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Trend analysis of water flow on Neka and Tajan rivers using parametric and non-parametric tests

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Abstract— River flow is an essential parameter in hydrology and water resources studies with mutual interaction with climate elements. So, studying the discharge change trend in the rivers is crucial for management programs and the design of irrigation and drainage systems. In the present study, river flow data measured at six hydrological stations at Neka (Ablu, Golverd, SefidChah) and Tajan (KordKhil, Rigcheshmeh, Soleimantangeh) rivers in Mazandaran Province have been studied by using Mann-Kendall test, age test, and regression analysis during the statistical period of 1976–2006. The MAKESENS 1.0 software was used to reveal annual and seasonal discharge change trends. Results of the present study showed that only two stations – Soleimantangeh and Rigcheshmeh – had decreasing trend at 5% significance level in yearly terms.

In contrast, the regression analysis showed just significant trends at Soleimantangeh station. No crucial trends have been observed in the seasonal scale; in spring and autumn, most of the stations had a non-significant negative trend. By considering the methods used to evaluate trends in this study (Mann-Kendall test, age test, and regression analysis), it was observed that all the rivers had had decreasing and negative trends. The performance of parametric and non-parametric tests was similar in most cases.

Key-words: Mann-Kendall test, MAKESENS, regression, Mazandaran station, catchment, discharge.

1. Introduction

Today, the global warming caused by increasing greenhouse gases and their impact on climate change is a scientific fact that many researchers have admitted to (*Kweku et al.*, 2017). Scientists believe that human intervention in the atmosphere and greenhouse gas concentrations resulting from fossil fuel consumption led to an increased mean air temperature worldwide. Rising temperatures can lead to changes in the process of some components of the hydrological cycle, including precipitation and stream in different parts of the world (*Lelieveld et al*., 2019; *Shindell* and *Smith*, 2019). It is necessary to study the trends and regular changes in hydroclimatic variables in each area to prepare against the undesirable effects of climate change and reduce the resulting losses. It is required to ensure that appropriate policies and programs for the development and management of water resources must be taken (*Faridah* et al., 2014). Due to this reason, recently, many studies about the process of trend changes in different meteorological and hydrological variables have been conducted (*Fathian et al.*, 2016; *Noori et al.,* 2013; *Salarian et al.,* 2015; *Tosunoglu* and *Kisi*, 2017).

The most common method for hydrology, meteorology, and time series analysis is to assess the presence or absence of trends in them using statistical tests (*Asfawet al*., 2018). So far, several methods for time series trend analysis have been provided, which are divided into two categories: parametric and non-parametric methods (*Kocsis et al*., 2017). Parametric tests are more accurate to determine the trend than non-parametric tests, and while using them, the data should be random (independent) and should have normal distribution. On the other hand, non-parametric tests can have only random data that are not sensitive to the data's normality (*Chen t al*., 2007).

In this regard, we can refer to the research on the trend of changes in meteorological parameters and climate change, such as rainfall *(Jakuschné Kocsis* and *Anda*, 2018; *Malik* and *Kumar*, 2020), drought (*Salarian et al.,* 2016; *Zarei et al.,* 2016), temperature (*Mohorji et al.,* 2017), evapotranspiration *(Khanmohammadi et al.*, 2018).

Korhonen and *Kuusisto* (2010) presented the characteristics of long-term changes in the discharge regime in Finland. The Mann–Kendall trend test was applied to assess changes in annual, monthly, and seasonal mean discharges, maximum and minimum flows, and, besides, the date of the annual peak flow. Trend analysis showed a change in the seasonal flow distribution and no overall change in the average annual flow. *Villarini, Smith, Serinaldi,* and *Ntelekos* (2011), used maximum annual and seasonal daily discharge time series for 55 stations in Germany, Switzerland, the Czech Republic, and Slovakia to measure flood frequency from a regional perspective. Analysis of records of maximum daily, seasonal, and annual discharges showed the existence of uniform patterns using Spearman and Man-Kendall tests. *Čanjevac* and *Orešić* (2015) discussed recent changes in the average annual and seasonal river discharges in Croatia. For assessment purposes, the Kendall-Theil (Sen) non-parametric trend test was carried out for the yearly and seasonal mean discharge values. The results show an increase in evacuation in autumn and winter and a decrease in evacuation in summer. *Chen, Guan, Shao,* and *Zhang* (2016), examined streamflow and precipitation trends in the Huangfuchuan Basin using wavelet analysis and the Mann-Kendall test. The comparative analysis with five MK test methods showed that the modified MK tests with complete serial correlation structure performed better when significant autocorrelations exhibited for more than one lag. *Fathian et al*. (2016) evaluated the trend of hydrological and climatic variables under the influence of four changes in the Mann-Kendall approach in the Urmia Lake Basin in Iran. The correlations between streamflow and climatic variables showed that the Urmia Lake basin's streamflow is more sensitive to temperature changes than precipitation. *Déry, Stadnyk, MacDonald,* and *Gauli-Sharma* (2016) conducted a recent study of recent trends and changes in river discharges in northern Canada for the years 1964–2013. Based on the Mann–Kendall test, no significant annual discharge trend is observed in the Bering Sea, western Arctic Ocean, Western Hudson, James Bay, and Labrador Sea. *Oluoch, Nyabundi*, and *Boiwa* (2017) analyzed meteorological data trends to determine the trend and size of tea production using the Man-Kendall and Sen's Slope estimate tests. The results showed that the weather parameters were still within limits required for optimum tea production despite the changes.

According to studies conducted in Iran, which are focused more on hot and dry areas, no assessments have been done about discharge trend changes in Iran's northern part. Therefore, this article attempts to assess the annual and seasonal trends of northern rivers in Iran. In the present study, the seasonal and annual trends of Neka and Tajan rivers located in northern Iran have been investigated using non-parametric tests. A parametric regression analysis test was also used to determine the trend and to compare it with a non-parametric test.

2. Research methodology

2.1. The case study

The area under study covers about 1906.72 km^2 in Mazandaran Province, and a small part of it is located in the western part of Golestan Province. The Tajan river basin covers an area of 4015.88 km^2 and is located in the range from 52° 50’ to 54° 50’ east longitudes and 35° 35’ to 36 '50° north latitudes. The Neka river basin also flows in the geographical area53° 17’ to 54° 44’ east longitudes and 36° 28’ to 36° 42’ north latitudes (*Fig. 1*).

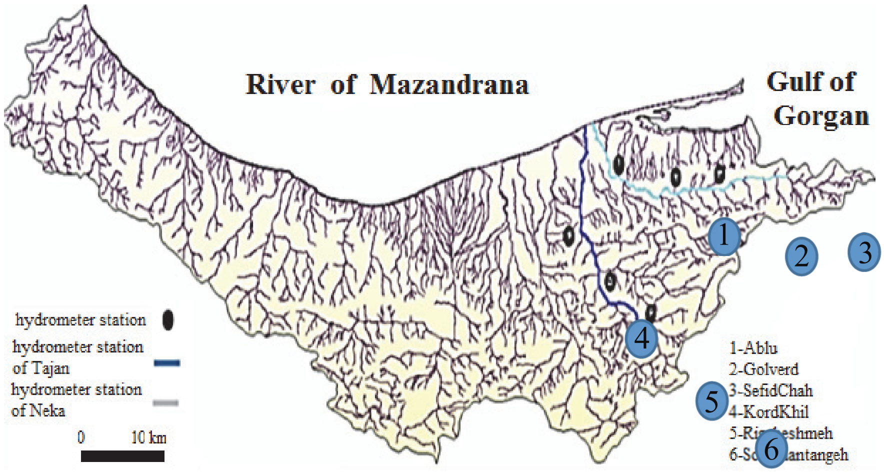


Fig. 1: The studied area of Tajan and Neka rivers.

2.2. The used data

Water discharge data have been used in both annual and seasonal scales to study the water flow in Neka and Tajan rivers. Discharge data were taken from the Regional Water Organization of Mazandaran Province relating to six hydrological stations of Neka (Ablu, Golverd, SefidChah) and Tajna (KordKhil, Rig Cheshmeh, Soleimanzadeh) rivers with a statistical length of 31 years from 1976–2006. The characteristics of these stations are summarized in *Table 1*. In this study, MAKESENS 1.0 (Mann-Kendall and Sea's slope estimates) Freeware is used to calculate the statistics related to the Mann-Kendall test and the age slope estimator. MAKESENS was developed at the Finnish Meteorological Institute in 2002 for detecting and estimating trends in time series of annual values. Determining the regression equations has also been performed by SPSS 16 software.

Table 1. Specification of the studied stations and some statistics about annual flow series in the statistical period (1976–2006).

station	**Geographical coordinates**	**Min**	**Max**	**Mean**	**SD**	**Cs**
Ablu	36º 31′ 38″ North 53º 19′ 26″ East	0.63	5.07	2.67	1.244	0.25
SefidChah	36º 36′ 9″ North 53º 11′ 53″ East	0.97	2.7	1.68	0.425	0.4
Golverd	36º 43′ 23″ North 53º 10′ 6″ East	1.03	3.64	2.05	0.749	0.464
KordKhil	36º 30′ 43″ North 53º 29′ 6″ East	0.77	5.08	2.79	1.141	0.305
Soleimantangeh	36º 25′ 9″ North 53º 23′ 17″ East	0.63	5.16	2.48	1.091	0.547
Rig Cheshmeh	36º 21′ 31″ North 53º 26′ 10″ East	0.91	4.96	2.56	0.990	0.269

(Source: Regional Water Organization of Mazandaran Province, 2016)
Mean: average annual flow (m^3/s), SD: standard deviation of annual flow (m^3/s), and Cs: coefficient of skewness (m^3/s)

2.3. Theoretical foundations

2.3.1. Mann-Kendall test

The Mann-Kendall test (*Kendall*, 1948) is one of the most common types of non-parametric tests to determine trends in hydrological data, when normal distributed data is not necessary for using (*Tabari* and *Talaee*, 2011). According to this test, the null hypothesis implies randomness and lack of trend in the data series. Accepting the alternative hypothesis (rejecting the null hypothesis) is evidence of trends in the data series. Statistic *S* can be obtained as follows:

$$S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n}\operatorname{sgn}(x_j-x_k), \tag{1}$$

$$\operatorname{sgn}(x_j-x_k)=\begin{cases} +1 & x_j-x_k>0 \\ 0 & x_j-x_k=0 \\ -1 & x_j-x_k<0 \end{cases}, \tag{2}$$

where *S* is statistics related to Mann-Kendall, x_j and x_k are the observed values related to *j*th and *i*th, respectively, the number of data, and sgn($x_j – x_k$) is the sign function m.

$$\operatorname{Var}(S)=\frac{[n(n-1)(2n+5)-\sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)]}{18}. \tag{3}$$

The number of identical groups (same set of sample data with the same values) and t_i are the same number of data in the *i*th category. In cases where the sample size is $n > 10$, the standard statistics *Z* is obtained as follows:

$$Z=\begin{cases} \frac{S-1}{\sqrt{\operatorname{Var}(S)}} & \text{if} \quad S>0 \\ 0 & \text{if} \quad S=0 \\ \frac{S+1}{\sqrt{\operatorname{Var}(S)}} & \text{if} \quad S<0 \end{cases}, \tag{4}$$

where positive Z values represent an increasing trend, while negative values indicate a decreasing trend. If the calculated *Z* is greater than 1.645, the data trend is significant at a confidence level 0.1, and otherwise, it is assumed to be insignificant. Similarly, if the calculated *Z* is greater than 1.96 and 2.58, the data trend is considered significant at the 0.50 and 0.01levels. Otherwise, the null hypothesis that there is a trend in the data in the considerable level of interest will be rejected (*Tabari* and *Talaee*, 2011).

2.3.2. Estimator method of slope (Sen)

If there is a linear trend in a time series, then the right slope (changes with time) can be estimated by using a simple non-parametric method which was proposed by *Sen* (1968). The slope value of the trend is calculated by using the following equation:

$$Q=\text{Median}\left(\frac{x_j-x_k}{j-k}\right)\forall\, k<j \quad , \tag{5}$$

where x_j and x_k, the data values are over time j and k ($j>k$), respectively. Also, the meaning of Median (u) is the median values of u. If u is even, the data median is the arithmetic mean of two current numbers in the middle sets of data relating to u in ascending or descending order. If the number of u is odd, the data median is the present number in the middle of the ascending or descending order. In this method, the unit slope of the trend line equals with the variable unit studied in the year (in the research cubic meters per second). In the age slope technique, positive and negative values of Q indicate increasing and decreasing data trends. This method is one of the most common scenarios in hydrological studies that are widely used as well.

2.3.3. Linear regression method

Linear regression analysis is also used to study trends in the time series like the Mann-Kendall test and age slope estimator method. The main statistical parameter of this method is the regression line's slope, which shows the desired variable changes. Positive values of this slope indicate an increasing trend, while negative values show a decreasing trend. In the current study, a linear regression model was fitted on the discharge time series data, and the significance of the slope was evaluated at the confidence level of 95% and 99% by using the Pearson correlation:

$$Y=a+bX\,, \tag{6}$$

where the Y is the variable understudying (in this study, discharge), "X" is the time, "a" is a constant number, and "b" is the slope of the regression line.

3. Research findings

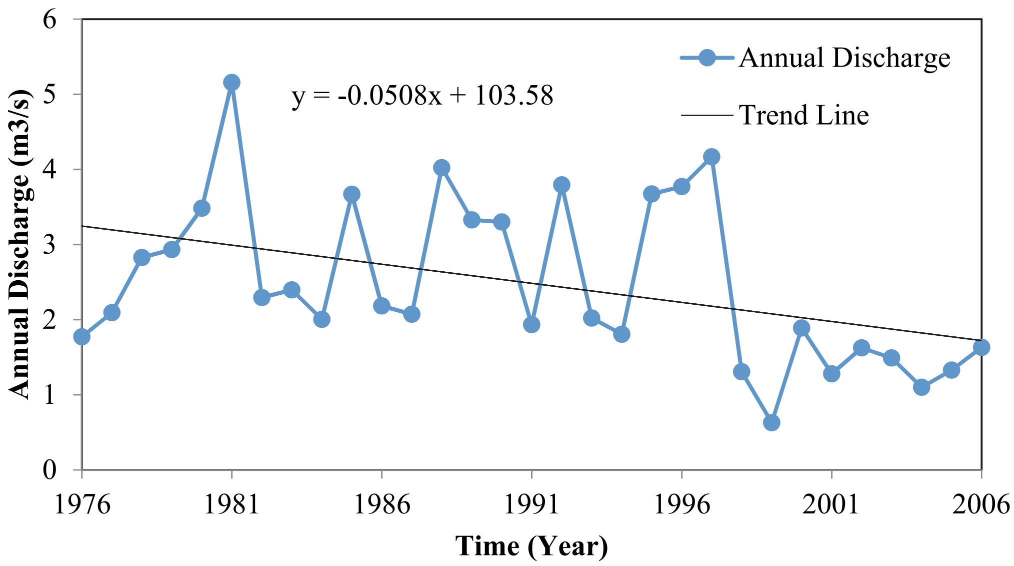
3.1. The Annual discharge trend

Table 2 shows the results from the annual discharge trend study (m^3/s) using Mann-Kendall test, age slope estimator method, and linear regression. According to the table, the obtained results of the different statistics for annual discharge in all stations have a decreasing trend. The linear regression process's annual accepted trend is almost the same as the Mann-Kendall test's obtained trend. The annual trend of most stations was not significant at the 1% and 5% levels. Still, the two stations, Soleimantangeh and Rigcheshmeh, both locate at the Tajan river, have a decreasing trend at the 5% level (indicated with an asterisk).

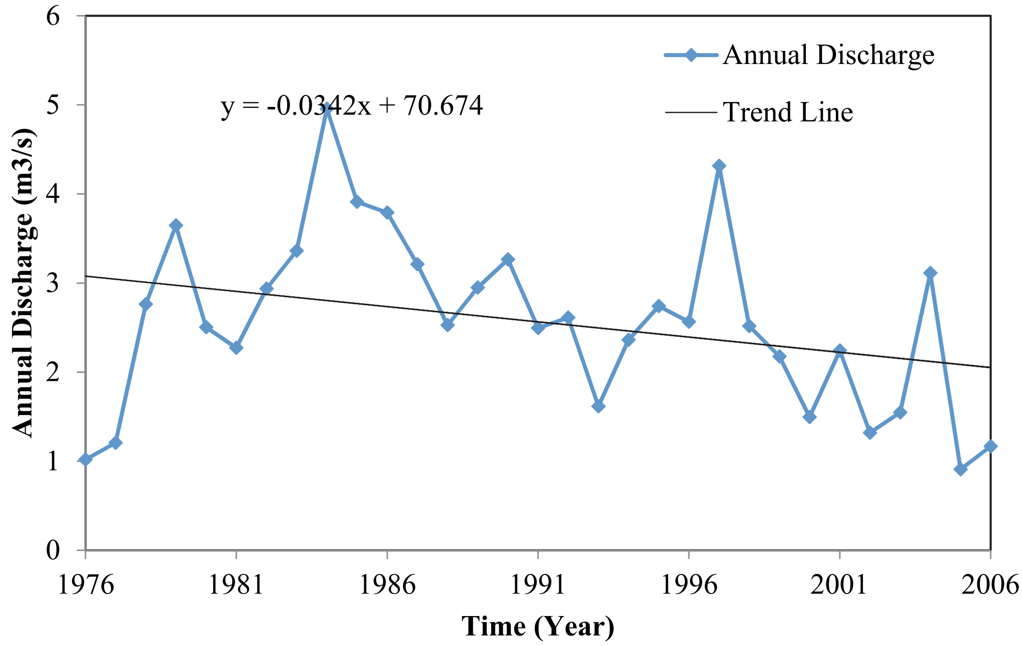
Table 2. Results of Mann-Kendall test, age slope estimator, and linear regression for the annual discharge

Station	Z	Q	b (m^3/s)	P-value
Ablu	-0.48	-0.018	-0.149	0.423
SefidChah	-0.92	-0.010	-0.155	0.404
Golverd	-1.05	-0.019	-0.228	0.218
KordKhil	-0.24	-0.006	-0.053	0.778
Soleimantangeh	-2.52*	-0.043	-0.423	0.018*
Rig Cheshmeh	-2.18*	-0.051	-0.314	0.085

The only significant observed trend has been obtained by regression analysis in the annual discharge data of Soleimantangeh station. Based on the regression line slope presented in (*Table 2*), it can be concluded that annual discharge has been decreased in Soleimantangeh, Rigcheshmeh, Galuverd, Sefidchah, Ablu, and Kordkhil stations 4.2, 3.1, 2.2, 1.55, 1.49, and 0.5 m^3 in the three decades understudying, respectively. It can be stated that these results are consistent with the results of Mir Abbasi Najaf Abadi and Din Pazhuh (2010). The annual significant decreasing discharge trend of Soleimantanghe and Rigcheshmeh stations is shown in *Fig. 2*.



Soleimantangeh



Rigcheshmeh

Fig. 2. The annual discharge changing trend of Soleimantangeh and Rigcheshmeh stations in the statistical period 1976–2006.

3.2. Seasonal trend

Spring: According to *Table 3*, based on the values of the Mann-Kendall test, most stations have an insignificant decreasing trend in spring, and only the Kordkheil station had a minor increasing trend. These results are in good agreement with the results of the regression analysis for spring. Based on the regression line slope given in *Table 3*, it can be concluded that the amounts of seasonal discharge in Soleimantangeh, Rigcheshme, Galuverd, Sefidchah, Ablu, and Kordkhil stations decreased to 2.88, 2.62, 1.04, 0.95, and 0.82 m^3 per decade, respectively. Just Kordkhil station increased to 1.06 m^3 per decade.

Table 3. Mann-Kendall test, age slope estimator and linear regression for spring and summer seasons

Station	Summer				Spring			
	Z	**Q**	**b**	**P-value**	**Z**	**Q**	**b**	**P-value**
Ablu	-0.39	-0.006	-0.115	0.538	-0.75	-0.019	-0.095	0.611
SefidChah	-2.20*	-0.026	-0.358	0.048*	-0.84	-0.007	-0.082	0.659
Golverd	0.31	-0.004	-0.057	0.761	-0.48	-0.010	-0.104	0.577
KordKhil	0.87	-0.015	-0.096	0.606	-0.76	-0.019	0.106	0.569
Soleimantangeh	-2.66**	-0.049	-0.354	0.051	-0.90	-0.023	-0.288	0.116
Rig Cheshmeh	-2.91**	-0.094	-0.531	0.002**	-1.12	-0.031	-0.226	0.222

Summer: According to *Table 3*, no station has had any significant increasing trend in the summer, and the decreasing trend has been observed for every six stations. In the meantime, SefidChah station at 5% level (marked with *) and Rigcheshmeh and Soleimantangeh stations at 1% level (marked with **) have a significant decreasing trend. Its extreme value *Z*= -2.91is for Rigcheshmeh station. According to the regression analysis results presented in *Table 3*, it can be deduced that the discharge values at Rigcheshme, SefidChah, Soleimantangeh, Ablu, Kordkhil, and Galuverd stations have been decreased to 31.5, 58.3, 54.3, 15.1, 96.0, and 57.0 m^3, respectively.

Autumn: According to *Table 4*, most stations had decreasing trend but insignificant in the autumn and spring. Rigcheshmeh station had a slightly increasing trend. According to the regression analysis results presented in *Table 4*, discharge amounts of SefidChah, Kordkhil, Ablu, Galuverd, and Soleimantangeh stations have been decreased to 7.06, 5.69, 3.28, 2.05, and 0.75 m^3 drop per decade, respectively. Discharge of Rigcheshmeh station has been increased to 1.7 m^3.

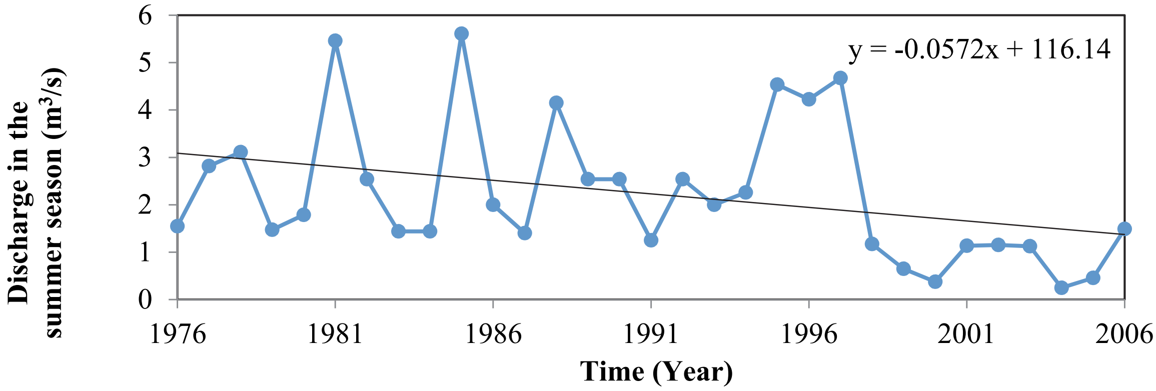
Table 4. Results of Mann-Kendall test, age slope estimator and linear regression for autumn and winter seasons

Station	Winter				Autumn			
	Z	**Q**	**b**	**P-value**	**Z**	**Q**	**b**	**P-value**
Ablu	-0.59	-0.025	-0.126	0.501	-0.85	-0.023	-0.182	0.328
SefidChah	0.07	0	-0.005	0.98	-0.78	-0.006	-0.07	0.706
Golverd	-1.14	-0.027	-0.225	0.223	-1.07	-0.019	-0.234	0.205
KordKhil	-0.82	-0.027	-0.098	0.599	-0.48	-0.010	-0.106	0.569
Soleimantangeh	-1.97*	-0.043	-0.316	0.084	-1.73	-0.042	-0.324	0.075
Rig Cheshmeh	-1.05	-0.016	-0.156	0.401	0.22	0.004	0.069	0.711

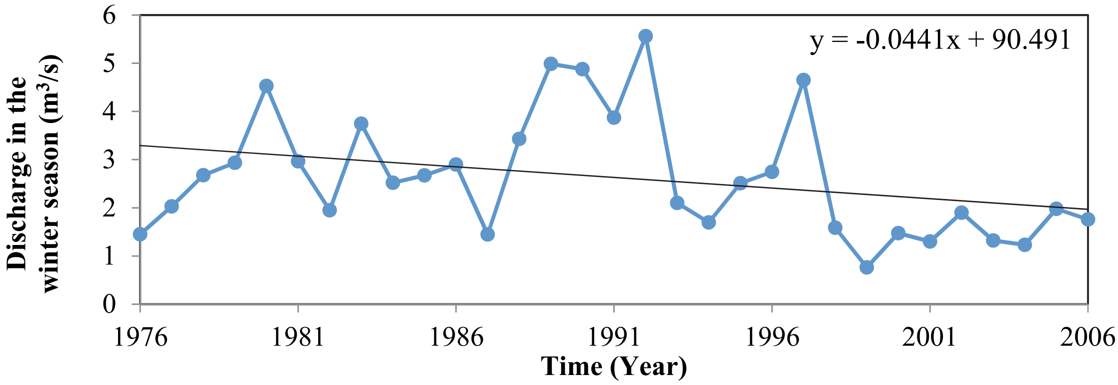
Winter: According to *Table 4*, all stations have a decreasing trend in the winter, and just Soleimantangeh station has a significant negative trend at 95% level with Z=-1.97 statistical value. Also, SefidChah station had an insignificant increasing trend. According to the results obtained from the regression analysis, the discharge of Kordkhil, Ablu, Rigcheshmeh, Galuverd, and Soleimantangeh stations has been decreased to 5.99, 5.01, 4.01, 2.23, and 0.84 m^3 per decade, respectively, and discharge of SefidChah station has been increased to 9.8 m^3.

Factors such as rising temperatures, decreasing rainfall, harvesting from the river for different uses, and climate change are among the reasons for reducing the slope in annual discharge changes at Sulaymaniyah and Rigcheshmeh stations.

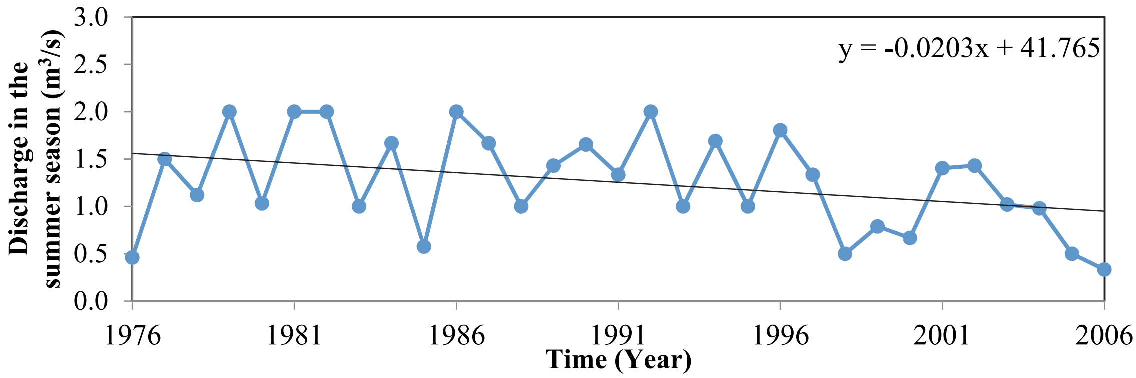
Fig. 3 shows the seasonal changing discharge of the stations having a significant decreasing trend. According to these decreasing trends it is evident, that it would affect the region's agricultural production.



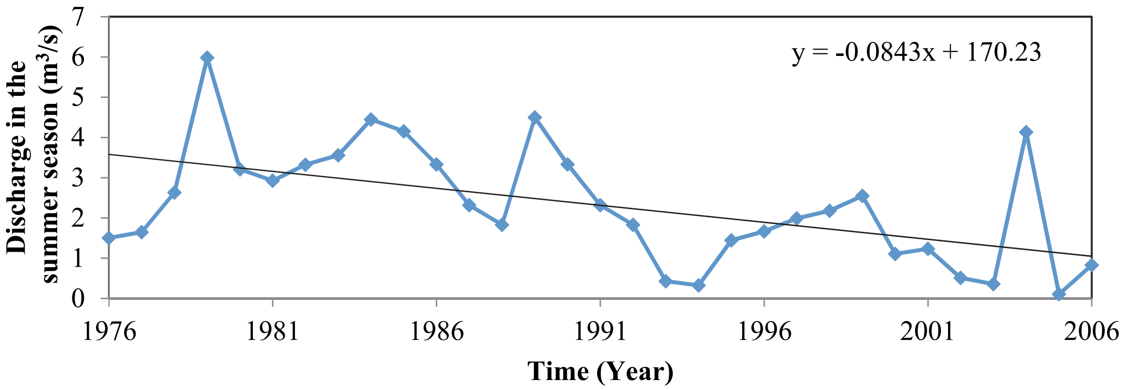
Soleimantangeh station



Soleimantangeh station



SefidChah station



Rigcheshmeh Station

Fig. 3. The seasonal changing discharge of the stations in the statistical period 1976–2006.

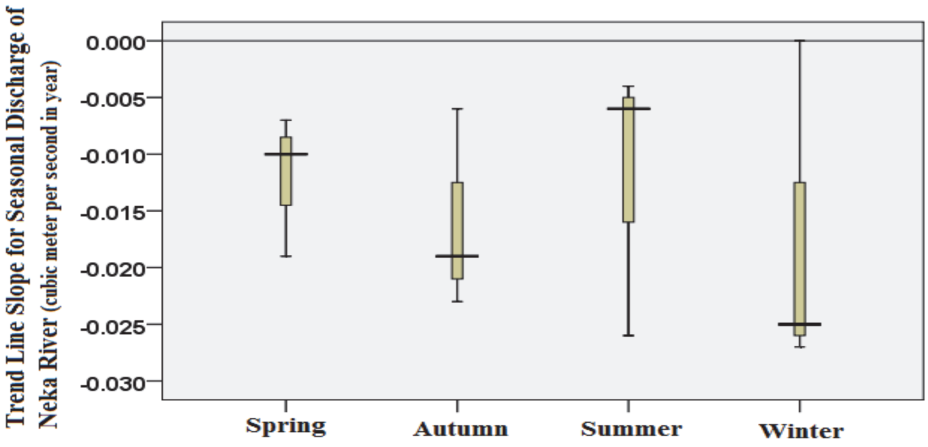
Although the present study shows a decreasing discharge in the Neka and Tajan rivers on annual and seasonal scales, many researchers worldwide have studied variable discharge flows (*Kahya* and *Kalaycı*, 2004). It can be noted, that they reported decreasing trend of water flow in the rivers of West Turkey by using the Mann-Kendall test, which is consistent with the results of this study. However, in some areas of the world, an increasing trend has also been reported for discharge flow rate. For example, *Lettenmaier, Wood*, and *Wallis* (1994) reported a rising trend for the river runoff in the United States of America, which does not match the obtained results of this study.

3.3. Results of trend line slope for the discharge data of the studied area

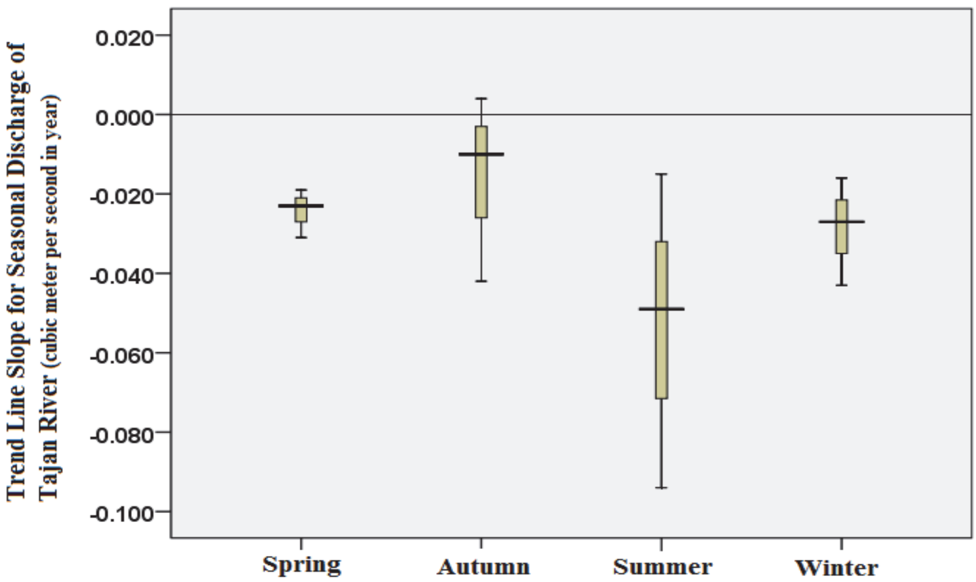
In this study, the trend line slope of quarterly and annual discharge data of six stations in Naka and Tajan rivers were calculated using the age slope estimator method. The obtained results have been demonstrated in annual and quarterly scales (*Tables 2, 3*, and *4*). Inferred from the trend line slope values presented in the tables, the frequency of negative slopes is far higher than that of positive slopes. On an annual scale, the steepest negative slope of the trend line belongs to Rigcheshmeh station with a -0.051 m^3/s per year, consistently with the results of the Mann-Kendall test. This indicates that the Tajan river discharge has been decreased somewhat in the last three decades.

On a seasonal scale, the trend line slope also had negative values for most stations. Only Kordkhil station in spring and Rigcheshmeh station in autumn had a positive trend line slope with the values of 0.019 and 0.004 m^3/s per year. These results are acceptably consistent with the results of the Mann-Kendall test and regression analysis. The steepest negative slope of the trend line on a seasonal scale (summer) belongs to Rigcheshmeh station, it is equal to -0.094 m^3/s per year. This indicates that the average discharged rate of Tajan river in Rigcheshemh station decreased every year in the summer season by about 94 liters per second which most likely due to increased harvesting and use of river water. The most important effect of reducing the amount of river flow is failing to provide sufficient water for agricultural, drinking, and industry use.

Fig. 4 shows the whisker plot of different discharge trends at Neka and Tajan rivers in the past three decades on a seasonal scale. In the box plot, each box shows median values, quartiles, and limit within a class. Lines at the bottom of the box (bottom and top of the rectangle) represent the slope values between the 25 and 75 percentiles, respectively, and the line in the box represents the middle value (mid-slopes). Top and bottom vertical lines represent the highest and lowest observed trend line slope values among the stations. As can be concluded from these figures, the mid-slopes of trend lines are negative for all seasons. Also, it can be concluded that the upper part of boxes is below the horizontal line of zero slopes; thus, the slope of the trend line in these seasons is negative for all stations in the study area. This indicates that the discharge of Neka and Tajan rivers has been decreased in the last three decades.



A- Neka River



B- Tajan River

Fig. 4. The whisker plot of seasonal discharge trend boxes for Neka and Tajan rivers in Mazandaran Province in the statistical period 1976–2006.

For Tajan river in the summer season and Neka river in the winter season, space between the lower and upper quartiles is higher than that of the other seasons. This approach suggests changes in the discharge trend slope in the summer season in Ablu, Golverd, and SefidChah stations located in the Tajan river and changes in the discharge trend slope in the winter season in Kordkhil, Rigcheshmeh, and Soleimantanghe stations, which are are far more than in other seasons. Mid-slope in winter season for Neka River and in summer season for Tajan River is the lowest and close to the 25% slope. This represents a decreasing trend of irrigation of most rivers in the area. In summary, based on the slope of the trend lines, it can be concluded that the discharge of Neka and Tajan rivers has been decreased over the three decades studied.

In general, it can be concluded that the efficacy of two non-parametric tests, the Mann-Kendall test and age the slope estimator, are similar in most cases regarding the quarterly and annual discharges and the difference between the parametric test (regression analysis) and non-parametric tests (Mann-Kendall and age slope estimator). The main reason for this difference may be related to the normal distribution degree, which corresponds with the result of *Huth* and *Pokorna* (2004).

4. Conclusions and recommendations

In this study, the seasonal and annual changes in Neka and Tajan rivers in Mazandaran Province, Iran were studied. For this reason, Mann-Kendall and age slope estimator tests and parametric tests of regression analysis were used. The data from 6 hydrological stations in Neka and Tajan rivers (*Table 1*) were used for 31 years from 1976 to 2006. The results of the present study showed that on an annual scale, only two stations, Solaeimantangeh and Rigcheshmeh, at 5% level (with 95% confidence), had a decreasing trend. The only significant observed trend by regression analysis is obtained in the annual discharge data of the Soleimantangeh station. On the seasonal scale, no significant trend has been observed in spring and autumn, and most of the stations in these seasons had insignificant negative trends. Only Rigcheshme station had a minor positive trend in autumn. In summer, both stations, Soleimaniyeh1 and Rigcheshmeh were at 1 percent level with a significant negative trend. In this season, Regression analysis results in Rigcheshmeh station are consistent with the results of the Mann-Kendall test. Also, in winter, just Soleimaniye station had a significant negative trend at the 5% level. The age slope estimator calculated the slope of the trend line. This test's obtained results showed that most of the stations had a negative trend that corresponds with the Mann-Kendall test and regression analysis results. Changes of discharge trend slope of the summer season are much higher than in the other seasons. Compared with the different seasons, the mid-slope in winter is the lowest and close to the 25% slope, indicating a decreasing trend of irrigation rivers in the region. Soleimaniye station located in the Tajan river has had a more significant decreasing trend than other stations.

This study's results can change the direction of the planning schemes of irrigation and water resources management in the future. Still, in the end, it is recommended that the decreasing water flow of rivers in this region and their downtrend will be carefully examined. The reported trends in this study are compared to the trends derived from other tests.

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References

Asfaw, A., Simane, B., Hassen, A., and *Bantider, A.,* 2018: Variability and time series trend analysis of rainfall and temperature in northcentral Ethiopia: A case study in Woleka sub-basin. *Weather Climate Extr. 19*, 29–41. https://doi.org/10.1016/j.wace.2017.12.002

Čanjevac, I., and *Orešić, D.,* 2015: Contemporary changes of mean annual and seasonal river discharges in Croatia. *Hrvatski Geografski Glasnik, 77*, 7–27. https://doi.org/10.21861/HGG.2015.77.01.01

Chen, H., Guo, S., Xu, C.-y., and *Singh, V.P.,* 2007: Historical temporal trends of hydro-climatic variables and runoff response to climate variability and their relevance in water resource management in the Hanjiang basin. *J. Hydrology 344*(3–4), 171–184. https://doi.org/10.1016/j.jhydrol.2007.06.034

Chen, Y., Guan, Y., Shao, G., and *Zhang, D.,* 2016: Investigating trends in streamflow and precipitation in Huangfuchuan Basin with wavelet analysis and the Mann-Kendall test. *Water 8*(3), 77. https://doi.org/10.3390/w8030077

Déry, S.J., Stadnyk, T.A., MacDonald, M.K., and *Gauli-Sharma, B*., 2016: Recent trends and variability in river discharge across northern Canada. *Hydrol. Earth Syst. Sci. 20*, 4801–4818. https://doi.org/10.5194/hess-20-4801-2016

Faridah, O., Mohammad, H., Mohammad, S. S., Mahmoud, R., and *Mahdi, S.P.*, 2014: The necessity of systematic and integrated approach in water resources problems and evaluation methods, a review. *Adv. Environ. Biol. 8*(19), 307–315.

Fathian, F., Dehghan, Z., Bazrkar, M.H., and *Eslamian, S*., 2016: Trends in hydrological and climatic variables affected by four variations of the Mann-Kendall approach in Urmia Lake basin, Iran. *Hydrol. Sci.s J. 61*, 892–904. https://doi.org/10.1080/02626667.2014.932911

Huth, R. and *Pokorna, L.*, 2004: Parametric versus non-parametric estimates of climatic trends. *Theor. Appl. Climatol. 77*, 107–112. https://doi.org/10.1007/s00704-003-0026-3

J*akuschné Kocsis, T.* and *Anda, A.* 2018: Parametric or non-parametric: analysis of rainfall time series at a Hungarian meteorological station. *Időjárás 122*, 203–216. https://doi.org/10.28974/idojaras.2018.2.6

Kahya, E. and *Kalaycı, S*., 2004: Trend analysis of streamflow in Turkey. *J.f Hydrol. 289*(1), 128-144. https://doi.org/10.1016/j.jhydrol.2003.11.006

Kendall, M.G. 1948: Rank correlation methods. 4th edition, Griffin, London.

Khanmohammadi, N., Rezaie, H., Montaseri, M., and *Behmanesh, J.*, 2018: The application of multiple linear regression method in reference evapotranspiration trend calculation. *Stoch. Environ. Res. Risk Assess. 32*, 661–673. https://doi.org/10.1007/s00477-017-1378-z

Kocsis, T., Kovács-Székely, I., and *Anda, A.*, 2017: Comparison of parametric and non-parametric time-series analysis methods on a long-term meteorological data set. *Centr. Eur. Geol. 60*, 316–332. https://doi.org/10.1556/24.60.2017.011

Korhonen, J. and *Kuusisto, E.*, 2010: Long-term changes in the discharge regime in Finland. *Hydrology Res. 41*, 253–268. https://doi.org/10.2166/nh.2010.112

Kweku, D.W., Bismark, O., Maxwell, A., Desmond, K.A., Danso, K.B., Oti-Mensah, E.A., . . . *Adormaa, B.B.*, 2017: Greenhouse effect: greenhouse gases and their impact on global warming. *J.Sci. Res. Rep. 17*(6), 1–9. https://doi.org/10.9734/JSRR/2017/39630

Lelieveld, J., Klingmüller, K., Pozzer, A., Burnett, R., Haines, A., and *Ramanathan, V.*, 2019: Effects of fossil fuel and total anthropogenic emission removal on public health and climate. *Proc. Nat. Acad. Sci. 116*, 7192–7197. https://doi.org/10.1073/pnas.1819989116

Lettenmaier, D.P., Wood, E.F., and *Wallis, J.R.*, 1994: Hydro-climatological trends in the continental United States, 1948-88. *J. Climate, 7*, 586–607. https://doi.org/10.1175/1520-0442(1994)007<0586:HCTITC>2.0.CO;2

Malik, A. and *Kumar, A.* 2020: Spatio-temporal trend analysis of rainfall using parametric and non-parametric tests: case study in Uttarakhand, India. *Theor. App. Climatol.140*, 1–25. https://doi.org/10.1007/s00704-019-03080-8

Mohorji, A.M., Şen, Z., and *Almazroui, M.*, 2017: Trend analyses revision and global monthly temperature innovative multi-duration analysis. *Earth Syst. Environ. 1*, 1–13. https://doi.org/10.1007/s41748-017-0014-x

Noori, M., Sharifi, M. B., Zarghami, M., and *Heydari, M.*, 2013: Utilization of LARS-WG Model for Modelling of Meteorological Parameters in Golestan Province of Iran. *J. River Engin. 1*(1), 5. https://doi.org/10.5281/zenodo.18265..

Oluoch, W., Nyabundi, K., and *Boiwa, M.,* 2017: Makesens trend analysis of agro-meteorological data from Kericho, Kenya. *Tea 38*(1), 9–14.

Salarian, M., Larijani, S., Heydari, M., and *ShahiriParsa,* 2016: Evaluation of drought changes of isfahan city based on the best Fitted probability distribution function. *Int. J. Engineer. Sci. Res. Technol. 5*, 623-631.https://doi.org/10.5281/zenodo.49807

Salarian, M., Najafi, M., Hosseini, S.V., and *Heydari, M.*, 2015: Classification of Zayandehrud river basin water quality regarding agriculture, drinking, and industrial usage. *Amer. Res. J. Civil Struct. Engin. 1*(1). 9, https://doi.org/10.5281/zenodo.18255

Sen, P.K., 1968: Estimates of the regression coefficient based on Kendall's tau. *J. Amer. Stat. Assoc. 63*(324), 1379–1389. https://doi.org/10.1080/01621459.1968.10480934

Shindell, D., and *Smith, C.J.* 2019: Climate and air-quality benefits of a realistic phase-out of fossil fuels. *Nature, 573*(7774), 408–411. https://doi.org/10.1038/s41586-019-1554-z

Tabari, H. and *Talaee, P.H.*, 2011: Temporal variability of precipitation over Iran: 1966–2005. *J. hydrology, 396*, 313–320. https://doi.org/10.1016/j.jhydrol.2010.11.034

Tosunoglu, F. and *Kisi, O.*, 2017: Trend analysis of maximum hydrologic drought variables using Mann–Kendall and Şen's innovative trend method. *River Res. Appl. 33*, 597–610. https://doi.org/10.1002/rra.3106

Villarini, G., Smith, J.A., Serinaldi, F., and *Ntelekos, A.A.*, 2011: Analyses of seasonal and annual maximum daily discharge records for central Europe. *J.hydrology 399*, 299–312. https://doi.org/10.1016/j.jhydrol.2011.01.007

Zarei, A.R., Moghimi, M.M., and *Mahmoudi, M.R.,* 2016: Parametric and non-parametric trend of drought in arid and semi-arid regions using RDI index. *Water Res. Manage. 30*, 5479–5500. https://doi.org/10.1007/s11269-016-1501-9