decrease in precipitation. Thus, it is expected that the annual average of precipitation (-0.37mm/decade; r=-0.84) decreases as 3.33mm by the year 2100. So, the trend of change of climate of the Lake towards warmer and more arid climate with a decrease in precipitation and an increase in temperature will be inevitable. With exception of two months of May (r=0.93) and July (r=0.99), a decreasing trend for other months is observed which indicates the shift towards a warm and arid climate. Similarly, the output of the annual trend of the climate shows a decrease of this coefficient (-0.10 IA /decade; r=-0.98) as IA= -0.90 by the year 2100. The overall average of changes in three components of temperature, precipitation and climate type has been investigated for six periods within the time span from 1970 to 2090. Regarding Figs 4, 5 and 6, although the average temperature will be increased during future periods, the trend for precipitation and climate conditions is expected to decrease. Such pattern indicates a shift towards a warm and arid climate type.

Table 4. The correlation coefficient of changes of trends in observational (1968-2011) and those of simulated data (2012-2100), the average temperature, precipitation and climate type of Lake Urmia over the time

Month climate parameters	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
average Temperature :currant data(1968-2011)	0.4	0.33	0.26	0.28	0.29	0.59	0.4	0.54	0.37	0.32	0.12	0.22	0.61
Precipitation: currant data(1968-2011)	0.05	0.01	-0.14	0	-0.22	-0.35	0.27	0.09	-0.11	-0.06	0	-0.2	-0.21
Type of climate :currant data(1968-2011)	-0.3	-0.17	-0.19	-0.06	-0.24	-0.36	0.25	0.06	-0.13	-0.08	-0.02	-0.2	-0.32
average Temperature simulation(2012-2100)	0.89	0.8	0.71	0.93	0.78	0.88	0.77	0.86	0.76	0.7	0.53	0.81	0.98
Precipitation simulation(2012-2100)	-0.998	-0.96	-0.997	-0.96	1	-0.99	0.99	-0.95	-0.93	-0.996	0.97	-0.996	-0.84
Type of climate simulation(2012-2100)	-0.94	-0.83	-0.86	-0.95	0.93	-0.99	0.99	-0.95	-0.94	-0.99	-0.04	-0.92	-0.98

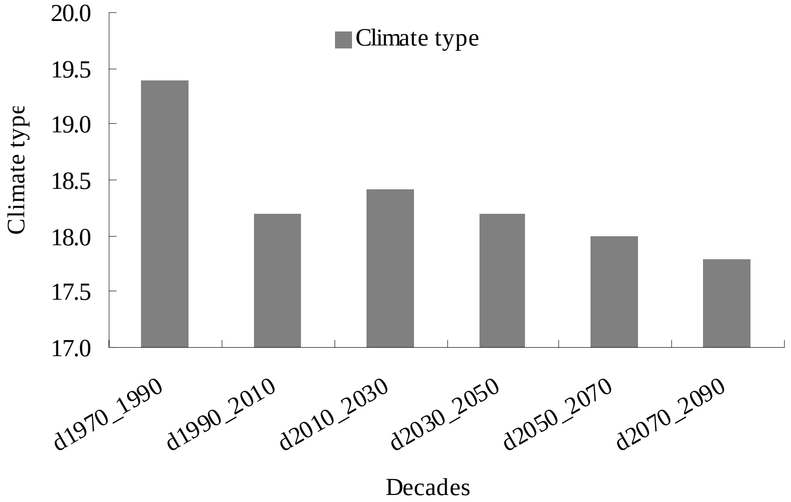

Fig. 4. The ten-year average (1970-2100) of trend of changes in climate components of the Lake

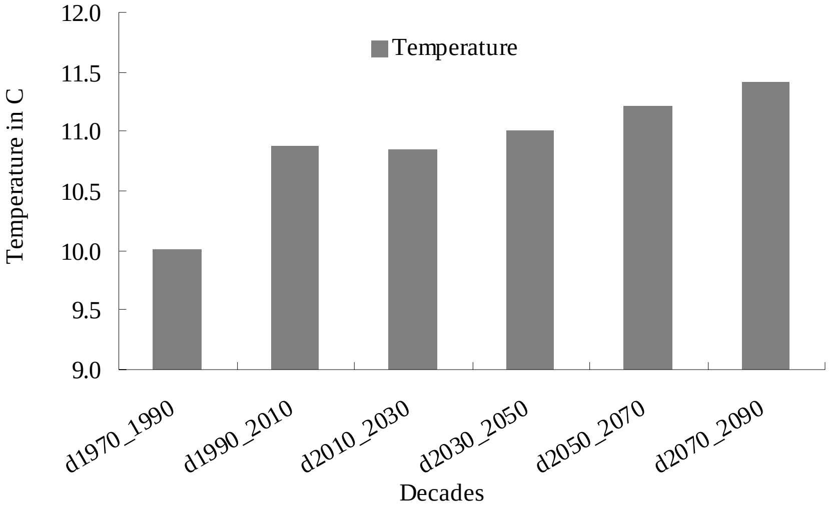

Fig. 5. The ten-year average (1970-2100) of trend of changes in temperature components of the Lake

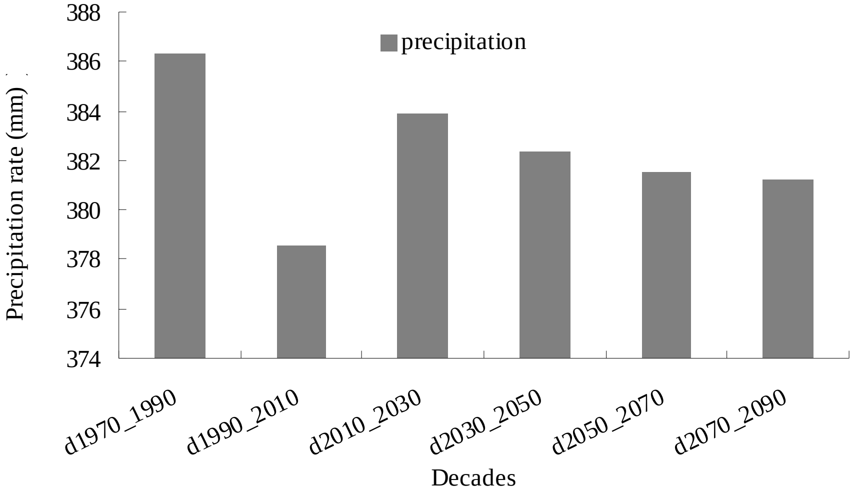

Fig. 6. The ten-year average (1970-2100) of trend of changes in precipitation components of the Lake

Lake levels from the previous year and current climate conditions were significantly correlated to current levels of the Urmia Lake for the control period (Table 5). The model was satisfactorily validated since the correlation coefficient between simulated and observed levels was high ($R^2 \sim 0.73$). Regarding the three simulation scenarios, it shows that the worst estimation of the decrease in water level as -2.70 meters in every decade belongs to the scenario A1B. So, it is expected that by the year 2100, the water level of the lake would experience a decrease of -24.28 meters. On the other hand, the best estimation indicating the least decrease in water level belongs to scenario B1. This scenario projects that in every decade from 2011 to 2100, in average 2.38 meters of water level will decrease, with an expectation of -21.41 meters decrease of water level of the Lake by the year 2100(Fig. 7). What is indicated by three scenarios and models about the overall changes is the decrease in the water level as -2.25 meters in every decade beginning from 2011 to 2100. Therefore, it can be estimated that by the year 2100, 20.25 meters of the water level of the Lake will decrease.

It is worthy to note that the decreasing process of water level in the last decades of the 21st century is far more than that in its first one; although the average of decrease in water level in every decade from 2011 to 2100 is -2.25 meters, this value is -1.86 and -3.52 meters for 2011-2020 and 2091-2100 decades, respectively. Therefore, it is estimated that, the difference of the water level of the Lake between the last decade of 21st century and the first one would be around 18 meters (Fig. 7).

Table 5. Summary of linear model

	Df	Deviance Resid.	Df	Resid.Dev	F	Pr(>F)
NULL			20	23.593		
level_mean_1	1	21.1095	19	2.4836	395.7482	1.039e-12
Axis1	1	1.3263	18	1.1573	24.8646	0.0001345
Axis2	1	0.1955	17	0.9618	3.665	0.0736251
Axis3	1	0.1083	16	0.8535	2.0307	0.1733657

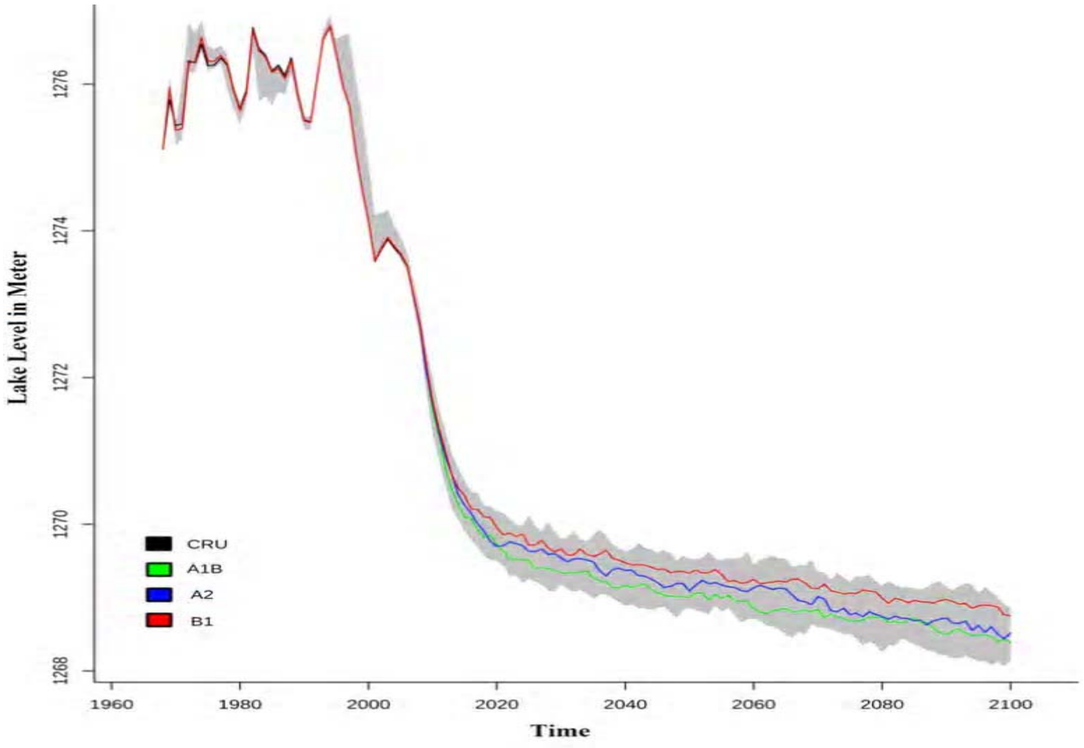

Fig. 7. Projected impact of climate change on Urmia lake levels from 2007 to 2100. Projected results are shown between 5th and 95th percentiles resulting from two GCMs, three SRES scenarios and ten Lake Model runs

The long-term average rainfall (1961-1990) for the Urmia Lake is 290 mm. In the period 1998 to 2001, the average annual precipitation fell for three consecutive long-term averages. Accordingly, the amount of precipitation, was about 124 mm, 121 mm and 94 mm less than the long-term average for the year 1998, 1999 and 2000, respectively. This is referred as the starting point for the lake level decline (Fig. 7). Anthropogenic parameters have also accelerated the Lake level decline and play a key role in deteriorating the status. It certainly cannot be stated that the main reason for the decline in lake levels is attributed to the climate change in recent years. But the human factor as one of the main processes, could exacerbate the lowering process of the lake level.

CONCLUSION

In the present research, due to the significance of lakes in natural ecosystems, the effect of climate change on Urmia Lake's level fluctuations has been studied. For the purpose of this research, effects of climatic components on Urmia Lake's level fluctuations have been assessed in both past and future scales. At first, Pearson correlation coefficients have been estimated in order to indicate relationship among the average temperature, precipitation rate and climate type of the study area. In the next step, GCM models have been used for simulating climatic components effects on the lake's water level fluctuations. One of the most significant results achieved for the future decades is the increase of the lake's temperature for around 1.5 degrees centigrade till 2100 in comparison with the long-term average of 1961 to 1990. Furthermore, the values extracted from precipitation rate and climate type of the zone also indicate a remarkable decrease of quantitative values in the future decades. Accordingly, the climate type extracted for the year 2100 with numeric value of around 17.75 will be entered a new phase called arid climate for the first time in recent decades. Also the results of this paper show that human effects and uncontrolled exploitation of water resources has caused the Urmia Lake water level to suffer a sharp drop during the recent decade. Within this period the Lake water level is dropped approximately 5 meters. Consequently, the Lake surface area is diminished from 5650 square kilometers in 1998 to about 2005 square kilometers in 2010. According to the results achieved by statistical models and time series, if this trend continues, the Lake level will be reduced around 3 more meters in 2100. Such issue would cause adverse environmental effects due to salt intensification within the region. The loss of adjacent agricultural lands because of salt transport by the winds and consequently a remarkable economic loss will be happened in the region. On other hand, the ever decreasing water level would increase the amount of saturated salt water (around 380 mg/lit at the time of this research). Such condition would endanger the survival of Artemia and consequently would disturb the migratory birds' habitat.

REFERENCES

Ahmadi, R., Mohebbi, F., Hagigi, P., Esmailly, L. and Salmanzadeh, R. (2011). Macro-invertebrates in the Wetlands of the Zarrineh estuary at the south of Urmia Lake (Iran), Int. J. Environ. Res., **5 (4)**, 1047-1052.

Ahmadzadeh Kokya, T., Pejman, A. H., Mahin Abdollahzadeh, E., Ahmadzadeh Kokya, B. and Nazariha, M. (2011). Evaluation of salt effects on some thermodynamic properties of Urmia Lake water. Int. J. Environ. Res., **5 (2)**, 343-348.

Arias, A. H., Piccolo, M. C., Spetter, C. V., Freije, R. H. and Marcovecchio, J. E. (2012). Lessons From Multi-decadal Oceanographic Monitoring at an Estuarine Ecosystem in Argentina. Int. J. Environ. Res., **6 (1)**, 219-234.

Ashrafi, Kh., Shafiepour, M., Ghasemi, L. and Najar Araabi, B. (2012). Prediction of Climate Change Induced Temperature Rise in Regional Scale Using Neural Network. Int. J. Environ. Res., **6 (3)**, 677-688.

Azari Takami, G. (1993). Uraemia Lake as a valuable source of Artemia for feeding sturgeon fry. J. Vet, Fac, Univ, Tehran, **47**, 2-14.

Baghvand, A., Nasrabadi T., Nabi Bidhendi G. R., Vosoogh, A., Karbassi A. R. and Mehrdadi N. (2010). Groundwater quality degradation of an aquifer in Iran central desert, Desalination, **260** (1-3), 264-275.

Blenckner, T., Omstedt, A. and Rummukainen, M. (2002). A Swedish case study of contemporary and possible future consequences of climate change on lake function. Aquat. Sci., **64**, 1–14.

Bouzinac, C., Font, J. and Johannessen, J. (2003). Annual cycles of sea level and sea surface temperature in the western Mediterranean Sea. Journal of Geophysical Research, **108 (C3)**, 3059.

Cabanes, C., Cazenave, A. and Le Provost, C. (2001). Sea level rise during past 40 years determined from satellite and in situ observations. Science, **294**, 840–842.

Chelton, D. B. and Davis, R. E. (1982). Monthly mean sea level variability along the west coast of North America. Journal of Physical Oceanography, **12**, 757–784.

Chen, J. L., Wilson, C. R., Tapley, B. D., Chambers, D. P. and Pekker, T., (2002). Hydrological impacts on seasonal sea level change. Global and Planetary Changes, **32**, 2 5–32.

David, M., Thomson, F., Gary P., Shaffer, J. and McCorquodale, A. (2002). A potential interaction between sea-level rise and global warming:implications for coastal stability on the Mississippi River Deltaic Plain, Global and Planetary Changes, **32**, 49– 59.

Fang, X., Stefan, H. G. and Alam, S. A. (1999). Simulation and validation of fish thermal DO habitat in North-Central U.S. lakes under different climate scenarios. Ecol. Model., **118**, 167–191.

Farzin, S., Ifaei, P., Farzin. N., Hassanzadeh, Y. and Aalami, M. T. (2012). An Investigation on Changes and Prediction of Urmia Lake water Surface Evaporation by Chaos Theory. Int. J. Environ. Res., **6 (3)**, 815-824.

Guinder, V. A., Popovich, C. A. and Perillo, G. M. E. (2012). Phytoplankton and Physicochemical Analysis on the Water System of the Temperate Estuary in South America:Bahía Blanca Estuary, Argentina, Int. J. Environ. Res., **6 (2)**, 547-556.

Hudak, P. F. (2011). Spatial Distribution of Solutes in Aquifer Outcrop Zones along the Brazos River, East-Central Texas. Int. J. Environ. Res., **5 (3)**, 595-602.

Hassen, H., Hanaki, K. and Matsuo, T. (1998). A modeling approach to simulate impact of climate change lake water quality: phytoplankton growth rate assessment. Water Sci. Technol., **37 (2)**, 177–185.

Hauser, F. R., Baron, J. S., Campbell, D. H., Fausch, K. D., Hostetler, S. W., Leavesley, G. H., Levitt, P. R., McKnight, D. M. and Stanford, J. A. (1997). Assessment of climate change and freshwater ecosystems of the Rocky Mountains, USA and Canada. Hydrol. Process., **11 (8)**, 903–924.

Houghton, J. T., Meira Filho, L. G., Callander, B.A., Harris, N., Kattenberg, A. and Maskell, K. (Eds.), (1996). Climate Change 1995:The Science of Climate Change. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge Univ. Press, Cambridge, UK, pp. 363–397.

IPCC, (1996). In: Moss, R. H., Watson, T. T., Zinyowera, M.C. (Eds.), Climate Change 1995: Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analysis. Cambridge University Press, UK, 879 pp.

Jones, P. G., Thomton, P. K. and Heinke, J. (2009). Generating characteristic daily weather data using downscaled climate model data from the IPCC’s Fourth Assessment. Project Report “Supporting the vulnerable: Increasing the adaptive capacity of agro-pastoralists to climatic change in West and Southern Africa using a trans-disciplinary research approach”.

Karbassi, A., Bidhendi, G., Pejman, A. and Bidhendi, M. (2010). Environmental impacts of desalination on the ecology of Lake Urmia. Journal of Great Lakes Research, **36 (3)**, 419-424.

Karbassi, A. R., Mir Mohammad Hosseini, F., Baghvand, A. and Nazariha, M. (2011). Development of Water Quality Index (WQI) for Gorganrood River. Int. J. Environ. Res., **5 (4)**, 1041-1046.

Kavian, A., Fathollah Nejad, Y., Habibnejad, M. and Soleimani, K. (2011). Modeling Seasonal Rainfall Erosivity on a Regional scale: A case Study from Northeastern Iran, Int. J. Environ. Res., **5 (4)**, 939-950.

Komatsu, E., Fukushim, T. and Harasaw, H. (2007). A modeling approach to forecast the effect of long-term climate change on lake water quality. ecological modeling, **209**, 351–366.

Lei, L., Jian, L., Yutao, W., Nvjie, W. and Renqing, W. (2011). Cost-benefit Analysis and Payments For Watershed-scale Wetland Rehabilitation: A Case Study in Shandong Province, China. Int. J. Environ. Res., **5 (3)**, 787-796.

Li, H., Wang, Y. , Shi, L.Q. , Mi, J. , Song, D. and Pan, X. J. (2012). Distribution and Fractions of Phosphorus and Nitrogen in Surface Sediments from Dianchi Lake, China, Int. J. Environ. Res., **6 (1)**, 195-208.

Madani, Sh., Ahmadian, M., KhaliliAraghi, M. and Rahbar, F. (2012). Estimating Total Economic Value of Coral Reefs of Kish Island (Persian Gulf). Int. J. Environ. Res., **6 (1)**, 51-60.

Magnuson, J. J., Webster, K. E., Assel, R. A., Bowser, C. J., Dillon, P. J., Eaton, J. G., Evans, H. E., Fee, E. J., Hall, R. I., Mortsch, L.R., Schindler, D. W. and Quinn, F. H. (1997). Potential effect of climate changes on aquatic systems: Laurentian Great Lakes and Precambrian Shield Region. Hydrol. Proc., **11 (8)**, 825–872.

Manju, M. N., Resmi, P., Gireesh Kumar T. R., Ratheesh Kumar, C. S., Rahul, R., Joseph, M. M. and Chandramohanakumar, N. (2012). Assessment of Water Quality Parameters in Mangrove Ecosystems Along Kerala Coast: A Statistical Approach. Int. J. Environ. Res., **6 (4)**, 893-902.

Michael, H., Marshall, A., Henry, F., Lamb, B., Sarah, J., Davies, F., Melanie, J., Leng, A., Kubsa, Z., Umer, M. and Bryant, C. (2009). Climatic change in northern Ethiopia during the past 17,000 years: A diatom and stable isotope record from Lake Ashenge. Palaeogeography, Palaeoclimatology, Palaeoecology, **279**, 114–127.

Mirbagheri, S. A., Sadrnejad, S. A. and Hashemi Monfared, S. A. (2012). Phytoplankton and Zooplankton Modeling of Pishin Reservoir by Means of an Advection-Diffusion Drought Model, Int. J. Environ. Res., **6 (1)**, 163-172.

Moernaut, J. D., Verschuren, F., Charlet, I., Kristen, M., Fagot, M. and Batist,D. (2010). The seismic-stratigraphic record of lake-level fluctuations in Lake Challa: Hydrological stability and change in equatorial East Africa over the last 140 ky., Earth and Planetary Science Letters, 290, 214–223.

Mooij, W. M., De Senerpont Domisa, L. N. and Janseb, J. H. (2009)..Linking species- and ecosystem-level impacts of climate change in lakes with a complex and a minimal model Ecological Modelling, **220**, 3011–3020.

Mortazavi, M. S. and Sharifian, S. (2011). Mercury Bioaccumulation in Some Commercially Valuable Marine Organisms from Mosa Bay, Persian Gulf. Int. J. Environ. Res., **5 (3)**, 757-762.

Mulholland, P. J., Best, G. R., Coutaut, C. C., Hornberger, G. M., Meyar, J. L., Robinson, P. J., Stenberg, J. R., Turner,

R. E., VeraHerrera, F. and Wetzel, R. G. (1997). Effects of climate change on freshwater ecosystems of southeastern United State and the Gulf of Mexico. Hydrol. Process, **11 (8)**, 949–970.

Nasrabadi, T., Nabi Bidhendi, G. R., Karbassi, A. R., Hoveidi, H., Nasrabadi, I., Pezeshk, H. and Rashidinejad, F. (2009). Influence of Sungun copper mine on groundwater quality, NW Iran. Environmental Geology, **58**, 693–700.

Nasrabadi, T., Nabi Bidhendi, G. R., Karbassi, A. R. and Mehrdadi, N. (2010). Partitioning of metals in sediments of the Haraz River, Southern Caspian Sea basin. Environmental Earth Sciences, **59**, 1111-1117

Nasrabadi T., Nabi Bidhendi G. R., Karbassi A. R. and Mehrdadi N. (2010). Evaluating the efficiency of sediment metal pollution indices in interpreting the pollution of Haraz River sediments, southern Caspian Sea basin. Environmental monitoring and assessment, **171 (1-4)**, 395-410.

Pamer, E., Vujovic, G., Knezevic, P., Kojic, D., Prvulovic, D., Miljanovic, B., and Grubor-Lajsic, G. (2011). Water Quality Assessment in Lakes of Vojvodina. Int. J. Environ. Res., **5 (4)**, 891-900.

Pei, H., Liu, Q., Hu, W. and Xie, J. (2011). Phytoplankton Community and the Relationship with the Environment in Nansi Lake, China. Int. J. Environ. Res., **5 (1)**, 167-176.

Reveshty, M. and Maruyama, Y. (2010). Study of Urmia Lake Level Fluctuations and Predict Probable Changes Using Multi-Temporal Satellite Images and Ground Truth Data Period (1976-2010) New Challenge about Climate Change or Human Impact, International conference in Map Asia 2010&ISG2010, Kuala Lumpur, Malaysia.

Roshan, Gh., R., Ranjbar, F. and Orosa, J. A. (2010). Simulation of global warming effect on outdoor thermal comfort conditions. Int. J. Environ. Sci. Tech., **7**, 571-580.

Roshan, Gh. R., Khoshakh lagh, F., Azizi, Gh. and Mohammadi, H. (2011).Simulation of Temperature Changes in Iran under the Atmosphere Carbon Dioxide Duplication Condition, Iran. J. Environ. Health. Sci. Eng., **8**, 141-146.

Rouse, W. R., Douglas, M. S. V., Hecky, R. E., Hershey, A. E., Kling, G. W., Lesack, L., Marsh, P., McDonald, M., Nicholson, B. J., Roulet, N. T. and Smol, J. P. (1997). Effects of climate change on freshwater of Arctic and Subarctic North America. Hydrol. Process., **11 (8)**, 873–902.

Rowshan, G. R., Mohammadi, H., Nasrabadi, T., Hoveidi, H. and Baghvand, A., The Role of Climate Study in Analyzing Flood Forming Potential of Water Basins, 2007, International Journal of Environmental Research, **1 (3)**, 231-236.

Sadatipour, S. M. T., Kiamehr, R., Abrehdary, M. and Sharifi, A. R. (2012). The Evaluation of Sea Surface Topography Models based on the Combination of the Satellite altimetry and the Global Geoid Models in the Persian Gulf. Int. J. Environ. Res., **6 (3)**, 645-652.

Sandeep, K., Warrier, A. K., Harshavardhana, B. G. and Shankar, R. (2012). Rock Magnetic Investigations of Surface and sub-surface soil Samples from five Lake Catchments in Tropical Southern India. Int. J. Environ. Res., **6 (1)**, 1-18.

Serbaji, M. M., Azri, C. and Medhioub, K. (2012). Anthropogenic Contributions to Heavy Metal Distributions in the Surface and Sub-surface Sediments of the Northern Coast of Sfax, Tunisia. Int. J. Environ. Res., **6 (3)**, 613-626.

Schindler, D.W. (1997). Widespread effects warming of freshwater ecosystem of North America. Hydrol. Process., **11 (8)**, 1043–1067.

Siddiqui, Z. (2011). Holistic Approach to Mitigate the Pollution Impacts in the Coastal Ecosystem of Thailand Using the Remote Sensing Techniques. Int. J. Environ. Res., **5 (2)**, 297-306.

Xing Fang, X., Heinz, G. and Stefan, G. (1998) .Potential climate warming effects on ice covers of small lakes in the contiguous U.S. Cold Regions Science and Technology, **27**, 119–140.

Ying, J. F., Xin, Ch. and Cheng, L. A. (2011). A Comparative Study on the Growth and Nutrient Uptake Characteristics of Fifteen Wetland Species in Taihu Lake Region of China. Int. J. Environ. Res., **5 (2)**, 361-370.