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Trend Detection of the Rainfall and Air Temperature Data in the Zayandehrud Basin

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Abstract: Climate change is one of the most important challenges among scientists and researchers. This phenomenon has a complex dynamic and time depending and it needs to an integrated long time study. The goal of this study is determining trend of rainfall and temperature that can be useful for better water management in the study area. In this study trend detection of these variables was used in annual and seasonal time scales in the Zayandehrud Basin stations namely, Isfahan, Damane Feridan, Varzaneh, Hamgin, Pole Zamankhan and Najafabad during a 40 years period (1966 till 2005). Parametric tests including t-test and linear regression and Non parametric tests of Mann Kendall, Mann Whitney and Spearman's rho was used for trend detection in the time series of data. Results indicated that there are not any linear and nonlinear significant trends among rainfall time series both annual and seasonal scale in the Zayandehrud basin except spring rainfall of Varzaneh station and summer rainfall of Pole Zamankhan station. But there are linear (results of t-test and linear regression) and nonlinear significant trends (results of Mann Kendall, Mann Whitney and Spearman's rho tests) in the most time series of selected stations. These trends in air temperature are mainly positive and show increasing of air temperature in the Zayandehrud basin. Thus it is require to a comprehensive study of impact assessment in this basin especially its impacts on the water supply systems and agriculture section.

Key words: Parametric test, nonparametric test, trend detection, climate change, Zayandehrud basin

ITRUDOCTION

Climate change is one of the main challenges in the world that have studied by scientists and researchers. This phenomenon can impact on human life both directly and indirectly. Scientific researches have shown that surface air temperature increased about 0.2 till 0.6°C during last century (Abaurrea and Cerian, 2001) and studies indicate that this parameter may increase about 1.5 to 4.5°C until 2100 (IPCC, 2004). It should be consider that this rate may varied in different geographical regions (Colin *et al*., 1999).

Global warming can effect on land ecosystems especially water cycle. Rainfall is a key input in management of agriculture and irrigation projects and any change in this variable can influence on sustainable management of water resources, agriculture and ecosystems. Mainly, studies of climate change science are focused on the probable changes in the annual series of a variable such as rainfall or temperature and variability of theses is important. There are physical and empirical methods for climate change detection. Physical methods use climate model for change detection. But generally a statistical method use empirical approaches. There are numerous studies that use trend analysis for climate change and global warming. Climate data may used directly (Van Belle and Hughes, 1984; Xie and Cao, 1996; Zhao and Dirmeyer, 2003; Yue and Hashino, 2003) or indirectly (Douglas *et al*., 2000; Knowles *et al*., 2007). Proedrou *et al*. (1997) in a study of winter air temperature in Creek found that this variable had decreasing trend during 1951 till 1993 but showed upward trend in the summer seasons. Kampata *et al*. (2008) have evaluated trend analysis in the rainfall of Zam bezi river basin in Zambia using Mann Kendall test in 5 rain gauges. Results indicated that there is a slow diminishing in this variable that it is not statistically significant.

A study on the trend condition of rainfall in the central and western Sahel regime showed that drought intensity has decreased in the central region compared with the past during 1990 till 2007. But there is a negative trend in the rainfall in the western region and more drought. Also variability of annual rainfall in study area is related to some large scale fluctuations of annual rainfall

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(Lebel and Ali, 2009). Mann Kendall test for trend detection in monthly, seasonal an annual scale of rainfall in the Kerala state of India during 1871 till 2005 showed that there is a significant descent in Monsoon rainfall in the Northwest region but it got an upward direction after this phenomenon. Also there was not any trend in the winter and summer seasons (Krishnakumar *et al*., 2009). Kumar and Jain (2010) studied trend detection in seasonal and annual rainfall and rainy days using Mann Kendall test in Kashmir valley. They used three time period of 41, 80 and 107 years. Results imply that there was an upward trend of rainfall and rainy days in one station but other stations showed decreasing trend for both variables. Annual and monthly data of rainfall and temperature in England was evaluated by Perry (2006) in a grid net of 5 km resolution during 1914 to 2004. He indicated that there was a significant trend in the rainfall. Summer rainfall has decreased but winter rainfall has increased in the North and western parts of the study area.T-test method for trend detection was used by Ghahreman (2006) who used this test for trend detection of mean annual air temperature in 34 stations of Iran and found that 50% of stations showed positive trend while 41% of station had negetive trend. Local and temporal changes in rainfall of Iran was studied by Asakerh (2007) who noted that 51.4% of Iran area was faced by rainfall changes that has high rate changes in mountains area and western part of Iran. Minimum of this change is -15.7 mm in Sarab station and its maximum is 29.6 mm in the Kouhrang station.

In a different study standard precipitation index with Mann Kendall test was used for trend analysis of drought in the Caspian Sea basin. This study implies that there was not any significant trend in this region with the confidential level of 95% for January, May and December months (Montazeri and Ghayour, 2009). Rainfall in the central basin of Iran has evaluated using 48 stations during 1971 till 2000. Mann Kendall and Sens Estimator Slop was used for trend detection. Results showed that rainfall series had significant negative trend. Also these two methods have similar capability for trend detection but, Sens method showed better results when a series includes Zero amount (Hajam *et al*., 2008).

Zayandehrud basin is located in the central part of Iran and has an important role in the socio economic development of Iran. This region is sustainable to drought phenomenon. In the other words, this region can be confronted by water supply stress. Thus for better management and programming, suitable studies related to rainfall and temperature is necessary of this region. These results can be used for local and regional programming of water resources sections and helps governors for selecting optimum strategies related to water management. In fact the goal of the study is determining trend of rainfall and temperature series that results is suitable of water supply organizers for better water management in the Zayandehrud basin.

MATERIALS AND METHODS

Study area: Zayandehrud River Basin is located in the central part of arid lands of Iran (Fig. 1) with area of 4334 km^2. There are some mountainous regions in the west (Zagros mountains) but plains and playas are the main feature of the geomorphology in the east section. So there is not a unit climate in this area. The average annual of precipitation in this area is about 150 mm (Yazdani *et al*., 2005) with high variability coefficient. There are 6 climatology stations that have longer period of data record; namely, Isfahan, Damane Feridan, Varzaneh, Hamgin, Pole Zamankhan and Najafabad (Table 1) that was used in this study. The time period for this study is considered 40 years from 1966 to 2005.

Methods: In this study, statistical method was used for trend detection in the rainfall and temperature series. Parametric tests of t-test and linear regression and nonparametric tests of Mann Kendall, Spearman's rho and Mann Whitney was used for trend detection in the time scales of annual and seasonal. Run test is used for homogeneity test of data (Mahdavi, 1999) and then data was controlled by legend stations.

T-test: In the parametric test such as t student, a linear regression is considered between random variable of (Y) during time of (X). Regression coefficient of b_1 (Pearson correlation coefficient) is calculated by data and t statistics is determined by the following equation:

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} = \frac{b_1}{s/\sqrt{ss_x}} \quad (1)$$

In this equation, t student distribution has freedom degree of n-2 that n is sample size, s is residual standard deviation and ss_x is sum square of dependent variable (time in trend analysis). Null hypothesis ($H_0: \rho = 0$ (or $\beta_1 = 0$)) and H1 hypothesis ($H_1: \rho \neq 0$ (or $\beta_1 \neq 0$) are determined in the significant level of α. ρ and β_1 are correlation coefficient and regression coefficient respectively. Lack of trend hypothesis can reject when the calculated t is more than its critical amount ($t_{\alpha/2}$) or p-value is lower than significant level (for example 0.01%) (Yue and Pilon, 2004).

Linear regression: Linear regression is a parametric test and it assumes that data has normal distribution and it evaluate existence of linear trend between time variable

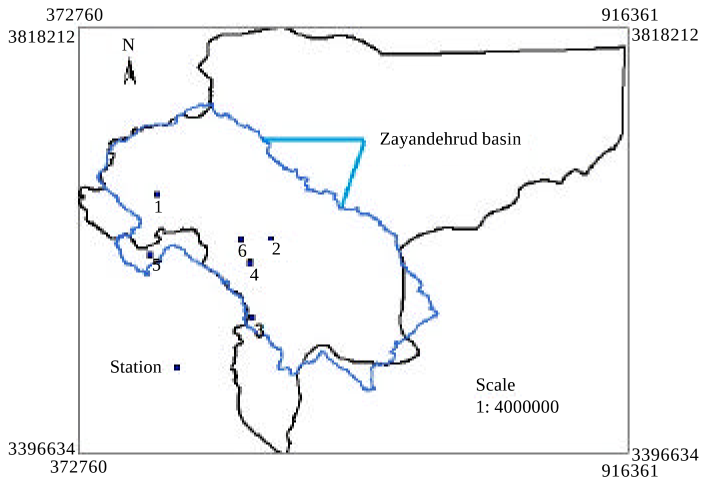

Fig. 1: Map of Zayandehrud River Basin and location of selected stations

Table 1: Selected climatology stations

	Geographical coordination			
Elevation (m)	Latitude	Longitude	Station name	Row
2300	33°01'	50°29'	Damane Feridan	1
1550	32°37'	51°40'	Isfahan	2
2150	31°55'	51°28'	Hamgin	3
1250	32°24'	51°27'	Varzaneh	4
1810	32°29'	50°24'	Pole Zamankhan	5
1649	32°37'	51°22'	Najafabad	6

(X) and desire variable (Y). Slop of regression line is calculated by following equation:

$$a = \bar{Y} - b\bar{X} \tag{2}$$

$$b = \frac{\sum_{i=1}^{n} (X_i - \bar{X}) - (Y_i - \bar{Y})}{\sum_{i=1}^{n} (X_i - \bar{X})^2} \tag{3}$$

And S statistics can calculate by:

$$S = b/\delta$$

S statistics has freedom degree of n-2 and it assumes data with normal distribution and errors are independent with the same distribution (normal) and has mean of zero:

$$\sigma = \sqrt{\frac{12\sum_{i=1}^{n} (Y_i - a - bX_i)}{n\,(n-2)\,(n^2-1)}} \tag{4}$$

Mann kendall test: A single variable statistics of Mann Kendall is defined for a special time series ($Z_K K = 1, 2, ..., n$) by following relation:

$$T = \sum_{j<i} \text{sgn}\,(Z_i - Z_J) \tag{5}$$

And

$$\text{sgn}\,(x) = \begin{cases} 1,......\text{if}...x > 0 \\ 0,......\text{if}...x = 0 \\ -1,....\text{if}....x < 0 \end{cases}$$

If there is not any relationship between variables and the series has not trend, thus It would have (Onoz and Bayazit, 2003):

$$E\,(T) = 0 \text{ and } Var\,(T) = n\,(n\text{-}1)\,(2n\text{+}5)/18$$

Spearman's rho test: This is a sequential nonparametric test. For data sets of {Xi, i = 1,2,…n} the null hypothesis is assumed that all X_i are independent and have the same distribution. But H_0 hypothesis is assumed that X_i decrease or increase corresponding to I and it means there is a trend in the data series. Test statistics of D is defined as:

$$D = 1 - \frac{6\sum_{i=1}^{n} [R\,(X_i) - i]^2}{n\,(n^2-1)} \tag{6}$$

where, R (X_i) is i th order of Xi observed data an n is sample size regard to null hypothesis, D has normal distribution symmetrically and its average and variance are (Sneyers, 1990):

$$E\,(D) = 0 \quad V\,(D) = 1/n\text{-}1$$

Mann-whitney test: This is a kind of nonparametric test that is used for trend detection in data and can compare two independent and accidental variables. U statistics is calculated as following:

$$U = n_1 n_2 + \frac{n_2(n_2+1)}{2} - \sum_{i=n1+1}^{n2} R_i \quad (7)$$

where, n_1 and n_2 are sample size of two variables and R_i is their rank.

RESULTS

Plots of data series versus time are represented in Fig. 2 and 3. Data sets should have normal distribution in the parametric test, thus normality test was carried out using Kolmogrov Smirnov test. Kolmogrov Smirnov test is a nonparametric test that can use for detection normal distribution of data. This test compares the observed cumulative distribution function for a variable with a specified theoretical distribution like normal distribution. The power of this test is detection departures from the hypothesized distribution. For using data in parametric tests, data should have normal distribution and we can check type of data distribution for these kinds o test using Kolmogrov Smirnov test. Thus all data distribution was controlled by this test.

Results indicated that all data time series except rainfall summer data has this type of distribution (Table 2) and for parametric test this series was omitted.

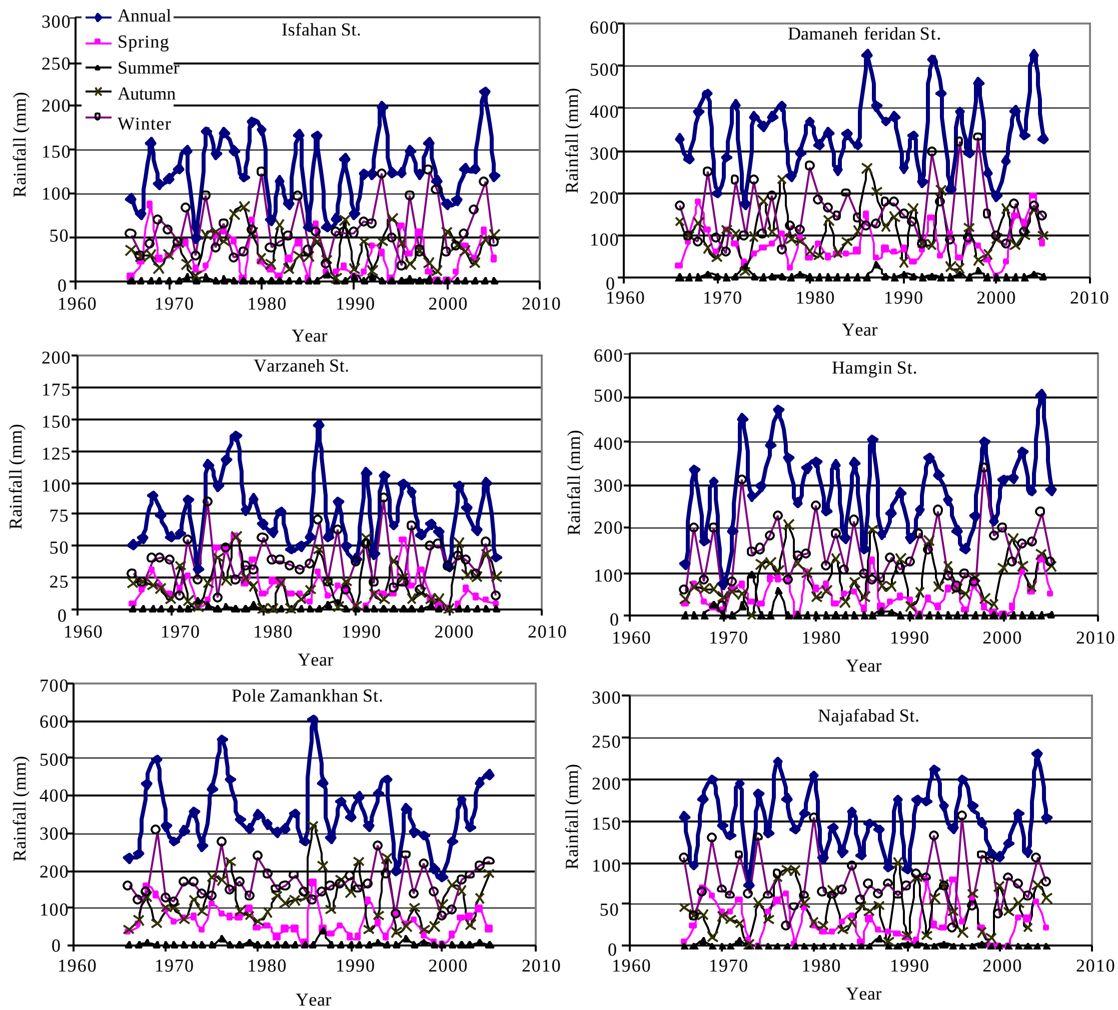

Fig. 2: Plots of annual and seasonal time series of rainfall in the selected stations

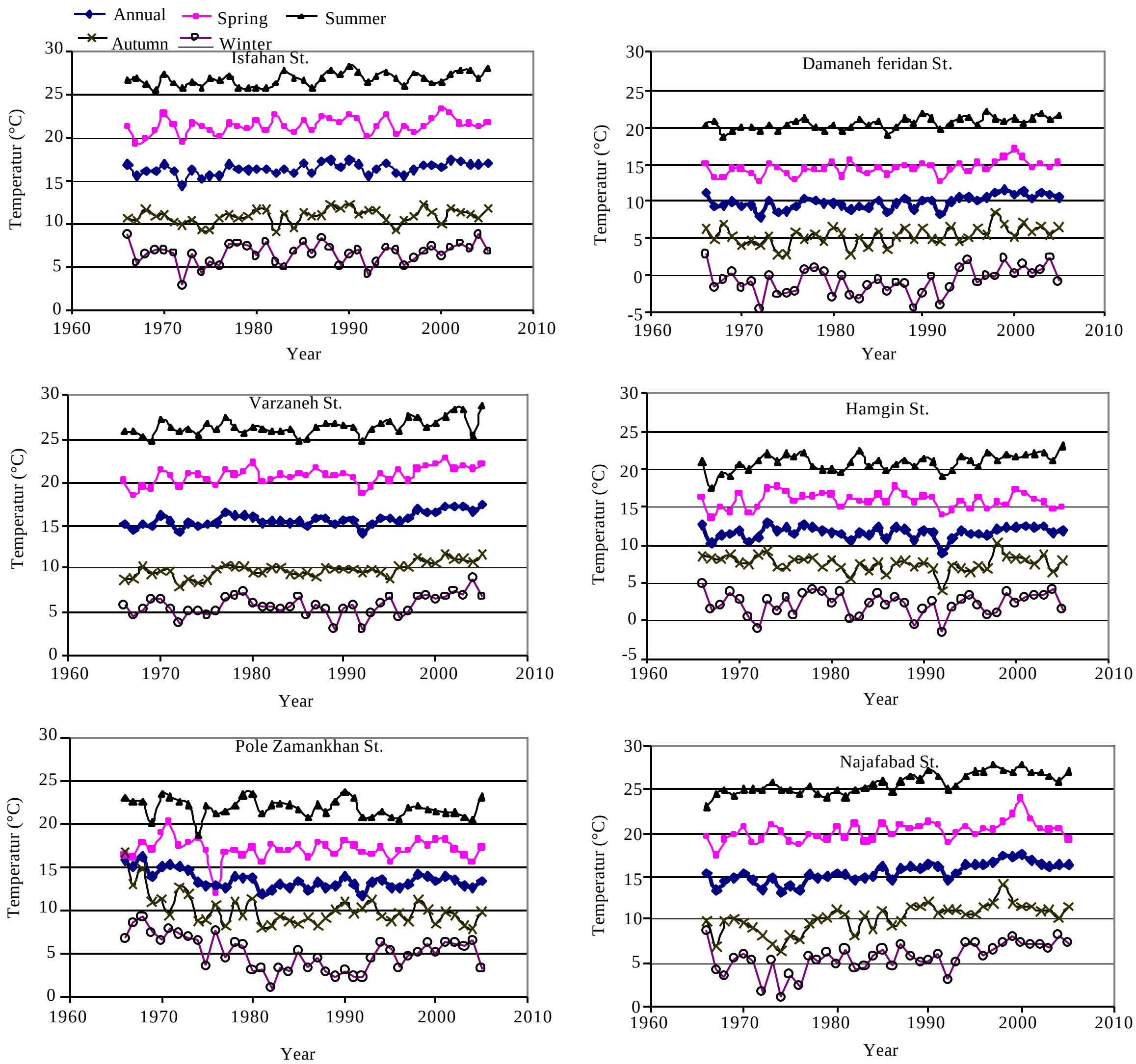

Fig. 3: Plots of annual and seasonal time series of temperature in the selected stations

Table 2: Normality test of data (with confidential level of 95 %)

		Value				Value				Value	
Station	Time	p	t	Station	Time	p	t	Station	Time	p	t
Isfahan	Annual	0.83	0.90	Varzaneh	Annual	0.53	1.00	Pole Zamankhan	Annual	0.79	0.85
	Spring	0.52	0.71		Spring	0.16	0.48		Spring	0.74	0.84
	Summer	0.00	0.56		Summer	0.00	0.70		Summer	0.00	0.42
	Autumn	0.90	0.75		Autumn	0.41	0.59		Autumn	0.68	0.96
	Winter	0.17	0.94		Winter	0.76	0.55		Winter	0.53	0.80
Damane Feridan	Annual	1.00	0.76	Hamgin	Annual	0.97	0.62	Najafabad	Annual	0.89	0.73
	Spring	0.39	0.56		Spring	0.60	0.52		Spring	0.36	0.60
	Summer	0.00	0.60		Summer	0.00	0.62		Summer	0.74	0.81
	Autumn	0.78	0.63		Autumn	0.21	0.58		Autumn	0.00	0.75
	Winter	0.71	0.42		Winter	0.80	0.59		Winter	0.96	0.75

According to Table 2, Maximum p value for rainfall data is 0.96 (winter data) and its minimum is 0 (summer data). But maximum p-value for temperature is 0.96 (autumn data) and the minimum is 0.42 (both in

Table 3: Results of t-test for data of rainfall and temperature data set

		Rainfall		Temperature				Rainfall		Temperature	
Station	Time	p-value	t	p-value	t	Station	Time	p-value	t	p-value	t
Isfahan	Annual	-0.13	0.90	-3.59	0.00	Hamgin	Annual	-0.15	0.89	0.24	0.81
	Spring	0.78	0.45	2.48	0.02		Spring	0.31	0.76	0.59	0.56
	Summer			4.09	0.00		Summer			-1.66	0.11
	Autumn	0.36	0.73	3.28	0.00		Autumn	-1.06	0.30	1.07	0.30
	Winter	-0.95	0.35	-0.86	0.40		Winter	0.04	0.97	0.41	0.69
Damane Feridan	Annual	-1.01	0.32	-3.04	0.01	Pole Zamankhan	Annual	-0.20	0.85	2.18	0.04
	Spring	-0.54	0.59	-2.67	0.02		Spring	1.07	0.30	-0.14	0.89
	Summer			3.86	0.00		Summer			1.50	0.15
	Autumn	-0.66	0.52	2.90	0.01		Autumn	-0.83	0.41	2.00	0.06
	Winter	-0.45	0.66	1.04	0.31		Winter	0.10	0.92	1.52	0.14
Varzaneh	Annual	0.02	0.99	-3.38	0.00	Najafabad	Annual	-0.04	0.96	-7.72	0.00
	Spring	2.56	0.02	-2.31	0.03		Spring	-0.22	0.83	-3.42	0.00
	Summer			-2.64	0.02		Summer			-8.33	0.00
	Autumn	-0.90	0.38	-5.07	0.00		Autumn	-0.40	0.69	-6.96	0.00
	Winter	-0.52	0.61	-0.55	0.59		Winter	-0.24	0.81	-3.35	0.00

Table 4: Results of linear regression test for rainfall data in the selected stations

		Statistics					Statistics		
Station	Time	b	a	S	Station	Time	b	a	S
Isfahan	Annual	0.30	118.94	0.54	Hamgin	Annual	1.192	260.41	0.88
	Spring	-0.27	33.40	-0.89		Spring	0.042	45.46	0.09
	Summer					Summer			
	Autumn	0.02	36.15	0.07		Autumn	0.889	66.58	1.33
	Winter	0.55	48.48	1.35		Winter	0.697	133.76	0.72
Damane Feridan	Annual	0.768	323.55	0.62	PoleZamankhan	Annual	-0.400	356.69	-0.32
	Spring	0.274	70.53	0.48		Spring	-1.070	82.39	-2.11
	Summer					Summer			
	Autumn	-0.085	107.61	-0.11		Autumn	0.437	110.04	0.49
	Winter	0.599	141.53	0.63		Winter	0.184	162.55	0.26
Varzaneh	Annual	-0.146	77.13	-0.38	Najafabad	Annual	-0.006	151.40	-0.01
	Spring	-0.348	23.83	-1.79		Spring	-0.259	34.56	-0.83
	Summer					Summer			
	Autumn	0.136	16.79	0.62		Autumn	0.206	39.07	0.57
	Winter	0.082	35.59	0.31		Winter	0.067	76.72	0.15

Table 5: Results of linear regression test for temperature data in the selected stations

		Statistics					Statistics		
Station	Time	b	a	S	Station	Time	b	a	S
Isfahan	Annual	0.026	15.85	3.18	Hamgin	Annual	0.007	11.51	0.62
	Spring	0.031	20.72	2.60		Spring	-0.005	15.97	-0.38
	Summer	0.030	26.10	3.26		Summer	0.044	20.03	3.16
	Autumn	0.022	10.41	2.00		Autumn	-0.015	7.88	-1.01
	Winter	0.020	6.16	1.18		Winter	0.002	2.18	0.12
Damane Feridan	Annual	0.040	9.04	3.90	PoleZamankhan	Annual	-0.044	14.35	-3.60
	Spring	0.037	13.63	3.29		Spring	-0.003	17.09	-0.19
	Summer	0.041	19.63	4.75		Summer	-0.023	22.30	-1.64
	Autumn	0.043	4.45	2.78		Autumn	-0.083	11.69	-3.75
	Winter	0.039	-1.55	1.60		Winter	-0.063	6.31	-2.42
Varzaneh	Annual	0.042	14.80	4.90	Najafabad	Annual	0.075	13.89	7.70
	Spring	0.044	19.84	3.80		Spring	0.049	19.13	3.71
	Summer	0.041	25.53	3.56		Summer	0.079	24.09	8.45
	Autumn	0.050	8.83	5.50		Autumn	0.093	8.30	5.90
	Winter	0.035	4.99	2.20		Winter	0.079	4.05	3.86

winter and summer) and seasonal data was divided into two groups with sample size of 20 (1966 till 1985 and 1986 till 2005) and then student t' test was used. The results of this test are presented in Table 3 for rainfall and temperature data. Results of Table 3 shows that maximum t statistics for rainfall data is 2.56 and so for temperature is 4.09. The minimum t statistics are -1.06 and -8.33 for rainfall and temperature, respectively. Results of

Table 6: Results of Mann Kendall test of rainfall and temperature data set

		Rainfall		Temperature				Rainfall		Temperature	
Station	Time	p-value	MK-Stat	p-value	MK-Stat	Station	Time	MK-Stat	p-value	MK-Stat	p-value
Isfahan	Annual	0.37	0.71	2.97	0.00	Hamgin	Annual	0.64	0.52	0.83	0.41
	Spring	-0.90	0.37	2.15	0.03		Spring	-0.34	0.74	-0.86	0.39
	Summer	0.74	0.46	2.97	0.00		Summer	-0.40	0.69	2.95	0.00
	Autumn	0.08	0.93	0.04	0.04		Autumn	1.31	0.19	-1.52	0.13
	Winter	1.07	0.28	1.01	0.31		Winter	0.63	0.53	0.29	0.77
Damane Feridan	Annual	0.19	0.85	3.67	0.00	PoleZamankhan	Annual	0.12	0.91	-2.38	0.02
	Spring	-0.01	0.99	2.96	0.00		Spring	-1.93	0.05	-0.12	0.91
	Summer	-0.18	0.86	3.88	0.00		Summer	2.23	0.03	-2.39	0.02
	Autumn	-0.31	0.75	2.63	0.01		Autumn	0.76	0.45	-2.48	0.01
	Winter	0.51	0.61	1.78	0.07		Winter	1.20	0.23	-2.21	0.03
Varzaneh	Annual	-0.16	0.87	4.03	0.00	Najafabad	Annual	-0.26	0.80	5.39	0.00
	Spring	-2.26	0.02	3.41	0.00		Spring	0.62	0.54	3.01	0.00
	Summer	-0.88	0.38	3.16	0.00		Summer	-1.03	0.31	5.49	0.00
	Autumn	0.72	0.47	4.08	0.00		Autumn	0.14	0.89	4.66	0.00
	Winter	0.19	0.85	2.30	0.02		Winter	0.59	0.55	3.77	0.00

Table 7: Results (p-value) of Mann Whitney and Spearman's rho tests for data set of rainfall and temperature

		Rainfall		Temperature				Rainfall		Temperature	
Station	Time	MW test	Sp-test	MW test	Sp-test	Station	Time	MW test	Sp-test	MW test	Sp-test
Isfahan	Annual	0.96	0.78	0.01	0.00	Hamgin	Annual	0.97	0.51	0.96	0.45
	Spring	0.34	0.30	0.05	0.03		Spring	0.46	0.75	0.32	0.50
	Summer	0.43	0.40	0.00	0.00		Summer	1.00	0.65	0.15	0.01
	Autumn	0.16	0.39	0.02	0.03		Autumn	0.22	0.15	0.19	0.17
	Winter	0.74	0.90	0.58	0.30		Winter	0.84	0.51	0.68	0.83
Damane Feridan	Annual	0.40	0.76	0.00	0.00	PoleZamankhan	Annual	0.68	0.96	0.07	0.01
	Spring	0.79	0.90	0.03	0.00		Spring	0.16	0.05	1.00	0.87
	Summer	0.61	0.91	0.00	0.00		Summer	0.01	0.02	0.05	0.03
	Autumn	0.69	0.81	0.03	0.01		Autumn	0.65	0.66	0.24	0.01
	Winter	0.85	0.61	0.25	0.10		Winter	0.66	0.28	0.04	0.01
Varzaneh	Annual	0.91	0.95	0.01	0.00	Najafabad	Annual	0.96	0.87	0.00	0.00
	Spring	0.04	0.03	0.03	0.00		Spring	0.47	0.66	0.00	0.00
	Summer	0.71	0.39	0.01	0.00		Summer	0.42	0.35	0.00	0.00
	Autumn	0.27	0.40	0.00	0.00		Autumn	0.30	0.88	0.00	0.00
	Winter	0.67	0.74	0.49	0.02		Winter	0.68	0.44	0.00	0.00

regression test indicate that S statistics for rainfall time series has maximum of 1.35 and minimum of -2.11. These values for temperatures are 8.45 and -3.75 (Table 5). Tables 4 and 5 show regression coefficient (a and b) and S statistics for determining significant level of trend of both variables. Results of Mann Kendall test and its p-value have shown in the Table 6. According to results of Table 6, minimum value of Mann Kendall statistics for rainfall and temperature are -2.26 (spring) and -2.48 (autumn), respectively. And so the highest value for rainfall is 2.23 in winter time, while for temperature is 5.42 in summer time. Test results of Mann Whitney showed that summer rainfall of Hamgin station has maximum p value of 1 and summer rainfall of Pole Zamankhan has minimum p value of 0.01.But for Spearman test, minimum and maximum p value is for Pole Zamankhan station for summer and annual series (0.02 and 0.96). Maximum p-value of Man Whitney of temperature is 1 for spring series of Pole Zamankhan and for Spearman test is 0.87 for this station. The minimum of p value for both tests is zero. p-value of Mann-Whitney and Spearman's rho tests for data series is represented in the Table 7.

DISCUSSION

This study was focused on the trend detection of annual and seasonal time series of rainfall and temperature at 6 stations in the Zayanderud Basin, including Isfahan, Damane Feridan, Varzaneh, Hamgin, pole Zamankhan and Najafabad during a 40 years period. Parametric tests of t-test and linear regression was used for linear trend detection and non parametric tests of Mann Kendall, Mann-Whitney and spearman's rho were used for nonlinear trend of date sets. Plots of rainfall data (Fig. 2) show irregular fluctuations in different time scale, but these fluctuations are smaller with clear trends in temperature time series (Fig. 3). For instance, there is a positive trend in the station of Najafabad and Isfahan. Results of different test are represented in following.

t-test method: Normality test of data indicated that all data have normal distribution except summer rainfall data that have not normal distribution with confidential level of 95%. Thus, this series was omitted in the test. t-test was performed for two separated groups with 20 sample sizes and each significant difference means existence of trend in data.

Rainfall series: Results indicated that there is not any trend in the rainfall data both seasonal and annual scale with confidential level of 95%. Only data of spring rainfall showed significant trend in the Varzaneh station. Significant level (p-value) is 0.35 for Isfahan station in winter and 0.9 for annual series. In Damane Feridan station p-value is 0.32 for annual scale and 0.66 for spring rainfall. P-value in Varzaneh station is 0.02 and 0.99 for spring and annual scale, respectively. The lowest p-value in Hamgin station is 0.3 for autumn season and the highest is 0.97 for winter time. Minimum and maximum p-value for Pole Zamankhan is 0.3 in spring and 0.92 in winter times. But significant level in Najafabad station is varied from 0.66 in autumn and 0.96 in annual data (Table 3).

Temperature series: Results of t-test for trend detection in temperature data depicted that there are trends in temperature series in stations of Isfahan, Damane Feridan and Varzaneh in all time scale except winter series. According to the former research (Ghahreman, 2006) there is same results for Isfahan station with temperature variable, although this work used only t-test for trend detection. But there is not trend in the temperature series of Hamgin station. Annual series of Pole Zamankhan station showed linear trend (p-value = 0.04), meanwhile other series were not involve any trend (p-value ranged from 0.06 till 0.89). Temperature series of Najafabad station have significant trends in annual and seasonal scales.

Mann-Kendall test

Rainfall: Spring data of Varzaneh station showed negative trend by this method (p-value = 0.02). Also summer data has positive significant trend (p-value = 0.03) in Pole Zamankhan station. Other series in annual and seasonal scales of stations didn't represent any significant trend. Results of one study with shorter time period in the same region of this study and Mann-Kendall test, showed same results, but they totally implied that there is negative trend in annual rainfall series of this region (Hajam *et al.*, 2008). One probable causes for this negative trend is global warming and sign of climate change and different geographical conditions can influence on the results.

Temperature: Evaluation of trends in temperature data illustrate that there is a positive trend in data series of Isfahan, Damane Feridan except winter series. Also trend of this variable is upward and completely significant in Varzaneh and Najafabad stations. Summer data of Hamgin station show a positive trend. Temperature series at Pole Zamankhan showed significant increasing trend but its spring data don't show any trend (p-value = 0.91) during selected period (Table 6).

Linear regression method

Rainfall: Evaluation of trend in annual and seasonal rainfall showed that there is not any significant trend in the selected period. But spring rainfall of Pole Zamankhan has a downward trend (S = -2.11). This result for Isfahan station is same as Asakerh funding in his study using this method. it should be consider that time period of his work is different of this study (Asakerh, 2007).

Temperature: Temperature series of Isfahan and Damane Feridan stations have significant positive linear trend except winter temperature.

But all data series showed significant trend in Varzaneh and Najafabad stations and slope of regression line in these data is ascending (positive trend). Only summer temperature in Hamgin station has trend significantly (S = 3.16). And all time scales of data was not involve significant trend with confidential level of 95% in the pole Zamankhan station (Table 5).

Mann-Whitney test: Nonparametric test of Mann-Whitney was performed on the rainfall and temperature series.

Rainfall: Data series of Isfahan, Damane Feridan, Hamgin and Najafabad have not any significant trend. But only, spring rainfall in Varzaneh station showed a negative trend with p-value of 0.04 and so summer rainfall in Pole Zamankhan station with p-value of 0.01.

Temperature: All temperature data except winter series have positive significant trend in the stations of Isfahan, Damane Feridan and Varzaneh. Data series of Hamgin have not any trend while winter temperature in Pole Zamankhan showed significant trend. Also all data series depicted an upward trend significantly in the Najafabad station.

Spearman's rho test

Rainfall: Results of this test indicated that there is not any trend in this variable in stations of Isfahan, Damane feridan, Hamgin and Najafabad. Spring rainfall in Varzaneh station and summer rainfall in Pole Zamankhan showed significant trend.

Temperature: Study of temperature series in the selected stations showed trends in all series of Varzaneh and Najafabad station and all series except winter temperature in Isfahan and Damane feridan stations. Summer series of

Hamgin station showed trend and while spring series in pole Zamankhan has not trend.

Results indicated that there are not significant linear and nonlinear trends in the rainfall data of Isfahan station using statistical methods. But temperature variable has positive trend in all time scale except winter series. This condition is same for Damane Feridan station. Only spring rainfall data of Varzaneh station showed a negative trend. All implemented tests except linear regression depicted a decreasing significant trend in this variable. But temperature data has a significant upward trend, although this trend is not statistically significant for winter temperature using t-test and Mann-Whitney methods (p-value are 0.59 and 0.49 for both tests, respectively). Rainfall and temperature data was not involved significant trend in Hamgin station but summer temperature showed trend by methods of linear regression, Mann-Kendall and Spearman's rho.

Annual, spring, autumn and winter rainfall had not trend in Pole Zamankhan station. While summer rainfall represented an increasing trend using Mann Kendall, Mann-Whitney and Spearman's rho tests. It means that only summer rainfall had nonlinear trend. Annual temperature showed linear trend (by t-test method) and nonlinear trend (by Mann Kendall and Spearman's rho). Spring temperature has not any trend and summer temperature has nonlinear trend (by Mann Kendall and Spearman methods). Also there is downward nonlinear trend in the autumn temperature (by Mann Kendall and Spearman methods) and winter data (by Mann Kendall and Spearman and Mann Whitney methods. Present study indicates that rainfall data had not any trend in Najafabad station, in contrast all temperature series had significant trend both linear and nonlinear during this period.

However, it is necessary to consider that the amount or rate of trend is varied in each region. Because each region has different climate and other related conditions can impact on the climate variables (Colin *et al*., 1999). Thus we can expect some differences in results between selected stations due to its different geographical condition of study area. On the other hand, time period of data can impact on the results (Soltani and Soltani, 2008).

According to the results, there was not linear and non linear significant trends in the rainfall time series in all stations of Zayandehrud basin, although there are two cases that showed trend statistically significant but it is clear that rainfall data in all time scale had not trend during the selected time period. But existence of linear and nonlinear trends in temperature data of stations represents an increasing air temperature in this basin. Also our finding suggested that mean annual and seasonal temperature (except winter data) in Isfahan station has increased about 0.02 centigrade degrees per year during this period. This augment rate is 0.04°C in Damane feridan station (except winter data), 0.04°C in Varzaneh station, 0.06°C in Najafabad station, 0.03°C for summer temperature of Hamgin. Contrastingly, mean annual temperature in Pole Zamankhan station has decreasing trend about 0.04°C per year.

Stability of rainfall variables and lack of positive trend in annual and seasonal scales in the most parts of the Zayandehrud basin and regard to positive trends in temperature variable in this region, it is expected that evaporation rate has increased due to warming of study area and this can cause stress on the water supply systems and limits agriculture practices. Matouq (2008) mentioned in his work that increasing air temperature caused increasing of evaporation. Increasing of air temperature and diminishing rainfall can influence a lot on water systems (Yasin, 2009). Also this positive trend of temperature can influence on the hydrologic cycle and it can impact on change of snowmelt time of upstream region and it may initiate problems in water supply system and extended irrigation networks in the down stream of this basin. Thus it is necessary that policy makers make an attempting to solve this problem and introduce proper programs in the regional and local scales toward diminishing negative impacts of the global warming.

In this study to access better results and comparison of the tests, not only Mann Kendall test that used by some researchers (Kampata *et al*., 2008; Krishnakumar *et al*., 2009; Kumar and Jain, 2010) but also other linear and nonlinear tests was used. Also some scientists indicated that Mann Kendall test is a suitable test for trend detection (Montazeri and Ghayour, 2009; Yue and Pilon, 2004) but some work suggest other test according to their funding (Hajam *et al*., 2008; Douglas *et al*., 2000). Onoz and Bayazit (2003) compared t-test and Mann Kendall test capability for trend detection and they indicated that The t-test has less power than the non-parametric test when the probability distribution is skewed.

CONCLUSION

Present finding showed that generally, t student and linear regression are suitable parametric tests for linear trend detection and so nonparametric tests of Mann Kendall, Man Whitney and Spearman rho have good capability for nonlinear trend detection in the climatology data series. It is recommended that several statistical tests are used for trend detection for a data series and it can decrease uncertainty of incorrect detection and interpretation compared with using a single test.

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