



# Changeability evaluation of hydro-climate variables in Western Caspian Sea region, Iran

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## Abstract

Trends of the three hydro-meteorological variables, including precipitation, temperature, and river discharge have been studied to detect the impacts of climate change on water resources in western Caspian Sea region, Iran. We used Kendall's tau, Spearman's rho, Sen's slope estimator, and Mann–Kendall approaches to detecting the annual and seasonal trends over the period 1981–2010. The nonparametric tests detected statistically significant decreasing trends in all of the hydrometric stations. In general, magnitude of an annual downward trend in the hydrometric stations was 2.17 m<sup>3</sup>/s per decade at the 5% significance level. As the results of the Pettitt test for detecting abrupt changes (jumps), the change points (or trends started) in river flow series were found in all hydrometric stations in the years of 1994–1999 at the significance level of 0.05%. Meanwhile, the outputs exhibited that majority of the annual and seasonally precipitation trends were increasing in contrast to the river discharge trends. Furthermore, on average, magnitude of annual temperature increasing trend was found (+) 0.43 °C per decade at the 0.05 significant level. Abrupt changes in the annual temperature as same as river flow series were at the 1990s over the period 1981–2010. The Pearson correlation was used to explore the relationships between river flow, temperature, and precipitation time series. Finally, the high correlation was obtained from the area-averaged temperature and discharge series at the autumn and annual time series with the value of the (–) 59 and (–) 50%. It is concluded that decreasing the river discharge might be related to increasing temperature and decreasing precipitation and anthropogenic changes in the study area.

**Keywords** Trend analysis · Pearson correlation · Precipitation · Pettitt test · Caspian Sea

## Introduction

Global change can be identified by changes in the mean or the variability of climate properties which persists for a decade or longer (IPCC 2014). Global climate has changed significantly in the last hundred years, and various hydro-climate variables have been affected by these changes (You et al. 2013). Globally, the average air temperature has increased over the twentieth century by about 0.7 °C, and it has affected on precipitation and river discharge. This condition could have important effects, which seriously threaten the population as well as agriculture, environment, economy, and industry (Yavuz and Erdogan 2012).

Trend changes in precipitation, temperature, and river discharge patterns can directly affect water resources management, drinking water supplies, agriculture, hydrology, and natural environment (Bostan and Akyüre 2007). Application of statistical methods such as trend analysis and change point detection in temperature, precipitation, and discharge series has been widely used throughout the world (Ventura et al. 2002; Aziz and Burn 2006; Partal and Kahya 2006; Karpouzou et al. 2010; Zongxue et al. 2010; Tabari et al. 2012; Abghari et al. 2013).

Lettenmaier et al. (1994) suggested that increasing trends in streamflow cannot be explained fully by observed trends in precipitation and temperature because of the effects of additional factors such as land use changes. An active subject for more than three decades up to now has been detecting trends in hydrologic, as well as climatic and other natural time series (Hamed 2008). Several trend detecting tests for this issue developed by researchers and have been used widely in different continents.

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Temperature and precipitation trends in Bologna, Italy, analyzed by Ventura et al. (2002) showed a significant positive trend in the temperature series while negative significant trend in precipitation data. Characterizing of hydro-climatic trends of the Yellow River basin in China by Guobin et al. (2004) revealed that the basin has become increasingly warmer over the last five decades with minimum temperature trends more significant than those of average and maximum temperatures. Additionally, the results of runoff and precipitation trend analyzing exhibited that the runoff of the region has decreased, but did not found a significant change in precipitation trend. Therefore, this is consistent with the global warming trend and is one of the major reasons leading to runoff decrease. Jiang et al. (2007) used the simple regression analysis and Mann–Kendall test, in the Yangtze River basin of China, for analyzing the temporal and spatial trends of rainfall and river discharge. They indicated a significant increasing trend in rainstorm frequency, summer precipitation, and flood discharges in most of the stations.

Trends of major hydro-climatic variables over the past 50 years analyzed by Zongxue et al. (2010) in the Tarim River basin, China showed that both average annual air temperature and precipitation experienced an increasing trend, while annual streamflow demonstrated a mixed trend of decreasing and increasing. Also, the results showed that the mountainous regions in the upstream had an increasing trend and the downstream regions exhibited a decreasing trend. Trend analysis of precipitation and discharge in the north of Iran by Ramazanpour and Roshani (2011) revealed an abrupt change in the data series. Additionally, they found a good fitting between discharge and precipitation trend in the area.

Tabari and Talaei (2011a) analyzed the long-term trends of the maximum, minimum, and average air temperatures and precipitation time series in some parts of Iran and suggested a warming trend in annual  $T_{\text{average}}$ ,  $T_{\text{max}}$ , and  $T_{\text{min}}$  at the majority of the stations which mostly began in the 1970s. Further, the magnitudes of the significant positive trends in annual  $T_{\text{average}}$ ,  $T_{\text{max}}$ , and  $T_{\text{min}}$  were (+) 0.412, (+) 0.452, and (+) 0.493 °C per decade, respectively. Abghari et al. (2013) have used nonparametric methods to detect annual and monthly trends of discharge data in northwest Iran and the results showed a statistically significant negative trend for the annual river discharge while no strong directional trend for the annual precipitation records. Roushangar and Alizadeh (2017) used the information theory and discrete wavelet transform in order to identifying the complexity of annual precipitation variation in Iran during 1960–2010 and obtained acceptable results to classification of the annual precipitation variation. In this regard, Farajzadeh and Alizadeh (2017) applied wavelet-SARIMAX-LSSVM conjugated model to predict the rainfall time series of Urmia Lake basin, and it was observed that the W-S-LSSVM's performance was improved in comparison with the other models.

The main aim of the present study is detecting of trends in the hydro-climatic parameters based on comprehensive nonparametric approaches in one of the susceptible areas to the natural environmental hazards. However, the current study focuses on the detecting of trends in the hydro-climatic parameters based on nonparametric approaches in Ardabil Province located in western Caspian, Iran over 1981–2010.

## Study area and data

Ardabil Province with an area of 19,751 km<sup>2</sup> is located in the northwestern edge of Iran. The average elevation in this province is 1450 m above sea level (a.s.l.), which lies in the neighborhood of the Sabalan Mountain and presents a cold and semi-cold, mountainous climate, with snowy winters in most of the area. Sabalan Mountain is located east of the province, which is the source of some rivers and the snow-melt flow through the several rivers, ultimately flowing into Yam-Chi dam reserve. In the current study, 25 gauging stations in the region, including 11 rain gauges, 7 hydrometric, and 7 temperature stations were selected (Fig. 1). The hydro-climatic records cover a period over 30 years (1981–2010) that could be assumed to be long enough for a valid average statistic (Kahya and Kalayci 2004; Karpouzou et al. 2010).

## Methods

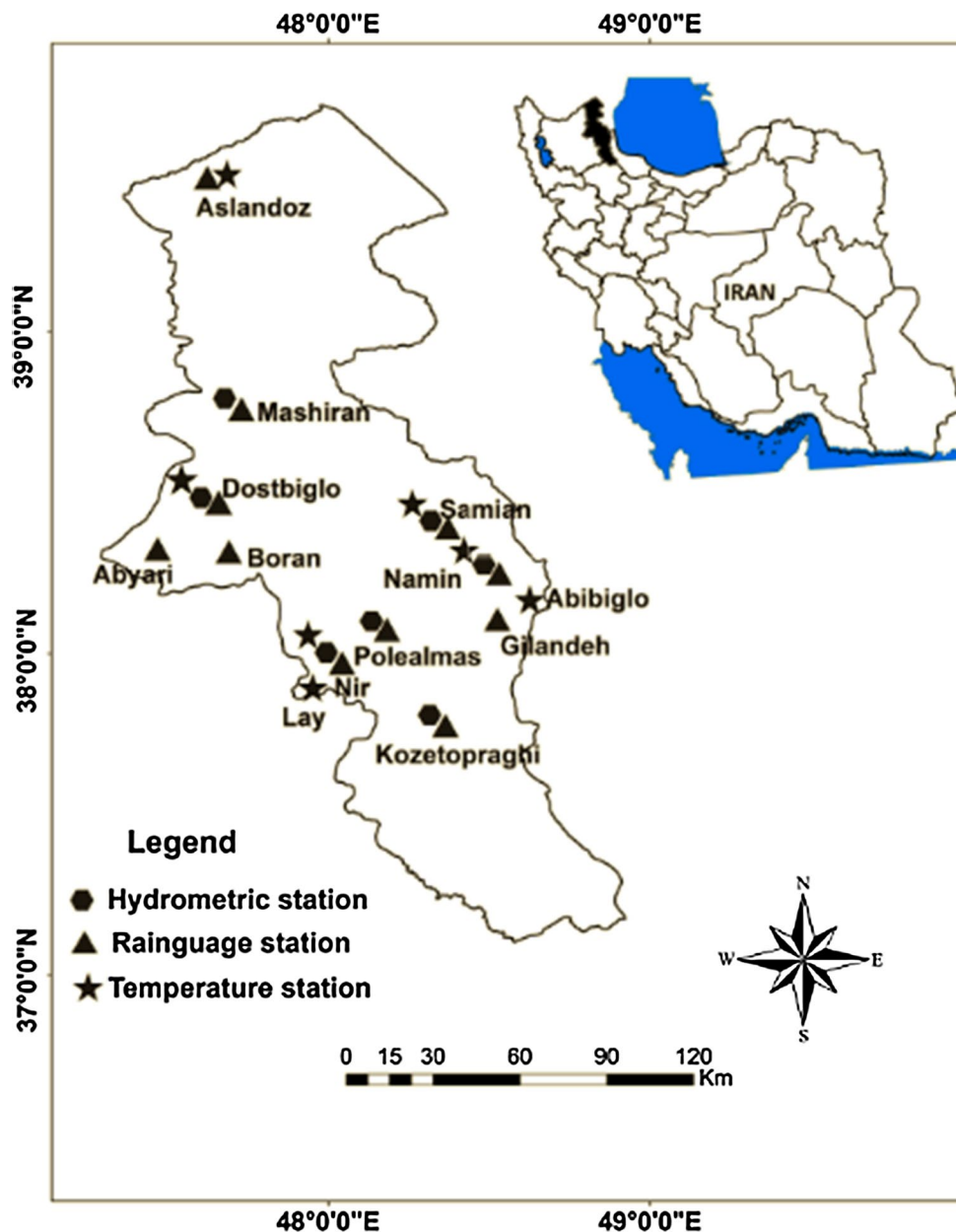
In this study, five commonly used nonparametric tests including the Mann–Kendall (Mann 1945; Kendall 1975), Sen's slope estimator (Sen 1968), Kendall's tau (Kendall 1975), Spearman's rho (Siegel 1956) and Pettitt (1979) were applied for the trend and change points identifying in hydro-climatic. Before using all-time series for trend analysis, we applied the homogeneity test via double mass curve method, independence structure, and outlier detecting tests. The trend analysis framework considered in this study is outlined in Fig. 2.

### Mann–Kendall test

The M–K tests if there is a trend in the time series data. According to the test, the null hypothesis  $H_0$  indicates that the depersonalized data  $(x_1, \dots, x_n)$  are a sample of  $n$  independent and identically distributed random variables (Hirsch et al. 1982; Karpouzou et al. 2010). Kahya and Kalayci (2004) expressed that the alternative hypothesis  $H_1$  of a two-sided test is that the distribution of  $x_k$  and  $x_j$  are not identical for all  $k, j \leq n$  with  $k \neq j$ . The test statistic  $S$  is computed by:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \text{sgn}(x_j - x_k) \quad (1)$$

Fig. 1 Hydro-climatic stations located in the study area



$$\text{sgn}(x) = \begin{cases} +1 & \text{if } (x_j - x_k) > 0 \\ 0 & \text{if } (x_j - x_k) = 0 \\ -1 & \text{if } (x_j - x_k) < 0 \end{cases} \quad (2)$$

In which  $\text{sgn}()$  is the signum function. The  $S$  statistic, in cases where the sample size  $n$  is larger than 10, is assumed to be asymptotically normal, with  $E(S) = 0$  and

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

where  $t$  is the extent of any given tie and  $\sum t$  states the summation over all ties. The standard normal variate  $z$  is

calculated by using the following equation (Douglas et al. 2000; Kahya and Kalayci 2004):

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

Therefore, in a two-sided test for trend, the  $H_0$  should be accepted if  $|Z| \leq Z_{\alpha/2}$  at the  $\alpha$  level of significance. A positive value of  $S$  determines an “upward trend,” and a negative value indicates a “downward trend.”

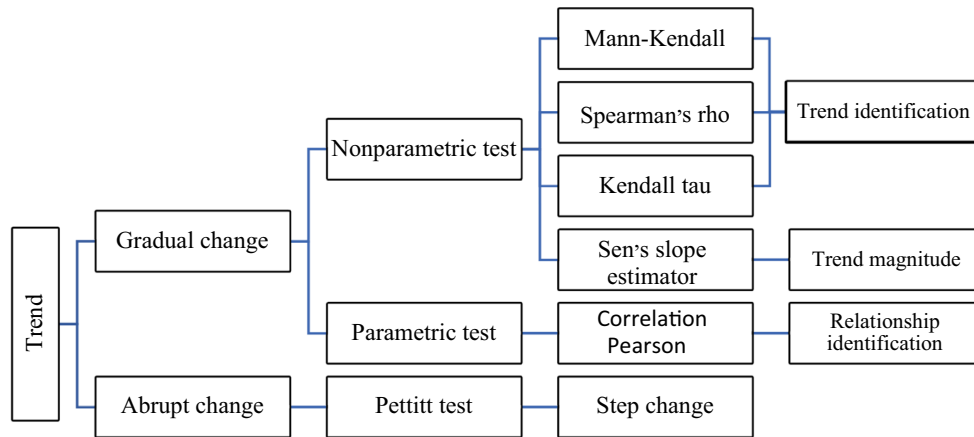


Fig. 2 Trend analysis framework used in this study

### Spearman's rho test

Rank-based nonparametric statistical Spearman's rho can also be used to detect a monotonic trend in a hydro-climatic time series (Yenigun et al. 2008). There is a significant trend only if the correlation between time steps and hydro-climatic time series is found to be significant. This test is computed by:

$$r_s = 1 - \frac{6(\sum R(x_i) - i)^2}{(n^3 - n)} \tag{5}$$

In which  $R(x_i)$  is the rank of the  $i$ th observation  $x_i$  in the sample of size  $n$ . The standard normal distribution is used, the test statistic of  $r_s$ ,  $S$  is calculated by:

$$S = r_s \sqrt{n - 1} \tag{6}$$

If  $|S| > z_\alpha$  at a significant level of  $\alpha$ , then the null hypothesis of no trend (in other words, values of observations are identically distributed) is rejected (McCuen 2002).

### Kendall's tau

Another statistic obtained on running the M–K test is Kendall's tau, which measures the strength of the relationship between the two variables. This method, like Spearman's rank correlation, is carried out on the ranks of data (Karmeshu 2012). In general, this test calculated by following equations (Bihanta and Zarehchahouki 2010):

$$\tau = \frac{2S}{N(N - 1)} \tag{7}$$

$\tau$  statistic is variable between  $- 1$  and  $+ 1$  that show negative correlation and positive correlation, respectively, where,  $S$  is the total difference in ranks and  $N$  refers to sample of size.

$$T = \frac{\tau \sqrt{n - 2}}{\sqrt{1 - \tau^2}} \tag{8}$$

$T$  statistic is the standard normal distribution and if  $|T| > t_\alpha$  at significant intervals of  $\alpha$ , then the null hypothesis of trend is accepted.

**Table 1** Descriptive statistics of the annual river flow time series at the hydrometric stations

Stations	Mean (m <sup>3</sup> /s)	Max (m <sup>3</sup> /s)	Min (m <sup>3</sup> /s)	SD (m <sup>3</sup> /s)	CV (%)
Nir	1.20	1.80	0.84	0.23	19.17
Polealmas	3.20	6.20	0.40	1.29	31.40
Gilandeh	2.23	5.06	0.01	1.31	58.74
Kozetopraghi	0.82	3.45	0.01	0.89	108.54
Dostbiglo	6.99	19.29	0.78	4.17	59.66
Mashiran	12.90	31.60	2.76	7.70	59.69
Samian	4.69	10.73	0.38	2.80	59.70

**Table 2** Values of statistics *S*, *T*, and *Z* nonparametric tests for the annual and seasonally river flow series, the bold values indicate the significance level at 0.05

Stations	Mann–Kendall test ( <i>Z</i> )					Kendall's tau ( <i>T</i> )					Spearman's rho ( <i>S</i> )				
	Annual	Summer	Spring	Winter	Autumn	Annual	Summer	Spring	Winter	Autumn	Annual	Summer	Spring	Winter	Autumn
Polealmas	-4.87	-0.28	-4.49	-4.49	-4.87	-4.29	-0.16	-3.77	-3.77	-3.67	-7.06	-0.16	-6.19	-6.19	-6.00
Kozetopraghi	-4.38	-0.72	-3.85	-3.53	-4.38	-3.22	-0.16	-2.97	-3.39	-3.77	-5.82	-0.11	-5.04	-6.00	-6.60
Dostbiglo	-5.42	-0.14	-4.35	-4.99	-5.42	-5.04	-0.21	3.97	-4.29	-4.18	-8.92	-0.37	-6.60	-7.06	-7.31
Mashiran	5.10	-0.89	-3.99	-5.14	5.10	-3.48	-0.26	-2.52	-1.08	-2.45	-6.00	-0.48	-4.53	-1.91	-4.07
Nir	-4.35	-0.43	-3.35	-1.53	-4.35	-5.82	-1.60	-3.87	-3.87	-3.87	-9.34	-2.38	-6.39	-5.34	-6.19
Samian	-5.50	-2.17	-4.60	-4.50	-5.50	-5.04	-0.26	-3.97	-4.18	-4.29	-8.92	-0.05	-6.60	-6.82	-7.31
Gilandeh	5.32	-0.38	-4.71	-4.87	-5.32	-4.65	-0.64	-3.22	-4.65	-3.48	-8.54	-0.64	-5.49	-8.19	-5.65

### Sen's slope estimator

The true slope (change per unit time) can be estimated by using a simple nonparametric procedure developed by Sen (1968), if a linear trend is present (Kahya and Kalayci 2004). The magnitude of the trend in the hydro-climatic time series was estimated using the nonparametric Sen's slope estimator (Theil 1950; Sen 1968) as follows:

$$\beta = \text{median} \left( \frac{X_i - X_j}{i - j} \right), \quad \forall j < i \tag{9}$$

where  $1 < j < n$ . According to Xu et al. (2003), the estimator  $\beta$  is the median overall combination of record pairs for the entire data set and is thereby resistant to the effect of extreme values in the observations.

### Pettitt test

Many of homogenization methods are developed to reduce the impact of non-climatic factors on climate series. This test is based on the rank,  $M_i$  of the  $K_i$  and ignores the normality of the series (Kang and Yusof 2012).

$$u_k = 2 \sum_{i=1}^k M_i - K(N + 1), \quad K = 1, 2, \dots, N \tag{10}$$

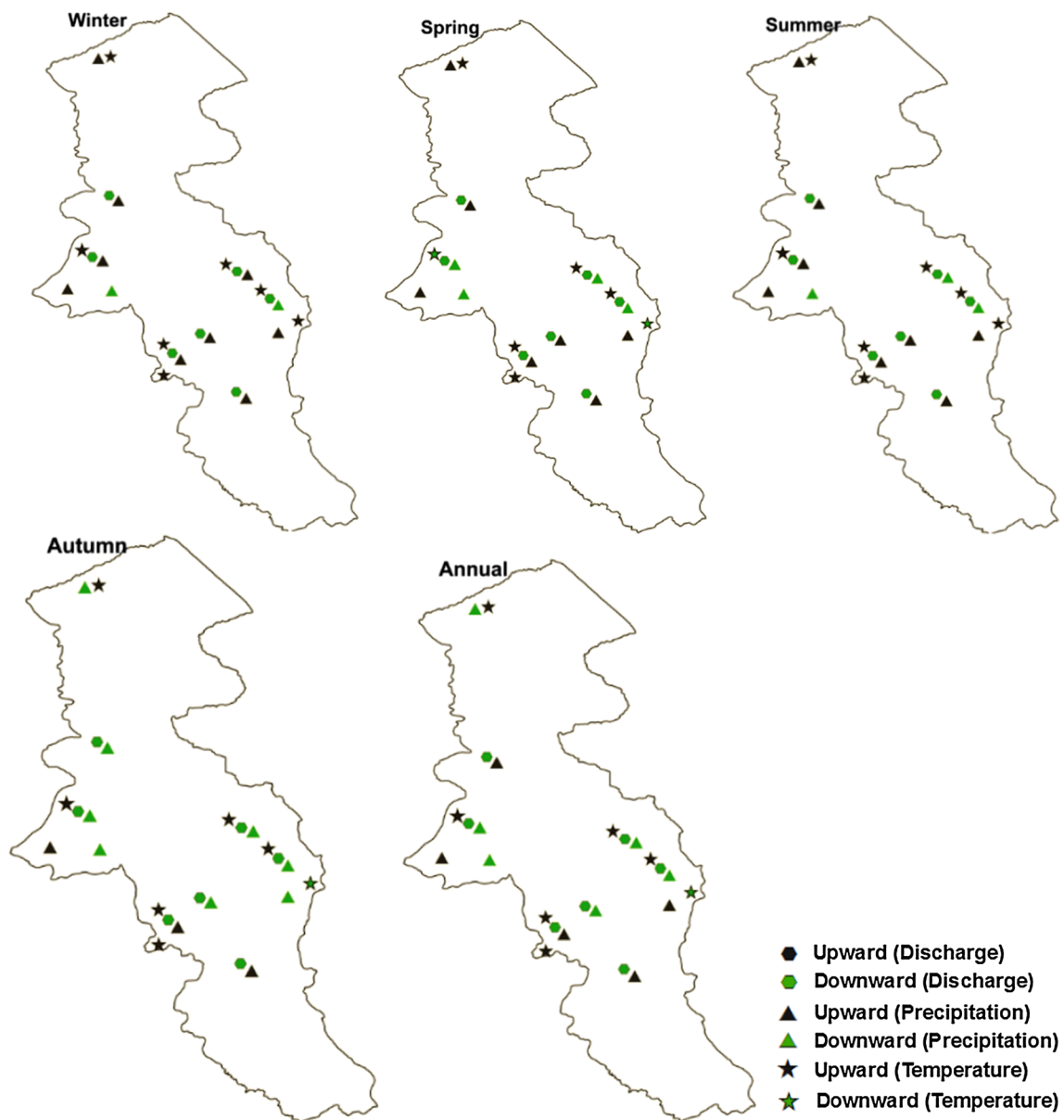
The break occurs in year  $k$  when:

$$X_K = \max |u_k| \quad N \geq K \geq 0 \tag{11}$$

The value is then compared with the critical value by Pettitt (1979).

### Results and discussion

Analysis of the annual river flow time series at the gauging stations showed that Kozetopraghi and Nir stations with average annual discharge of 0.82 and 1.20 m<sup>3</sup>/s have the lowest annual water yields (Table 1). In contrast, the highest annual water yields were found in the Mashiran and Dostbiglo gauges located in the north of area with average annual discharges of 12.90 and 6.99 m<sup>3</sup>/s, respectively. Furthermore, the highest temporal variability of the annual river flow time series characterized in the Kozetopraghi and Samian stations with coefficient of variations (CV%) of 108.54 and 59.70 while the lowest coefficient of variations (19.17 and 31.40) was determined in Nir and Polealmas stations, respectively (Table 1).

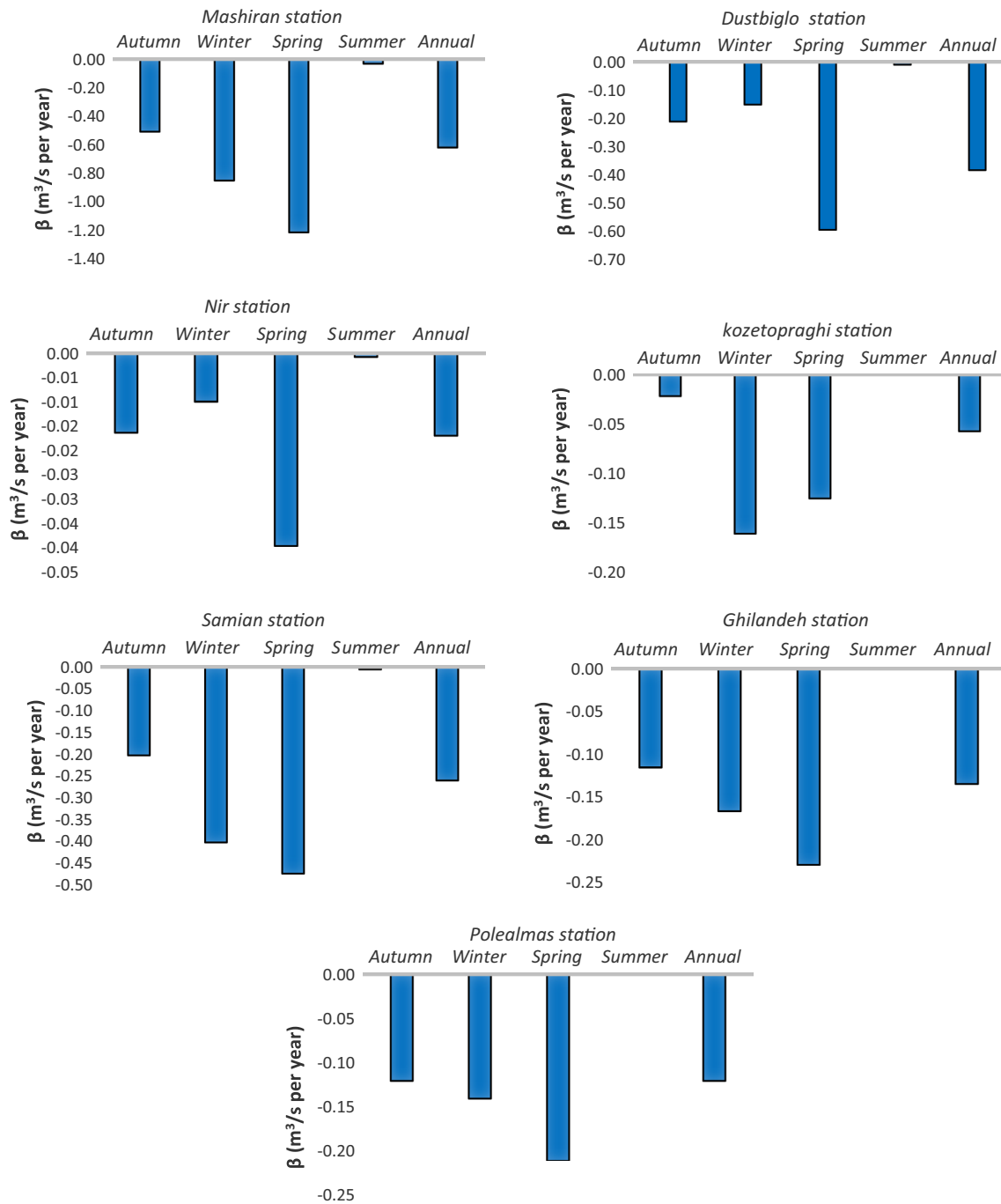


**Fig. 3** Spatial distributions trend for the annual and seasonal time series data by M–K test

### River discharge trends

Table 2 shows the values of  $S$  (Spearman's rho),  $T$  (Kendall's tau), and  $Z$  (Mann–Kendall) statistics for the seasonally and annually river discharge series for the period 1981–2010. The result of Mann–Kendall test on the annual and seasonally river time series is depicted in Fig. 3. As shown, all of the hydrometric stations had decreasing trends at the annual discharge time series, and the Mann–Kendall, Spearman's rho, and Kendall's tau trend tests were considered statistically significant at the 0.05 intervals. In general, statistically decreasing trends were detected in all of the stations by Mann–Kendall, Kendall's tau, and Spearman's rho tests.

Here, it is a good point for understanding of the future water resources scarceness in the study area. Moreover, the results of three tests for detecting trends at the annual and seasonally river flow time series provide the same conclusion about trend existence. In other word, annual and seasonally trends consideration indicated that the annual, autumn, spring, and winter river time series, except in Nir station, had significantly negative trend at the significance level of 0.05. In contrast, at the summer river time series except Samian station did not show significantly trend at the significance intervals of 0.05. This could be considerate due to most river flow time series were zero value at the summer time series that used tests did not detect trend in this study.



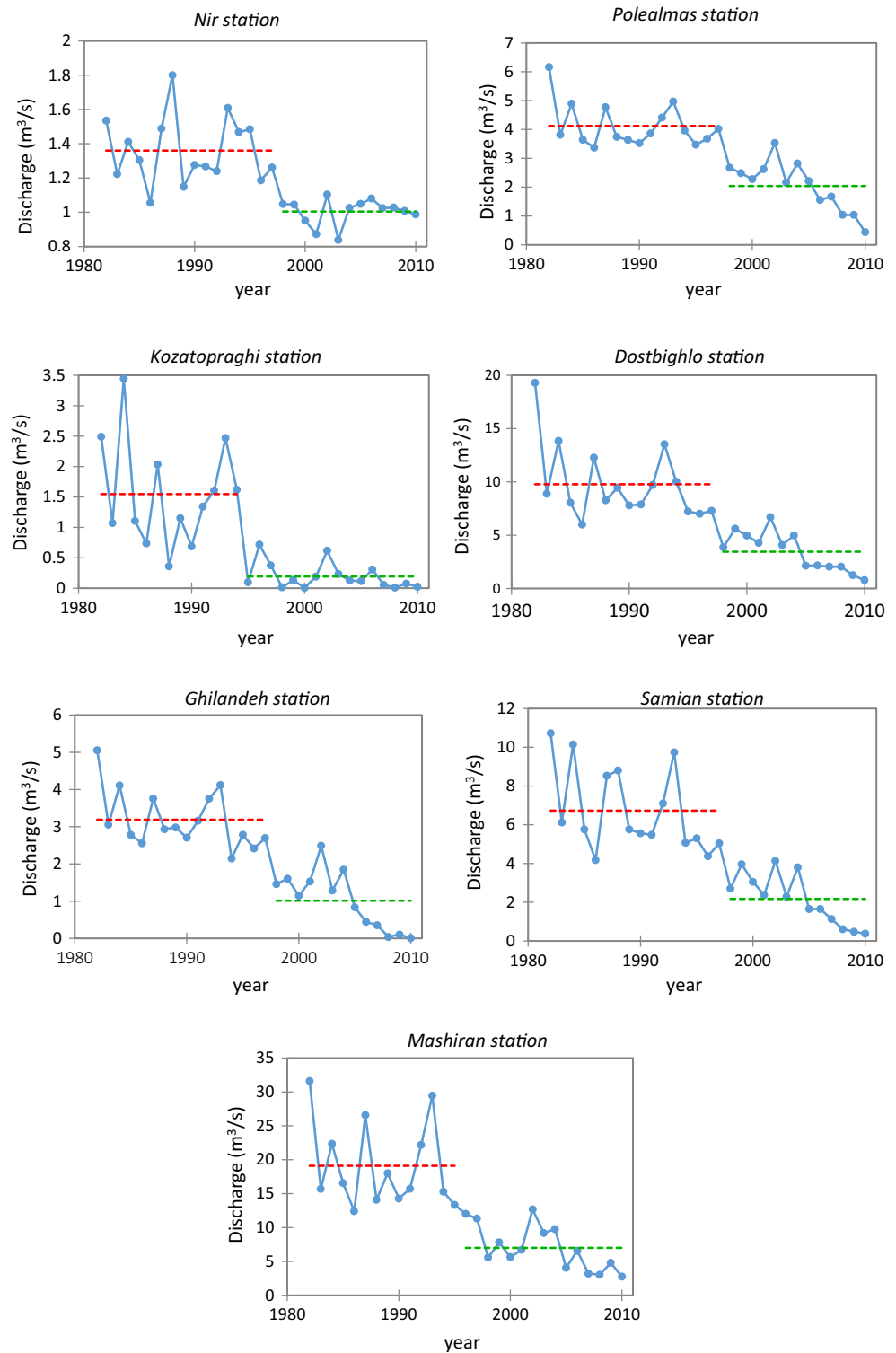
**Fig. 4**  $\beta$  statistics of the Sen's slope estimator method for the annual and seasonally river flow time series

Magnitude of trends for the annual and seasonally river flow time series shows the decreasing tendency of annual and seasonally river flow at the all of stations (Fig. 4). As shown, magnitude of annual downward trends in the Polealmas, Kozetopraghi, Dostbiglo, Mashiran, Nir, Samian, and Gilandeh stations were detected at the rate of 1.2, 0.5, 3.8, 6.1, 0.17, 2.6, and 1.3 m³/s per decade, respectively. The results of Sen's slope estimator revealed that the highest

decreasing trends in most of the stations were found at the spring and winter discharge time series while the lowest decreasing trends identified at the summer discharge time series, which is likely related to the dry situation of the season in most of the rivers.

In this area, spring is important the season due to providing the most runoff volume by snowmelt. Moreover, it is suggested that from standpoint of climate change, the

**Fig. 5** Abrupt change of the Pettitt test method for annual river flow time series



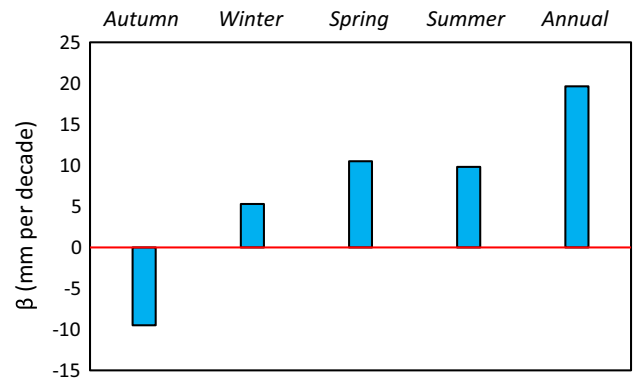
mountain's watershed is the most vulnerable environments due to vulnerability to temperature changes which affect ice melt, snowfall, and rainfall (Birsan et al. 2005; Abghari et al. 2013). Other works throughout the world, for example, Guobin et al. (2004) in China and Kahya and Kalayci (2004) in Turkey are consistent with the results of current study.

The Pettitt test characterized different change points, with statistically significant change in the time series as also confirmed by  $t$ -test (Tekleab et al. 2013). Meanwhile, it is important to identify that year occurred an abrupt change over the past years. However, we applied the Pettitt test which showed only change points for discharge and average



**Table 3** Values of statistics *Z*, *T*, and *Z* nonparametric tests for the annual and seasonally precipitation series, the bold values indicate the significance level at 0.05

Stations	Mann–Kendall test ( <i>Z</i> )					Kendall's tau ( <i>T</i> )					Spearman's rho ( <i>S</i> )				
	Annual	Summer	Spring	Winter	Autumn	Annual	Summer	Spring	Winter	Autumn	Annual	Summer	Spring	Winter	Autumn
	Aslandoz	-0.07	0.36	0.36	0.07	-0.43	-0.09	1.13	0.47	0.09	-0.47	-0.07	1.33	0.47	0.19
Nir	1.64	1.11	1.11	<b>1.74</b>	0.46	<b>2.05</b>	<b>1.84</b>	1.33	<b>2.16</b>	0.56	<b>3.08</b>	<b>3.20</b>	<b>1.84</b>	<b>3.72</b>	0.75
Polealmas	-0.11	0.11	0.11	0.14	-0.32	-1.53	1.24	0.09	0.19	-0.37	-0.28	1.95	0.19	0.56	-0.47
Gilandeh	1.11	1.14	1.14	<b>1.76</b>	-0.30	1.33	1.64	1.43	<b>2.27</b>	-0.37	<b>2.27</b>	<b>2.16</b>	<b>2.16</b>	<b>3.87</b>	-0.28
Kozetopraghi	1.50	-0.37	1.14	1.07	0.87	<b>1.84</b>	<b>2.16</b>	1.43	1.33	1.04	<b>2.84</b>	<b>3.2</b>	<b>2.05</b>	<b>2.27</b>	<b>1.84</b>
Namin	<b>-3.5</b>	-0.5	-0.37	<b>-1.71</b>	<b>-2.39</b>	<b>-5.27</b>	-1.04	-0.47	<b>-2.16</b>	<b>-3.20</b>	<b>-9.07</b>	-1.64	-0.65	<b>-2.72</b>	<b>-4.92</b>
Samian	-1.18	-0.5	-0.5	0.32	-0.21	-1.43	-0.19	-0.65	0.37	-0.28	<b>-2.16</b>	-0.65	-1.24	0.47	-0.37
Doostbiglo	-0.29	-0.36	-0.36	1.00	-0.21	-0.37	<b>1.95</b>	-0.47	1.24	-0.28	-0.09	<b>2.84</b>	-0.37	<b>1.73</b>	-0.47
Mashiran	0.96	0.79	0.79	0.36	-0.21	1.24	0.28	0.95	0.47	-0.28	1.64	0.19	<b>2.05</b>	1.04	-0.37
Boran	<b>-1.71</b>	-0.09	-0.09	<b>-1.80</b>	-1.20	<b>-2.16</b>	-0.47	-0.09	<b>-2.27</b>	-1.53	<b>-3.33</b>	-0.47	-0.28	<b>-3.08</b>	<b>-1.84</b>
Abyari	<b>2.32</b>	0.64	0.64	<b>2.74</b>	0.73	<b>3.08</b>	<b>2.96</b>	0.75	<b>3.72</b>	0.85	<b>4.92</b>	<b>4.00</b>	1.53	<b>6.88</b>	1.24



**Fig. 6**  $\beta$  statistics of the Sen's slope estimator method for the annual and seasonally areal precipitation

temperature time series in the annually time scales. For the precipitation data, change point detection results were insignificant and are not presented here. Abrupt change of the Pettitt test approach for annually river discharge series (1981–2010) is shown in Fig. 5. The outputs of this test identified that change points in the Polealmas, Kozetopraghi, Dostbiglo, Mashiran, Nir, Samian, and Ghilandeh were at the years of 1997, 1994, 1997, 1995, 1997, 1997, and 1997, respectively, which show five change points referring to the year of 1997 at the significant level of 0.05%. In other word, abrupt changes in all of the stations at the annual and seasonally time series have occurred in the annual time range of 1994–1997.

### Precipitation trends

The result of the Mann–Kendall test on the annual and seasonal precipitation time series is shown in Fig. 3, and also the results of the Mann–Kendall test, Kendall's tau, and Spearman's rho for the annual and seasonally precipitation time series are shown in Table 3. The results revealed that majority of the annual and seasonally precipitation trends were increasing in contrast to the river discharge trends. Analyzing of annual precipitation series showed negative trends in 45% of the rain gauge stations over three last decades.

The results of seasonally time series analysis indicated the most positive trend at winter time series while the springtime series had the most negative trends. The increasing winter temperature can be identified mainly due to the increasing rainfall in this season (Tabari and Talaei 2011a). For example, rainfall occurred instead of snow in winter season generates a higher percentage of liquid precipitation. Generally, in most of the stations, the trend tests did not identify any significant trend in the annual and seasonal

**Table 4** Values of statistics Z, T, and Z nonparametric tests for the annual and seasonally average temperature, the bold values indicate the significance level at 0.05

Stations	Mann–Kendall test (Z)					Kendall's tau (T)					Spearman's rho (S)				
	Annual	Summer	Spring	Winter	Autumn	Annual	Summer	Spring	Winter	Autumn	Annual	Summer	Spring	Winter	Autumn
	Aslandoz	<b>3.65</b>	<b>2.8</b>	0.95	<b>2.35</b>	<b>3.30</b>	<b>2.40</b>	1.635	0.48	1.36	<b>2.10</b>	<b>5.02</b>	<b>2.73</b>	0.69	<b>2.40</b>
Lay	<b>2.4</b>	1.50	1.34	<b>2.31</b>	<b>2.60</b>	1.41	0.78	0.69	1.30	1.53	<b>2.31</b>	1.26	0.96	<b>2.10</b>	<b>2.31</b>
Nir	<b>2.89</b>	<b>1.96</b>	<b>2.32</b>	<b>2.39</b>	<b>2.24</b>	1.69	1.11	1.30	1.36	1.26	<b>3.46</b>	<b>2.10</b>	<b>2.31</b>	<b>2.47</b>	<b>1.89</b>
Dostbiglo	1.36	<b>1.69</b>	-0.21	1.32	1.36	0.69	0.91	-0.12	0.69	0.73	1.11	1.06	-0.28	1.00	0.87
Abibiglo	-1.25	<b>2.17</b>	- <b>2.15</b>	1.12	-0.79	-0.64	1.20	-1.20	0.61	-0.40	-1.26	<b>2.31</b>	- <b>2.16</b>	0.87	-0.57
Namin	<b>4.07</b>	<b>3.16</b>	1.39	<b>2.42</b>	<b>2.08</b>	<b>2.92</b>	<b>2.02</b>	0.73	1.36	1.15	<b>5.44</b>	<b>3.24</b>	1.06	<b>2.40</b>	<b>1.77</b>
Samian	<b>2.70</b>	<b>4.41</b>	0.07	1.41	1.52	1.59	<b>3.34</b>	0.04	0.73	0.78	<b>2.40</b>	<b>7.50</b>	0.04	1.15	1.11

precipitation series. This is consistent with the results of Tabari and Talaei (2011b) and Abghari et al. (2013).

The  $\beta$  statistics of the Sen's slope estimator method for the annual and seasonally areal precipitation trends showed increasing trend for the annual, summer, spring, and winter areal precipitations time series except autumn (Fig. 6). Meanwhile, magnitude of the increasing trend for the different time series, annual, summer, spring, and winter areal precipitations time series, was found with the value of (+) 19.63, (+) 9.81, (+) 10.50, and (+) 5.29 mm per decade, respectively, while it was (-) 9.49 mm and decreasing trend for autumn areal time series. As the results of the Pettitt test, the change point test did not detect an abrupt change in precipitation time series.

### Average temperature trends

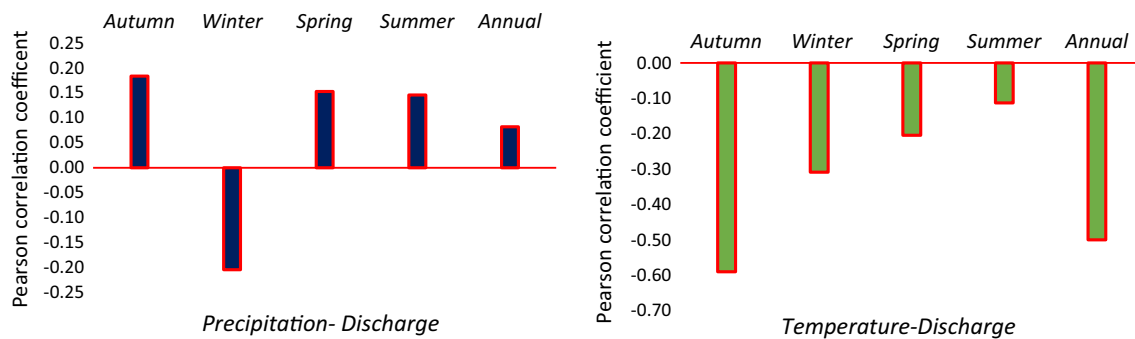
The results of the different trend tests showed an increasing trend for the annual temperature time series in almost all of the stations (i.e., in 86% of the stations) except Abibiglo station (Table 4). Among all stations, the Aslandoz, Nir, Lay, Samian, and Namin stations had the significantly increasing trends at the 0.05 significant intervals.

Seasonally analyzing trend showed that the summer season had the most significantly increasing trends at the 0.05 level. Another seasonal time series indicated that except of the Nir station at the springtime series, positive trends in the study area. Nir station is located in the vicinity of the Sabalan Mountain, and it can be concluded that this station is influenced by it. This is in good agreement with the results of Zarenistanak et al. (2014) in the southwest Iran and Christopher et al. (2012) in the USA.

Annual temperature trends were found in the Lay, Abibiglo, Aslandoz, Doostbiglo, Namin, Nir, and Samian at the rate of (+) 0.6, (-) 1, (+) 0.6, (+) 0.3, (+) 0.7, (+) 1.1, and (+) 0.7 °C per decade. The highest increasing of the temperature trends were found at the winter time series while the spring temperature time series had the lowest increasing trend. According to Schaefer and Domroes (2008), "Global warming" and "climate change" are major keywords in the present-day global change discussion. Therefore, emissions of greenhouse gases and aerosols due to human activities go on alter the atmosphere commonly recognized to affect the climate. The results of Pettitt test for annual average time series showed that the majority of stations experienced abrupt change in the 1990s.

### Relationships between hydro-climatic variabilities

In this regard, the Pearson correlation was used to explore the relationships between river flow, temperature, and precipitation time series (Fig. 7). The statistically significant



**Fig. 7** Results of the Pearson correlation coefficient between area-averaged river flow, precipitation, and temperature

correlations were observed at the autumn and winter precipitation data with river flow time series in the 0.05 significant level. In all of various time series except winter, the relationships between the precipitation and river flow time series were found positive. This means that both of the area-averaged precipitation and river discharge had a decreasing trend over the period 1981–2010. Furthermore, analyzing the relationship between area-averaged temperature and discharge series indicated negative correlation at the significance of 0.05 levels in different time series. Additionally, the high correlation was obtained from the area-averaged temperature and discharge at the autumn and annual time series with the values of (–) 59 and (–) 50%, respectively. We can conclude that decreasing the river discharge may be related to increasing temperature and decreasing precipitation in this region. The results of the Pettitt test for the analyzing abrupt change showed relatively similar pattern in the change points of temperature and river discharge series. Presence of trends may be due to a negative trend in precipitation while a positive one in temperature (Kahya and Kalayci 2004). Hence, it is important to characterize the variability of hydro-climatic parameters and its effects on water resources, hydrology, and natural environments.

## Conclusion

The trend and change point analysis were carried out for precipitation, temperature, and stream gauging stations in the western Caspian Sea region in Ardabil Province, Iran, based on comprehensive nonparametric approaches. The results indicated statistically decreasing trends in all of the gauging stations by Mann–Kendall, Kendall’s tau, and Spearman’s rho tests. In general, magnitude of annual downward trend in the hydrometric stations was 2.17 m<sup>3</sup>/s per decade at the 5% significant level. As results of the Pettitt test for detecting abrupt change in the all hydrometric stations, change points (or trends commenced) were identified in the in the years of 1994–1997 at the significant level

of 0.05%. In trend analysis of precipitation time series, the outputs exhibited that majority of the annual and seasonally precipitation trends were increasing in contrast to the river discharge trends. The Pearson correlation was used at the 0.05 significant intervals to explore the relationships between the river flow, temperature, and precipitation time series. We only determined statistically significant correlations in the autumn and winter precipitation with river discharge time series. Furthermore, analyzing the relationship between area-averaged temperature and discharge series in the different time series was found negative correlation at the significance intervals of 0.05. Additionally, the high correlation was obtained from the area-averaged temperature and discharge at the autumn and annual time series with the value of the (–) 59 and (–) 50% over the studied period. It is concluded that any decreasing trend in the river discharge might be related to the increasing temperature and decreasing precipitation, drought periods, and also anthropogenic changes in the study area. For future research, it is suggested to study the hydrological and meteorological drought periods and land use changes in the studied area in order to identifying natural and anthropogenic changes.

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