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Trends in precipitation and stream flow in the semi-arid region of Atrak River Basin, North Khorasan, Iran

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Abstract

In this paper trends of precipitation and stream flow are analyzed in the Atrak River basin in the North Khorasan province. *Normal score linear regression*, *Mann-Kendall*, and *Seasonal Kendall* trend tests were adopted. Three precipitation variables and two stream flow variables including total precipitation, maximum daily precipitation, and number of rainy days, mean discharge and peak discharge were studied. Annual, seasonal, and monthly trends of these variables were examined during a 35-year period starting from 1971 in six hydroclimatological stations. The results with all tests showed that despite no evidence of significant trend for the precipitation variables, trends for the hydrologic variables found to be significant. Whereas for most of the stations significant downward trend was observed for mean discharge, and for one third of the stations significant upward trend was observed for peak discharge. The results of seasonal trend analyses indicated that downward trends in the mean discharge are almost completely homogeneous across the seasons and significant for autumn, winter and spring flows in most of stations. Overall, although the precipitation pattern is considered as the major driving variable for the river discharge regime, but it is not the only possible cause and other causes such as landscape, land use changes and increased evapotranspiration due to higher temperature may play a role.

Keywords: Trend; Discharge; Precipitation; Mann-Kendall; Atrak River basin

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) report (McCarthy *et al*., 2001) stated that due to atmospheric concentration of carbon dioxide, mean global temperature increased by 0.6 ± 0.2°C during the 20th century and it has also predicted that it will further increase by 1 to 3.5 °C during the 21st century. Also, the results of General Circulation Model (GCM) studies indicated that increased global temperature could lead to regional increases in the amount and intensity of precipitation (Karl and Knight, 1998). On the contrary, Koutsoyiannis *et al*. (2001) by introducing future climatic uncertainties in the results of several scenarios of GCM's indicated a significant increase of temperature in the future beyond the uncertainty bands, while no significant changes of rainfall or runoff (using a hydrologic rainfall-runoff model) were observed as they lie well within uncertainty limits. However, according to the most recent IPCC report (IPCC, 2007), annual average river runoff is projected to increase by 10 – 40% at high latitudes and in some wet tropical areas, and decrease by 10 – 30% over some dry regions at mid-latitudes and in dry tropics by mid century. Therefore, there is a general belief that global warming will lead to changes in spatial and temporal distributions of regional water resources and the global hydrological cycles (Qader, 2002; Labat *et al*., 2004). This has lead more and more researchers to carry out many regional and a number of national streamflow trend studies, particularly in the North America and Europe (Lettenmai er *et al*., 1994; Robson *et al*., 1998; Lins and Slack, 1999; Douglas *et al*., 2000; Zhang *et al*., 2001; Burn and Elnur, 2002; Yue and Pilon, 2003; Birsan *et al*., 2005; Abdul Aziz and Burn, 2006; Han, 2007). A

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comprehensive review of the results of these studies reflects the great diversity in the regional and global trends of the climate and hydrological variables. In other words, the results of these studies vary widely depending on the spatial scale and location of the study area. For instance, Zhang *et al*. (2001) in a study on the monthly mean streamflow in Canada concluded that there is almost no basin exhibiting upward trend. In contrast, Lettenmaier *et al*. (1994), Hubbard *et al*. (1997), and Lins and Slack (1999) presented the upward streamflow trend for most of the United States.
The sensitivity of streamflow to changes in precipitation, and other climatic parameters, is well documented, hence it is informative to investigate whether streamflow records exhibits evidence of increasing or decreasing trends which may be linked to climate change (Douglas *et al*., 2000). It will be even more important when one concerns about the implicit assumption of stationarity of the hydrologic time series data in all water resources engineering works. Being aware of potential impacts of climate changes on hydrologic variables, a number of studies have been conducted within North America. Like the results of regional streamflow-trend studies, the findings of these studies are controversy. Lettenmaier *et al*. (1994) stressed that the trend in streamflow are not fully parallel to the changes in precipitation and temperature. However, Burn and Elnur (2002) indicated the similarities in trends and patterns of the hydrological and meteorological variables, implying the relations between the two groups of variables.

If climatic effects are causing observable changes to the hydrologic regime, then clearly it is important to recognize them (Robson *et al*., 1998). Therefore, this study focuses on the likely impacts of climate changes (i.e. precipitation pattern) on the hydrologic variables within the Atrak River Basin in the north east of Iran. In fact, this paper examines statistically: (1) the time series of precipitation and river discharge records at 6 hydroclimatological stations, (2) the existence of trends and their directions and magnitudes, and (3) the likely relationship between precipitation and discharge trends. It worth to note that although many studies on trend analysis of climatic variables such as temperature, precipitation and evapotranspiration have been conducted in Iran but to our knowledge the relationship trend analysis of streamflow and its relationship with precipitation has not been covered previously (Shirgholami *et al*., 2004; Ghahrema, 2006; Modarres and Silva, 2007; Raziei *et al*., 2007; Ghahrema and Taghavian, 2008; Hejam *et al*., 2008).

2. Materials and methods

2.1. Study area and data sources

This study has been conducted to detect the likely long term trends in the precipitation and discharge data in the Atrak river basin in north east of Iran. It between 54° to 59° 04′ East longitude and 38° 17′ to 38° 57′ North latitude (Figure 1). The elevation ranges from -22 m a.s.l. at the river mouth at eastern shore of the Caspian Sea and 2903 m a.s.l. at the highest point in the most eastern parts of the basin. Average slope of the basin and the main river are 3.2 and 2.7 percent, respectively. From physiographic point of view, the Atrak river basin has two distinct sections: mountains and flat plains. The precipitation pattern varies depending on the physiographic condition. In higher mountains it occurs mostly as snow in autumn and winter and as rainfall in other seasons. In plains it mostly occurs as rainfall except in winter seasons which mostly falls as snow. This precipitation patterns influence the hydrologic behavior of the river basin which fluctuates seasonally.

The Atrak River is one of the major rivers of Iran with a length of about 520 km draining an area of approximately 25627 km^2. A small tributary of Sumbar originates and drains from Turkmenistan. Due to the physiographic and climatic condition, flash floods and seasonal flows are common hydrologic characteristics of the area. Within the Atrak River Basin, floods and droughts are the most frequent natural hazards, respectively. As an average, 8 major floods occur per year, which incur large damages to the agricultural fields and infrastructures (Tavakkoli, 2001).

To examine the existence of trends in precipitation and discharge, 6 hydroclimatological stations which have more than 30 years continuous records were chosen. Table 1 presents the information of the stations. At these stations precipitation and discharge are recorded on daily basis. However, the peak discharge data were available only on an annual basis. Two hydrologic variables were examined, namely mean discharge and peak discharge. Regarding the precipitation, three variables of total precipitation, maximum daily precipitation, and number of rainy days (only days with rainfall amount of more than 1 mm were considered as rainy days) were studied. All the mentioned variables are needed annually, only to apply the Seasonal Kendall method, monthly data are required. Therefore, this method was not applied to the peak discharge variable due to unavailability of data on monthly basis.

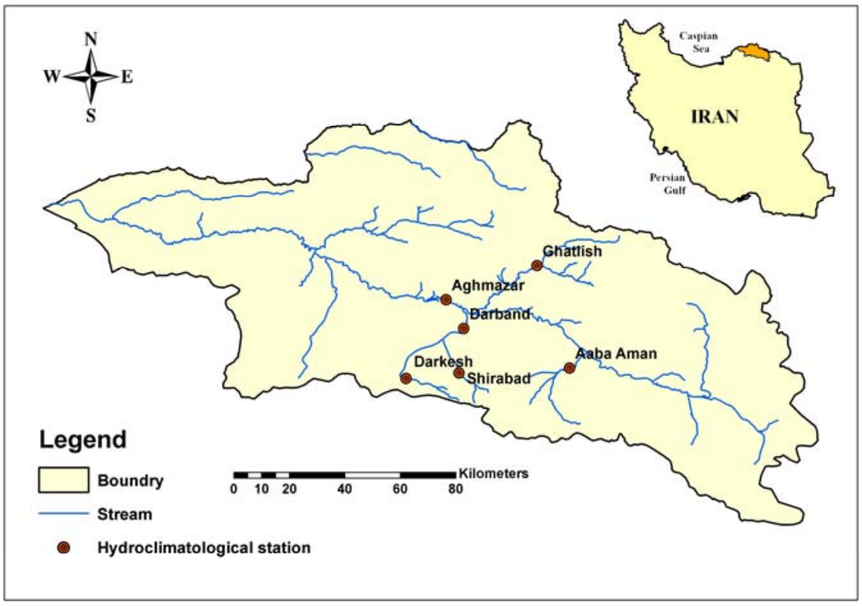

Fig. 1. Location of the study area and hydroclimatological stations

Table 1. Geographic characteristics of the hydroclimatological Stations.

Station	Longitude	Latitude	Elevation (m a.s.l)	Upstream watershed area (km^2)	Average precipitation (mm)	Average discharge (m^3/sec)
Aghmazar	56° 54′	37° 41′	560	12004	237.7	6.50
Baba Aman	57° 26′	37° 27′	1010	1232.6	288.4	1.37
Darband	56° 58′	37° 36′	680	1087	309.4	0.87
Darkesh	56° 44′	37° 26′	1040	114.5	468.8	0.52
Ghatlish	57° 16′	37° 48′	960	1355.2	229.3	1.02
Shirabad	56° 55′	37° 30′	850	183.5	406.4	0.91

2.2. Methodology

The linear regression method is a simple and widely used parametric trend analysis method which requires the assumptions of normality and independence of observations. However, environmental data are rarely sufficiently symmetric to be modelled by a normal distribution (Helsel and Frand, 2006). Another problem which is usually encountered in applying of the linear regression method is due to the presence of missing data which are usually unavoidable especially in the developing countries. Therefore, in this study three non-parametric trend tests including *normal score linear regression*, *Mann-Kendall* and *Seasonal Kendall* were applied to examine existence of the likely trends in the precipitation and discharge data of the Atrak River Basin. In the following sections these tests are explained briefly.

2.2.1. Normal scores linear regression

This is a robust non-parametric test that is based on linear regression but involves transforming the data so that the assumption of normality is satisfied. Errors are assumed to be independent and distributed identically. The transformation requires ordering the data values and replacing them by the corresponding normal score statistics, i.e. the *i*th largest observation is replaced by the expected value of the *i*th largest value of a sample of the same size drawn from a normal distribution (Robson *et al*., 1998). To calculate the normal score statistics the Van der Waerden’s method was applied as follows.

$$S = \Phi(p) = \Phi\left(\frac{r}{n+1}\right)$$

Where S is normal score for an observation in the data series, r is the rank for that observation, n is the total number of data in the series and $\Phi(p)$ is the p^{th} quantile from the standard normal distribution. Then a linear regression is sought between normal score as the dependent variable and time as independent variable.

2.2.2. Mann-Kendall

The Mann-Kendall test is the most widely used non-parametric trend test in the previous hydrologic studies. It is based on the correlation between the ranks of time series and their time order (Hamed, 2008). According to Mann (1945), the null hypothesis H_0 states that the deseasonalized data ($x_1, x_2 ... x_n$) are a sample of n independent and identically distributed random variables (Yu *et al.*, 1993). The alternative hypothesis H_1 of a two-sided test is that the distribution of x_i and x_j are not identical for all $i, j \leq n$ with $i \neq j$. The test statistic S is calculated with Equations (2) and (3).

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(x_i - x_j) \tag{2}$$

$$sign\ (x_i - x_j) = \begin{cases} +1 & if \quad (x_i - x_j) > 0 \\ 0 & if \quad (x_i - x_j) = 0 \\ -1 & if \quad (x_i - x_j) < 0 \end{cases} \tag{3}$$

The test statistic S has mean zero and its variance is calculated with equation (4).

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i (i)(i-1)(2i+5)}{18} \tag{4}$$

Where m is the number of groups of tied ranks (equal observations), each with t_i tied observations.

Kendall (1975) showed that for the cases that n is larger than 10, the distribution of S tends to normality and the standard normal variate z is computed by using the equation (5).

$$Z = \begin{cases} \frac{S-1}{\sigma} & if \quad S > 0 \\ 0 & if \quad S = 0 \\ \frac{S+1}{\sigma} & if \quad S < 0 \end{cases} \tag{5}$$

In a two-sided test for trend, the H_0 should be accepted if $|z| \leq z_{\alpha/2}$ at the level of significance. A positive value of S indicates an upward trend and a negative value indicates a downward trend (Kahya and Kalayci, 2004).

2.2.3. Seasonal Kendall

Hirsch *et al.* (1982) suggested use of the seasonal Kendall test for monthly water quality time series. The test is also discussed by Hipel and McLeod (2005). This test is used for time series with seasonal variations and does not require normality of time series. This test is intended to assess the randomness of a data set $X = (X_1 ... X_{12})$ and $X_i = (x_{i\,1} ... x_{i\,n})$, where X is a matrix of the entire monthly data over n years at a station. To compute the seasonal Kendall test statistic, the test statistic for each month is separately computed and summed up.

$$S_s = \sum_{k=1}^{n_s} S_k$$

Where S_k is Kendall's S for the kth month which is computed by Equation (2), n_s is the number of seasons (months). The interpretation of the rest of the test is similar to that of the Mann-Kendall, except the calculation of the variance of the test statistics which is done by equation (7).

$$Var(S_s) = \sum_{k=1}^{n_s} \frac{n_k (n_k - 1)(2n_k + 5)}{18} + 2\sum_{k=1}^{n_s - 1} \sum_{l=k+1}^{n_s} \sigma_{kl}$$

Where σ_{ij} is the covariance of the test statistic in season i and season j. The advantage of performing a seasonal analysis is that trends in seasons with small values are not dominated by larger values (Lettenmaier *et al.*, 1994).

3. Results

Trend analyses tests require that data are serially independent. This is the main assumption for both parametric and non-parametric tests. The majority of studies regarding trend analysis have assumed that recorded hydroclimatological time series are usually serially independent. While, some of the variables such as annual mean and low flows data may display statistically significant serial correlation (Yue *et al.*, 2003). Therefore, in this study to check the likely presence of serial correlation, the Auto Correlation Function (ACF) analysis has been conducted. The results of ACF indicated that for most of the stations, the serial correlations of time series of the variables of interest are either non-significant at 95% confidence level or relatively small which have been ignored in this study. As an example, Figure 2 presents the autocorrelation of time series for the Baba Aman station.

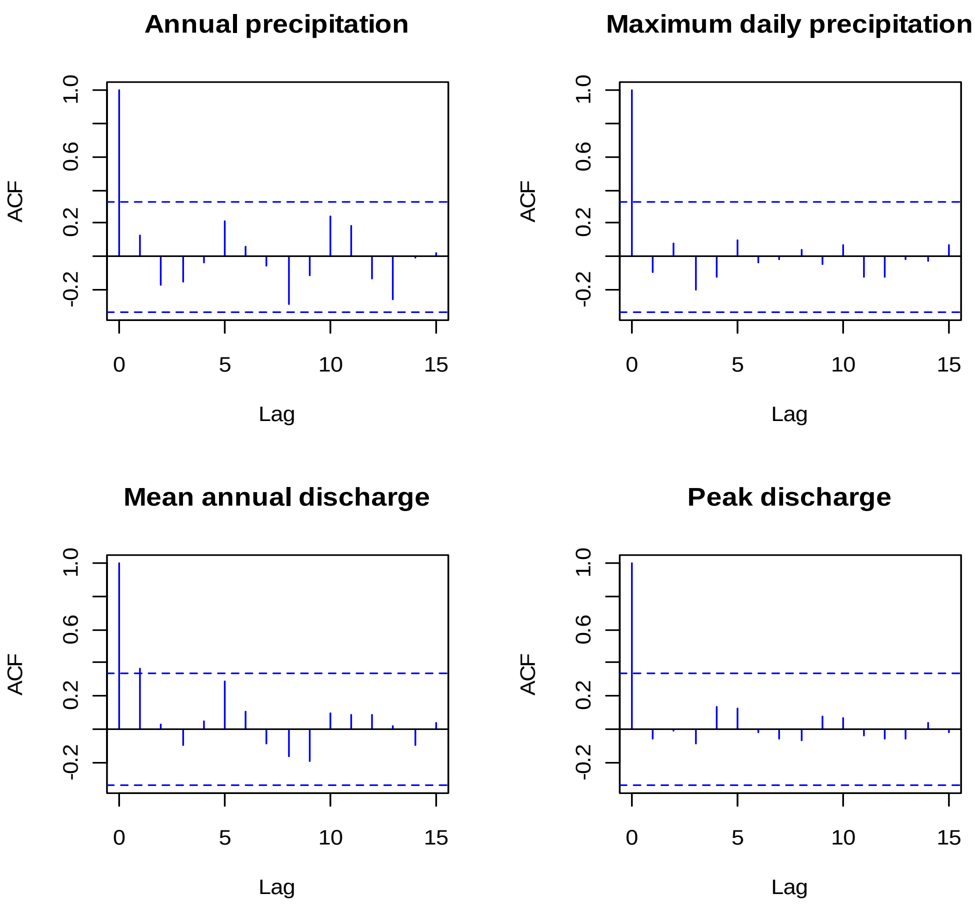

Fig. 2. Autocorrelation function analysis graph for time series of hydroclimatological variables in the Baba Aman station. Dashed lines indicate 95% confidence interval

3.1. Annual trends

The results of the trend analysis using the three methods of normal score linear regression, the ordinary Mann-Kendall, and the seasonal Kendall for all variables of interests have been presented in Table 2. Two different levels of confidence have been assumed for trend significance. The significance level of 5% indicates the existence of a strong trend and the significance level of 10% indicates the existence of a weak trend. As can be seen in Table 2, the results of the normal score linear regression and the Mann-Kendall tests are very similar to each other, while the results of the seasonal Kendall test shows a slight disparity. Also it is clear that despite no apparent and no homogeneous trends for precipitation variables there is an apparent and homogenous decreasing trend for the annual mean discharge and a relatively apparent and completely homogenous increasing trend for peak discharge.

In general there is no apparent and no homogenous trend across the stations in the study area for annual precipitation, except for the Aghmazar station which shows a strong decreasing trend at 5% significance level using all three trend tests. This indicates that despite the year to year variations, the average amount of precipitation in the Atrak River basin has not changed during the last three decades. Maximum daily precipitation shows almost no trend across the stations in the Atrak River basin. Only for the Aghmazar station, the seasonal Kendall shows a strong decreasing trend. Half of the studied stations show no trend in the number of days experiencing a precipitation amount of more than 1 mm. All three tests of trend present a strong evidence of increasing trend in the number of rainy days in the Baba Aman and Ghatlish stations. While in the Darband station it shows a weak downward trend significant at 10%.

Table 2. The results of trend analysis with three different nonparametric tests for different variables

Station	Normal score linear regression					Mann – Kendall					Seasonal Kendall			
	P_{tot}	P_{max}	P_{NRD}	Q_m	Q_p	P_{tot}	P_{max}	P_{NRD}	Q_m	Q_p	P_{tot}	P_{max}	P_{NRD}	Q_m
Aghmazar	↓	-	+	↓	+	↓	-	+	↓	+	↓	↓	+	↓
Baba Aman	+	+	↑	↓	+	+	-	↑	↓	+	+	-	↑	↓
Darband	-	+	▼	↓	+	-	+	▼	↓	+	-	-	-	↓
Darkesh	-	-	+	-	+	-	-	+	-	↑	-	-	+	↓
Ghaltlish	+	+	↑	▼	↑	+	+	↑	↓	↑	+	+	↑	▼
Shirabad	-	+	+	-	↑	-	+	+	-	+	+	+	+	↓

(P_{tot}: total annual precipitation; P_{max}: maximum daily precipitation; P_{NRD}: number of rainy days; Q_m: mean annual discharge; Q_p: peak discharge). ↑ and ↓ indicate strong upward and downward trends (significant at < 0.05 level), respectively; ▼ shows weak downward trends (significant at 0.05 to 0.10 level); + and - present upward and downward trends (not significant at 0.10 level), respectively.

Generally speaking, annual mean discharge has shown a downward trend across all stations during the last three decades. The results of all tests indicate that observed downward trends for 50 percent or more of the stations are significant at 5% level. Considering the seasonal Kendall's, all the stations present a significant decreasing trend at 10% level. In general, the floods magnitude or peak discharge has been increased across all stations. Results of both tests of normal score linear regression and Mann-Kendall indicate strong upward trends for two out of six stations.

3.2. Seasonal trends

Looking at the seasonal distribution of precipitation and discharge in Figures 3 and 4 shows that more than 70% of them occur in two seasons of winter and spring. The amount of winter precipitation is slightly greater than the spring precipitation, while the spring discharge is slightly greater than the winter discharge. This is mainly due to the precipitation regime of the Atrak River basin where precipitation in winter is usually falls as snow. Therefore long term changes in the winter and spring precipitation and discharge will have a large influence on their annual trends. Figures 5 and 6 show the seasonal trends of precipitation and discharge in the hydroclimatological stations of the Atrak River basin, respectively. Winter precipitation in 4 out of 6 stations and spring precipitation in all stations shows a decreasing trend of which only the spring precipitation in the Aghmazar station is significant at 5% level. Considering the autumn precipitation, although it shows a strong decreasing trend in the Aghmazar station, but no homogeneous and significant trend was observed across the other stations. Summer precipitation shows homogeneous increasing trends across the stations which is significant at 5% level only at the Ghatlish station. Although there are no homogeneous spatial (across the stations) and temporal (across the seasons) trends in the seasonal precipitation, there is clear homogeneous spatial and temporal trends in the seasonal discharge across the stations except the Ghatlish station. About 4 out of 6 stations show significant decreasing trends in the autumn, winter, and spring discharge at 10% level whereas except the spring discharge in the Baba Aman station and the autumn discharge in the Ghatlish station are also significant at 5% level. Despite non-significant homogeneous increasing trends in the summer precipitation across the stations, there are non-significant decreasing trends for 3 out of 6 stations.

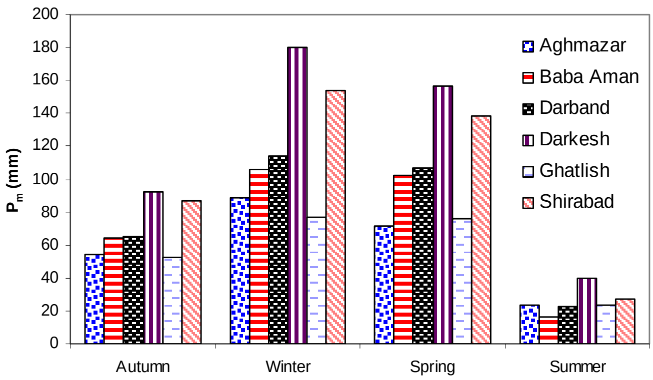

Fig. 3. Seasonal distribution of mean precipitation for Atrak River basin's hydroclimatological stations.

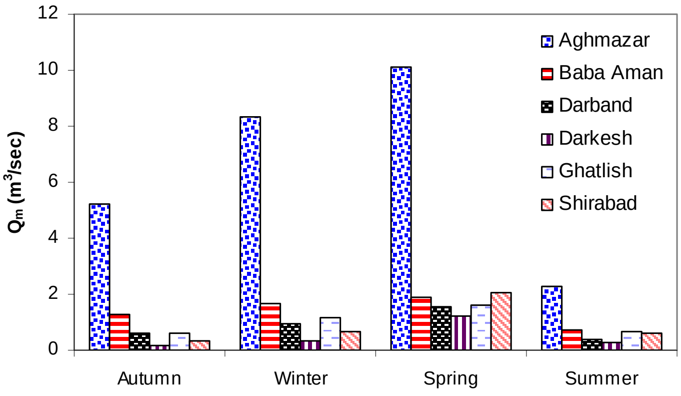

Fig. 4. Seasonal distribution of mean discharge for Atrak River basin's hydroclimatological stations.

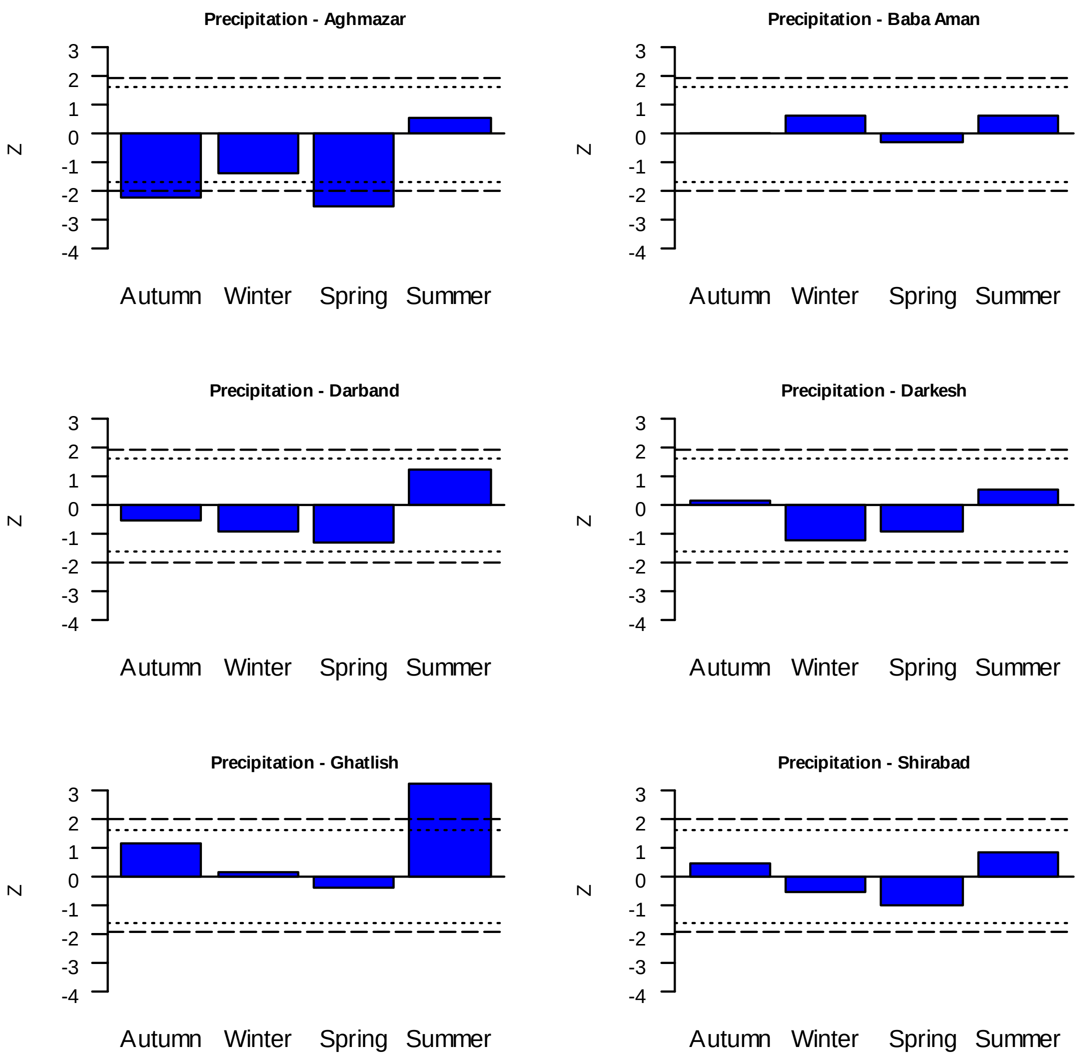

Fig. 5. Trend test statistics Z computed for seasonal precipitation in Atrak River basin's hydroclimatological stations.

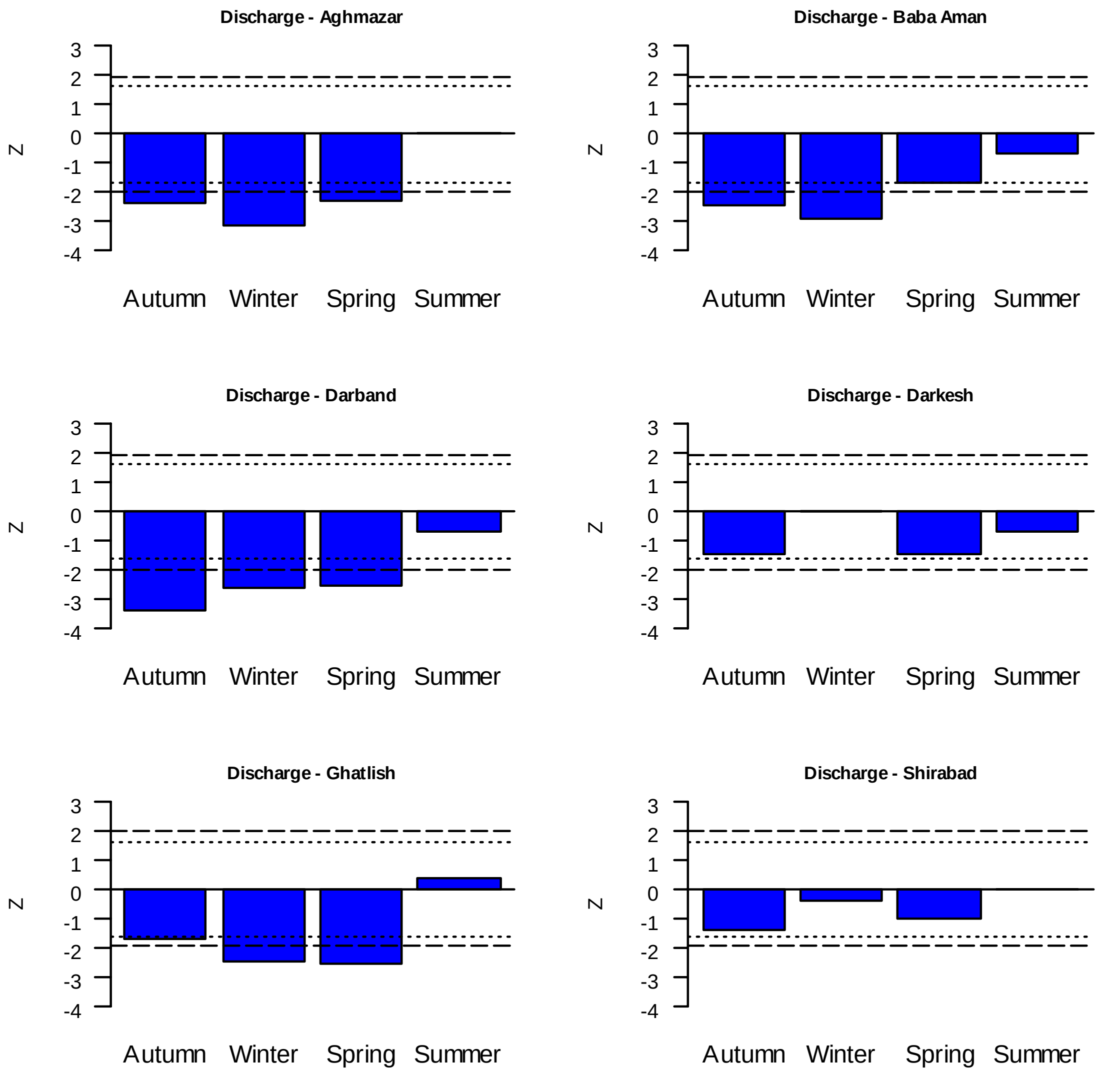

Fig. 6. Trend test statistics Z computed for seasonal discharge in Atrak River basin's hydroclimatological stations.

3.3. Monthly trends

In order to check whether all months within each season show a homogeneous trend, the monthly trend statistics have been calculated for total precipitation and mean discharge. The results for precipitation and discharge have been presented in Figures 7 and 8, respectively. As can be seen in Figure 7 precipitation across all months within each season does not show a homogeneous trend. Precipitation in December shows a significant decreasing trend for half of the stations. In 4 out of 6 stations the august precipitation shows a significant increasing trend. In the first three months of the year which constitute the rainy season of the region no significant decreasing or increasing trend across the stations are observed.

Considering the monthly discharge, as shown in Figure 8, there is a homogeneous decreasing trend across all months of the autumn, winter, and spring seasons across all stations. However, for summer months there is no homogeneous trend across the stations. In 4 out of 6 stations, all winter months show a significant decreasing trend at 5% level. Also, in most of these stations, the spring months show significant trends at 5% level.

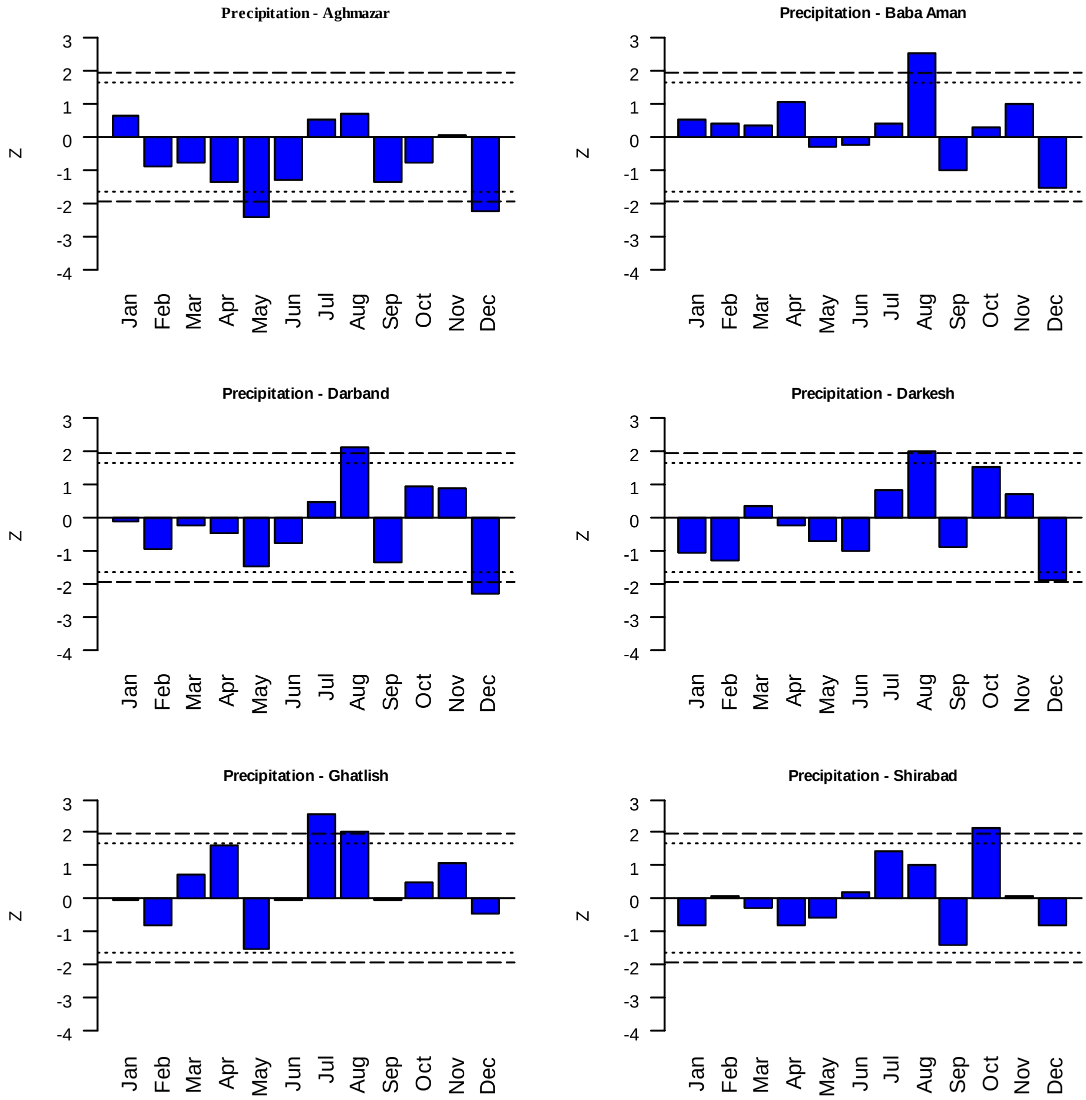

Fig. 7. Trend test statistics Z for monthly total precipitation. Dashed lines indicate 95% confidence level and dotted lines indicate 90% confidence level.

4. Conclusion

The results of different trend tests showed that they give relatively comparable results across the stations in the Atrak River basin, particularly, the normal score linear regression and the Mann-Kendall tests ended up with very similar results. The slight disparity of the results of the seasonal Kendall test in comparison with the other two tests can be related to the heterogeneity of the trend direction in different seasons. When the trend is heterogeneous between seasons, an estimate of overall trend statistics will be misleading and in such cases it is recommended to carry out separate Mann-Kendall tests for each season (Yu *et al*., 1993). In a recent study regarding the discharge trends in the same study area, Sheikh *et al*. (2009) also concluded that the results of three non-parametric trend tests of Mann-Kendall, Spearman's Rho, and Tiel-Sen are similar.

The trend results for annual mean discharge are in weak agreement with the trend results for the annual precipitation in this study, where both of them demonstrate a decreasing trend in general. But the observed trends in the annual mean discharge are stronger than the trends in the annual precipitation. Furthermore, although there is no apparent and homogeneous trend across the stations for the maximum daily precipitation but there is a homogeneous increasing trend across all the stations for the peak discharge which is significant in one third of stations at 5% level. The observed increase in peak discharge in this study is in agreement with the findings of Tavakkoli (2001) who reported that the number and magnitude of floods in the Atrak River basin have increased considerably during the period of 1977–1996. These findings indicate that observed trends in the hydrologic regime can only partly be explained by the changes in the precipitation regime. Amongst other causes are land use changes, other anthropogenic activities, and increased evapotranspiration rate due to higher temperature which we assume as most likely causes of trends in the hydrological regime of the Atrak River basin.

Generally speaking, despite no apparent and homogenous trends for the precipitation variables, there is an apparent and homogenous trend for the streamflow variables across the stations in the Atrak River basin. In fact, trends in streamflow variables can not be fully explained by the precipitation variables. Therefore, further studies should be carried out to get insight into the causal aspects of trends in streamflow.

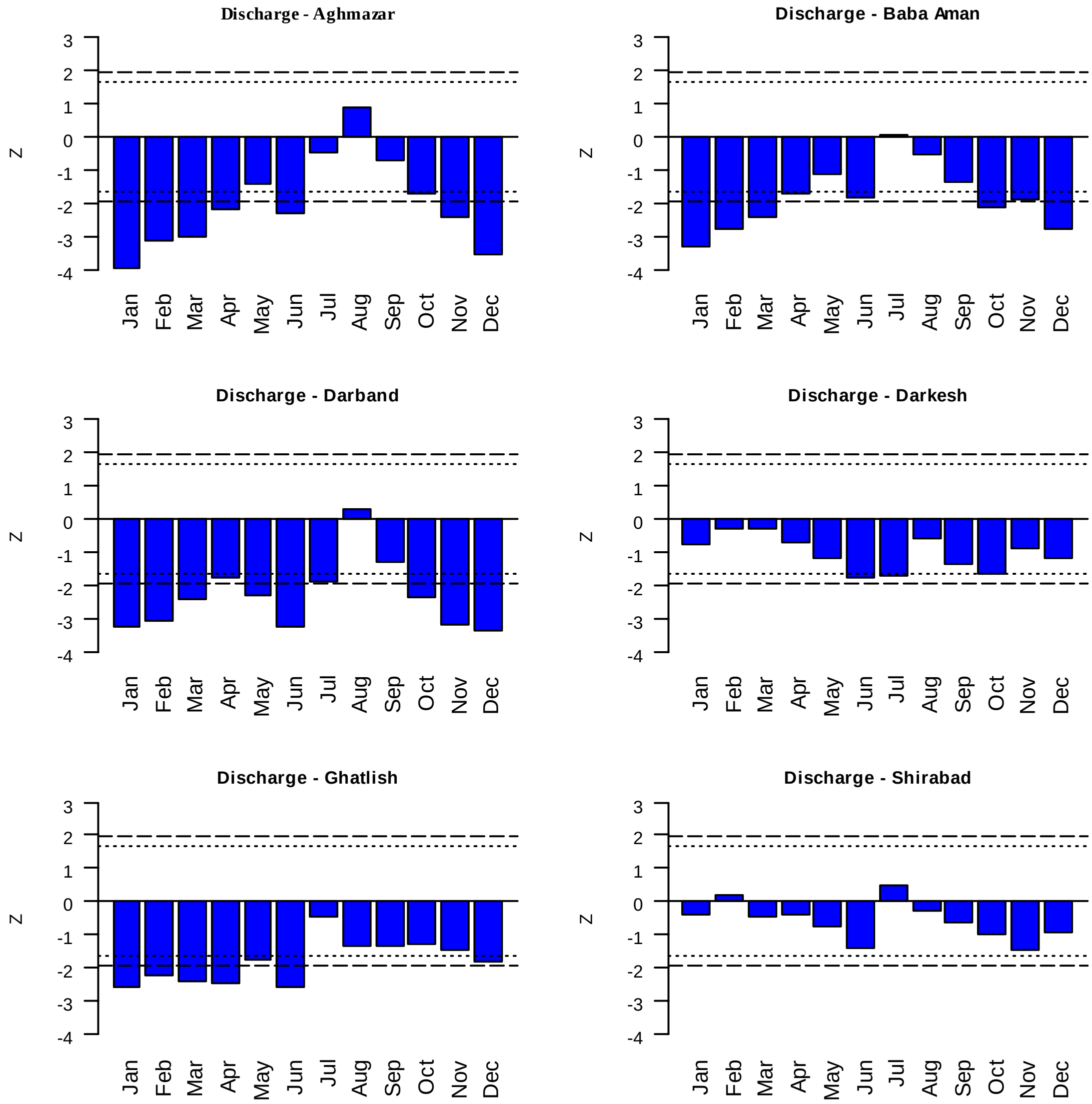

Fig. 8. Trend test statistics Z for monthly discharge. Dashed lines indicate 95% confidence level and dotted lines indicate 90% confidence level.

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References

Abdul Aziz, O.I., and D.H. Burn, 2006. Trends and variability in the hydrological regime of the Mackenzie River Basin. J. Hydrol., 319: 282-294.

Birsan, M.V., P. Molnar, P. Burlando, and M. Pfaundler, 2005. Streamflow trends in Switzerland. J. Hydrol., 314: 312-329.

Burn, H.B., and M.A. Elnur, 2002. Detection of hydrologic trends and variability. J. of Hydrol., 255: 107-122.

Douglas, E.M., R.M. Vogel, and C.N. Kroll, 2000. Trends in floods and low flows in the United States: impact of spatial correlation. J. of Hydrol., 240: 90-115.

Ghahreman, B. 2006. Time trend in mean annual temperature of Iran. Turkish Journal of Agriculture and Forest, 30(6): 439-448.

Gharhreman, B., and M. Taghavian, 2008. Investigation of annual rainfall trends in Iran. Journal of Agricultural Sciences Technology, 10: 93-97.

Hamed, K. H., 2008. Trend detection in hydrologic data: The Mann-Kendall trend test under scaling hypothesis. J. Hydrol., 349: 350-363.

Han, D., 2007. Seasonal rainfall and flow trends within three catchments in south-west England. In: S. Begum *et al*., (Eds.), Flood Risk Management in Europe. Springer. Pp. 275-292.

Hejam, S., Y. Khoshkhu, and R. Shamsoddinvandi, 2008. Trend analysis of annual and seasonal rainfall variation within the Iran centeral basin by using non-parametric tests. Journal of Geographical Researches, (64): 157-168 (in Persian)

Helsel, D.R., and L.M. Frans, 2006. Regional Kendall test for trend. Environ. Sci. Technol., 40(13): 4066 – 4073.

Hipel, K.W. and A.I., McLeod, 2005. Time Series Modelling of Water Resources and Environmental Systems.
http://www.stats.uwo.ca/faculty/aim/1994Book/.

Hirsch, R.M., J.R., Slack, and R.A. Smith, 1982. Techniques for trend assessment for monthly water quality data, Water Resour. Res. 18: 107-121.

Hubbard, E.F., J.M. Landwehr, and A.R. Barker, 1997. Temporal variability in the hydrologic regimes of the United States. In: A. Gustard, (Ed.), and FRIENDS'97 – Regional Hydrology: Concepts and Models for Sustainable Water Resource Management.
IAHS Publication, Vol. 246. IAHS, Oxfordshire, UK.

IPCC (Intergovernmental Panel on Climate Change), (2007). Summary for policymakers. In: M. Parry, et al., (Eds.), Climate Change 2007, Impacts, Adaptation, and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovermental Panel on Climate Change. Cambrifge University Press. Cambridge, UK, 11 pp.

Kahya, E., and S. Kalayci, 2004. Trend analysis of streamflow in Turkey. J. of Hydrol., 289: 128 – 144.

Karl, T.R., and R.W. Knight, 1998. Secular trends of precipitation amount, frequency, and intensity in the United States. Bull. Of Am. Meteorol Soci.. 79(2): 231-241.

Kendall, M.G., 1975. Rank Correlation Methods. Griffin. London, UK, 202 pp.

Koutsoyiannis, D., A. Efstratiadis, and K. Georgakakos, 2007. Uncertainty assessment of future hydroclimatic predictions: a comparison of probabilistic and scenario-based approaches. J. Hydrometeorol., 8(3): 261-281.

Labat, D., Y. Godderis, J.L. Probst, and J.L. Guyot, 2004. Evidence for global runoff increase related to climate warming. Adv. in Water Resour., 27: 631-642.

Lettenmaier, D.P., E.F. Wood, and J.R. Wallis, 1994. Hydro-climatological trends in the Continental United States, 1948-88. J. of Climate, 7: 586-607.

Lins, H.F., and J.R. Slack, 1999. Streamflow trends in the United States. Geophys. Res. Lett., 26(2): 227–230.

Mann, H.B., 1945. Nonparametric tests against trend. Econometrica, 13: 245-259.

Mc Carthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken, and K.S. White, (Eds.), 2001. IPCC. Climate Change 2001 – Impacts, Adaptation and Vulnerability Contribution of Working Group II to the Third Assessment Report of the Intergovermental Panel on Climate Change. Cambrifge University Press. Cambridge. 1032 pp.

Modarres, R., and P. R. Silva, 2007. Rainfall trends in arid and semi-arid regions of Iran. Journal of Arid Environments, 70(2): 344-355.

Qader, M.M., 2002. Global warming and changes in the probability of occurrences of floods in Bangladesh and implications. Global Environmental Change, 12: 127-138.

Raziei, T., P.D. Arasteh, and B. Saghafian, 2005. Annual rainfall trend in arid and semi arid region of Iran. ICID 21st European Regional Conference, 15-19 May 2005 - Frankfurt (Oder) and Slubice - Germany and Poland, pp. 1–8.

Robson, A.J., T.K. Jones, D.W. Reed, and A. Bayliss, 1998. A study of national trend and variation in UK floods. Inter. J. of Climatol., 18:165 – 182.

Sheikh, V., A. Bahremand, and Y. Mooshakhian, 2009. Comparing trends of hydrologic variables in the Atrak River basin using non-parametric trend tests. 5th National Conference on Watershed Management, 22-23 April 2009, Gorgan, Iran (in Persian)

Shirgholami, H., B. Ghahreman, A. Alizadeh, and J. Bodaghjamali, 2004. Trend analysis of reference evapotranspiration in Iran. Caspian Research Letters of Agricultural Sciences and Natural Resources, 3: 11-27 (In Persian).

Tavakkoli, M., 2001. Flood hazard zonation and its characteristics in the middle section of the Atrak river basin. MSc thesis in Watershed Management Engineering, Gorgan University of Agricultural Sciences and Natural Resources. (In Persian)

Yue, S., and P. Pilon, 2004. A comparison of the power of the t test, Mann-Kendall and bootstrap tests for trend detection. Hydrol. Sci. J., 49(1): 21-37.

Yue, S., P. Pilon, and B. Phinney, 2003. Canadian streamflow trend detection: impacts of serial and cross-correlation. Hydrol. Sci. J., 48(1): 51-63.
Zhang, X., K.D. Harvey, W.D. Hogg, and T.R. Yuzyk, 2001. Trends in Canadian streamflow. Water Resour. Res., 37(4): 987-998.