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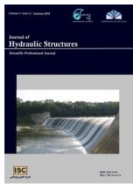

Determination of the effective factors on the water balance of Urmia Lake basin with a focus on precipitation trends

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Abstract

Prevention of water loss for the Urmia Lake due to the drought is environmentally crucial for the lake basin and it seems that, the analysis of the historical process of factors governing the water mass balance equation for the catchment leading to the lake can provide insights on what has to be done. In order to do that, statistical significance for potential breaking points and rate of changes over time points of precipitation and runoff for 25 hydrological basin stations based on the data regarding Annual precipitation and Annual runoff related to the whole span of the lake basin from 1977 to 2019 has been studied and surveyed using Mann-Kendall test, Petit test and Sen's Slope Estimator. For all hydrological basin stations breaking points have been observed in the water discharge time points from 1993 to 2005 and the decline of water discharge. Significant increase in precipitation in the entire Urmia catchment area of about 0.16 mm at a indicates its stability during the study period. The annual runoff of the studied basins into Lake Urmia in the two time periods before and after the discharge drop were estimated at 4.671 and 1.885 billion cubic meters per year, respectively, indicating volume reduction of 2.786 billion cubic meters (59.6%). Looking at the Lake Urmia sub-basins annual discharge reduction data, it can be seen that Zarrinehroud with the largest share of 34.5% and Mahparishai with smallest share of 0.2%, and the rest in between, contribute to the occurrence of draught for Lake Urmia.

Keywords: Annual Discharge, Man-Kendall, Patit test, Sen's Slope Estimator, water crisis.

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1. Introduction

Climate change is considered as one of global challenges affecting life of all organisms on Earth because of various environmental effect such as higher than normal temperatures, More frequent droughts, floods and natural disasters such as hurricanes, tornadoes, and etc. One of the significant impacts of this global warming is the unavoidable shift in water cycle as a result of changes in precipitation and temperature patterns [1]. Iran is no exception to the large-scale change and its impact is recognizable in many basins throughout the country. On the other hand, climate change, as an indirect result of human activities, is not the only factor affecting water resources. Among the human factors that can directly affect water resources, are population growth, economic development, growing cities, change in the vegetation and land use, dam construction and water use for various uses. Water is a renewable resource, however it limited. It is an indispensable component of daily life contributing to the growth and development and enabling human civilizations to flourish. Iran is an arid and semi-arid land, so that its average annual precipitation is even less than one third of the world average precipitation. In addition, the timing and the location of precipitation do not serve well the needs of agriculture sector.

Therefore, having a solid and reliable understanding of the hydrological processes in the basin is one of the important principles to ensure proper quantitative and qualitative management of surface water resources available in the corresponding basin.

In recent years, due to the increasing frequency of droughts in arid and semi-arid areas of the country, water level of lakes has subsided significantly and in addition to environmental damages, has caused economic and social hardship to the community.

Facing with severe difficulties that are on the rise, the Lake Urmia is about to reach to the point of drought and complete demise and this has caught the attention of many in the nation towards this crisis [2].

Looking back at the precipitation statistics for Urmia basin, we find that average precipitation in this basin in the 40s and 50s was much less than in recent decades. However, Lake Urmia, despite short-term retreats in the past, has never experienced a crisis of this magnitude. Therefore, drought is not considered as the only reason for the annual decline of the lake water. One of the biggest problems of Urmia basin is traditional irrigation with excessive water waste and very low efficiency (i.e. of about 30%) [3]. In addition, planting crops with high water consumption, not utlizing appropriate cultivation pattern to produce agricultural products with less water consumption and finally, population growth in recent decades and the main employment of basin residents being in the agriculture sector, reduced water level Lake Urmia receiving from resources of surface and groundwater. Another factor affecting the drying of the lake is the increase in the area of agricultural lands and consequently their water use [4]. Comparison of changes in the lake shoreline and depth shows that most of the changes have occurred in the southeastern and southern parts due to the shallow depth of these areas. Accordingly, the level of saline land in the area around the lake has increased. With the continued reduction in the lake level and due to strong winds in summer and to some extent in autumn, high quality agricultural lands of Azerbaijan, especially the fertile plains of Maragheh, Bonab and Tabriz in East Azarbaijan Province are inching towards salinization and finally desertification. If this trend is not met with proper environmental management at the national and regional levels, in the long run, we will undoubtedly observe large-scale biological crises in the area and the excessive population flow in the northwest of the country which will result in significant imbalance in population distribution of this area and later to the whole nation making it much more costly [5]. Now, it should be noted that the total conservation of the environment in the form of preventing natural and unnatural disasters is one of the issues that are directly related to the safety of living beings. The importance of the issue is such that unpredicted calamities can affect all human activities and, if neglected, can continue for many years, resulting in loss of life and property, as well as serious political-security, physical, mental and psychological damage to the people within that region. Many future events are predictable. Some the problems we are facing at present are due to the lack forward envisioning in the past. To be clear, current crises and problems are the very reason to be concerned about the future, and it goes without saying that today's crises are the result of not forcibly addressing obstacles and problems before they turn into crises [6].

Studying the effect of global warming on the climate of cities located in Lake Urmia basin and changes in 14 climatic variables on three annual and wet and dry season scales using two methods of Mann-Kendall and least squares error, Sari Saraf et al. [7] showed that temperature increase on an annual and seasonal scale (average temperature of the area by 0.06 ^{o}C per year) and also reduction in precipitation (about 4 mm per year). The effect of climate change on the management of surface reservoirs and runoff flow in the branches of Gorgan River Basin by statistical method of probability distribution function under different scenarios totally showed a reduction by about 4% in annual average precipitation and an increase by 0.05 ^{o} C in annual temperature. These changes in runoff flow in the branches of the study basin predicted a 4 and 10% reduction in the average total volume of water in the reservoirs under the influence of climate change scenario for the next statistical 25-year period (1414-2011) [8]. In order to investigate the effect of climate fluctuations on multilayered groundwater aquifers (free and pressurized aquifers in a multilayered groundwater system) in Gorgan plain, meteorological and hydrological drought indicators, correlation analysis method was used. The results showed that the aquifers under pressure had high reliability and affected the aquifers only when arid or humid climate conditions prolonged [4]. The study results of hydrological and meteorological drought trends in Karkheh basin indicated the effect of drought with a 1-2-month delay on surface water resources in the study area [9]. Soheili et al. [10] in their study on the temporal and spatial analysis showed that Kor River discharge trend was decreasing in all timeframes. The significant decreasing trends were observed at 95% confidence level on a monthly and yearly scale and warm months since May to September in terms of location at the middle stations of the basin near the agricultural plains. A significant increasing trend at Dorodzan dam station indicates the effect of discharge of water released from the dam for agricultural purposes, especially in hot seasons of the year. The study results of Gharachai et al. [11] on the annual trend of precipitation, runoff and evapotranspiration potential of three sub-basins of Lake Urmia basin for the period 1972-2012 showed that the effect of long-term changes in hydrological and climatic variables on runoff in all three sub-basins has changed a lot while precipitation and evapotranspiration potential of all three sub-basins had been almost constant. Although precipitation has had a decreasing trend in all sub-basins, but the decline was not significant in any of the locations. Similar to the results of precipitation, the potential evapotranspiration of the two sub-basins of Ajichai and Nazluchai rivers showed no obvious decreasing trend.

Urmia Lake, hyper saline lake in northwest of Iran, is a terminal basin, and its salinity depends on the water balance [12]. The lake has been shrinking in recent decades, that cause challenges to economy and environment of the region. It is important to find the major contributors to this disaster. Water level reduction of Urmia Lake Basin is the main problem in northwest of Iran during 2001–2017. Climate change and human activity have affected the water resources in this basin. The comparison of these parameters with each other indicates high contribution of climate change and human activity in the reduction of lake water level. Restoration and sustainability of this lake are very important to the water management resources of Urmia Lake Basin [13]. Shirmohammadi et al. (2020) [14] showed that by adopting appropriate irrigation efficiency, it is possible to achieve a better balance between environmental needs and regional economic and agricultural development. The results provide insight into possible sustainable development options and also provide guidance for managing other Urmia Lake sub‐basins, whereas the approach of integrated assessment of climate, land use change, and land management options is also applicable in other conditions to help with sustainable management.

In one study [15] investigated and analyzed precipitation trend in Tamilnadu, India, which has a great economic importance for the region, using Mann-Kendall test and Sen's slope. The results showed that spatial and temporal changes in monthly precipitation for 33 years (1981-2013) at four rain gauge stations ranged from a maximum of 43.83 mm per year at Nagar station to 29.37 mm per year at Nalar station. A significant trend was found in the annual and monthly time series. The study results of Hassan et al. [16] on the temporal changes in precipitation at the two rain gauge stations of Chittagong and Cox Bazaar in a 63-year period (1949-2011) in the southeastern part of Bangladesh demonstrated a trend for the changes. Failure dates at both stations in 1990 are specified with an annual increase by 21 and 8%, respectively. this pattern of annual precipitation is not evenly distributed between the four seasons (an increase by 3 mm per year in the pre-monsoon season). An insignificant decreasing trend was observed in precipitation time points in the monsoon season and an increasing trend was observed before and after the monsoon season with Sen's slope of 10 mm per year. Rufayda et al. [17] conducted a study on the effect of climate change on annual precipitation in Egypt at 31 precipitation stations. The results of their study showed that the intensity and frequency of storms and floods due to human activities have changed significantly and caused severe floods following heavy rains. Analysis of annual maximum precipitation, total annual precipitation, and number of rainy days using Mann-Kendall test of about 29% of the studied stations showed a significant trend without any specific pattern with the majority having a decreasing trend [18]. The results of the study for the changes in climate parameters during four decades (1975-2014) in Ghana using Mann-Kendall test and Sen's slope showed a significant trend at 95% confidence level for temperature and runoff time series (seasonal and annual scale) increasing trend and decreasing trend for water and evaporation level with failure points in the time series.

By accepting the fact that natural conditions can be an important factor for the current crisis and through applying comprehensive water resources planning, the authors believe that current crisis can be mitigated considerably. Considering the above-mentioned points, understanding the trends concerning precipitation and discharge of hydrological units and their impact on water balance of the basin would be critical. By estimating the changes in each of the hydrological factors at the sub-basin level, the goal is to provide methodical and practical solutions to moderate this national obstacle (minimizing volume reduction and, consequently, water level of Lake Urmia).

2. Materials and methods

2.1 Study area

The basin of Lake Urmia is located in northwestern Iran and is surrounded by the northern part of Zagros Mountains and the southern slopes of Sabalan Mountains, as well as the northern, western and southern slopes of Sahand Mountains. This basin is located between the geographical coordinates of 44 ° 07 ' to 47 ° 53 ' east longitude and 35 ° 40 ' to 38 ° 30 ' latitude. The area of this basin is 51761.9 square kilometers, of which about 33537 square kilometers are mountainous areas (64.79%), 12589 square kilometers are plains and foothills (24.32%) and 5750 square kilometers (10.89%) are Lake Urmia. Forms. The height of its points varies from 3800 to 1280 m above sea level. Most of the study area is located on Lake Urmia at an altitude of 1280 to 2000 m. Figure 1 shows the geographical location of the study area on the map of Iran.

Figure 1. Location of the study area

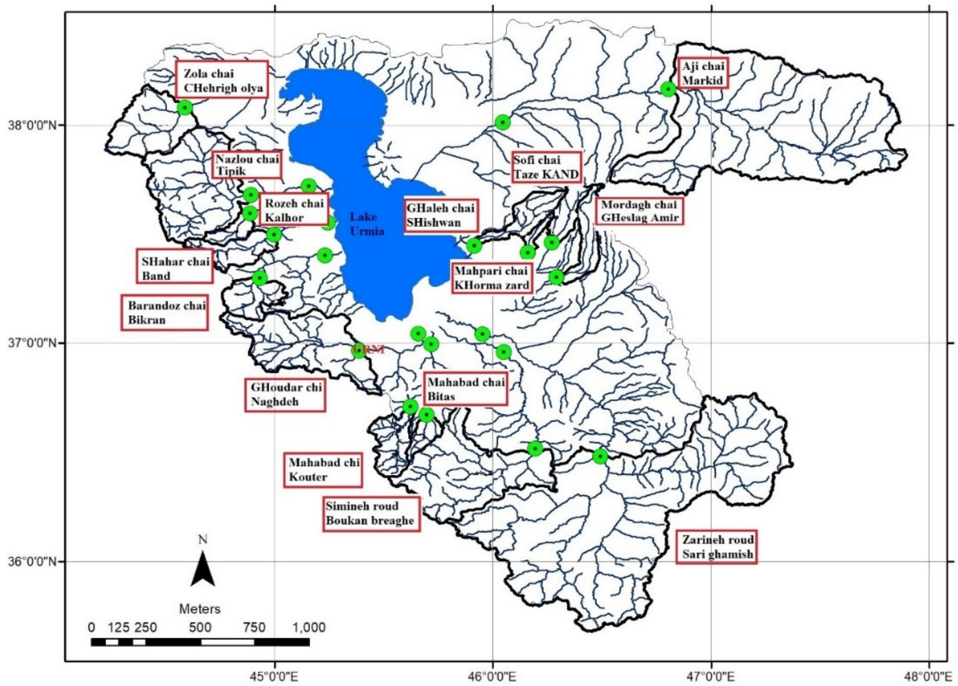
The existence of high mountains and their location in the route of Mediterranean and North Atlantic air currents, has caused the emergence of areas with more than 9 months of snow cover and slopes with abundant springs and this zone as an eternal water of many large and small rivers. Due to these characteristics, the study area has climatic characteristics of semi-high plains, and mid-latitudes with the general climate of cold winters and relatively mild summers. The average annual precipitation varies from 300 to 700 mm and its main source is Mediterranean systems with little summer precipitation. The main rivers of the basin are located in the southern half of it and the most important ones are Aji Chai, Zarineh Rud, Simineh Rud, Mahabad Rud, Barandozchai, Zolachai and Nazlouchai. On the other hand, the rivers of the northern part mainly have small and scarce basins [19].

2.2 Selection of hydrological units and study areas

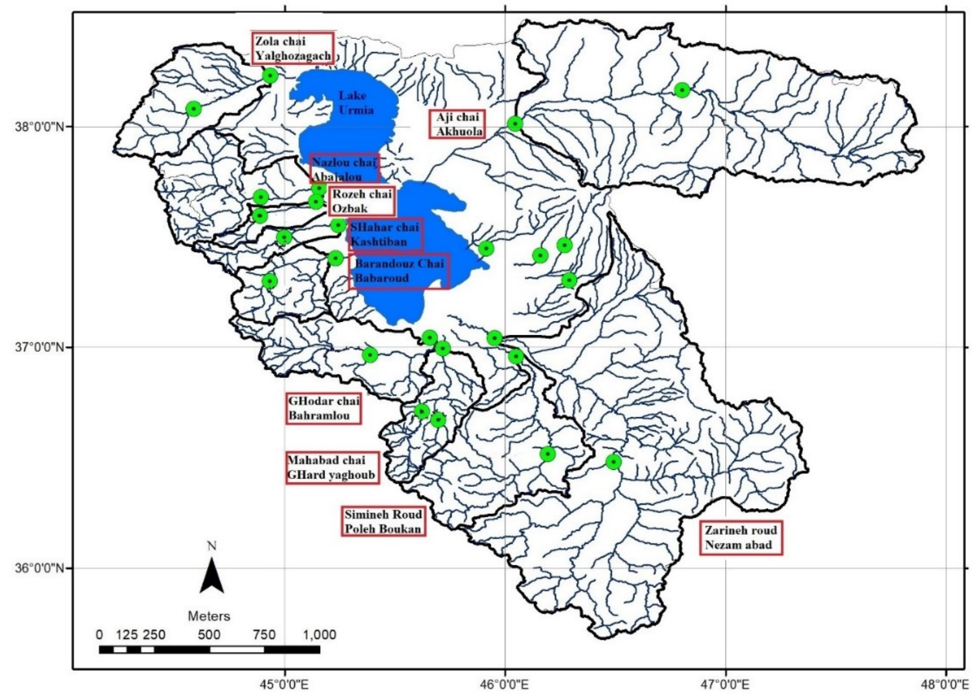
The selection of hydrological units and study areas is one of the most important needs in order to facilitate investigation of water resources. For this purpose, in order to investigate the trend of hydrological parameters, the views of professors and experts in water sciences were used and hydrological units in the basin of Lake Urmia (about 78% of the total area of the basin) were determined as shown in Table 1 (Table 1). Most of the selected study areas include two hydrological units telescopically limited to hydrometric stations leading to the plain (mountain basin characteristics) and Lake Urmia (mountain and plain characteristics) in each sub-basin of Lake Urmia aimed to investigate precipitation and runoff time series trend behavior. ArcHydro tools by ArcGIS were used to identify channels and sub-basins. This program is able to separate the sub-basins with the desired accuracy by the user, through identifying channels in the bottom line of each area and according to their slope direction (Figure 2).

Table 1. Selected the hydrological units of Urmia Lake catchment area

Row	Name of catchment	Area (square kilometers)	Percentage	Code
1	Total urmia basin	51761.9	100	30
2	Zolachai	2261.1	4.37	3011
3	Nazlouchai	1881.6	3.64	3013
4	Rozehchai	458.1	0.89	3014
5	Shaharchai	712.3	1.38	3015
6	Barandouzchai	1362.8	2.63	3016
7	Ghadarchai	2092.6	4.04	3021
8	Mahabadchai	1508	2.91	3022
9	Siminehroud	3785	7.31	3031
10	Zarinehroud	11841.2	22.88	3032
11	Mardoughchai	497.8	0.96	30332
12	Soufichai	1096.1	2.12	3041
13	Mahparichai	702.1	1.36	3051
14	Ghalehchai	699.4	1.35	3042
15	Ajichai	11608.4	22.43	305
	Total area stady	40506.5	78.26 %	



(A)



(B)

Figure 2. A. Map of selected up basin hydrological units of Urmia Lake catchment area B. Map of selected down basin hydrological units of Urmia Lake catchment area

In this study, precipitation and discharge data of rain gauge and hydrometric stations of regional water companies of East Azerbaijan, West Azerbaijan and Kurdistan and Iran Water Resources Management Company were obtained. Also, the reports of updating the comprehensive water plan of the country were used to extract the required information.

2.3 Basin precipitation

The information obtained from rain gauges indicates the amount and intensity of precipitation at the measuring points. Since there is no precipitation in large quantities with the same amount and intensity, geo-statistical methods are needed to convert point precipitation data to regional average. The changes in precipitation in an event, especially in mountainous areas, are greater and require more point information. In larger areas, where several rain gauges simultaneously measure and record precipitation data and show different values, it is necessary to convert precipitation into the average precipitation of the area so that the volume of precipitation can be determined in the whole area [20]. Due to the lack of precipitation gauge stations in the western part of the study basin and adjacent to Turkey and Iraq in terms of lack of statistical access and to increase accuracy of computational precipitation, 70 precipitation gauge stations inside and outside the basin were used. After extending the station statistics by HEC-4 software and analyzing the missing data by box-plot method, the annual precipitation values for each hydrological unit were estimated. Kriging method was used to calculate precipitation in the basin using GIS software. Using the above-mentioned precipitation statistics, precipitation map was drawn for different years since rainy 1977-1978 to 2017-2018 for the whole basin and each selected hydrological unit.

2.4 Investigation of the trend in precipitation and runoff of hydrological units

Mann-Kendall test [18], Sen's slope [21] and petit test [20] were used to calculate and investigate the trend, trend slope and failure point in precipitation and runoff parameters. The equation used to achieve the objectives of these tests are described below.

2.4.1 Presence or absence of the trend using Mann-Kendall test

When there is no trend, the measured data are distributed independently and equally over time. The assumption of independence means that observations are not serially correlated over time. In this study, this test was used for all data of precipitation and flow. In this test, the data are arranged in order of time and each data is compared with the data after it and the sum of these differences is indicated by the statistic S.

$$S=\sum_{\mathrm{i=n}}^{\mathrm{n-1}}\sum_{\mathrm{j=i+1}}^{\mathrm{n}} sign(\mathrm{x}_i-\mathrm{x}_j) \quad (1)$$

x_i and x_j are the observed values for data i and j, n is the number of data, and $\mathrm{x}_i-\mathrm{x}_j$ is sign function, which have the following three states:

$$\text{Sing}(x) = \begin{cases} +1 & if\ (x_i - x_j) > 0 \\ 0 & if\ (x_i - x_j) = 0 \\ -1 & if\ (x_i - x_j) < 0 \end{cases} \tag{2}$$

In order to determine the significance, z test is used, in this regard, the variance of the data should first be calculated by the following equation:

$$var(s) = \frac{n(n-1)(2n+5)\sum_{t=1}^{m} t(t-1)(2t+5)}{18} \tag{3}$$

In order to remove the effect of repeated data on variance in Equation (4), they should be identified (represented by t in this equation) and m parameter is the number of series in which repeated data are present.

$$z = \begin{cases} \frac{s-1}{\sqrt{var(s)}} & if \quad s > 0 \\ 0 & if \quad s = 0 \\ \frac{s+1}{\sqrt{var(s)}} & if \quad s < 0 \end{cases} \tag{4}$$

The positive values of s indicate a positive trend, and vice versa, Z is in the corresponding Table and specifies a significant level ($\bar{\alpha}$). In Mann-Kendall test, the initial assumption is that the data are random and that the given time series is not autocorrelation. Hence, the effect of autocorrelation should be removed first and for this it is enough to modify variance according to the following method. First, significance test of autocorrelation, in which we have autocorrelation test k (r_k) is calculated by the following equation:

$$r_k = \frac{\frac{1}{n-k}\sum_{i=1}^{n-k}(x_i - \mu)(x_{i+k} - \mu)}{\frac{1}{n}\sum_{i=1}^{n}(x_{i+k} - \mu)\ \hat{}\ 2} \tag{5}$$

If the correlation coefficient of k order is $\frac{1-1.645\sqrt{n-k-1}}{n-k} \le r_k \le \frac{1+1.645\sqrt{n-k-1}}{n-k}$, then at the level of 10% it is assumed independent and vice versa, r_k interval becomes larger for lower levels such as 5 or 1%. The following formula is used to calculate the modified variance:

$$V(s)^* = V(s) - \frac{n}{n^*} \tag{6}$$

$$\frac{n}{n^*} = 1 + \frac{2}{n(n-1)(n-2)}\sum_{i=1}^{n-1}(n-i)(n-i-1)(n-i-2) + r_i \tag{7}$$

2.4.2 Sen's slope estimator

A very useful indicator in Mann-Kendall test is the slope of the trend line or so-called Sen's slope. This large estimate shows the uniformity of the trend. In order to calculate the slope of the trend, we use the following equations provided by Theil (1992) and Sen (1968):

$$\beta = \mathrm{M}\left(\frac{x_j - x_i}{j-i}\right) \qquad \forall\, i > j \tag{8}$$

Where β is the trend line slope estimator and x_i and x_j are the observational values of i and j, respectively. The positive values of β indicate an increasing trend and negative values indicate a decreasing trend. This method has been widely used in hydrological studies and estimation of Sen's slope is required to calculate the modified Mann-Kendall test.

2.4.3 Petit test

Petit test is a non-parametric test that was developed by Petit (1979). This method is used to find points of change in a time series. Petit test is a test with rank base and without distribution to detect significant changes in the average time series and it is important when there is no hypothesis about the time of change. First, the time series Petit test statistic is calculated according to the following formula.

$$\mathrm{Ut,n} = \sum_{i=1}^{t} \sum_{j=i+1}^{n} sign(x_i - x_j) \tag{9}$$

In the above equation, n is the number of data and t is the sequential number of time series data until the point of change and after that. sign $x_i - x_j$ function is also calculated by Equation (10). The value of k is calculated by the following equation and is substituted in Equation (11) and the statistic P is obtained:

$$K = \max\,(\mathrm{Ut, n}) \tag{10}$$

$$P = 2 * e^{(-6k^2)/(n^3+n^2)} \tag{11}$$

In this test: 1) H0: indicates homogeneity of data, and 2) H1: indicates the year of failure in the studied time series.

If the calculated value of P is less than α or the value of the significance level is 0.05, this point of change can be considered statistically significant in the time series. In fact, the calculated value of P is the value of risk or error of rejecting H0, which if this error is less than 5%, this change can be considered significant. In Petit test, due to the existence of heterogeneity in the series, the year of failure can be achieved [22].

3. Results

3.1 Basin precipitation

Table 2 shows the average precipitation values for Lake Urmia basin in the long run on annual and seasonal scales and Figure 3 presents the annual precipitation map in the basin. Then, based on precipitation maps, precipitation values were extracted in the statistical base period for each hydrological unit limited to selected hydrometric stations (Table 2).

Table 2. Amounts of annual rainfall statistics and seasons of Urmia Lake catchment area

Time scale	Average rainfall (millimeters)	Average rainfall (%)	Maximum rainfall (mm)	Minimum precipitation (mm)	Standard deviation
Spring	106.28	38.6	177	27	33
Summer	13.45	4.9	51	1	10
Autumn	80.04	29.1	176	8	33
Winter	75.33	27.4	115	42	16
yearly	275.10	100	404	179	56

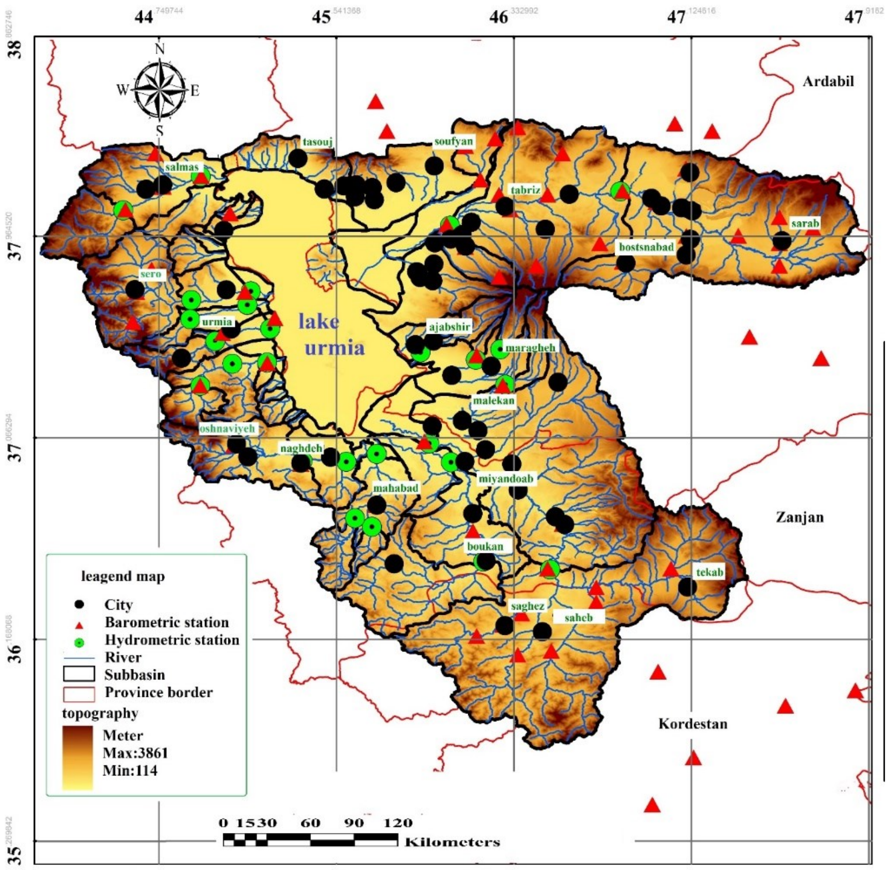
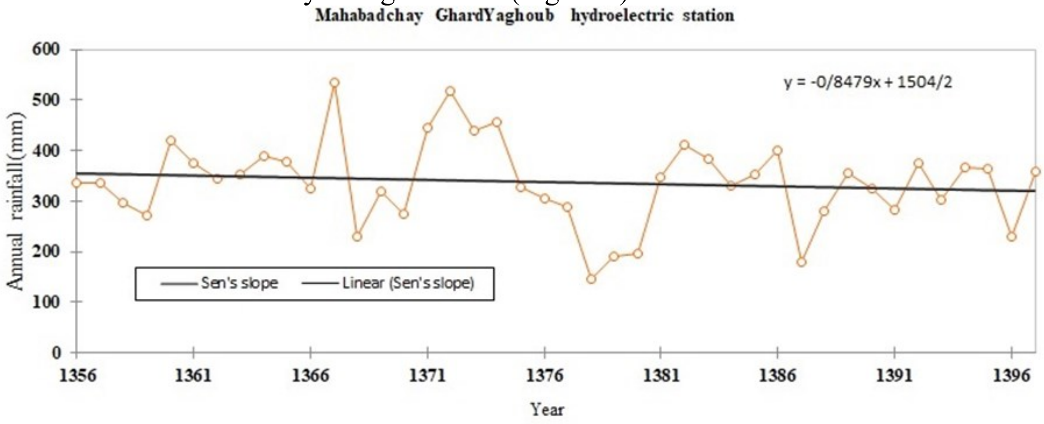


Figure 3. Map of hydrological units, distribution of barometric and hydrometric stations, precipitation calculations by kriging method

3.2 Investigation of precipitation trend of hydrological units

The study results of the annual precipitation trend in 41-year time series (1977-2018) calculated by kriging method showed a trend only in two downstream hydrological units of Baranduzchai limited to Babarrood hydrometric station and Mahabadchai limited to Yaghoub station and no trend was observed in other hydrological units (Figure 4).



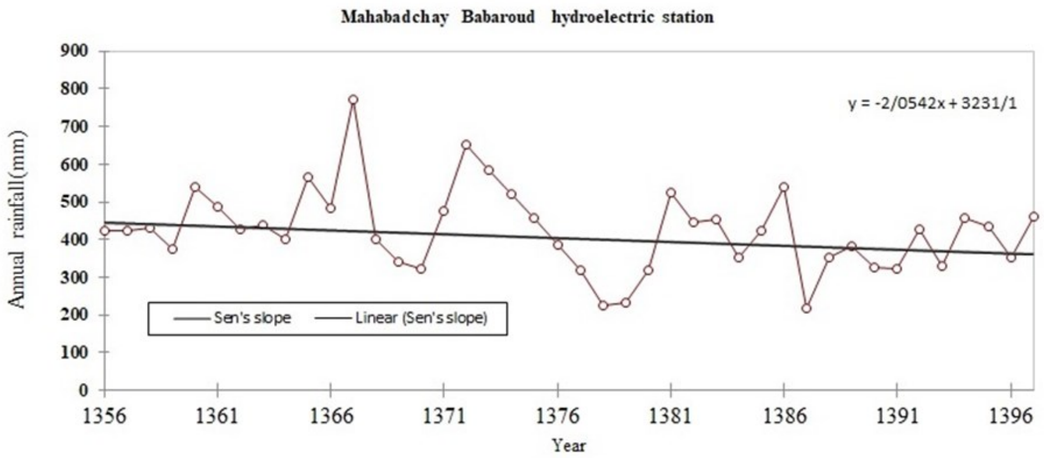


Figure 4. Time series diagram and Sen's Slope of annual rainfall of Barandozchay and Mahabadchai

Sen's slope or the same rate of reduction or increase in annual precipitation (mm per year) in the whole basin, Akhola, Tazeh Kand, Khorramzard, Shishvan, and Yalghuzaghach had a slight positive increase and in other hydrological units had a decreasing trend in Babarood and this reduction was significant (Table 3).

Table 3. Statistics of man-Kendall, significant level and Sen's Slope of average annual rainfall basin of Urmia Lake

Row	Hydrological unit	Hydrometric station	Man-Kendall statistic	Significant level	Average rainfall (mm/year)	Sen's Slope (mm/year)
1	Nazlouchai	Tipik	0.089	0.334	375	0.644
2	Nazlouchai	Abajalousofla	-0.034	0.762	295	-0.331
3	Ajichai	Markid	0.073	0.502	288	0.534
4	Ajichai	Akhoula	0.087	0.423	277	0.634
5	Barandouzchai	Bikran	-0.168	0.135	457	-2.581
6	Barandouzchai	Babaroud	-0.166	-0.017*	424	-2.054
7	Rozechai	Kalhor	-0.050	0.672	412	-0.639
8	Rozechai	Ozbak Bridge	-0.066	0.544	334	-0.231
9	Ghodarchai	Naghdeh	-0.173	0.109	389	-1.652
10	Ghodarchai	Bahramlou Bridge	-0.175	0.104	338	-1.578
11	Siminehroud	Boukan Bridge	-0.129	0.233	374	-1.572
12	Siminehroud	Miyandoab Bridge	-0.171	0.068	362	-2.688
13	Soufichi	Tazehkand Alaviyan	0.055	0.618	338	0.691
14	Mahparichi	Khormazard	0.113	0.298	306	1.187
15	Ghalehchai	Shishvan	0.059	0.588	330	0.752
16	Mardoughchai	Gheshlagh Amir	-0.017	0.879	325	-0.126
17	Shaharchai	Band	-0.101	0.303	426	1-1.193
18	Shaharchai	Kashtiban	-0.080	0.461	331	-0.566
19	Mahabadchai	Kouter	-0.110	0.160	354	-0.988
20	Mahabadchai	Bitas	0.094	0.256	351	-0.888
21	Mahabadchai	Ghardyaghoub	-0.080	0.007*	337	-0.848
22	Zarinehroud	Sarighamish	-0.110	0.308	391	-1.137
23	Zarinehroud	Nezamabad	-0.092	1.000	326	-0.996
24	Zolachai	Charigholiya	0.075	0.434	326	0.922
25	Zolachai	Yalghouzaghach	0.062	0.431	386	0.637
26	Urmia	Total Basin	0.001	1.000	275	0.004

*. Significance level: 5(%)

Petit test is used to find points of change in a time series. The test results showed that the time series of precipitation at the probability level of 5% occurred only in Baranduzchai hydrological unit limited to Babarood hydrometric station in 1995 with an average reduction of 99.7 mm compared to the first period (Figure 5).

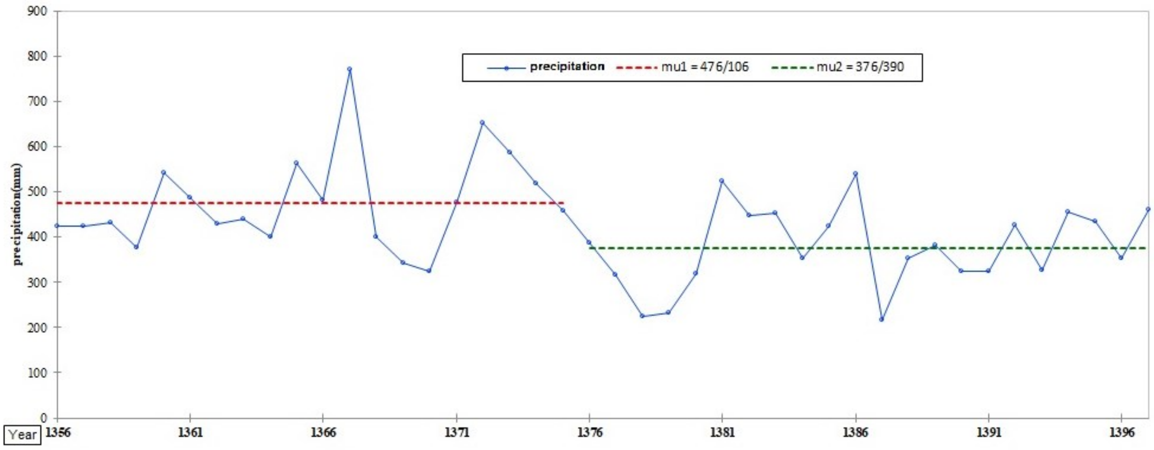


Figure 5. the chart of Patit test annual Discharge of Barandozchai hydrological unit

3.3 Water balance of hydrological units

The results of Petit test showed that the annual discharge limited to the hydrometric station and the characteristics of Lake Urmia (volume, area and level), except for Rozechai (Kalhor hydrometric station) all have a decreasing trend (at a probability level of 5%) (Figure 6).

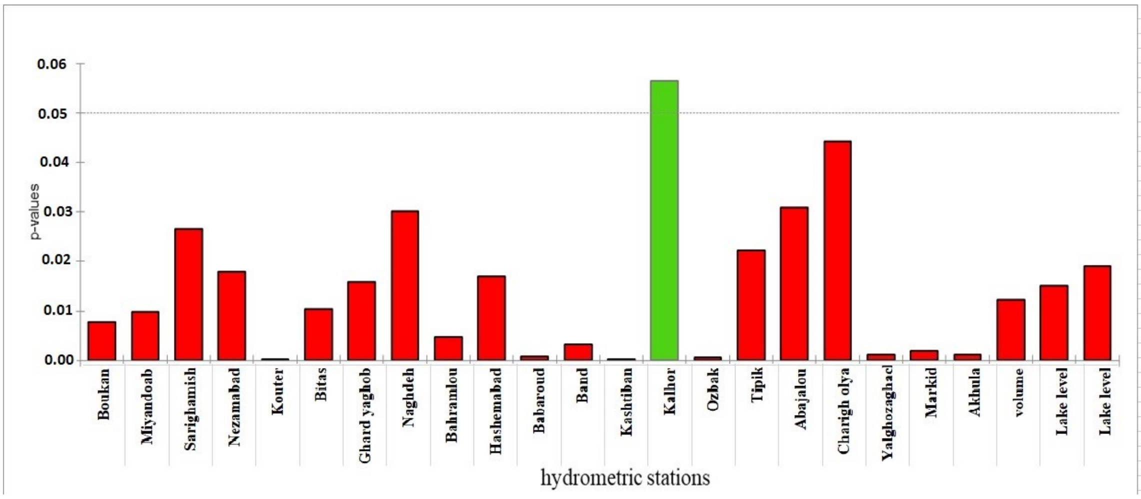


Figure 6. Chart of the significant trend of the annual Discharge Man-Kendall test of hydrological units and parameters of Lake Urmia

The results of Petit test at the probability level of 5% showed that in all-time series of discharge rate of hydrological units, as well as the characteristics of volume, surface and level of the lake, there are break points. According to the results obtained from data analysis, failure date, changes in discharge rate of hydrological units and characteristics of Lake Urmia basin were estimated in two time series (Table 4). With an overview of the failure dates in the time series (average failure date of all hydrological units), the occurrence of a sharp reduction in water balance in

Urmia basin has started almost on average since 1995 and has ended in 2004. The changes in the annual volume reduction (water balance) of the study basin in all hydrological units of the study area was estimated 2819160720 cubic meters. Considering a reduction by 17.437 billion cubic meters of the lake volume during the second period of the time series and the reduction in the total annual volume of sub-basins, it can be said that this reduction in balance occurred during about six years after the failure date.

Table 4. Changes in the discharge in two time series of hydrological units and the characteristics of Lake Urmia catchment area

Row	Hydrological unit	Hydrometric station	Petit Statistics	Q_1 (m^3/s)	Q_2 (m^3/s)	The broke year	Volume changes (Cubic meters)	discharge changes (%)
1	Nazlouchai	Tipik	0.000	13.835	7.766	1376	Upper basin	44
2	Nazlouchai	Abajalousofla	<0.0001	8.832	3.833	1376	191391984	57
3	Ajichai	Markid	0.0001	8.810	3.723	1375	Upper basin	58
4	Ajichai	Akhoula	<0.0001	16.097	4.429	1375	367962048	72
5	Barandouzchai	Bikran	<0.0001	9.262	5.661	1376	Upper basin	39
6	Barandouzchai	Babaroud	0.0001	9.743	4.770	1376	156828528	51
7	Rozechai	Kalhor	0.001	1.486	0.834	1375	Upper basin	44
8	Rozechai	Ozbak Bridge	0.0001	1.503	0.611	1374	38130112	59
9	Ghodarchai	Naghdeh	0.001	12.294	7.495	1375	Upper basin	39
10	Ghodarchai	Bahramlou Bridge	<0.0001	13.616	5.157	1376	266763024	62
11	Siminehroud	Boukan Bridge	0.000	15.438	9.033	1376	Upper basin	41
12	Siminehroud	Miyandoab Bridge	<0.0001	22.335	10.073	1373	386694432	55
13	Soufichi	Tazehkand Alaviyan	<0.0001	4.326	2.840	1377	46862496	34
14	Mahparichi	Khormazard	0.001	0.341	0.175	1376	5234976	49
15	Ghalehchai	Shishvan	<0.0001	2.421	0.525	1376	59792256	78
16	Mardoughchai	Gheshlagh Amir	<0.0001	2.826	1.468	1377	42825888	48
17	Shaharchai	Band	<0.0001	5.582	2.941	1376	Upper basin	47
18	Shaharchai	Kashtiban	0.0001	3.502	0.695	1383	88521552	80
19	Mahabadchai	Kouter	0.000	7.437	4.706	1377	Upper basin	37
20	Mahabadchai	Bitas	0.000	1.536	0.708	1381	Upper basin	55
21	Mahabadchai	Ghardyaghoub	<0.0001	7.634	2.606	1377	158563008	66
22	Zarinehroud	Sarighamish	0.002	56.301	35.619	1377	Upper basin	37
23	Zarinehroud	Nezamabad	0.000	52.450	22.000	1377	960271200	58
24	Zolachai	Charigholiya	0.000	4.702	2.501	1370	Upper basin	47
25	Zolachai	Yalghouzaghach	<0.0001	2.488	0.607	1376	59319216	76
26	Urmia	*Volume	<0.0001	24.117	6.680	1378	17437000000	72
27	-	**Area	<0.0001	5176.224	3180.429	1378	-	39
28	-	***level	<0.0001	1276.237	1272.127	1378	-	26

*the unit. Billion cubic meters, ** the unit. square kilometer, *** the unit. M above sea level

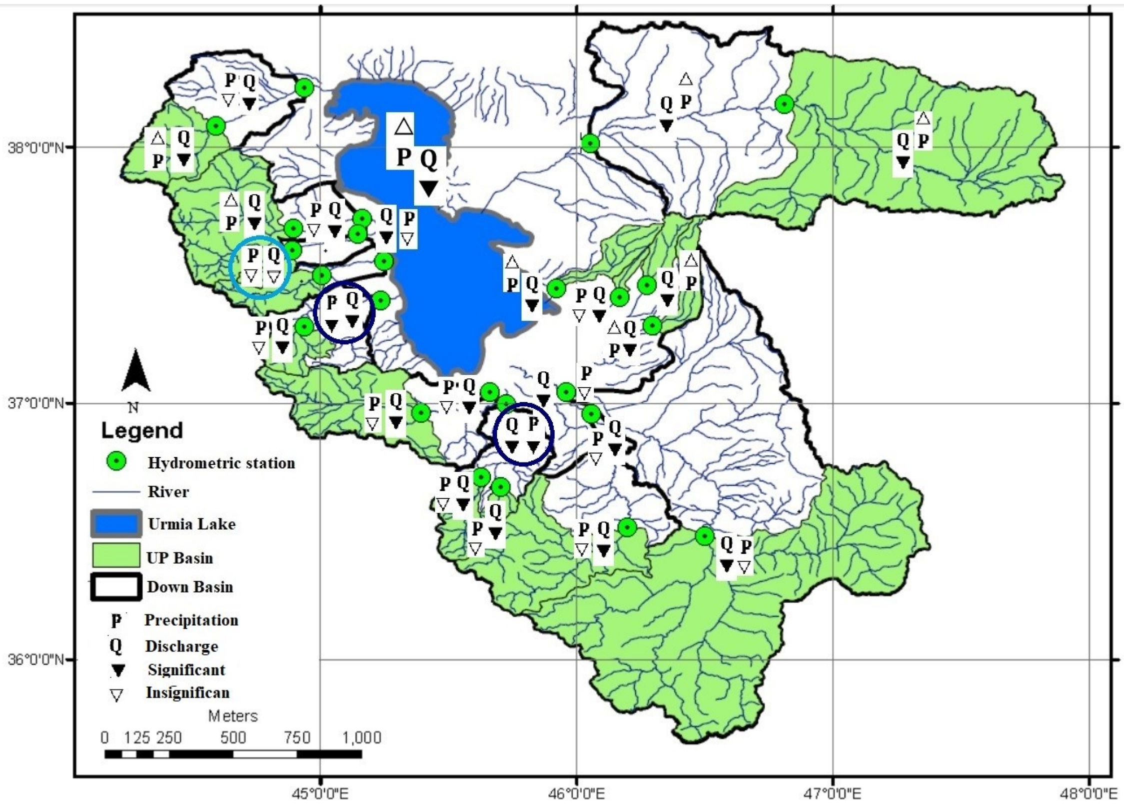


Figure 7.Decrease and increase of precipitation and discharge of Urmia catchments

4. Discussion and conclusion

The water entering Lake Urmia is naturally supplied through direct rainfall and river runoff. Significant increase in precipitation in the entire Urmia catchment area of about 0.16 mm at a rate of 0.004 mm per year indicates its stability during the study period. According to Figure 7, the amount of precipitation in the northern hydrological stations has an upward trend while the stations in the south indicate a declining trend. Both trends are not statistically significant. From annual precipitation standpoint, most of the hydrological units located in upstream and downstream in the west and south side of the field of study showed a decline that was not significant.In terms of discharge, all upstream and downstream hydrological units indicated a significant decline in the discharge with the Shahrchai (Keshtiban) hydrological unit having biggest drop of 80% and the Sofi Chai (Tazehkand) hydrological unit with minimum drop of 34%.

Discharge reduction in downstream hydrological units is more pronounced than those in upstream units (Shahrchai Basin with being maximum at 33% and Mahabadchai with being a minimum at 11%). The annual runoff of the studied basins into Lake Urmia in the two time periods before and after the discharge drop were estimated at 4.671 and 1.885 billion cubic meters per year, respectively, indicating volume reduction of 2.786 billion cubic meters (59.6%) (Table 4). Looking at the Lake Urmia sub-basins annual discharge reduction data (Fig 8), it can be seen that that Zarrinehroud with the largest share of 34.5% and Mahparishai with smallest share of 0.2%, and the rest in between, contribute to the occurrence of draught for Lake Urmia.

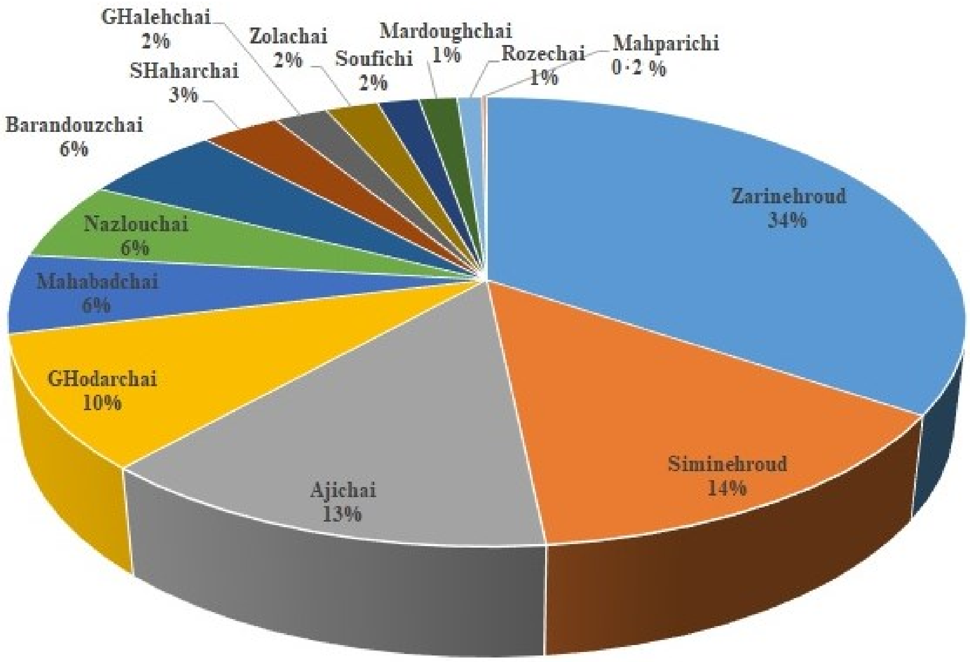


Figure 8. Percentage of the effect of reducing the annual volume discharge of Lake Urmia sub-basins

The results of present study are in agreement with other studies conducted in this field confirming an increase in the cultivation and development of non-economical agriculture with high water consumption in the current situation, construction and development of dams and water barriers in the region. The results of this study in the Urmia Lake catchment area, point to ineffectiveness of its water resources management. It is essential to have a careful and expert analysis the current system, and along with developing a short-term planning to quickly address this national debacle. The occurrence of man-made hydrological drought before the occurrence of meteorological drought has disrupted the balance of hydrological cycle and consequently caused a gross error in the calculations of runoff coefficient of the basin in all researches conducted in this study area.

Studies have shown that a significant percentage of the annual precipitation in the study area occurs during winter and early spring. The results of Mann-Kendall test and the changes as well as the failure date of the precipitation timepoints of hydrological units indicate that no significant trend is found in the precipitation level. The study results of *Sen's slope* values of annual precipitation are consistent with the study results of Sari Saraf et al. [7], Hejazizadeh et al. [22], and Nouri et al. [23]. The results of Mann-Kendall test and the changes as well as the failure date in the discharge time series and the volume and level characteristics of the lake showed that a significant decreasing trend was found in all sub-basins and in downstream hydrological units more than upstream. The decrease in yield is greater. The study results consistent with the study results of Goodarzi et al. [24], Soheili et al. [10], Adib and Tavancheh [25] indicate that the amount of precipitation is not significant but the flow at hydrometric stations has a decreasing trend. By comparing the test results of the two parts of precipitation and discharge of hydrological units, it can be stated that at the basin level, the amount of sub-basin yield indicates the strong involvement of human and non-natural factors. According to the study results of

Qudusi et al. [28], land use change (300% increase in agricultural lands and 376% increase in salt marshes) in this basin indicates a 51% reduction in runoff and a 13% increase in actual evapotranspiration during three decades in Ajichai basin. Therefore, considering the sensitivity of Urmia basin and its current drought conditions, as well as the consequences of economic and social problems, there is a need to review the general policy of water resources at the macro level of the basin and the country.

Limited water resources, population growth and consequently the urgent need for food supply, uncontrolled and uneconomical use of water and soil resources, unprofessional management of water demand, especially in the agricultural segment, failure to adopt appropriate and timely policies related to managing water resources in both supply and demand segments, have led to unfavorable water resources conditions and it impact on security and economic indicators has become inevitable.

One of the main challenges for the government to achieve sustainable development, is the ability to provide adequate water for various uses. And therefore, over time, what becomes important in the strategic management of water resources and plays a key role in national development, is making the right decision by managing the resources of the region of interest, not only to meet the current needs, take steps to provide, improve or develop the existing conditions but also to have developmental plan based on the needs in the future. It is recommended to pay close attention to the "virtual water" index in defining the outline of production and trade of agricultural products. In addition, while dealing with the water crisis, the strategic planners on the national level, must also consider to the economic value of water.
In summary the following can be mentioned:

1. The study results are an implicit confirmation of the causes for abnormal drying of Lake Urmia. One clear example of this is the comparison of the conditions of Lake Urmia and Lake Van in Turley (150 km apart) with the same climate. Hesari and Tayefeh Naskili [27] have studied the interaction between changes in the surface of Lake Urmia and Lake Van and according to the study results, two lakes have the same behavior and their changes have the same trend during the statistical period until 1995, however since 1995, both faced a declining trend in the water level, however, the decline has been much more severe for Lake Urmia.
2. The annual runoff of the studied basins into Lake Urmia in the two time periods before and after the discharge drop showed a significant reduction by about 60%. A slight reduction in the precipitation and a severe reduction in discharge indicated a direct correlation between this basin and occurrence of numerous consequential problems such as climate change, over-exploitation of rivers flowing into the lake, increasing water salinity, increasing levels of salt marshes and creating suitable conditions for salt storms leading to endangering agricultural lands in the region.
3. Therefore, in order to maintain a sustainable environment, a balance should be struck between the water value and water requirements of various sectors, especially agriculture sector. In order to solve this problem and rescue the lake, three beneficiary provinces must have full cooperation in controlling the water in-take for the lake. In order to effectively manage the limited and precious water resources of Lake Urmia basin, a balanced approach should be taken between water resources on one hand and

water usage on the other hand through choreographed coordination in the management of water supply, distribution and consumption. A comprehensive planning and development of basin water resources with a systemic approach should be developed and implemented.

4. It is recommended to impose restrictions on the farming of produce with high water usage and issue the necessary permits for the import of corresponding produce into the region in order to alleviate the need to grow the same produce in the region based on simple supply-demand balance. It is critical to have full collaboration among participant agencies and organizations in performing their assigned tasks and missions, as well as creating collective harmony as one body. The higher goal would be ease social tensions caused by lack of water resources in the region and to work towards creating a sustainable development in the region.

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