CHARACTERISTICS OF THE TEMPORAL VARIATION IN TEMPERATURE IN ZHANGHE RIVER REGION, CHINA

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ABSTRACT: Monthly and seasonal trends in maximum and minimum temperature were analyzed by using non-parametric Mann-Kendall method and Sen's slope estimator at 5% significance level. For this study temperature data from eight stations over the period 1980-2010 were used. Increasing and decreasing trends with significance and insignificance levels were found in both maximum and minimum temperature series. Yushe station had negative trends on monthly basis in both maximum and minimum temperature, while the remaining stations showed positive trend. Such kind of increasing trends in temperature at all stations during 30 years exhibit the behavior of global warming and increasing trends in temperature resulting in increasing tendency of water stress resulting in drought conditions. It was found that a maximum negative trend in the temperature starts from September and the maximum positive trends starts in January at 50% rate of stations.

Keywords: Trend analysis, Temperature, Statistical test, Zhanghe River, Drought

INTRODUCTION

Global warming as a result of climate change is a hot topic in recent years for both governments and researchers. [1,2] Reported that during the last century surface temperatures increased globally that caused changes in the hydrological cycle and boost up the drought phenomena around the world. Many studies showed that drought conditions occurred more often and on a large scale around the world such as Asia, Africa, Europe and America [3-10]. East Asia faced severe drought in 1950 with adverse effects in all the development sectors and on human [11, 12]. China faces the regular occurrence of severe droughts in 1997, 1999 and during 2002, it is important to reduce and control the adverse effects of drought in these areas[13]. Research is required to understand the drought dynamics and its influencing factors. According to [14, 15] temperature has risen from 0.3°C to 0.6°C over the past century and from 0.2°C to 0.3°C during the four past decades. During 1970, the northern hemisphere temperature increased at record, reaching latitude 40°N and 70°N. [16] Reported that during the 20th century, global surface temperature increased at the rate of 0.6°C during 50 years. High temperature or less amount of precipitation creates drought and affects agriculture [17, 18]. Zhanghe river basin comes under semiarid climate area. A comprehensive analysis of climatic variables over Zhange River is still lacking. The main objectives of this research are: (1) using Mann-Kendall to investigate whether there have been any significant changes in the extreme temperature during three decades (2) to analyzed and discuss the trends of temperature on monthly and seasonal basis: and (3) to analyze the impact of global warming on the trends of temperature in Zhanghe river basin.

DATA AND METHODS

Study region

In this study, eight weather stations were analyzed which are located at upstream of Zhanghe river of china and data of maximum and minimum temperature comprising of 30 years from (1980 to 2010). Figure 1 shows the geographical map of the study area.

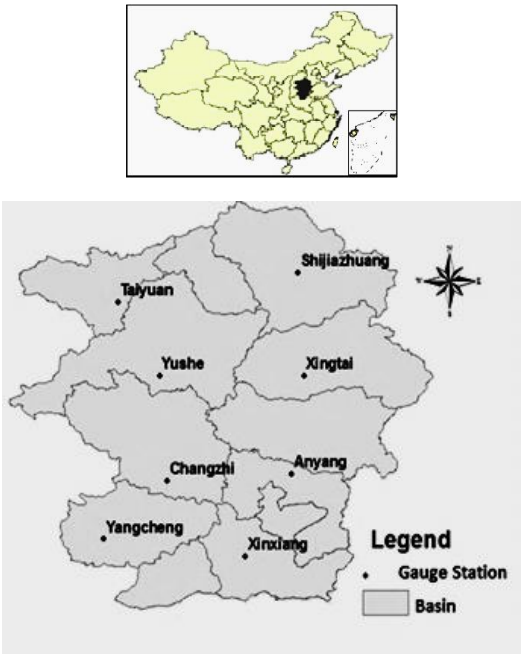

Figure 1 - Geographical map of Study area.

TREND DETECTION METHODS

Mann-Kendall Method

In this study non parametric Mann-Kendall trend test was used [19, 20]. Kendall's test was used at monthly basis in order to avoid the auto- correlation errors. The Z statistics [21-24] was calculated as:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} Sgn\left(x_j - xk\right) \quad (1)$$

$$Sgn\left(x_j - x_k\right) = \begin{cases} +1 \; if \; x_j - x_k > 0 \\ 0 \; if \; x_j - x_k = 0 \\ -1 \; if \; x_j - x_j < 0 \end{cases} \quad (2)$$

Where n is the number of observed data, x_j and x_k are the values in periods j and k respectively, $j > k$ for $n \geq 10$.

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{VAR(S)}} & if \; S > 0 \\ 0 & if \; S = 0 \\ \dfrac{S+1}{\sqrt{VAR(S)}} & if \; S < 0 \end{cases} \quad (3)$$

Where VRA(S) is calculated as:

$$VAR\left(S\right) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p-1}^{q} t_p\left(t_p - 1\right)\left(2t_p + 5\right)\right] \quad (4)$$

Where q is the number of tied groups and t_p is the number of data in the p_{th} group If Z is positive it shows increasing trend while Z negative indicate decreasing trends. In this paper, the significance level of α = 5% was used. 5 % significance level, then null hypothesis of no trend is rejected if Z > 1.96.

2.2.2 Sen's slope estimator

Sen [25] developed the non-parametric procedure for estimating the slope of trends in the series of data:

$$Q_i = \frac{x_j - x_k}{j-k} \quad for \; i = 1, ..., N, \quad (5)$$

Where x_j and x_k are the data values at times j and k ($j > k$), respectively. If there is only one datum in each time period, then $N = \frac{n(n-1)}{2}$; where n is the number of time periods. If there are multiple observations in one or more time periods, then $N < \frac{n(n-1)}{2}$; where n is the total number of observations. The values of Q_i are ranked from smallest to largest and the median of slope or Sen's slope estimator is calculated as:

$$Q_{med} = \begin{cases} Q_{[(N+1)/2]} & if \; N \; is \; odd \\ \dfrac{Q_{[N/2]} + Q_{[(N+2)/2]}}{2} & if \; N \; is \; even \end{cases} \quad (6)$$

The Q_{med} sign reflects data trend reflection, while its value indicates the steepness of the trend. To determine whether the median slope is statistically different than zero, one should obtain the confidence interval of Q_{med} at specific probability. The confidence interval about the time slope [26, 27] can be determined as:

$$C_\alpha = Z_{1-\alpha/2} \sqrt{VAR(S)} \quad (7)$$

Where $VAR(S)$ is defined in Eq. (4) and $Z_{1-\alpha/2}$ is obtained from the standard normal distribution table. In this study, the confidence interval was computed at significance (α = 5%) level.

Table 1 - Statistical parameters of annual temperature at different stations during the period 1980-2010.

Station name	Min (C°)	Max(C°)	Mean(C°)	SD (C°)	CV (%)
Anyang	22.600	33.408	27.448	2.58	11.43
Changzhi	19.571	29.542	24.216	2.41	12.65
Shijiazhuang	22.600	33.133	27.326	2.51	11.62
Taiyuan	19.725	29.125	24.274	2.25	12.23
Xingtai	22.492	33.342	27.566	2.6	12.14
Xinxiang	22.992	32.383	27.438	2.22	9.62
Yangcheng	20.933	30.817	25.544	2.41	11.24
Yushe	19.550	28.950	23.649	2.26	12.27

RESULTS AND DISCUSSION

Preliminary Analysis:

Statistical parameters of annual temperature at different stations from the period 1980-2010 are summarized in Table 1. The mean annual minimum temperature is ranged from 19.55C° to 22.99 ºC in Yushe and Xinxiang stations respectively. It is clear from the table that Anyang station had the maximum annual temperature 33.4 ºC. The highest and lowest mean annual temperature during 1980-2010 was found in Xingtai at the rate of 27.56 ºC with 2.6 SD and in Yushe was 23.64 ºC with 2.26 SD. The highest coefficient of variation (CV) of the temperature was detected in Xingtai station at the rate of 12.65, while the lowest CV of 9.62 was observed at Xinxiang. The average variation of the temperature over the complete river basin was 11.65%.

Analysis of max: temperature on Seasonal basis by Mann-Kendall and Sen's Slope:

Seasonal trends of temperature at different stations during the period of 1980-2010 are presented in figure 2. Trends of temperature are considered statistically significance at the 5% level by using the Mann-Kendall test. Both increasing and decreasing trends in maximum and minimum temperature during 1980-210 on seasonal basis were found. Figure 2(a)

shows the both positive and negative trends in maximum temperature during the 1980-2010 on Mann- Kendall basis. Almost there were positive trends in four seasons but during summer in Xingtai station and in winter season at Xinxiang there are negative trends.

The maximum temperature was increased in Taiyuan at 5% significance level during the three decades. Figure 2(a) depicts that two stations Taiyuan and Yushe showed high temperature throughout four seasons from 1980-2010. It is clear from the Figure 2(a) that the temperature during autumn was less and similar at Changzhi, Shijiazhuang and Xingtai stations but during winter temperature increased at these stations with Changzhi station. Figure 2(b) shows positive and negative trends in maximum temperature on Sen's Slope basis. Results based on Mann-Kendall and Sen's Slope presented same positive and negative trends of maximum temperature during three decades. Sen's estimator method also present negative trend in maximum temperature in Xingtai station during summer and at Xinxiiang station in winter season Figure 2(a). No significance variation was found in the Sen's slope but figure shows maximum temperature was increased in Yushe station during an autumn season. [28] Emphasized on the importance of increase and improve global communication about climate extreme research. Global warming has adverse effects in arid and semi-arid regions where precipitation is the main key factor for social and agricultural development. In 2006, global mean surface temperature ranged between 0.42 to 0.54°C [29,30] Also noted northwest China is more sensitive with respect to changes in temperature.

Analysis of min: temperature on Seasonal basis by Mann-Kendall and Sen's Slope:

Trends in minimum temperature at the eight stations during three decades on Mann-Kendall basis are shown in Figure 2(c). The results indicated increasing trends in minimum temperature at all stations and during four seasons except Yushe station in spring season. Figure 2(c) presented same increasing trend in all seasons at the eight stations. Minimum temperature was found in Yushe station in all seasons while maximum in Taiyuan station during 1980-2010. Figure 2(d) showed the results of analysis of minimum temperature on Sen's slope. Results showed same trends flow as shown in the analysis of minimum temperature on the basis of Mann-Kendall. Sen's slope also shows negative trends in Yushe during spring season. From figure 2(a to d) it is clear that during three decades temperature in Yushe station was stable and there is no big variation in temperature both maximum and minimum while other remaining seven stations faced global warming during 1980-2010. Sen's slope test showed in case of minimum temperature maximum temperature trends

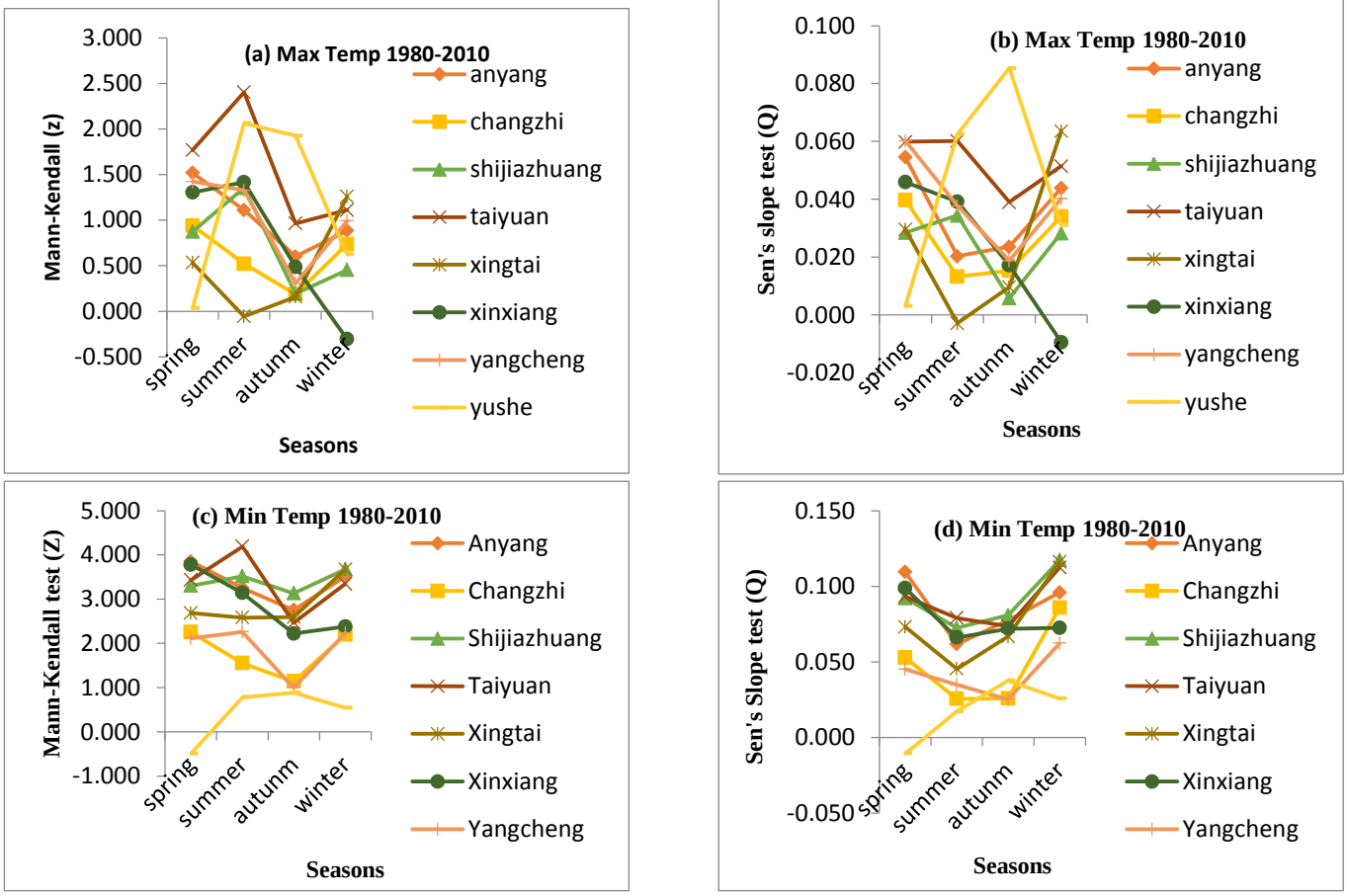

Figure 2: Seasonal analysis of (Maxi: and Min: temp) on the basis of Mann-Kendall and Sen's slope

was increased at Shijiazhuang, Xingtai and Taiyaun stations in winter season. Both test depicted that minimum temperature
was in Shijiazhuang and Xingtai stations and represented same positive trend during winter season for the study period.
Annual (Max and Min) temperature on the basis of Mann-Kendall and Sen's Slope
Results of annual maximum temperature on the basis of Mann-Kendall and Sen's Slope are presented in figure 3(e). Figure 3 showed there are increasing trends in the maximum temperature at all eight weather stations during 30 years. Mann-Kendall and Sen;s slope tests showed positive trends with different magnitude of temperature at all stations but both tests showed Taiyuan station have more temperature during 1980-2010. While figure3 (f) highlights the trends of minimum temperature on the basis of Mann-Kendall and Sen's Slope methods. Results of the Mann-Kendall and Sen's tests for the annual minimum temperature showed increasing trends at all stations. During the period of analysis the annual minimum temperature at Xingtai, Shijiazhuang and Taiyuan stations showed increasing trends
Results on Monthly Maximum and Minimum Temperature:
Monthly trends of maximum temperature obtained by statistical methods are given in Table 2. From the results, positive and negative trends were observed at various stations at 5% significance level. The maximum negative trend in maximum temperature was found in September and January respectively at 65% and 50% of the stations. The maximum positive trends with 5% significance level were observed in February and March at 50% rates of the stations.

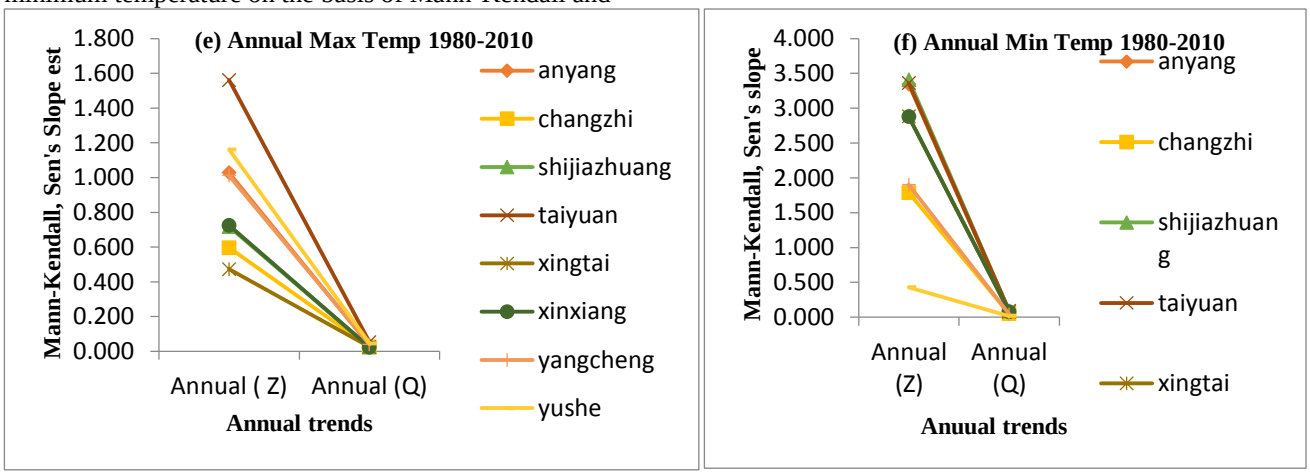

Figure 3: Annual analysis of (Maxi: and Min: temp) on the basis of Mann-Kendall and Sen's slope
***Statistically significant trends at the 5% significance level**

Results shows that during these two months three same stations Changzhi,Taiyuan and Yangcheng had positive trends of the maximum temperature at 5% significant level. From the statistical results during three decades maximum negative trends in the temperature started in the September and the maximum positive trends started in January at 50% rate of stations. Xinxiang station showed maximum negative trend of maximum temperature (-1.258) with the slope of -0.05°C°/month in January month and minimum trend was observed at Shijiazhuang station (-0.068) with slope of -0.003°C°/month during September. Taiyuan and Yangcheng stations had maximum positive trends of maximum temperature of 2.48 with 5% significance level. It is also observed that Yangcheng station had maximum 5% significance level in the months of February, March and June during 1980-2010. Table 3 shows the statistical results of minimum temperature from 1980-2010 through Mann-Kendall and Sen;s slope. Except at Yushe station all the other seven remaining stations had positive trends in minimum temperature significantly or insignificantly. Maximum number of stations that have significant positive trends at 5% was observed in August at Xingtai, Xinxiang and Yangcheng stations. Results of statistical analysis of minimum temperature showed that Yangcheng station had maximum positive trends at 35% rate of the stations while Xingtai had 25% rate of stations. Results also exhibited that positive trends with high and low magnitude was observed in Yangcheng station (2.54 at 5% significance) with slope of 0.051°C°/month during December and (2.00 at 5% significance) with slope of 0.025°C°/month in May month. Statistical results obtained by Mann-Kendall and Sen's slope showed that negative trends of minimum temperature was observed in Yushe station While other stations had positive trends of temperature. Increasing trend of temperatures has results to an exceptional numbers of droughts and these droughts create critical conditions for agriculture in the China [31, 32].

Table 2 - Statistical Results on Maximum Temperature by Mann-Kendall and Sen's Slope over (1980-2010) on Monthly Basis.

Station	Test	January	February	March	April	May	June	July	August	September	October	November	December
Anyang	Z_Z	0.374	2.07*****	2.61	1.122	0.81	2.75	-0.37	0.95	-0.442	1.156	1.088	0.204
	Z_Q	0.02	0.095	0.116	0.026	0.022	0.057	-0.009	0.013	-0.015	0.040	0.046	0.016
Changzhi	Z_Z	-0.170	2.24*****	2.51*****	0.306	0	1.39	0.13	0.03	-0.731	0.680	0.612	0.136
	Z_Q	-0.008	0.105	0.115	0.006	-0.002	0.035	0.005	0.000	-0.023	0.029	0.040	0.005
Shijiazhuang	Z_Z	-0.272	1.597	1.75	-0.119	0.98	1.64	1.63	0.78	-0.068	0.646	0.000	0.034
	Z_Q	-0.010	0.093	0.072	-0.006	0.020	0.050	0.039	0.014	-0.003	0.02	0.000	0.001
Taiyuan	Z_Z	-0.136	2.37*****	2.48*****	1.156	1.66	2.99	2.88	1.32	0.884	0.646	1.360	1.088
	Z_Q	-0.004	0.118	0.099	0.035	0.046	0.092	0.063	0.026	0.025	0.021	0.071	0.040
Xingtai	Z_Z	1.088	1.93	1.80	-0.204	0	0.33	-0.13	-0.37	-0.646	0.476	0.646	0.748
	Z_Q	0.048	0.111	0.097	-0.009	0.000	0.007	-0.007	-0.009	-0.015	0.015	0.029	0.031
Xinxiang	Z_Z	-1.258	1.155	1.97*****	0.272	1.66	2.71	1.15	0.37	0.204	1.394	-0.136	-0.816
	Z_Q	-0.05	0.060	0.085	0.005	0.048	0.082	0.026	0.009	0.009	0.050	-0.008	-0.038
Yangcheng	Z_Z	0.204	2.22*****	2.48*****	1.054	0.73	2.10*****	0.98	0.88	-0.510	0.612	0.816	0.544
	Z_Q	0.006	0.097	0.125	0.026	0.030	0.056	0.028	0.009	-0.016	0.027	0.046	0.018
Yushe	Z_Z	0.170	1.35	1.15	-0.374	-0.67	1.73	2.61	1.83	1.93	1.802	2.039*****	0.340
	Z_Q	0.010	0.076	0.056	-0.023	-0.023	0.040	0.083	0.065	0.053	0.090	0.112	0.008

***Statistically significant trends at the 5% significance level**

Table 3 - Statistical Results on Minimum Temperature by Mann-Kendall and Sen's Slope over (1980-2010) on Monthly Basis.

Station	Test	January	February	March	April	May	June	July	August	September	October	November	December
Anyang	Z_Z	3.17	2.99	4.04	3.56	3.94	3.87	2.92	2.95	3.39	2.99	1.86	4.38
	Z_Q	0.061	0.127	0.142	0.092	0.094	0.081	0.057	0.047	0.073	0.092	0.068	0.100
Changzhi	Z_Z	1.26	3.26	3.63	1.43	1.69	1.16	2.17*	1.33	1.34	0.75	1.33	2.07*
	Z_Q	0.038	0.147	0.101	0.030	0.028	0.017	0.042	0.018	0.036	0.012	0.030	0.073
Shijiazhuag	Z_Z	3.85	3.97	3.26	2.71	3.92	4.26	3.26	3.02	4.04	3.29	2.05*	3.19
	Z_Q	0.120	0.152	0.118	0.071	0.087	0.083	0.081	0.053	0.088	0.086	0.069	0.080
Taiyuan	Z_Z	3.19	3.36	3.50	2.78	4.01	3.94	4.35	4.28	3.97	2.31*	1.12	3.46
	Z_Q	0.085	0.144	0.110	0.088	0.082	0.073	0.096	0.068	0.113	0.068	0.040	0.109
Xingtai	Z_Z	3.36	4.41	3.33	1.80	2.92	2.03*	3.53	2.17*	2.65	3.05	2.07*	3.22
	Z_Q	0.102	0.159	0.104	0.054	0.061	0.047	0.058	0.031	0.064	0.070	0.066	0.087
Xinxiang	Z_Z	1.33	2.99	3.70	3.34	4.283	4.07	2.85	2.48*	2.88	2.34*	1.43	2.82
	Z_Q	0.022	0.125	0.127	0.079	0.090	0.098	0.063	0.037	0.069	0.087	0.060	0.071
Yangcheng	Z_Z	1.22	2.92	3.39	0.95	2.00*	1.71	2.65	2.41*	2.07*	0.75	0.17	2.54*
	Z_Q	0.032	0.104	0.092	0.017	0.025	0.026	0.051	0.027	0.044	0.026	0.006	0.051
Yushe	Z_Z	0.03	1.12	0.27	-1.17	-0.58	-1.78	2.65	1.48	1.86	1.5	-0.71	0.48
	Z_Q	0.000	0.065	0.012	-0.033	-0.011	-0.027	0.058	0.021	0.077	0.068	-0.033	0.012

CONCLUSIONS

The basic purpose of this study was to analysis the monthly and seasonal temperature trends and assess the impact of global warming in the Zhanghe river basin during 1980-2010. Results obtained by Mann-Kendall and Sen's slope tests demonstrated that trends in maximum and minimum temperature on monthly and seasonal basis during the study period are comparatively homogeneous. Both positive and negative trends were observed at different significant levels. In this study 5% significance level was used. According to results, it was found that except Yushe station all stations were have positive trends of temperature and it shows that due to global warming these trends increased with different magnitude at every stations during three decades of study. Increasing tendency of trends in temperature resulting in increasing tendency of water stress and such kind of water stress create drought conditions. [33-35] realized that higher temperatures results to increased evapotranspiration reduced the stream flow and create drought situations. Statistical results showed that from 1980-2010 maximum negative trends in temperature was found in the September and maximum positive trends were in January at 50% rate of stations. This work would be helpful to work out on the drought, flood, agricultural and environmental planning related with climate change in the Zhanghe river basin.

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