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Original Research

Study on Recent Trends of Climate Variability Using Innovative Trend Analysis: The Case of the Upper Huai River Basin

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Abstract

The upper part of the Huai River basin is spatially extensive, with pronounced environmental gradients driven primarily by precipitation and temperature on broad scales. Therefore, it is an ideal region in which to examine the climate dynamics of the region. This study investigates the annual precipitation and temperature time serious variability, at six designated representative stations, by using the innovative trend analysis method (ITA), Mann-Kendall (MK) and Sen's slope test estimator. The result showed that the trend of annual precipitation was slightly decreasing in Xiangcheng (Z = -2.04), Zhumadian (Z= -0.43), Gushi (Z = 0.26), Xinyang (Z = -2.22), and Xichong (Z = -0.59) stations. Increasing trend was observed only in Fuyang station (Z = -0.97). Summer is characterized by high temperature and its major rain season in the study area, which contributes about 49.3% of total rainfall. In all stations the trend of annual temperature in Xiangcheng (Z = 6.72), Zhumadian (Z = 7.04), Gushi (Z = 6.96), Fuyang (Z = 7.07), Xinyang (Z = 7.04) and Xichong (Z = 2.85) sharply increased. The average air temperature has significantly increased by 1.2ºC during the past 56 years. The ITA was found to be reliable and consistent as MK and Sen's slope test estimators for the study region. Furthermore, ITA can present the data in graphical format for better understanding of the results through detecting a sub trend series. Therefore, this study can be an inordinate resource to other researchers for studying climate variability and their impacts to eco-hydrology using the ITA method.

Keywords: precipitation, temperature, innovative trend analysis (ITA), upper Huai River basin

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Introduction

Over the last century, the global mean surface temperature has increased by about 0.74°C [1-7]. The decade of the 2000s was the warmest decade, with 2005 and 2010 being the warmest years in more than a century of global records [8]. Recently, climate change is exerting a growing impact on water resources in China [9-10]. In June 2007, the Chinese government released China's National Climate Change Program, making water resources a key target area for the country to address the climate change challenge [10]. Countermeasures and goals were also specified in the document. Global climate change is also a potential factor, which directly affects China's future national security and sustainable social, economic and ecological development [11].

Precipitation and temperature are two of the most important variables in the field of climate science and hydrology frequently used to trace the extent and magnitude of climate change and variability [12]. Scholars emphasized that in countries where their economy is heavily dependent on low-productivity rain-fed agriculture, rainfall trends and variability are frequently mentioned factors in explaining various socioeconomic problems [13-14]. As a result, investigating the spatio-temporal dynamics of these meteorological variables is very crucial, so as to provide input for policymakers and practitioners that help to make informed decisions.

It has been noted that trend analysis of climatic variables has recently received a great deal of consideration from researchers [15-27]. Characterization of the intra-and inter-annual spatio-temporal trend of meteorological variables in the context of a changing climate is vital to assess climate-induced changes and suggest feasible adaptation strategies [28-30]. As a result, careful observation, recording and analysis of meteorological data is very essential. The long-term climatic change related to changes in precipitation patterns, rainfall variability, and temperature are most likely to increase the frequency of droughts and floods in the Huai River basin [31].

The upper Huai River basin is a suitable area to study climate change impacts. The area is characterized by a unique geographical future. The geomorphology is very special, where the percentage of the mountain is smaller while farmland is larger. The climate of the area is special as it lies between the southern and northern parts of the hemisphere. The area is known by its water shortage and distorted ecosystem function [32]. The area is spatially extensive, with pronounced environmental gradients driven primarily by precipitation and temperature on large scales. Situated in a subtropical monsoon zone, the upper Huai River basin is a transitional belt from a humid region to a semi-arid one [33]. Though fairly abundant, its rainfall is mainly concentrated in the flood season and varies significantly from year to year. Natural disasters such as droughts and flooding are frequent occurrences. Uneven spatial and temporal distribution of water resources and deteriorating water quality has caused a huge impact on people's lives and on industrial and agricultural production throughout the region [34].

Therefore, it is an ideal region in which to examine climate patterns in order to get compressive information regarding the climatic conditions of the study basin, which helps to predict the fate of the hydrological system and ecology of the study area. The hydro-climatic changes can also lead to a shift in hydrology parameters, ecosystem and river conditions in these areas.

Thus this study aims to investigate recent serious changes in annual precipitation and temperature from 1960 to 2016 using historical climatic data and multiple trend test parameters – innovative trend analysis method (ITA), Mann-Kendall (MK) and Sen's slope estimator test – to bring accuracy and to compare the reliability of an ITA with that of MK and Sen's slope test estimators results. ITA is a recently introduced trend analysis method which was introduced by Sen, 2014 [35] for water resources. Numerous researchers have used the ITA to analyze the time series data together with other test estimators. For instance, monthly trends of precipitation have been analyzed in different parts of Turkey using ITA, and four significant trends at two provinces and trends of monthly precipitation on 25 different stations were investigated by ITAM and found a decreasing and increasing trend in Algeria on Macta watershed as indicated by [36]. Thus, ITA has been widely used and is an applicable method in comparison to MK. Subsequently, no study has yet been undertaken to analyze climate variabilities over the upper Huai River basin using the innovative trend test estimator. Is detection of climate variability using ITA reliable to the study area? Such studies would improve our understanding of the existence of dynamic relationships between climate variables in order to make a planning decision and take climate change adaptation measures to protect the eco hydrology of the basin.

Study Area

The upper Huai River basin is located between the Yellow River (Huanghe) and the Yangtze River (Changjiang) – the two longest rivers in China – with an area of approximately 30,937 km^2 in eastern China. The western, west-south and northeast part of the Huai basin is the Funiu, Dabie and Yimeng Mountains, respectively, accounting for approximately 33.3% of the total area (Fig. 1). The basin features the continental monsoon climate of temperate zone, characterized by synchronization of high temperature and ample precipitation. The annual average precipitation is 883 mm, but the spatiotemporal distribution is markedly

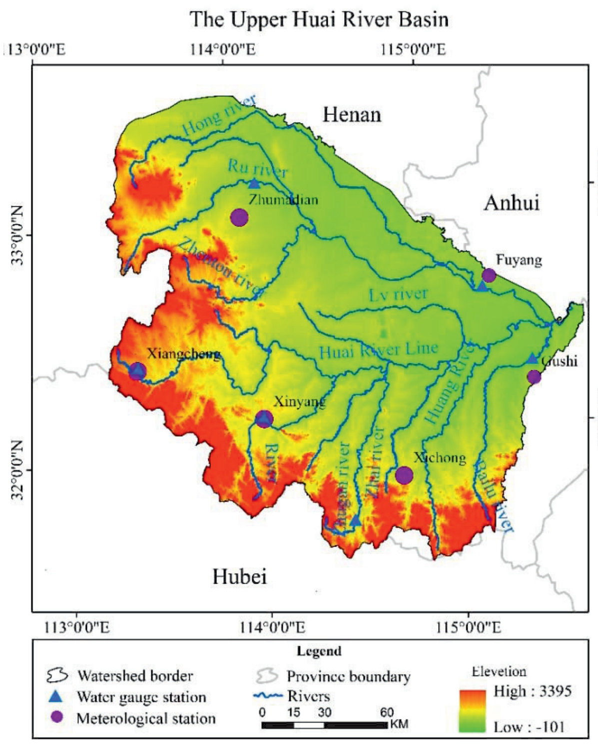


Fig. 1. Map of the upper Huai River basin .

uneven. Annual average water surface evaporation ranges between 900~1500 mm. The annual average temperature is 11~16ºC, and the annual average frost-free period is 200~240 days. In this study, the study area selected was the watershed above the Wan Jia Ba Hydrological Station on the upper stream of the Huai River, situated between 115°35′~49°32′E and 32°25′~40°27′N. [37].

Materials and Methods

Data Source

For this study, climatic data were gathered from six different representative meteorological stations located throughout the upper Huai River basin. The compatibility of the data were compared with the data obtained from the National Centers for Environmental Information, NOAA's National and Centers for Environmental Information (NCEI) hosts. The time series are 56 years long (from 1960 to 2016). Table 1 provides the locations of these meteorological stations. Monthly data were derived from daily data, and the annual data were derived from the monthly data. The 56-year period investigated was considered long enough to ascertain reliable climatic conclusions for which to reveal the true state of temporal precipitation and temperature changes that have occurred in the upper part of the Huai River basin.

To provide insight into the variability of extreme precipitation, the year was divided into four seasons: winter (December, January, and February), spring (March, April, and May), summer (June, July, and August), and autumn (September, October, and November). To select climate stations in the study basin, the following factors were taken into consideration: 1) location and dispersion of stations; 2) capacity of stations; 3) physic-geographical regionalization of the stations; and 4) whether it is close to the upper part of the river system and has the tenacity to represent the study basin (Table 1).

Methods

Analyses of long-term trends in both the observed and adjusted data were done using the Mann-Kendall test, with linear changes in the data represented by Kendall-Theil robust lines. Trend analysis is used to investigate whether the trend is upward, downward, or no trend in data value points. The non-parametric Mann-Kendall (MK) test has been applied in most studies to detect the trends in hydro-meteorological observations that do not need the normal distribution of data points. This paper used the innovative trend analysis method (ITA) to detect the trends in precipitation and temperature time series data. To evaluate the reliability of ITA the results were compared with MK and Sen's slope estimator test. In addition, annual and seasonal precipitation temperature variability time series data were investigated by ITA. The study region has four distinct seasons: summer (June-August), autumn (September–November), winter (December-February)

Table 1. Representative meteorological station information.

Station name	Elevation (m)	Latitude N	Longitude E	Annual mean Precipitation (mm)	Annual mean temperature (ºC)
Xiangcheng	149.1	32.383333	113.416667	1124.69	15.37
Zhumadian	82.7	33,533333	114.016667	953.42	15.12
Gushi	42.9	32.166667	115.616667"	1064.62	15.64
Fuyang	60.5	31.733333	116.5"	910.07	15.34
Xinyang	68.1	31.493333	116.316667"	839.09	15.52
Xichong	71.5	31.566667	114.116667	1089.32	15.77

and spring (March-May). Significance levels at 10%, 5%, and 1% were taken to assess the climate time's series data by MK, ITA, and Sen's slope estimator method. 10% was considered as a threshold level to show a significant trend.

Mann-Kendall Trend Test

The Mann-Kendall (MK) test method is a ranked non-parametric test used to analyze trends of hydro-meteorological series. The method also shows upward and downward trends with statistical significance. The strength of the trend depends on the magnitude, sample size, and variations of data series. The trends in the MK test are not significantly affected by the outliers occurring in the data series since the MK test statistic depends on positive or negative signs [38].

Annual and seasonal data series were used for trend analysis in this study. The trends of annual precipitation and temperature were analyzed.

Individual time series data of climate and discharge were compared with all corresponding time series data of the year. When the data point of later years is larger than the data point of the previous year, the MK statistics are increased by one, otherwise the MK statistics are decreased by one. Thus, the MK statistics is the cumulative result of all the data values. The Mann-Kendall test statistics "S" is then equated as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\left(x_j - x_i\right) \tag{1}$$

The trend test is applied to x_i data values ($i = 1,2,...n - 1$) and x_j ($j = 1,2,...n - 1$). The data value of each x_i is used as a reference point to compare with the data value of x_j, which is given as:

$$sgn\left(x_j - x_i\right) = \begin{cases} +1 \text{ if } \left(x_j - x_i\right) > 0 \\ 0 \text{ if } \left(x_j - x_i\right) = 0 \\ -1 \text{ if } \left(x_j - x_i\right) < 0 \end{cases} \tag{2}$$

…where x_j and x_i are the values in period j and i. When the number of data series greater than or equal to 10 ($n \geq 10$), MK test is then characterized by a normal distribution with the mean $E(S) = 0$ and variance $Var(S)$ is equated as:

$$E(S) = 0 \tag{3}$$

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

…where m is the number of the tied groups in the time series, and t_k is the number of ties in the kth tied group.

Test statistics Z is as follows:

$$Z = \begin{cases} \dfrac{s-1}{\delta} & \text{if } S > 0 \\ 0, & \text{if } S = 0 \\ \dfrac{s+1}{\delta} & \text{if } S < 0 \end{cases} \tag{5}$$

Although positive values of Z indicate increasing trends, negative values show decreasing trends. When testing upward or downward monotonic trends at the α significance level, the null hypothesis was rejected for an absolute value of Z greater than $Z1-\alpha/2$, which is found from the normal cumulative distribution tables.

When Z is greater than zero, it indicates an increasing trend and when Z is less than zero, it is a decreasing trend.

Innovative Trend Analysis Method (ITA)

ITA has been used in many studies to detect hydro meteorological observations, and its accuracy has been compared with the results of the MK method. In ITAM, the hydro meteorological observations were classified into two classes and then the data points arranged independently in increasing order. Then the two halves were placed on a coordinate system (x_i : i = 1,2,3,...$n/2$) on X-axis and (x_j : $j = n/2 + 1, n/2 + 2,...n$) on Y-axis. If the time series data on a scattered plot are collected on the 1:1 (45°) straight line, it indicates no trend. However, the trend is increasing when data points accumulate above the 1:1 straight line and decreasing trend when data points accumulate below the 1:1 straight line.

The mean value difference between x_i and x_j could give the trend magnitude of data series. The first observed data point was not considered in this study when classifying the time series data into x_i and x_j data plots since the total number of observed data points were 56 years from 1960-2016. The direction of the trend is also affected by x_i data series. The trend indicator of ITA is multiplied by 10 to make the scale similar with the other two tests. The trend indicator is given as:

$$\phi = \frac{1}{n}\sum_{i=1}^{n} \frac{10\,(x_j - x_i)}{\mu} \tag{6}$$

…where ϕ = trend indicator, n = number of observation on the subseries, x_i = data series in the first half subseries class, x_j = data series in the second half subseries class and μ = mean of data series in the first half subseries class.

A positive value of ϕ indicates an increasing trend. However, a negative value of ϕ indicates a decreasing trend. However, when the scatter points closest around the 1:1 straight line, it implies the non-existence of a significant trend.

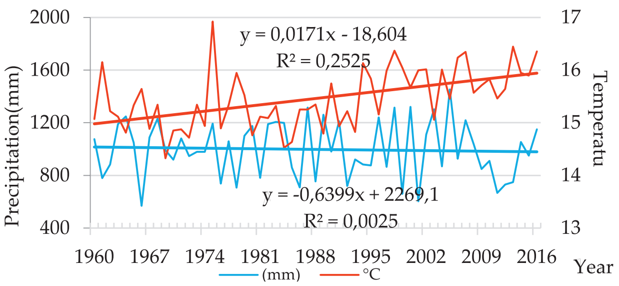


Fig. 2. Annual mean precipitation and temperature of the study region (1960-2016).

Sen's Slope Estimator Test

The trend magnitude is calculated by [39] slope estimator methods. The slope Q_i between two data points is given by the equation:

$$Q_i = \frac{x_j - x_k}{j - k}, for\ i = 1,2, \ldots N \tag{7}$$

…where x_i and x_k are data points at time j and ($j>k$), respectively. When there is only a single datum in each time, then $N = \frac{n(n-1)}{2}$; n is number of time periods. However, if the number of data in each year is many, then $N < \frac{n(n-1)}{2}$; n total number of observations. The N values of slope estimator are arranged from smallest to biggest. Then the median of slope (β) is computed as:

$$\beta = \begin{cases} Q[(N+1)/2] & \text{when } N \text{ is odd} \\ Q[(N/2) + Q(N+2)/(2)/(2)] & \text{when } N \text{ is even} \end{cases} \tag{8}$$

The sign of β shows whether the trend is increasing or decreasing.

Results and Discussion

Monthly, Seasonal Annual Variability of Precipitation

Annual mean precipitation of the study region from 1960 to 2016 was found to be 996.87 mm. Minimum and maximum recorded annual average precipitation is 1940.5 and 366.8 mm respectively. A histrionic decreasing trend of precipitation was observed during 1966 and 2011. On the other hand, a little increasing trend was observed (R^2 = 0.0025) during 2005 (Fig. 1). The summer season is characterized by heavy rainfall. The seasonal precipitation varied from spring 234.07 mm to summer 492.85 mm, autumn 198.99 mm to winter 73.44 mm (Table 2).

The annual trend analysis of precipitation in all stations using MK, ITA, and Sen's slope estimator test result are presented in Table 3. The MK curve annual

Table 2. Monthly and seasonal precipitation across stations.

Months, season	Xiangcheng	Zhumadian	Gushi	Fuyang	Xinyang	Xichong	Average Precipitation (mm)	Z-Score
January	23.45	17.62	30.50	22.83	14.88	22.59	21.98	(-1.1)
February	34.28	24.58	42.38	32.49	22.37	39.06	32.53	(-0.91)
March	54.41	45.80	72.94	53.50	41.47	60.37	54.75	(-0.51)
April	82.99	63.32	84.54	61.44	74.11	97.72	77.35	(-0.1)
May	109.38	86.25	102.66	85.23	92.04	136.19	101.96	0.33
June	167.24	122.26	154.43	136.30	111.89	159.02	141.86	1.05
July	218.30	203.76	214.22	204.68	175.78	248.81	210.93	2.3
August	174.28	159.31	125.27	116.06	133.34	132.10	140.06	1.02
September	118.20	104.91	88.617	86.97	81.23	73.16	92.18	0.16
October	72.81	62.48	67.18	54.71	56.15	66.10	63.24	(-0.36)
November	47.73	39.26	54.27	44.41	36.13	39.54	43.56	(-0.71)
December	20.78	17.31	25.15	18.54	13.96	17.83	18.93	(-1.16)
Spring	246.79	195.38	260.14	200.20	207.62	294.28	234.1(23.4%)	2.72
Summer	559.83	485.34	493.93	457.05	421.01	539.94	492.8(49.3%)	7.4
Autumn	238.75	206.66	210.07	186.11	173.53	178.81	198.9(19.3%)	2.09
Winter	78.52	59.53	98.03	73.87	51.22	79.49	73.4(7.3%)	(-0.17)

Note; the numbers in the brackets for z score indicates low precipitation rates

Table 3. Results of Z-statistic of MK, IT (ϕ), and Sen's slope estimator test (β).

S/No.	Name of stations	Z (MK)	ϕ	β
1	Xiangcheng	-2.04	-0.33	-2.55
2	Zhumadian	-1.43	-0.60	-2.20
3	Gushi	-1.07	-0.35	-1.30
4	Fuyang	0.97*	1.02	0.75
5	Xinyang	-2.22	-0.32	-2.04
6	Xichong	-0.59	-0.11	-0.61
7	Average	−0. 48	−0.14	−0. 71

* Trends at 0.1 significance level; ** Trends at 0.05 significance level; *** Trends at 0.01 significance level.

precipitation (changing parameters) shows a sharp decreasing trend in Xiangcheng from 2009 to 2013 (Z = -2.04) and in Zhumadian from 1992 to 2013 (Z = -1.43). A high-pitched decreasing trend was observed in Gushi from 2001 to 2014 (Z = -1.07), and a similar trend was found in Xiyang and Xichong station, whereas a statistically significant increasing trend was observed only in Fuyang sation from 1983 to 2009 (Z = 0.97***). Overall, a statistically significant decreasing trend was observed in all six stations from 1979 to 2013 (Z = -0.48) (Fig. 3). The trend in ITA test shows an increasing trend in Fuyang and a decreasing trend in other stations. Hence, the increase and decrease in innovative trend analysis ϕ test value predict that the magnitude becomes strong and weak, respectively.

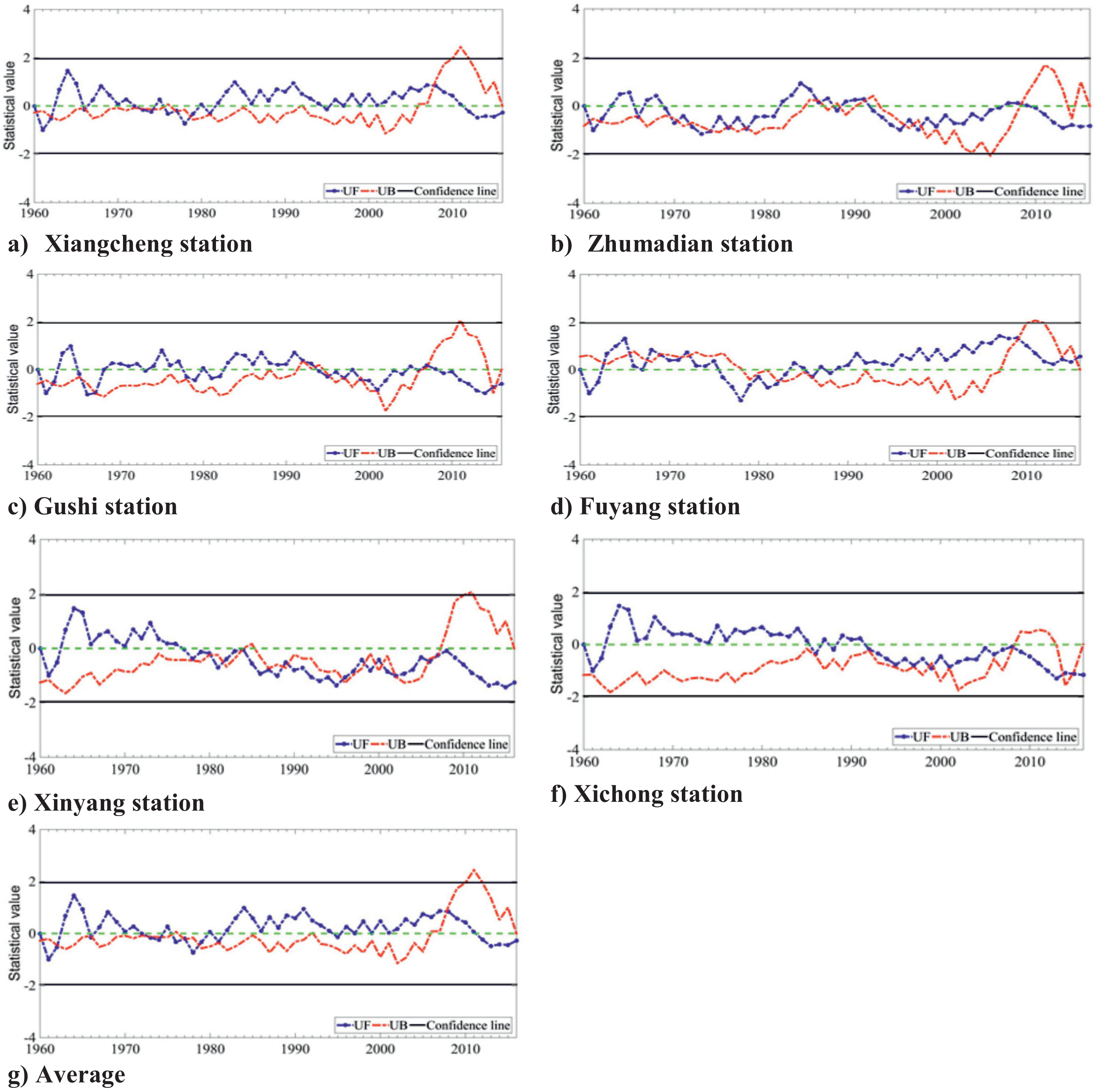


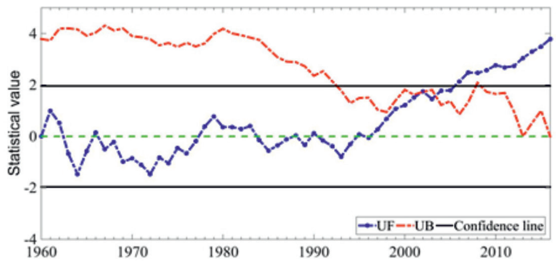
Fig. 3. Trends of annual precipitation across stations (note: UF and UB are changing parameters where UB = -UF).

Both positive and negative trends were observed by the MK test, ITA and Sen's slope estimator, in seasonal and annual average precipitation, in the study area, and displays temporal variations [40]. This is in good agreement with observations in different parts of China [41]. In the study basin, there is a general decreasing trend of precipitation. As a result, the expected decrease in rainfall will possibly cause a reduction in water availability in the future [42]. A decrease in precipitation during the wet period can have severe effects on the hydrological cycle, and water supply for ecosystems and the people [43]. Summer is the major rain season in the study area, which contributes about 49.3% of the total rainfall, which clearly revealed the presence of a high concentration of rainfall. The short rainy season,

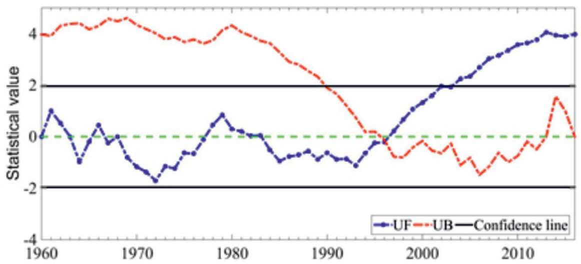
Table 4. Results of Z-statistic of MK, IT (ϕ), and Sen's slope estimator test (β).

S/No.	Name of stations	Z (MK)	ϕ	β
1	Xiangcheng	6.72***	0.3	0.017
2	Zhumadian	7.04***	0.45	0.021
3	Gushi	6.96***	0.46	0.081
4	Fuyang	7.07***	0.36	0.015
5	Xinyang	8.12***	0.38	0.021
6	Xichong	8.73***	0.45	0.024
7	Average	7.12***	0.36	0.019

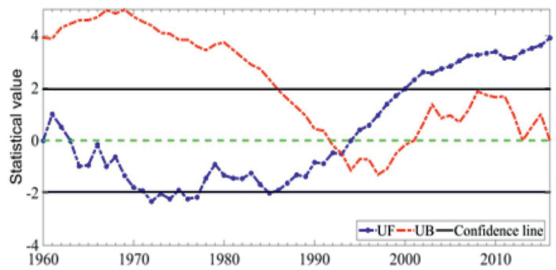
* Trends at 0.1 significance level; ** Trends at 0.05 significance level; *** Trends at 0.01 significance level.



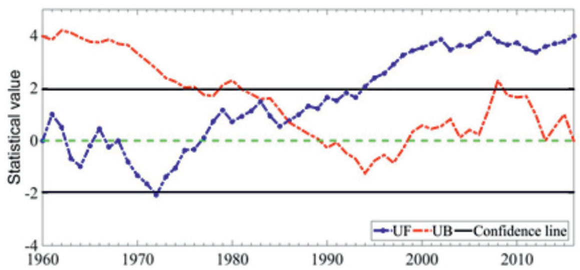
a) Xiangcheng station



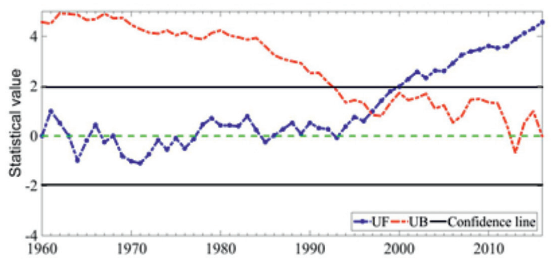
b) Zhumadian station



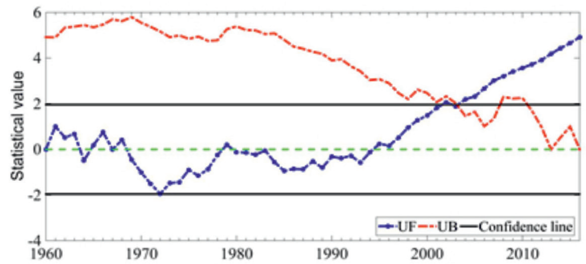
c) Gushi station



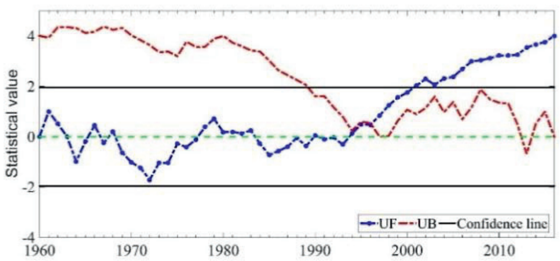
d) Fuyang station



e) Xinyang station



f) Xichong station station



g)Average

Fig. 4. Trends of annual temperature across stations (note: UF and UB are changing parameters where UB = -UF).

which lasts from December to February (winter), contributes a light amount of rainfall of around 7.3% of the total rainfall. The results of light precipitation intensity showed that winter is more vulnerable to the occurrence of prolonged drought events [44]. Different trend analysis studies have been conducted in China at different spatio-temporal scales and came up with mixed results using different trend test parameters. Sun et al. (2018) revealed a statistically significant increasing trend of temperature, whereas the case for precipitation was mixed. Also in the present study, comparable results were found [45].

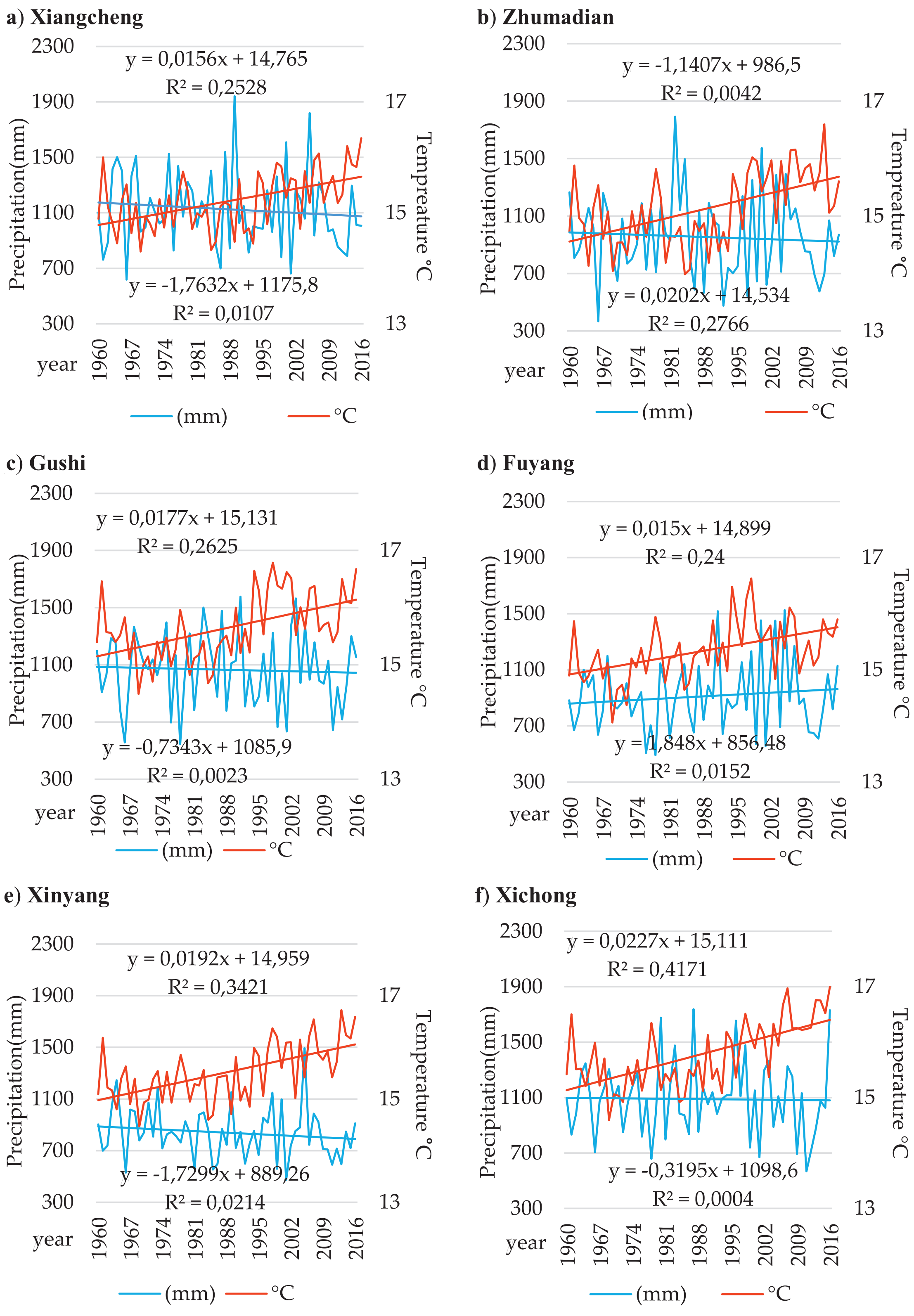


Fig. 5. Temperature and precipitation trends for 1960-2016.

Analysis of Mean Annual Temperature from 1960-2016

The MK curve annual temperature (changing parameters) shows a statistically sharply increasing trend in Xiangcheng from 1993 to 2016 (Z = 6.72), and a similar increasing trend was observed in Zhumadian station from 1994 to 2016 (Z = 7.04), a statistically sharp increasing trend in Gushi station from 1985 to 2016 (Z = 6.96), in Fuyang station from 1973 to 2016 (Z = 7.07), in Xinyang station (Z = 8.12) from 1970 to 2016 and in Xichong station (Z = 8.73) from 1973 to 2016 were observed. Overall, an average statistically significant increasing trend was detected in all stations (Z = 7.12) (Fig. 3).

The annual trend analysis of temperature in all stations using MK, ITA, and Sen's slope estimator test results is presented in Table 4. The trend in the IT test shows an increasing trend in all stations. Hence, the increase and decrease in innovative trend analysis ɸ test value predicts that the magnitude becomes strong.

An increase in temperature is among the indices of global climate change. The global average temperature has increased by 0.85ºC from 1880 to 2012, and this may even accelerate in the near future [46]. The temperature of worldwide large inland water bodies has been rapidly warming since 1985 at an average rate of 0.045±0.011ºC/year and with the highest rate of 0.10±0.01ºC/year [47]. There has been an observed abruptly increasing trend of mean annual temperature in the upper reaches of the Huai River basin by 1.2ºC or 0.021ºC/year during the deliberated historical period from 1960 to 2016. This is almost twice as much as the global average warming rate of 0.012ºC/year [48]. The annual average temperature of the study basin was found to be 15.5ºC. A dramatic increase in temperature was observed from 1990 onwards. The increasing trend of air temperature may result from global warming, due to the greenhouse effect, "urban heat island", and long-term climate variability. In the study basin, the magnitude of temperature during summer season was higher. Also, Gu et al. (2017) found that both significance and magnitude of an increasing trend for air temperature in summer seasons were larger than those in other seasons [49].

The long-range anomalies of mean annual temperature showed inter-annual variability, while the trend after 1990 was higher than the long-term average, which is evidence for the presence of a warming trend since the last decade of the 20th century [50]. MK, ITA and Sen's slope estimator test results revealed that the annual average temperatures have been significantly increasing. The overall increase in annual temperature in the study area is, therefore, largely attributed to an increase in the minimum temperature. The empirical result agrees with the views of respondents – particularly the dwellers around the study basin – which has confirmed the increasing trend of temperature through

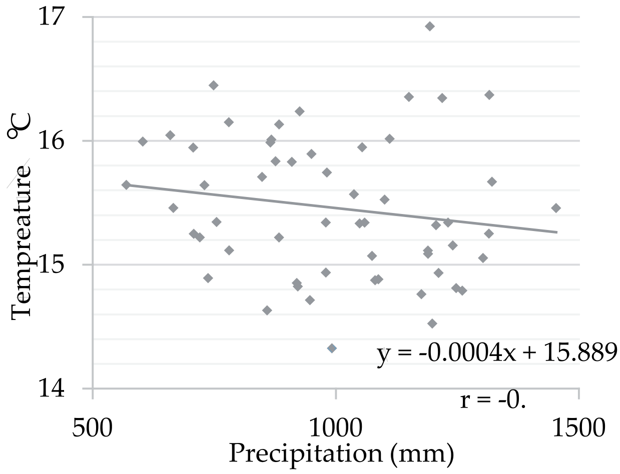


Fig. 6. Correlation between precipitation and temperature.

time. The temperature and precipitation time serious variability within the representative six stations shows a different value (Fig. 4).

Correlation between Temperature and Precipitation

The relationship between temperature and precipitation is negative (Fig. 5). They are weakly correlated (r = -0.17) from 1960 to 2016. During this period, precipitation has decreased. Conversely, temperature has increased sharply since 1990, which implies that when the temperature is increased, the rainfall amount decreases. This could be, when there is high range of temperature in the region, it directly affects the eco-hydrology patterns. In the essence of climate change, a warmer atmosphere increases the evaporation rate from land, resulting in more moisture circulating throughout the troposphere. Hence, it is expected to have more intense precipitation events, and longer and more severe droughts [51-52]. Therefore, the vegetation system in the area is found to be distorted and then it affects the hydrology system [53-55]. This in turn affects the precipitation pattern, and rainfall becomes variable, erratic and declining in the region. In fact, a change in the precipitation quantity results in changes in runoff and affects groundwater recharge rates, which in turn affect the water supply. In terms of the agricultural demand, both rained and irrigated crops may face soil moisture deficits associated with low precipitation [56-57].

Conclusions

In the present study, the time serious trends in mean annual precipitation and temperature variability were analyzed using the innovative trend test (ITA), Mann–Kendall trend test (MK), and Sen's slope test estimator. ITA was employed for the first time in the study region to analyze variability and time series trends of precipitation and temperature. Thus ITA was found to be as efficient, reliable and consistent an estimator as MK and Sen's slope test estimators. Furthermore, ITA can present the data in graphical format for better understanding of the results through detecting sub-trend series. From the result, we can conclude that precipitation in the study area is characterized by high coefficient of variation (CV>1.5), erratic, declining and concentrated into summer season. Mean annual precipitation has revealed a statistically significant declining trend. A statistically significant increasing trend was observed only in Fuyang station during the period from 1960 to 2016. Conversely, temperature showed an increasing trend in all representative stations.

This implies that there have been significant changes in rainfall and temperature patterns, which designates the occurrence of climate change in the study region. It is, therefore, imperative to adjust the water consumption activity, with the variability situation and design planned climate change adaptation strategies, and reducing all carbon emission mechanisms so as to enhance adaptive capacity by taking the declining and erratic nature of rainfall, and the increasing trend of temperature into consideration. This helps to use the available basin water resources rationally, and as a result it could help the ecology of the basin acquire optimal stream flow by allocating more water resource to the ecology. Since the upper part of the Huai River basin has unique climatic features, it is vital to conduct more climatic research and study their impact on the hydrology and ecosystem in detail using more stations, and the ITA method with multiple statistical models, and this study can be an inordinate resource to other researchers.

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Conflict of Interest

The authors declare no conflict of interest.

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