Research Journal of Biological Sciences 11 (1): 10-16, 2016
ISSN: 1815-8846

The Relationship Between Precipitations, Temperature and Water Fluctuation of Lake Zarivar Utilizing Idrisi Software and Statistical Analyses Conducted by SPSS Software

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Abstract: Lake Zarivar is one of the most important aquatic ecosystems in Iran if in which any changes occur, vast socio economic and hydrologic effects are caused. In order to investigate the relationship between water fluctuations of the lake and temperature changes, precipitation, water level and river discharge, time series of the variables were gathered and adjusted during the statistical period of 1981-2010; the homogeneity and randomness of the data were investigated through Ron nonparametric test. To assess the changes in variables and the influence of the independent variables on the dependent variable (water level of Zarivar lake), Mann-Kendall non parametric method, Pearson parametric correlation and regression analysis were used. Results show that up to 30% of changes in the water level are justified based on temperature and precipitation variables. Hydrologic models suggest that 42% of the fluctuations of the water level are caused by changes in river discharge and water levels of under ground waters in the area and high temperature has influenced the decrease of water level of the lake more than reduction in precipitation. This study showed that the increase in the rate of temperature has begun since 2014, the reduction of precipitation and river discharge have begun since 2015, the increase in the rate of water level and the reduction of water level of the lake with a delay of 4 years have begun since 1998.

Key words: Precipitation, discharge, Zarivar lake, temperature, water level

INTRODUCTION

As Iran is located in an arid and semi-arid area, it lacks proper water resources and does not have a very desirable situation compared with global average. Due to drought, fluctuations of climate and irregular and reduced precipitation has caused ever increasing food and water problems for people in the area. Consequently, since ancient times, people in the area have had to use underground waters to meet their needs in agriculture, in economy and in industry and also to supply their drinking water above all, since it has been the easiest way. On the other hand, an increase of greenhouse gases especially carbon dioxide have changed precipitation patterns and temperature followed by changes in some components of hydrologic cycle in recent decades. Lake Zarivar is one of the most important aquatic ecosystems in Iran in which any systematic and substantial changes occur, vast socio economic, climate and hydrologic effects are caused. Hence, investigation into and monitoring of changes in the lake water level and their relationship with changes in the area's climate and hydrologic system is of great importance. Several studies have been conducted which can be mentioned as follows.

Singh (2013) at the Association of Research and Technology in Bhopal in India, investigated the Bhopal lake's surface water and management using remote assessment and through adopting combined method. The results of this study showed that satellite data can be used to study and monitor large water tanks used during different periods. Kish studied the balance of water levels of Lake Jackson and Lake Florida based on climatic factors (precipitation and evaporation) using remote assessment technology. The results of the study showed that it is possible to evaluate and monitor periodic fluctuations in the water level of both lakes with GIS and remote assessment technologies accurately over time. Bryant (1999) studied short-time changes in flood regimes sensitive to weather conditions in South Tunisia. The results of this study confirmed satellite images used to monitor dynamic phenomena and environments sensitive to weather conditions. In addition, Ayenew (2004) studied

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water level of lake Byata in Africa for the years 1976-2000. The results suggested a declining trend in the water level of the lake up to 4 m.

In another study, Mistery and Conway (2003) investigated the effects of climate change on the increase in water level of Lake Victoria in East Africa. The results obtained showed that there is a direct correlation between the lake's water level fluctuations and precipitation on the lake. Also there is a lag time between the period of maximum precipitation and the time at which the lake's water level peaks. Aytzngr *et al*. (2004) conducted another study to investigate the impacts of climate change on low-water Lake Nyvsydlr in East Australia for the years 2020-2040. The results showed a rise in temperature, reduced precipitation and the lake's water level in the first decade compared with the second.

Kaskan studied precipitation-runoff modeling for the watershed of Lake Van in East Turkey using satellite images. The results of this study showed that remote assessment tools are favorable ones to analyze the relationship between runoff and precipitation within the watershed.

Panda *et al*. (2007) in a research, used Mann-Kendall nonparametric statistical methods to identify and find changes in underground water levels in Orissa region in India and the impact of drought and human intervention. Their results showed that the drop in water level due to high temperatures and human interference and lack of rainfall during dry years have not been compensated through wet years. Before the monsoon season, changes showed that 59% of monitoring stations experienced a drop in underground water levels while 51% of the stations showed general changes for the studied area after the season.

Fluctuations in the volume and level of water for Lake Zarivar, also its decreased area during past years has attracted a lot of attention and has created great concern. After reviewing conducted research, it can be inferred that a comprehensive study has not carried out on the effects of climatic factors, underground water levels and rivers discharge (independent variables) on the fluctuations of the lake water levels (dependent variable) based on the share of each of them yet; hence, this study aims to analyze climate and hydrological factors and elements on the lake's water level fluctuations and their impact on the water level of lake using statistical methods (Abedi *et al*., 2012).

MATERIALS AND METHODS

Lake Zarivar is a small lake located in the North-Western part of the city of Marivan at the geographical coordinates $35\text{-}30^{31}\text{-}35\text{-}37^{6}$ of to Northern latitude and $46\text{-}03^{52}$ to $46\text{-}10\text{-}^{47}$ Eastern longitude (Fig. 1). The highest point in the studied area has an altitude of 1895 m above sea level in the North-Western part of the lake. Lake Zarivar is the only natural lake and the most important aquatic ecosystem in Kurdistan province. The lake has emerged as a result of severe erosions, geological sedimentations in the region and the creation of faults. The lake's basin area has an annual average precipitation of about 980 mm which is mainly composed of rain. The average annual temperature in the region is 13° and the average minimum temperature is 5.8° and the average maximum of 20.6°C (Abedi *et al*., 2011).

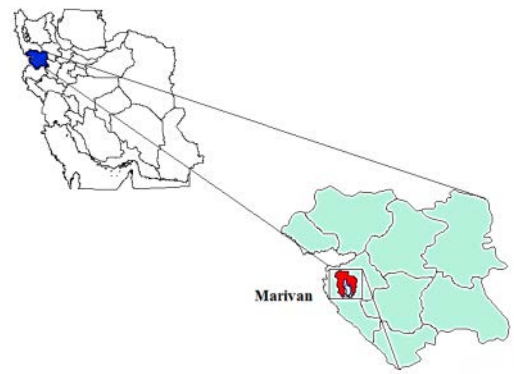

Fig. 1: The geographical location of lake Zariver

According to the research objectives, ground and meteorological temperature and precipitation data for Zarivar station for the statistical period of 1981- 2010, from the Organization of Meteorology and underground water level data, rivers discharge at the lake's watershed and the lake's water level data were received from Iran water Resources Management Organization. To adjust water level data of underground waters, 123 wells were selected out of 1054 wells which had complete data in statistical periods and also river discharge time series data were gathered from seven major river flowing into the lake's basin (Abedi and Rostami, 2012; Ayenew, 2004). Then, time series files of annual and seasonal temperature and precipitation and underground water levels and the lake's water levels data were considered as annually and monthly. In this study, temperature, precipitation, underground water levels and river discharge are considered as independent variable and water level of the lake as dependent variable. For more information on homogeneity and the randomness of the data and the likelihood of any trend in time series, Ron nonparametric test was used. Random variables with a probable error of

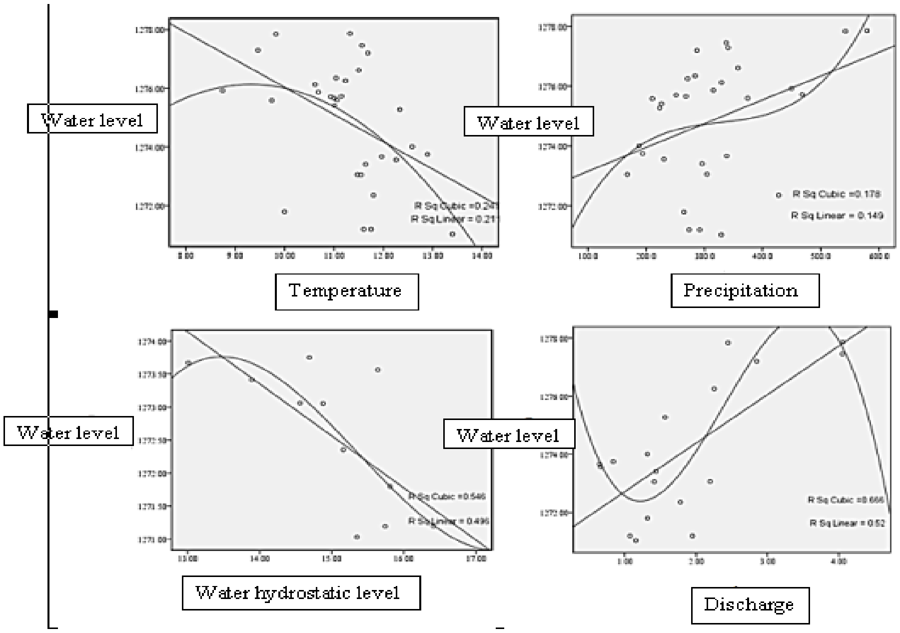

Fig. 2: Distribution diagram and the relationship between independent variables and the lake's water level using linear and cubic methods

0.05 were analyzed and their homogeneity was assured. The test showed that the data are homogeneous at a level of 0.05.

Pearson correlation method was used to calculate the relationship between independent and dependent variables for which the calculation process can be seen in Eq. 1, 4, 7 and 9. (Abedi and Rostami, 2012; Asakereh and Ashrafi, 2011; Bryant, 1999; Bayazidi *et al.*, 2011):

$$r_{xy} = \frac{\sum_{r=1}^{n}\left(x_i - x^-\right) - \left(y_i - y^-\right)}{\sqrt{\sum_{t-1}^{n}\left(x_i - x^-\right)^2 - \left(y_i - y^-\right)_2}} \quad (1)$$

In this equation, x and y are independent and dependent variables and r is a number between +1 and -1 which the closer to +1 and -1, the stronger the equation is (Jahanbakhsh and Shirvani, 2009)

For selecting and using parametric and non parametric tests, frequency distribution curves of time series, and also normal curve diagram using Shapiro-Wilk test and Kolmogorov-Smirnov method were plotted and analyzed (Sharifikia, 2010; Mahsafar *et al.*, 2010). For using regression equations, researchers must consider policy preconditions such as data normalization and Watson camera assessment (Rahimzadeh, 2011). For this purpose, standard error values are calculated, then the related normalized diagram is plotted and then a comparison is drawn between the two diagram s (Ha and Ita, 2006). Also, in order to investigate the separation of the errors, Watson camera assessment test was used and after investigating various tests according to achieved results and different parametric and nonparametric on the data in this research, multivariable regression parametric and nonparametric Mann-Kendal tests were suitable for this research's data (Seleshi and Zanke, 2004).

Mann-Kendal diagram ic method and its statistics: this test does not require a normal frequency distribution or linear data and is very strong for amount of data with a high skewness and kurtosis (especially rainfall) and data with a significant linear deviations, and is used to evaluate the process (Partal and Kahya, 2006). Using Mann-Kendal statistical and diagram ic test, the process, type and time of changes applied in the software MATLAB is calculated in which the statistics are firstly calculated (t_i, grading i in relative to previous grades). And then, the cumulative frequency statistics t_i is obtained. In the following, mathematical expectation E_i and variance V_i are calculated and Mann-Kendal index is calculated based on Eq. 2 (Naderianfar *et al.*, 2010):

$$U_i = \frac{\left(\sum t_i - E_i\right)}{\sqrt{V_i}} \quad (2)$$

To investigate the changes, index U_i should be determined. After determining the value of statistics t_i and the calculation of mathematical expectancy, the value of index U_i obtained from the Eq. 3:

$$U_i = \frac{\left(\sum t_i - E_i\right)}{\sqrt{V_i}} \quad (3)$$

From a statistical point of view, when a time series change, another statistical distribution is applied to the data. The intersection of two diagrams u and u', represents a significant point of change and the process itself; as if these lines intersect within the critical range (±1.96), sudden change in the data occur and if they intersect outside the critical limits, it indicate a trend in time series. U' behavior after the intersection indicates the condition of series trend. The 2 non-intersecting indices indicate unchanged time series (Eitzinger *et al*., 2004; Bonaccorso *et al*., 2005).

RESULTS AND DISCUSSION

Changes in various climate and hydrological parameters such as temperature, precipitation, river discharge, underground water levels and their impact on fluctuations in Lake Zarivar's water level during the statistical period was the most important objective of this study. For this purpose, statistical variations in these parameters will firstly be evaluated during the statistical period (Table 1).

In this research, in order to investigate changes in underground water hydrostatic levels, changes in the height of wells from the ground were considered according to which an increase in water hydrostatic levels indicates a drop in water levels and also in water inside wells. The correlation coefficient is also used to assess the possibility or impossibility of the relationship between independent and dependent variables and to determine line slope with time. If correlation exists between X and +1 Y and -1, it is feasible to predict completely and accurately each variable considering other variables; otherwise, predictions are approximate. As seen in Table 2, there is a rather strong correlation between independent variables and fluctuations in the lake's water level, and are mostly meaningful at 0.01 which indicates the reliability and strength of the linear relationship between them, also the susceptibility of dependent variables to independent ones. Negative slope indicates inverse relationship between the lake's water level, dependent variables and the statistical period and positive slope shows direct relationship (Jahandideh and Shirvani, 2009; Mistry and Conway, 2003).

Among the four affecting independent variables, the lowest correlation exist between climatic factors and changes in the lake's water level which is likely due to other factors such as geology, precipitations periods, rocks characteristics, vegetation and geological texture and pattern whereas their effects on hydrological factors can cause the values of the correlation coefficient to reverse with the lake's water level; so that this factor for river discharge and water level is 0.72 and -0.71, respectively (Mahdavi and Taherkhani, 2012).

Also in Table 2, the results of Pearson correlation coefficient is a linear slope that shows significance during the period (years) with an increase in time. The linear slope is negative for discharge, precipitation and water level and is positive for water hydrostatic level and temperature, i.e., reduced precipitation and discharge, and increased water hydrostatic level depth and temperature cause the lake's water level to decrease during the statistical period.

After proving the relationship between variables, Mann-Kendall nonparametric test was used to recognize the type of relationship in SPSS Software. As the significance level is lower than 0.05 and Watson camera is between 1 and 3, thus this test can be used in the research. To investigate the relationship between variables, distribution diagram or diagram of changes in values of two variables in relation to each other were plotted. The results indicated a linear relationship between various couples, so that the distributed points are seen around the correlation line and variables linking to each other and to time and water level is quite evident.

The slope of the regression line in the distribution (Fig. 2) shows that the more the amount of precipitation, the higher the water level. In Table 3, negative and positive values indicate declining and increasing trends, respectively. The highest decline of -2.56 is related to annual precipitation. Increased temperatures and reduced precipitation can cause decreased snowfall, increased evaporation and transpiration and consequently, reduced inflow to the lake which this declining rate is 0.18 m per year (Panda *et al*., 2007).

Table 4 shows regression coefficients for different parameters time series. Due to the interacting effect of climate and hydrological factors and to overcome this issue, regression models and equations are calculated and analyzed in different time periods. Analysis determining coefficient in this table shows that with other factors constant, almost 30% of the change in the lake's water level can be justified using temperature and precipitation variables. Independent variables and the dependent variable are likely to have a linear relationship (water level) which is not strong and indicates that other factors such as human factors and hydrology (using underground waters, building dams, changes in river discharge etc) are also involved in reducing the lake's water level. As a

Table 1: Results of descriptive statistics of studied variables in the area

Variables	Average	Deviation	Kurtosis	Maximum	Minimum	Range of changes
Discharge	1.83	1	1.14	4.06	0.65	3.41
Water level	15.013	0.96	-0.78	16.41	13.01	3.4
precipitation	315	99.2	1.055	579.5	167.2	412.3
temperature	11.26	1.01	-0.41	13.4	8.74	4.66
The lake's water level	1276.9	2.05	-0.445	1277.86	1271.03	6.83

Table 2: The relationship between independent variables, water level (dependent) and trends during the statistical period

Variables	Discharge	Hydrostatic level	Precipitation	Temperature	Water level
The statistical period	-0.06	0.55	-0.24	0.58	-0.76
Water level	0.72	-0.71	0.39	-0.46	1.00

Table 3: Variables' trend in the statistical period

Variables	Trend	Sig.	Watson camera
Annual temperature	0.07	0.000	1.27
Discharge	-0.113	0.009	1.1
The lake's water level	-0.18	0	1.16
Annual precipitation	-2.7	0.05	1.48
Water hydrostatic level	0.013	0.04	1.05

Table 4: Multiple regression models between independent variables and the lake's water level

Period	Models	Numbers	Values
Hydrological changes	Hydrostatic level	1284/375 -0/787E	0.5
	River discharge	1271/042 + 1/672D	0.52
	Hydrostatic level and river discharge		0.42
	Climate change	1281/662 -0/755T + 0/005P	0.3

result, we take the second step to determine and develop the hydrological parameters model. If climatic factors are assumed constant, and discharge and hydrostatic water level is taken into account, it is found that 42% of water level fluctuations are caused by changes in river discharge and hydrostatic water level of underground water levels in the region.

If effects of constant climatic variables are considered, we can say that for every unit increase in river discharge, the lake's water level increases by 1.67 m and for every unit of drop in hydrostatic water level, the lake's water level decreases by 0.787 m. This model has had some separate and mixed predictions for time series of all variables which we avoid inferring them due to limited number of pages and lack of necessity. By studying the regression models, we find that changes in hydrological parameters related to human factors affect fluctuations of the lake's water level more than climatic factors (Rasouli *et al*., 2007; Modarres and da Silva, 2007). Also, an increased temperature affects a decline of the lake's water level more than a decreased precipitation. Figure 3 shows the relationship between hydrological and climate factors and the lake's water level for linear and cubic methods that both tests' significance level is relatively low.

One of the main advantages of graphic and statistical Mann-Kendal test is the identification of variance, type and time of the changes in variables. To do this, using components u and u', Mann-Kendal diagram was plotted for different variables and time, variance and change are obtained. The critical level in these diagrams has been

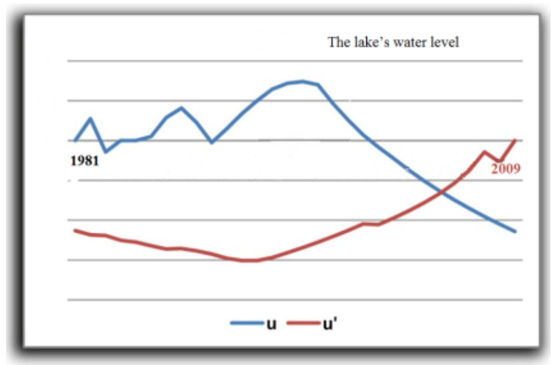

Fig. 3: Diagram of changes in components u and u

1.96. This means that if of u' is higher than 1.96, there is a positive or negative trend but if two sequences intersect within the range, it marks the beginning of a sudden change in the time series.

Water level diagrams fluctuations must have a time delay compared with water hydrostatic level and river discharge fluctuations; but the delay is weak here in which factors such as altitude, slope, water runoff and discharge rates interfere.

Investigation into Mann-Kendal diagrams show that temperature has an increasing trend with a sudden change since 2014. The temperature change along with change in and the beginning of reduced precipitation and discharge in 2014-2015 and as a result, an increased water hydrostatic level depth with a delay of 4 years occurred (in 1998) which is considered as a normal

Table 5: The statistics of Mann-Kendal's u and u´ components during the statistical period

Variables	The lake's water level	Hydrostatic water level	Discharge	Temperature	Annual precipitation
u´	-1.53	0.4	-0.27	0.8	-0.64
u	-0.4	0.12	-0.78	1.15	0.16

phenomenon. This frequent changes have reduced the water level in 1998. Results obtained from models, regression coefficient b and Pearson correlation linear slope have been confirmed through Mann-Kendal graphic statistics which are clearly evident in Table 5.

CONCLUSION

The results of Pearson correlation coefficient test show a significant linear relationship between independent and dependent variables with each other and with the statistical period. The linear slope of the regression and Pearson correlation coefficient tests for discharge, precipitation and water level is negative and for water hydrostatic level and temperature is positive, i.e., reduced precipitation and discharge on one hand and increased water hydrostatic level and temperature on the other hand, the lake's water level is reduced during the statistical period. This test suggested that there is a rather strong correlation between independent variables and the lake's water level fluctuations which is significant at 0.01 indicating strength and reliability of the linear correlation, and susceptibility of dependent variable to independent ones.

Regression analysis determining coefficient shows that if constant factors are assumed, nearly 30% of changes in the lake's water level can be justified by temperature and precipitation variables. By calculating hydrological models it was found that if climate factors are assumed constant considering the effects of discharge and water hydrostatic level, 42% of fluctuations in water level are caused by changes in river discharge and underground water hydrostatic levels. If the effects of hydrological factors are considered to be constant in the equation, we can say that for each millimeter increase in precipitation, the lake's water level rises by 0.005 m and for each degree Celsius increase in annual temperature, the lake's water level is reduced by 0.755 cm (Turkeo *et al*., 2002). If other factors are assumed constant, for each unit increase in river discharge, the lake's water level increases by 1.672 m and for each unit drop in water hydrostatic level, the lake's water level decreases by 0.787 m. By investigating regression models we will see that change in hydrological parameters affects the fluctuations of Lake Zarivar water levels more than climatic factors. Also, increased temperature affects the drop in the lake's water level more than precipitation decline. Mann-Kendal test was used to evaluate the trend, variance and time of changes in variables. An investigation into Mann-Kendall diagrams showed that temperature is increasing and this variance has started, since 1993. Simultaneous increase in temperature and decrease in precipitation and river discharge in 2014-2015 greatly appeals to mind with an increased water hydrostatic levels and a decreased underground water levels with a delay of 4 years beginning since 1998. These frequent changes has cause a decrease in the lake's water level, since 1998.

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