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Research Article

Trends of Hydroclimate Variables in the Upper Huai River Basin: Implications of Managing Water Resource for Climate Change Mitigation

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The present study attempted to investigate the trends of mean annual temperature, precipitation, and streamflow changes to determine their relationships in the upper Huai river basin. The Mann–Kendall (MK), Sen's slope test estimator, and innovative trend detection (ϕ) (ITA) methods were used to detect the trends. According to the findings, average annual precipitation shows a descending trend ($\phi = -0.17$) in most stations. An increasing trend was found only in Fuyang station ($\phi = 1.02$). In all stations, the trends of mean annual temperature ($\phi = 0.36$) were abruptly increased. During the past 57 years, the mean air temperature has considerably increased by 12°C/10a. The river streamflow showed a dramatic declining trend in all stations for the duration of the study period (1960–2016) ($\phi = -4.29$). The climate variability in the study region affects the quantity of the streamflow. The river streamflow exhibits decreasing trends from 1965 onwards. The main possible reason for the declining stream flow in the study area is the declining amount of precipitation on some specific months due to the occurrence of climate change. The outcomes of this study could create awareness for the policymakers and members of the scientific community, informing them about the hydroclimatic evolutions across the study basin, and become an inordinate resource for advanced scientific research.

1. Introduction

On land and water surface, global mean temperatures have increased over the past three spans [1]. According to the records that have been going for more than a century, the 2000s was found to be the warmest decade while the years 2005 and 2010 were the hottest periods. Global hydrological cycles and water resource distribution are significantly affected by human-induced "greenhouse effects" that result in the change in climates across the globe [2]. Climate change affects the entire water cycle. Both surface and underground waters are equally exposed to changes in water quantity and quality. Natural disasters have occurred frequently in China such as droughts, floods, and typhoons, in which flooding is the most destructive causing substantial financial, human, and environmental damages. In recent years, climate change had an emergent effect on water resources in China [3]. The government of China declared China's National Climate Change Program, by preauthorizing water resources as a key regional goal for the country to address the climate change challenge [4]. Countermeasures and goals were also specified in the document. Global climate change is also a potential factor that directly affects China's future national water security and that can impact sustainability of social, economic, and ecological development [5].

Water resources and river hydrology systems are widely determined by climate and intensely modified by human actions [6]. Climate change disturbs river streamflow, predominantly from side-to-side precipitation and through the changes of potential evaporation [6, 7]. Human activities, such as reservoir buildings, land use/cover change, and direct water withdrawal from surface water and groundwater, modify river streamflow. For water abstraction, water resource administrations and planning quantifying the magnitude of climate change are an important task in order to make accurate and relevant decisions. Currently, through the aggregate inadequacy of water resources, decision makers, and policymakers, and the hydrologists have paid significant consideration to how much of the detected transformation in annual streamflow can be accredited to climate variation [8].

Studying the trends of precipitation temperature and streamflow has infinite use for scientists identifying the spatial and temporal variability and management of inadequate water resources for future economic development. Analyzing the trends of hydroclimate variables is also vital to research looking into the effects of climate change in water resources forecasting and management. Some studies suggest that the alterations of hydroclimate variables demonstrate a highly assorted pattern in spatial-temporal trends at regional and global scales because of the natural resource difference. Moreover, these climatic variabilities will have unforeseen consequences with respect to the frequency and intensity of temperature and precipitation variability [9, 10].

The upper Huai river basin is an appropriate region to explore climate variation influences on the watershed. The area is known for its water shortage and for the distorted functioning of its ecosystem function. The region is spatially all-encompassing, with prominent environmental gradients primarily driven by precipitation and temperature on a broad scale. The upper Huai river basin is a transitional zone from a humid region to a semiarid one [11]. Though fairly abundant, its precipitation is principally concentrated in the flood season and varies significantly from year to year. Natural catastrophes like flooding and droughts have frequently occurred in the basin. Irregular spatial and temporal dissemination of water resources and flagging water quality has caused a huge impact on industrial, agricultural production and people's lives throughout the region [12].

Therefore, it is a crucial area to detect the hydroclimate patterns, in order to get compressive information regarding the hydrology of the study basin, which helps to predict the fate of the hydrological system and ecology of the study area. Due to the fact that the hydroclimatic variation is able to cause a change in the ecosystem, hydrology parameters and rivers conditions in the region should be studied. However, there are many studies conducted in the upper Huai river basin, regarding hydroclimate variability, but study would help to get adequate data regarding the current condition of the river basin using different method, especially the innovative trend analysis method, which was recently introduced by Sen, 2014, and has never been used before in our study area [13].

The overall value of this study is enhanced by its innovative use of acceptable methods of research in the field. The investigation into time serious changes of annual streamflow, precipitation, and temperature beginning combines historical hydroclimatic data from 1960 to 2016 with multiple trend test estimators (Mann–Kendall (MK), innovative trend analysis method (ITA), and Sen's slope estimator test) to bring accuracy and to assure the reliability of the results by using different widely acceptable methods [14]. The specific objectives of this study are (1) to analyze the relationships and trends of climate variables and streamflow for the past 56 years and (2) to assess the temporal variability of temperature, precipitation, and streamflow.

2. Materials and Methods

2.1. Study Site. Among the largest rivers in China, the upper Huai river is a major portion of the Huaihe river basin, which is located in the eastern part of China. The study basin is located in between 31°57′N~34°50′N and 113°56′E~116°15′E with an area coverage of 30,937 km^2 [15]. The mean annual precipitation of the region is 883 mm, with an uneven distribution pattern. The mean annual surface water evaporation occurs between 600 and 1500 mm. The region has an average air temperature ranging from 11 to 16°C. The area is known for its water shortage and for the distorted functioning of its ecosystem. The river crosses three provinces: Henan, Anhui, and Hubei (Figure 1). The region is spatially all-encompassing, with prominent environmental gradients primarily driven by precipitation and temperature on a broad scale. Plains and hills are the dominant topography, with plains areas accounting for about 70%. Land cover types in the Huai river basin is comprised of wetlands, grasslands, forests, barren land, constructed land, and cropland [15].

2.2. Data Sources. For the current study, climatic and hydrological data from 1960 to 2016 were obtained from the record of nine different representative meteorological stations and six water gauge stations located across the study basin. The time series is 57-year extended data (from 1960 to 2016).

Climatic conclusions disclose the factual conditions of historical precipitation and temperature fluctuations that have occurred in the Huai river basin.

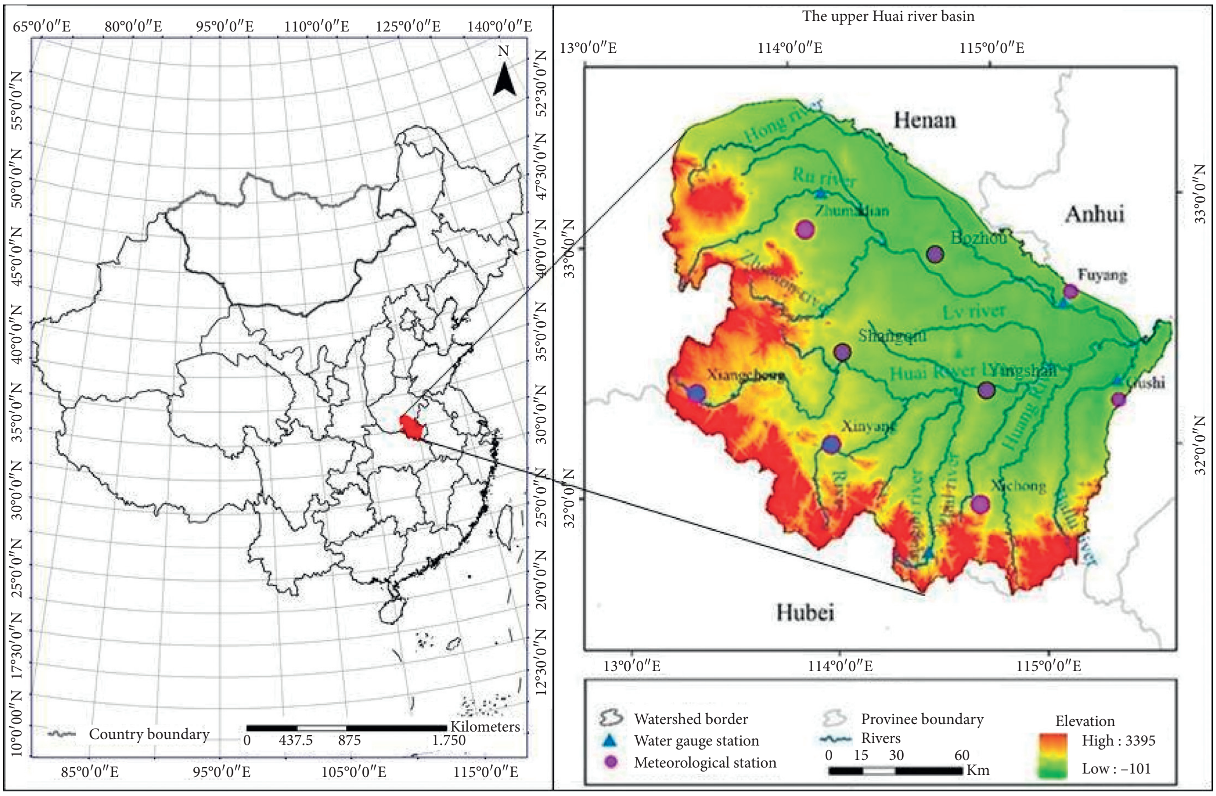


Figure 1: Locations map of the study area.

2.3. Methods of Data Analysis. Trend analysis is used to examine whether the trend is ascending, descending, or if there is no trend data value point. The following trend analysis methods, innovative trend analysis method, Mann–Kendall test, and Sen's slope estimator, were used to detect the various trends of climate and river discharge in the periods from 1960 to 2016. Innovative trend analysis method (ITA) divides a time series into two equal parts, and it sorts both subseries in ascending order [16]. The Mann–Kendall trend test (MK) proposed by Kendall and Mann is a nonparametric test [17]. The MK is also used to quantify the significance of trends in hydrometeorological time series. This method does not require the data to be normally distributed and has a low sensitivity to outliers in the time series. Sen's slope estimator is the magnitude of the trend computed by slope trend detection methods [18]. To assess the hydroclimate variables time series data, significance levels at 1% (0.01), 5% (0.05), and 10% (0.1) were considered. MATLAB was used to run the statistical test.

2.3.1. Mann–Kendall Trend Detection. The Mann–Kendall (MK) test method is a nonparametric test used to investigate trends of hydrometeorological time series data. The Mann–Kendall (MK) test 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 statistics depends on positive or negative signs [16, 17].

In the present study, we used to detect the annual precipitation and temperature time series data.

The Mann–Kendall test statistics "S" is given as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}\left(x_j - x_i\right),$$
$$\operatorname{sgn}\left(x_j - x_i\right) = \begin{cases} +1, & \text{if } \left(x_j - x_i\right) > 0, \\ 0, & \text{if } \left(x_j - x_i\right) = 0, \\ -1, & \text{if } \left(x_j - x_i\right) < 0, \end{cases} \tag{1}$$

where x_j and x_i represent the data points in periods j and i. While the amount of data series is larger than or equivalent to ten ($n \geq 10$), MK test is then categorized by a standard distribution with the mean $(S) = 0$ and variance var (s) is given as [19]

$$E(s) = 0,$$
$$\operatorname{Var}(s) = n(n-1)(2n+5) - \sum_{K=1}^{m} t_k\left(t_k - 1\right)\left(2t_k + 5\right), \tag{2}$$

where m is the number of the tied groups in the time series and t_k is the number of ties in kth tied group. From this, the test Z-statistics is obtained using an approximation as follows:

$$Z = \begin{cases} \frac{s-1}{\delta}, & \text{if } S > 0, \\ 0, & \text{if } S = 0, \\ \frac{s-1}{\delta}, & \text{if } S < 0. \end{cases} \quad (3)$$

Positive values of Z indicate an increasing trend; however, negative values show decreasing trends. When testing upward or downward monotonic trends at α significance level, the null hypothesis was rejected for an absolute value of Z greater than $Z_1 - \alpha/2$ which is found from the normal cumulative distribution tables.

A positive z value indicates an increasing trend whereas a negative z value indicates a decreasing trend.

In time sequence, the statistics is defined independently:

$$UF_k = \frac{dk - E(dk)}{\sqrt{\operatorname{var}(dk)}}, \quad (K = 1, 2, \ldots, n). \quad (4)$$

Initially, given the confidence level α, if the $UF_k > UF\alpha/2$, this indicates that the sequence has a significant trend. Then, the time sequence is arranged in reverse order. According to the equation calculation, one makes

$$\begin{aligned} UB &= -UF_k \\ &= n + 1 - k. \end{aligned} \quad (5)$$

As a final point, UB_k and UF_k are drawn as UB and UF curve. If there is an intersection between the two curves, the intersection is the start of the change [20].

2.3.2. Sen's Slope Trend Detection. The magnitude of the trend is computed by slope trend detection methods [18, 21]. For two data points, the slope Q_i is equated as

$$Q_i = \frac{x_j - x_k}{j - '}, \quad \text{for } i = 1, 2, \ldots, N, \quad (6)$$

where x_j and x_k stand for data points at the phase j and $j > k$, respectively, where there is single datum for each period at time; then, $N = (n-1)/2$, where n is the number of time periods. However, if the amount of data for each year is numerous, at that time $N < (n-1)/2$; n is the total number of observations. N values in the slope trend test detector are arranged from the lowest to the largest. The median of slope (β) is equated as

$$\beta = \begin{cases} Q\left[\frac{(N+1)}{2}\right], \\ Q\left[\frac{N}{2} + Q\frac{(N+2)/(2)}{(2)}\right]. \end{cases} \quad (7)$$

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

2.3.3. Innovative Trend Detection. Innovative trend detection method (ITA) has been widely used to detect the trends of meteorological variables. The ITA divides a time series data into two equal parts and it categorizes both subseries in ascending direction. Then after that, the two halves are placed on a coordinate system ($i = 1, 2, 3, \ldots, n/2$) on X-axis and (x_j: $j = n/2 + 1, n/2 + 2, \ldots n$) on Y-axis. If the time series data on a scattered plot is collected on the 1 : 1 (45) straight line, this indicates no trend. On the other hand, the tendency is increasing, once data points gathered beyond the 1 : 1 straight line and the tendency is declining when data points gathered below the 1 : 1 straight line.

The mean value difference among x_i and x_j can give the tendency magnitude of the data series. The total number of experimental data points for this study was 57 years from 1960 to 2016. The ITA is equated as

$$\phi = \frac{1}{n} \sum_{i=1}^{n} \frac{10\left(x_j - x_i\right)}{\mu}, \quad (8)$$

where ϕ represents the trend indicator, n stands for the number of observations on the subseries, x_i is the data series in the first half subseries class, x_j is the data series in the second half subseries class, and μ represents the average data series in the first half subseries class.

A positive and negative value of ϕ indicates an upward and downward trend, respectively. However, when the scattered points are close enough around the 1 : 1 conventional line, this indicates the absence of a significant trend [22–24].

3. Results

3.1. Trends Analysis of Air Temperature from 1960 to 2016. As presented by the MK curve, the annual temperature demonstrates a statistically abrupt upward trend in Xiangcheng in the period from 1993 to 2016 ($R2 = 0.11$) (Figure 2). Similarly, an increasing trend was observed in Zhumadian station from 1994 to 2016 ($Z = 7.04$), and statistically abrupt increasing trends 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, on average, a statistically significant increasing trend was detected in all stations ($Z = 7.12$) (Figure 2).

The results of the trend examination for mean annual temperature on all stations by using the MK, ITA, and Sen's slope estimator test present in Table 1. In all the trend test parameters, an increasing tendency was found in all stations. Therefore, the increase and decrease in the trend test parameters (ϕ, Z (MK), and β) determine that the magnitude turns out to be robust.

3.2. Trends Analysis of Precipitation. The annual average precipitation in the study basin from 1960 to 2016 was 996.87 mm per year ($R^2 = 0.028$). The minimum and maximum annual average precipitations were 1940.5 and 366.8 mm per year, respectively. A slightly downward trend

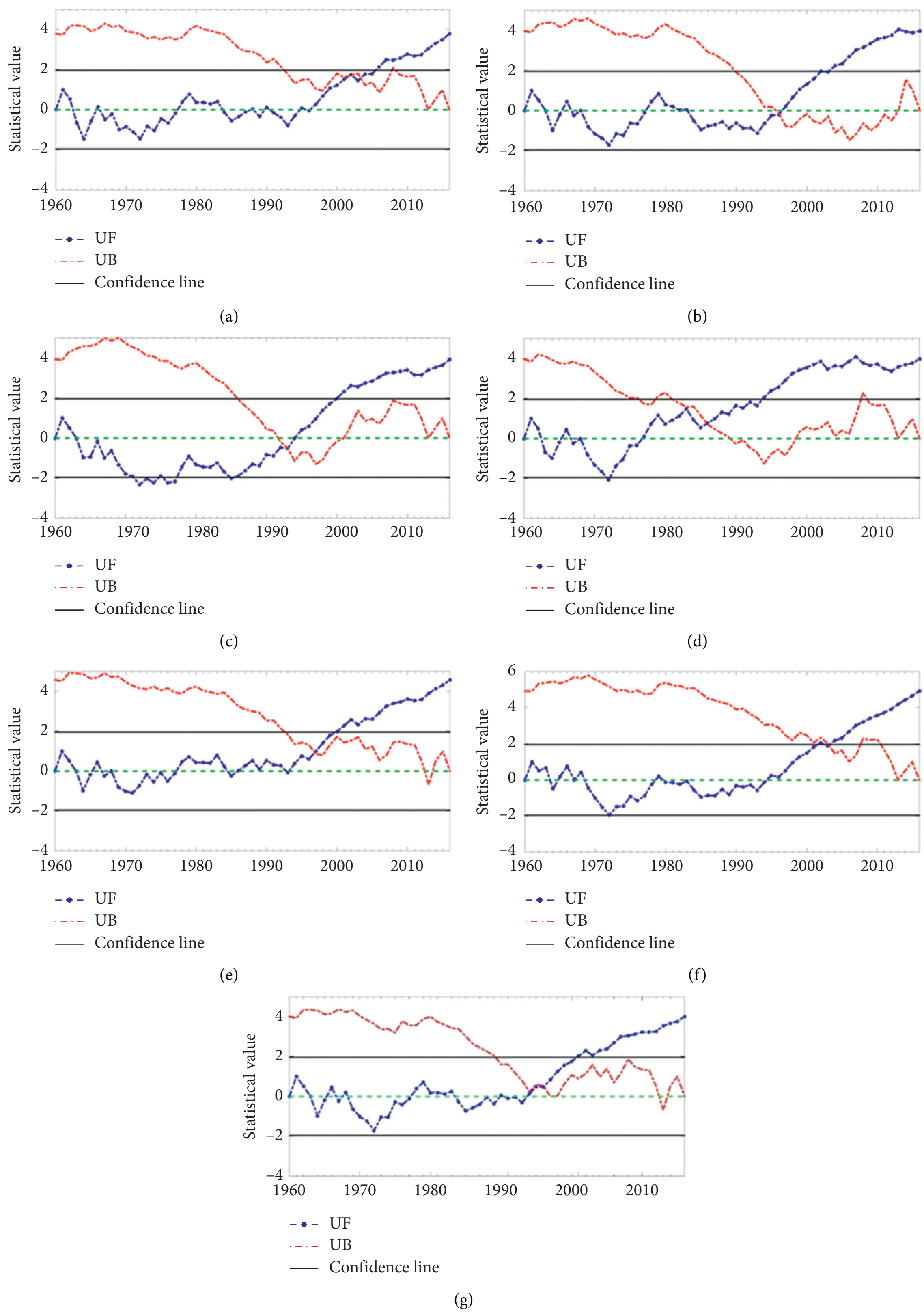


Figure 2: The trends of mean annual temperature through stations. (a) Xiangcheng station. (b) Zhumadian station. (c) Gushi station. (d) Fuyang station. (e) Xinyang station. (f) Xichong station. (g) Average condition.

Table 1: Z-statistic results of MK, ITA (ϕ), and Sen's slope estimator test (β).

Station's no.	Station's name	Z (MK)	(ϕ)	(β)
1	Xiangcheng	6.72***	0.30	0.017
2	Zhumadian	7.04***	0.45	0.021
3	Gushi	6.96***	0.46	0.018
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

***Tendencies at 0.01 significance level; * tendencies at 0.1 significance level; ** tendencies at 0.05 significance level.

of precipitation was detected for the duration of 1966 and 2016 (Table 2).

The summer season is characterized by heavy rainfall. Monthly trend analysis showed increasing order from January to December ($R^2 = 0.3$) and decreasing pattern that is exhibited for the seasons from spring to winter ($R^2 = 0.01$). The seasonal precipitation varied from spring 234.07 mm to summer 492.85 mm and autumn 198.99 mm to winter 73.44 mm per year (Figure 3).

The results from the trend examination of mean annual precipitation across all the stations by using MK, ITA, and Sen's slope estimator test are presented in Table 3. As presented by the MK curve, the annual precipitation demonstrates a statistically abrupt downward trend in Xiangcheng in the period from 2009 to 2013 ($Z = -2.04$) and in Zhumadian from 1992 to 2013 ($Z = -1.43$), while a high-pitched downward trend was detected in Gushi from 2001 to 2014 ($Z = -1.07$). Likewise, a comparable trend was found in Xiyang and Xichong station. However, a statistically significant increasing trend was detected in Fuyang station from 1983 to 2009 ($Z = 0.97^{***}$). Generally, a statistically significant declining trend was detected in all six representative stations from 1960 to 2016 ($Z = -0.48$) (Figure 4). In all the trend test parameters, a downward tendency was found in all stations except Fuyang station. Through the increase and decrease in the trend test parameters (ϕ, Z (MK), and β) test rate, it can be determined that the magnitude is robust.

3.3. Analysis of Annual River Streamflow in the Upstream of Huai River Basin. As presented by the MK curve, the annual streamflow determines a statistically high-pitched downward trend in the period from 1960 to 2016. A statistically declining tendency is shown in Xiangcheng starting from 1970 to 2016 ($Z = -3.61$). Similarly, a significant declining tendency in Fuyang from 1965 to 2016 ($Z = -9.494$) and in Xinyang was detected with ($Z = -7.803$) from 1967 to 2016. Overall, downward trends were observed in all stations ($Z = -7.313$) (Figure 5). The results of mean annual river streamflow all over the stations by using the Mk, ITA, and Sen's slope estimator test are presented in Table 4. The trend test estimators show a uniform trend in all stations. River streamflow trend generally exhibited a downward trajectory from 1960 to 2016. Particularly, it shows a sharp decreasing trend in all stations since 1967.

3.4. Correlation Matrix between Climate Variables and River Streamflow. Precipitation and river streamflow had a resilient positive relationship in the studied periods ($R^2 = 0.66$) (Figure 6). It implies that the volume of the river discharge increases when the intensity of precipitation increases. The association factor between air temperature and river streamflow had a weak negative relationship in the study years ($R^2 = 0.36$). In this case, the volume of the river will decline while the air temperature increases which leads to a decline in river discharge. Figures 7 and 8 show that the river streamflow has a declining trend since 1965. This could show that when there is a high range of temperature in the region, it directly affects the ecohydrology patterns. In the principle of climate alteration, a warmer atmosphere escalates the evaporation degree from land, causing more moisture circulating all over the troposphere. Henceforth, it is anticipated to have more extreme precipitation events and severe and longer droughts [19]. As the vegetation system in the area is found to be distorted by drought, this adversely impacts the hydrology system [25–27]. This, in turn, affects the precipitation pattern, becoming variable, erratic, and declining in the region. In effect, a variation in the precipitation amount causes a change in streamflow/runoff and affects groundwater recharge degrees that have knock-on effects on water resources. For agricultural demand, both rained and irrigated crops could face soil moisture shortfalls related to low precipitation [10].

4. Discussion

In the study region, positive and negative tendencies were revealed by MK test estimator, IT analysis, and Sen's slope test estimator. According to the result of the trend analysis, the annual mean precipitation displays temporal variations. It lies in a good agreement with interpretations and studies in diverse parts of China [28–30]. The study basin exhibits an overall declining tendency of precipitation, and, accordingly, the anticipated reduction in precipitation determination will probably cause a decline in water accessibility in the future [13, 20].

A reduction in precipitation during the wet season could disturb the hydrological cycle and water resource supply for the ecological units and for society [31]. The summer season is the major rainy period in the study region. Average rainfall during this period subsidizes nearly 49.3% of the region's total precipitation showing the existence of high intensity of rainfall/snowfall. Also, during this season, there is optimum streamflow. The short rainy period, which lasts from December to February (winter), contributes to a light amount of precipitation around 7.3% of the total. The fallouts of light precipitation concentration revealed that wintertime is further susceptible to the incidence of persistent drought [32, 33]. Several trend exploration studies have been piloted in China at diverse spatiotemporal measures and approached with wide range of results using different trend test parameters. Some scholars found a comparable result with the present study. They have found a statistically substantial increasing trend of air temperature; however, the condition for precipitation was various.

Table 2: Seasonal and monthly precipitation through the stations.

Months and season	Xiangcheng	Zhumadian	Gushi	Fuyang	Xinyang	Xichong	Shangqiu	Yingshan	Bozhou	Mean precipitation (mm)	Z-score
Jan.	23.45	17.62	30.50	22.83	14.88	22.59	25.28	31.41	19.84	23.16	(−1.51)
Feb.	34.28	24.58	42.38	32.49	22.37	39.06	30.31	28.6	41.25	32.81	(−0.92)
Mar.	54.41	45.80	72.94	53.50	41.47	60.37	50.75	44.85	66.82	54.55	(−0.52)
Apr.	82.99	63.32	84.54	61.44	74.11	97.72	72.13	67.12	81.56	76.10	(−0.10)
May	109.38	86.25	102.66	85.23	92.04	136.19	87.72	89.24	111.81	100.06	0.32
Jun.	167.24	122.26	154.43	136.30	111.89	159.02	127.44	121.52	144.21	138.26	1.02
Jul.	218.30	203.76	214.22	204.68	175.78	248.81	177.96	174.23	206.94	202.83	2.1
Aug.	174.28	159.31	125.27	116.06	133.34	132.10	142.61	146.32	162.97	143.06	1.03
Sep.	118.20	104.91	88.617	86.97	81.23	73.16	85.28	81.19	79.94	88.81	0.14
Oct.	72.81	62.48	67.18	54.71	56.15	66.10	59.80	119.5	68.20	69.64	(−0.39)
Nov.	47.73	39.26	54.27	44.41	36.13	39.54	46.37	75.31	37.15	46.56	(−0.72)
Dec.	20.78	17.31	25.15	18.54	13.96	17.83	17.78	24.86	15.97	19.93	(−1.17)
Spring	246.79	195.38	260.14	200.20	207.62	294.28	233.45	191.54	201.89	225.36	2.67
Summer	559.83	485.34	493.93	457.05	421.01	539.94	490.23	498.37	513.47	495.63	7.5
Autumn	238.75	206.66	210.07	186.11	173.53	178.81	183.65	214.59	180.73	196.99	2.07
Winter	78.52	59.53	98.03	73.87	51.22	79.49	77.29	70.45	63.76	72.46	(−0.16)

Annotation: the values in the braces show lower precipitation amounts.

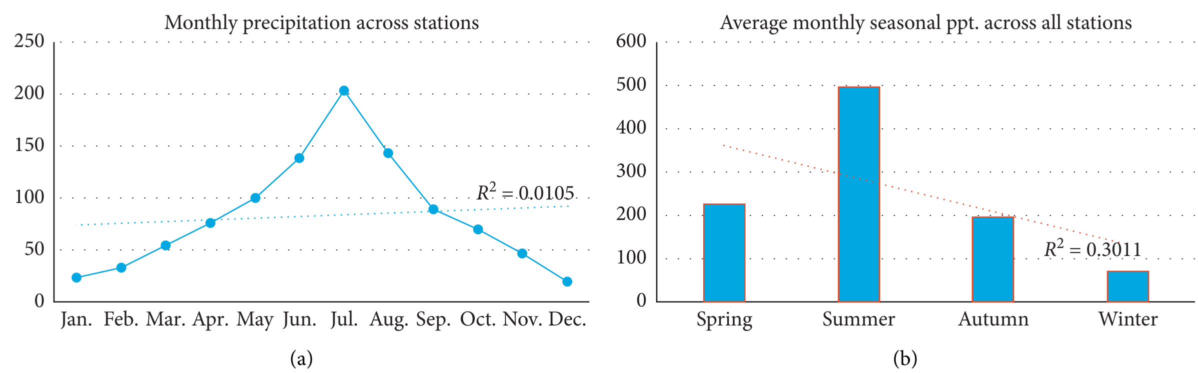


Figure 3: (a) Average monthly precipitation. (b) Average seasonal precipitation of the study area.

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

Station's no.	Station's name	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	Shangqiu	−1.75	−0.33	−1.41
8	Yingshan	−0.62	−0.29	−0.99
9	Bozhou	−0.32	−0.02	−0.30
10	Average	−0.80	−0.17	−0.96

MK = value of Mann–Kendall test; (ϕ) = value of innovative trend analysis; (β) = value of Sen's slope. *** Tendencies at 0.01 significance level; * tendencies at 0.1 significance level; ** tendencies at 0.05 significance level.

A rise in temperature is amongst the main indices of global climate transformation. The global mean air temperature has amplified by 0.85°C per year from 1880 onwards, which is expected to increase in the near future [34, 35]. The temperature of large inland water areas around the world has been promptly heating ever since 1980, by a rate of 0.05 ± 0.012°C/year and by the maximum rate of 0.1 ± 0.011°C/year [36]. There has been an abruptly upward trend of average annual air temperature detected in the upper reaches of Huai river basin via 1.2°C or 0.021°C/year during the deliberated chronological period from 1960 to 2016 (Figure 3(b)). This rise is virtually twofold compared to

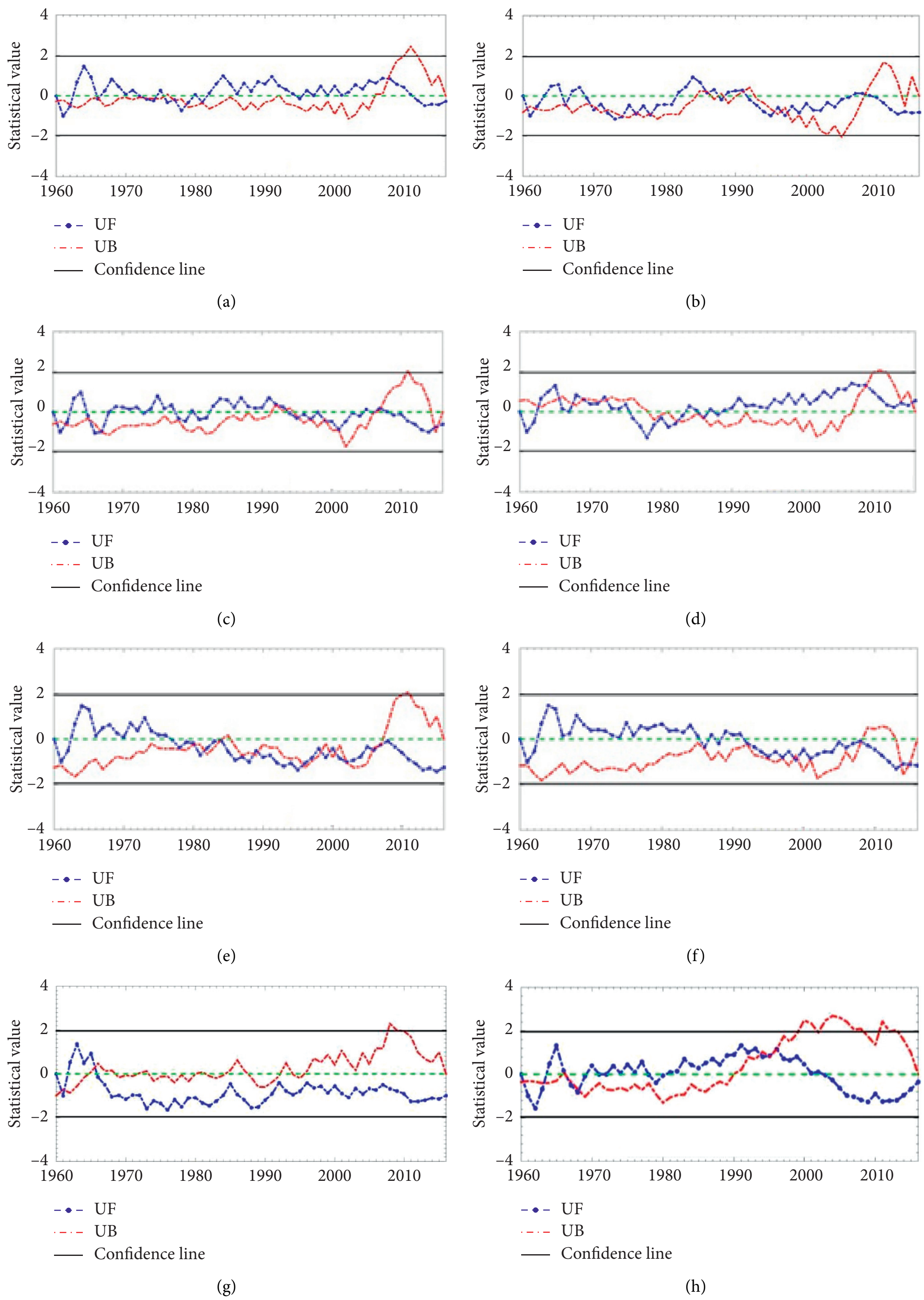


FIGURE 4: Continued.

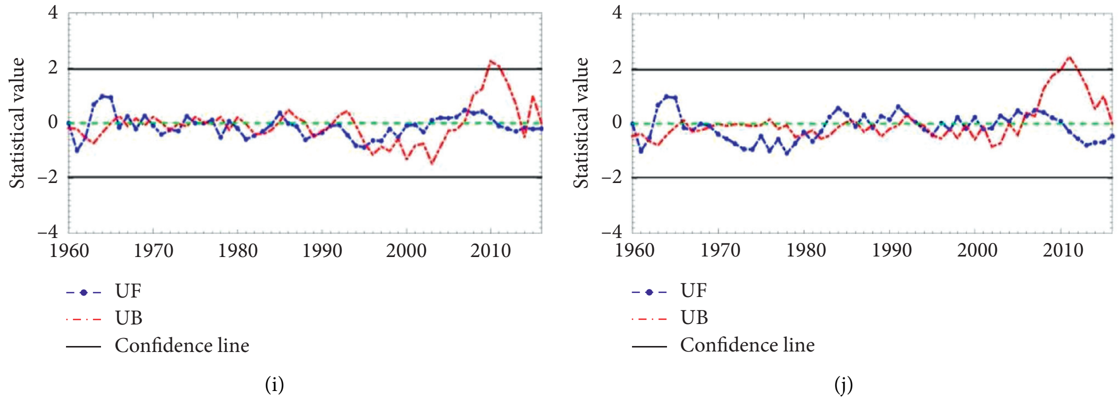
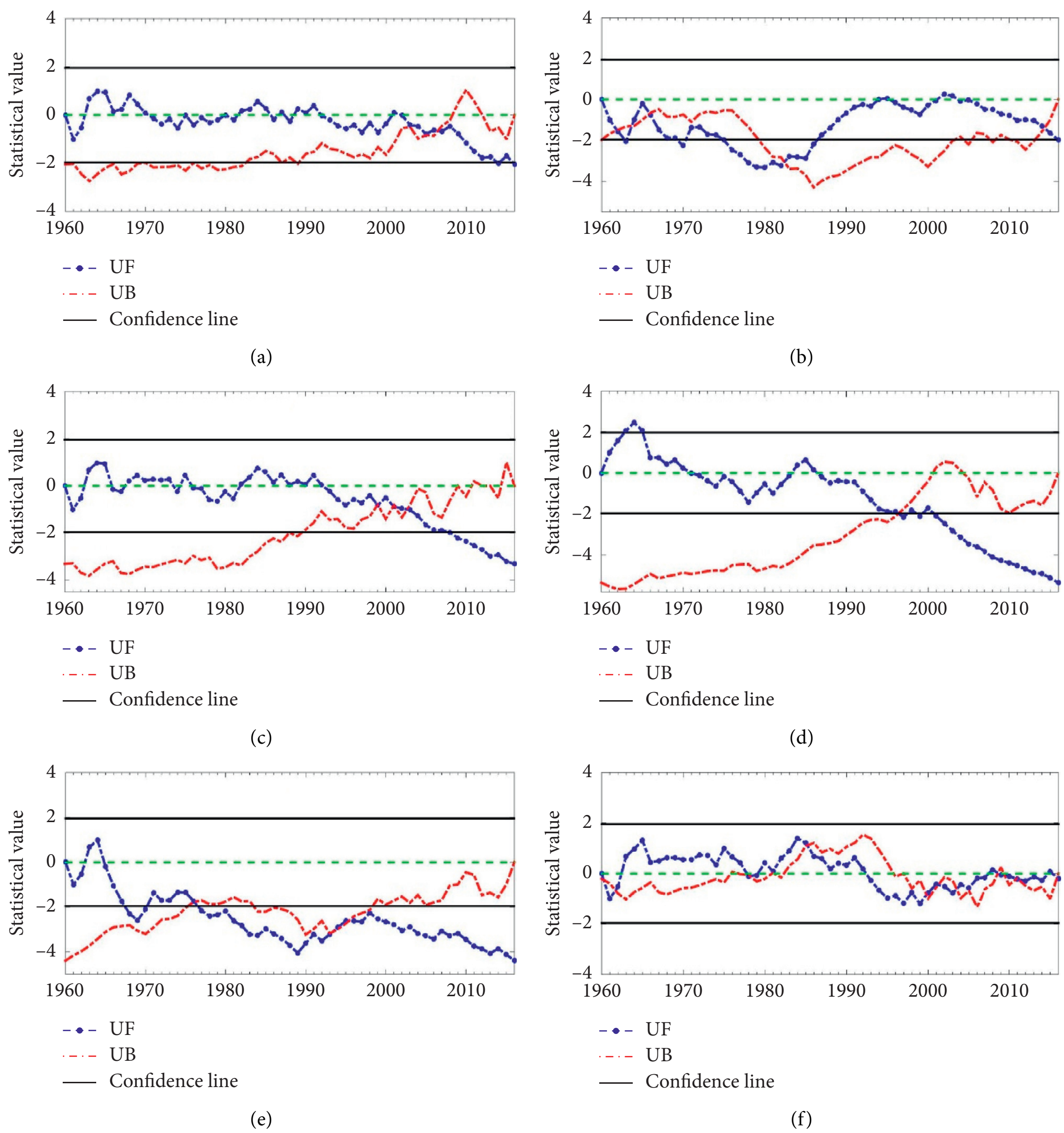


Figure 4: The trends of mean annual precipitation across stations. (a) Xiangcheng station. (b) Zhumadian station. (c) Gushi station. (d) Fuyang station. (e) Xinyang station. (f) Xichong station. (g) Shangqiu station. (h) Yingshan station. (i) Bozhou station. (j) Average condition.



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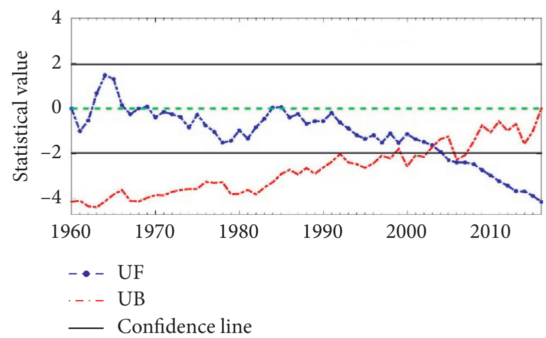


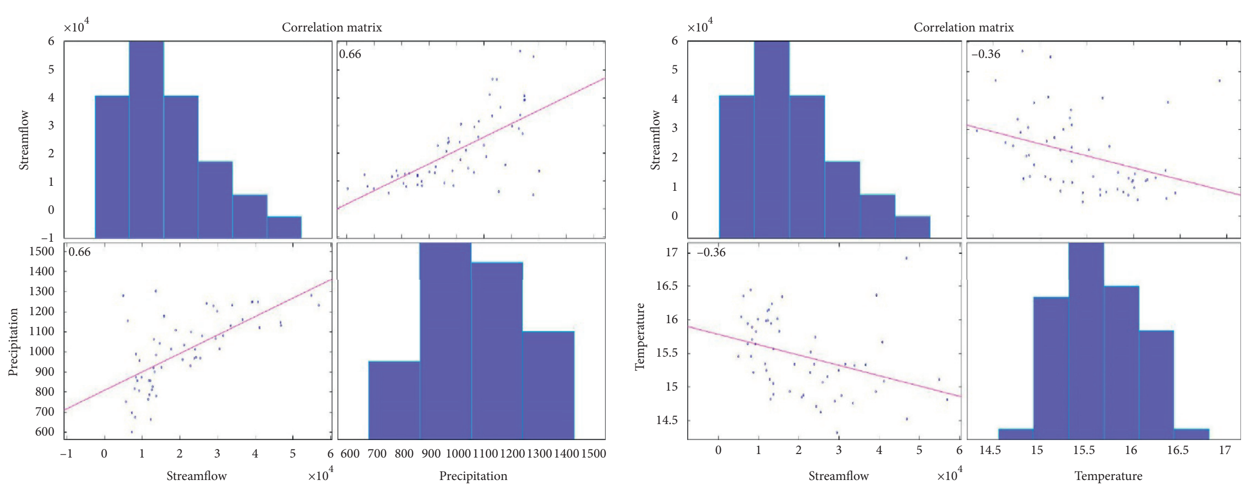
(g)

Figure 5: Change point analysis of mean annual streamflow through the stations. (a) Xiangcheng station. (b) Zhumadian station. (c) Gushi station. (d) Fuyang station. (e) Xinyang station. (f) Xichong station. (g) Average condition.

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

Station's no.	Station's name	Z (MK)	(ϕ)	(β)
1	Xiangcheng	−3.61***	−2.28**	−99.30***
2	Zhumadian	−3.52***	−0.35	−76.83***
3	Gushi	−5.87***	−3.84***	−867.79***
4	Fuyang	−9.494***	−7.05***	−684.02***
5	Xinyang	−7.803***	−4.76***	−283.64***
6	Xichong	−0.355	−1.16*	−6.59***
7	Average	−7.313***	−4.29***	−348.78***

MK = value of Mann–Kendall test; (ϕ) = value of innovative trend analysis; (β) = value of Sen's slope. ***Tendencies at 0.01 significance level; *tendencies at 0.1 significance level; **tendencies at 0.05 significance level.



(a) (b)

Figure 6: Correlation matrix: (a) between precipitation and stream flow and (b) between temperature and streamflow.

worldwide mean heating rate (0.012°C/year) [37]. The mean annual temperature of the basin was found to be 15.5°C. This signifies a dramatic increase in temperature being observed from 1976 onwards (Figures 7 and 8).

The MK, ITA, and Sen's slope test estimator show declining trends of river streamflow through all stations. The river streamflow exhibits sharp decreasing trends from 1965 onwards (Figure 7). This result is also supported by Zhang et al. who examined monthly average streamflow in Canada and indicated that there were virtually no basins revealing an increasing trend [38]. The foremost possible reason for the declining stream flow in the upper Huai river basin is the declining amount of precipitation on some specific months. The operation of floodgates and dams strengthened the

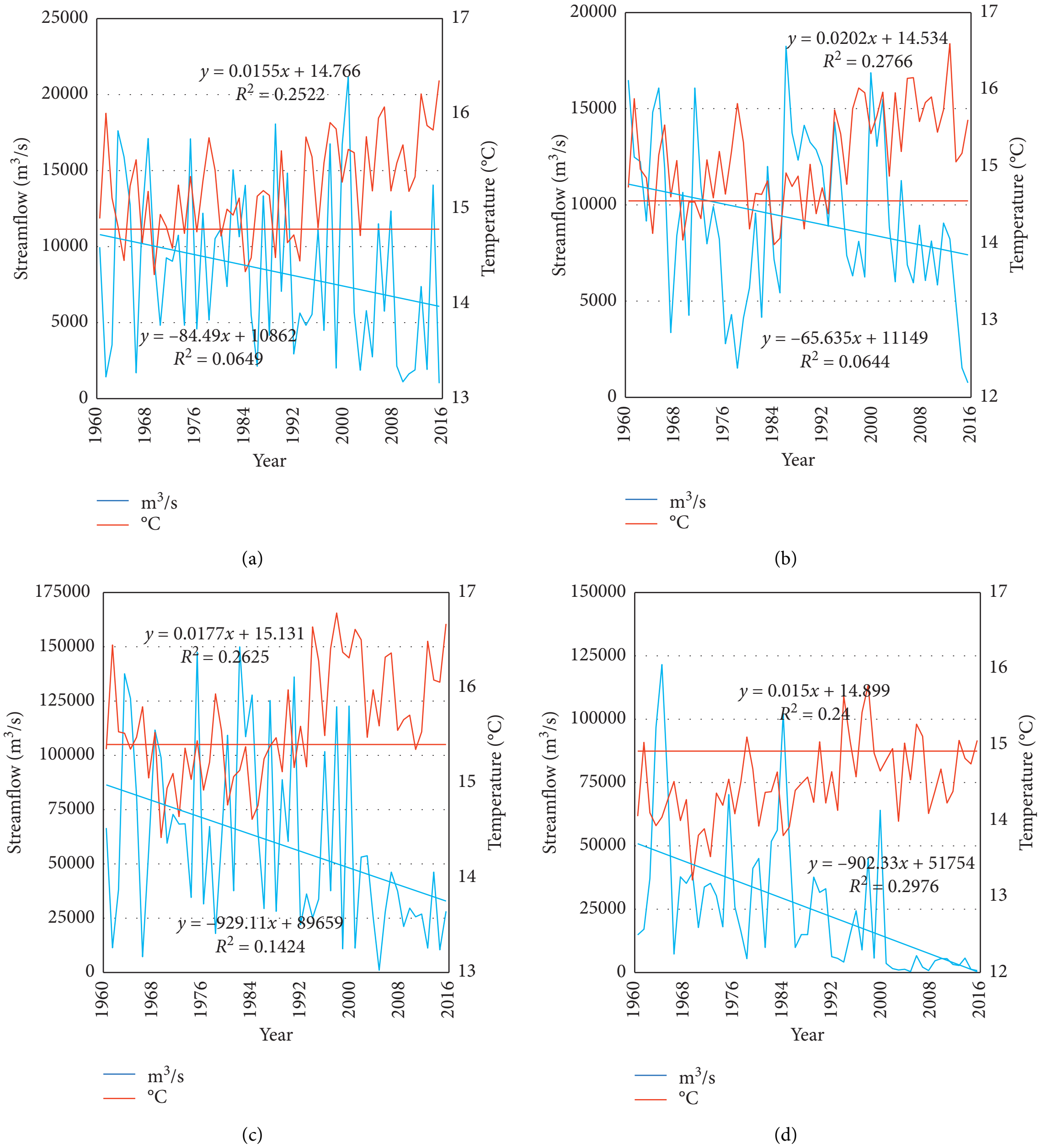
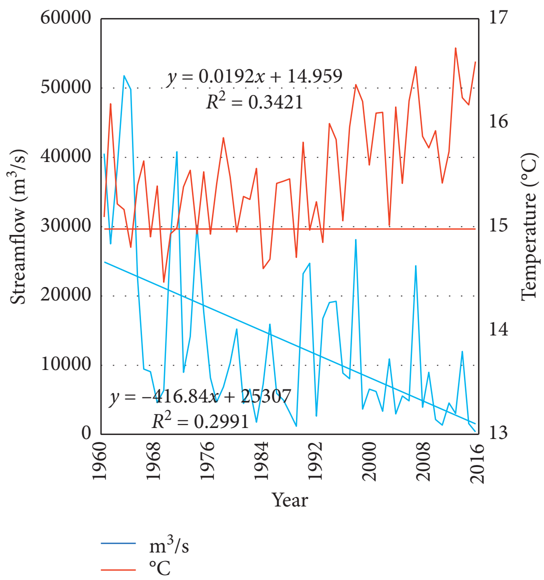
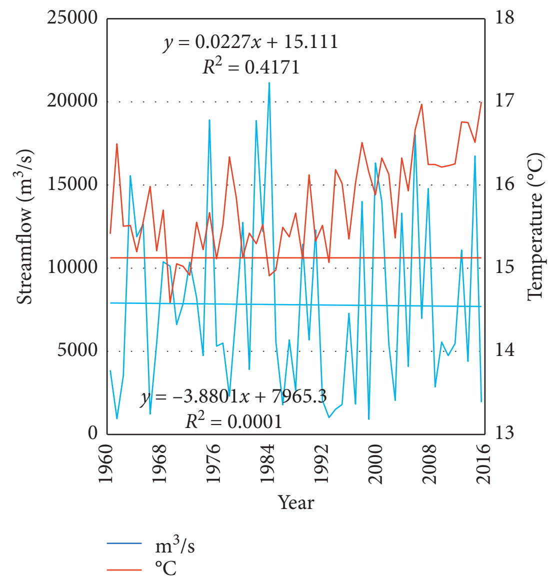


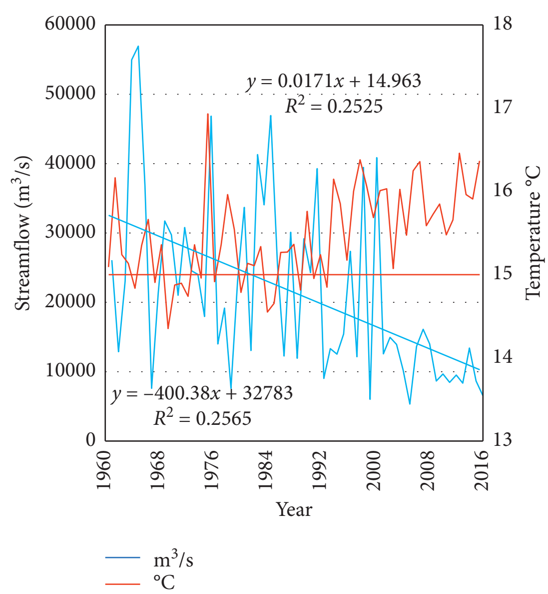
Figure 7: Continued.



(e)



(f)



(g)

FIGURE 7: Long-term relation between temperature and streamflow variation, in the course of 1960–2016. (a) Xiangcheng. (b) Zhumadian. (c) Gushi. (d) Fuyang. (e) Xinyang. (f) Xichong. (g) Average condition.

reduction of streamflow, exclusively in the dry periods, as most floodgates and dams were closed in order to serve water demand intended for agricultural irrigation.

Agricultural irrigation, frequently accompanied in the early summer, from May to June, is intended for crops to mature before harvest, and irrigation in the late autumn (October) is used for planting seeds. The water resource consumption by irrigation, to some extent, balances the effects of precipitation on streamflow fluctuations. The upper Huai river basin is situated in a semihumid region, warm-temperate and subtropical humid zone. For this topographical reason, evaporation plays an imperative role in the regional hydrologic cycle.

The numbers of industries serviced by the basin are continually increasing, which currently include coal mines, chemicals, papers industry, textiles factories, and food processing plants. The major industry that has developed substantially on the basin is agriculture, which has been used to produce wheat, cotton, soya bean, and rice. These industries could be a bottleneck to maintain optimum streamflow in the basin. The main driving force of this problem is also an intense socioeconomic activity occurring in the study basin where most of the land is converted into farmland and the basin water is highly extracted for irrigation purposes [39–42]. As a result, the temporal distribution of precipitation and temperature can produce

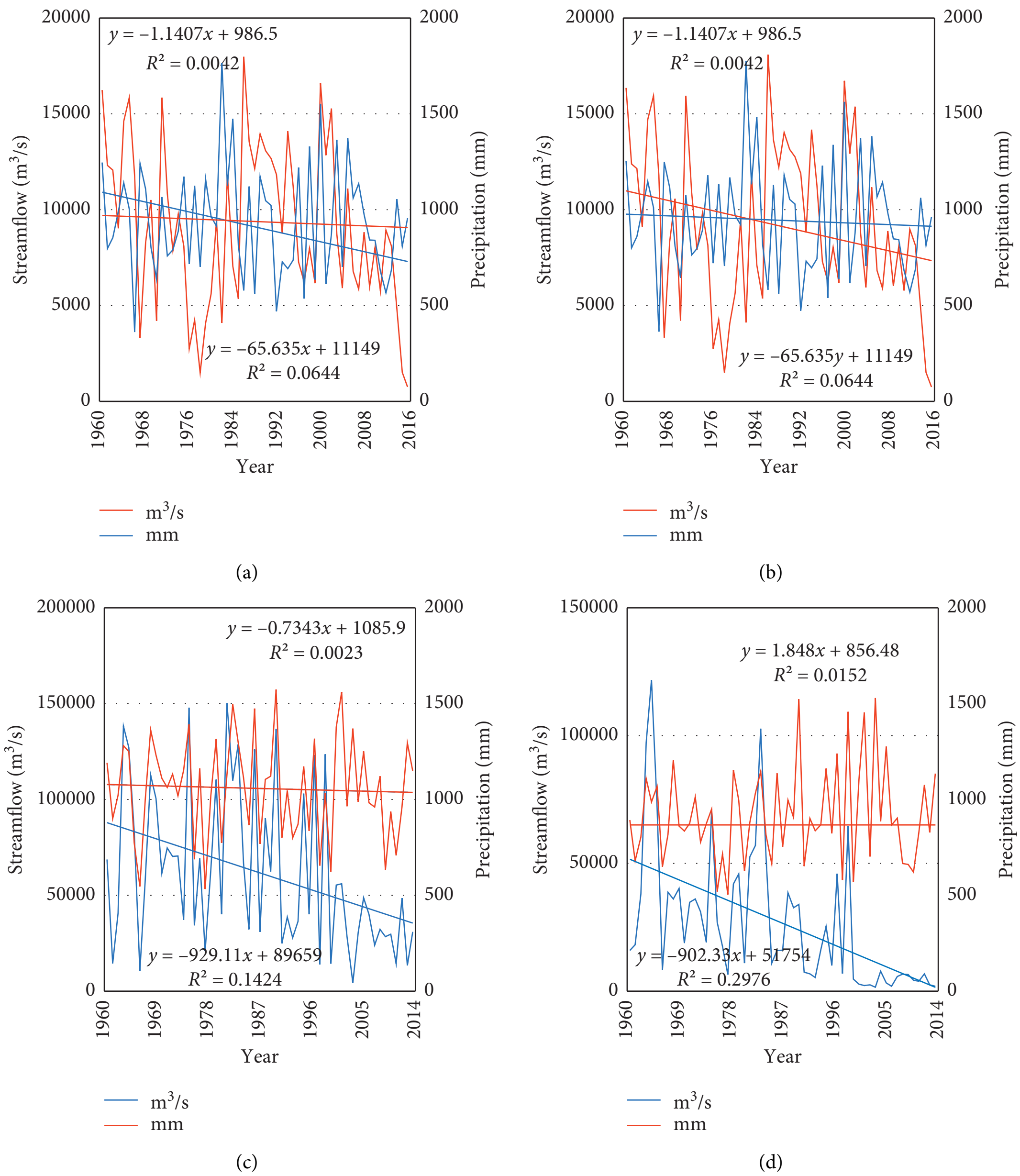
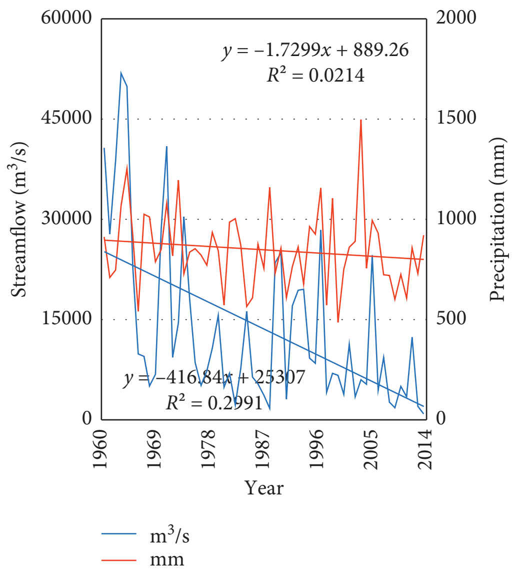


Figure 8: Continued.



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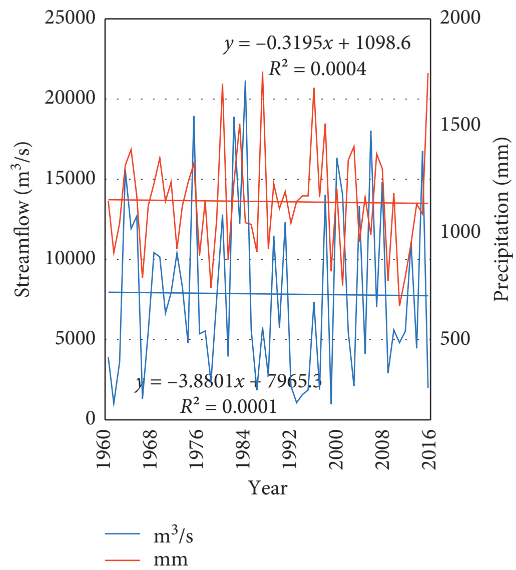

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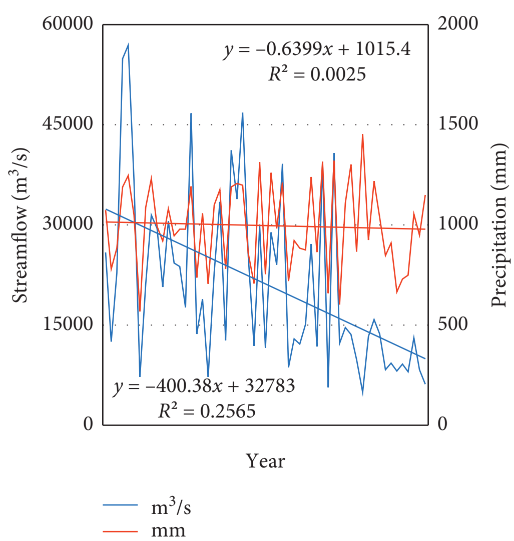

(g)

Figure 8: Long-term relation between precipitation and streamflow variation, in the course of 1960–2016. (a) Xiangcheng. (b) Zhumadian. (c) Gushi. (d) Fuyang. (e) Xinyang. (f) Xichong. (g) Average condition.

noticeable effects on the streamflow across the upper Huai river basin, and these kinds of variation are of particular interest for flood planners, water manager's soil erosion prevention, and water availability assessment in natural ecosystems. This calls for further studies on land used dynamics of the study region.

5. Conclusions

This study analyzed the climate and streamflow changes in the Huai river basin using Mann–Kendall trend test (MK), innovative trend test (ITA), and Sen's slope test estimator. From the results, we can determine that precipitation in the study region is described by high coefficient of variation (CV > 1.5), irregular declining, and resolute into the summer season. Mean annual precipitation has revealed a statistically significant declining trend. An increasing trend was observed only in Fuyang station, during the period from 1960 to 2016. Reversely, temperature showed a significant escalation in all representative stations. The river streamflow showed a significantly high-pitched declining trend at all stations during the study period years ($\phi = -4.29$).

The implication of the results means that there has been substantial variation in precipitation, temperature, and streamflow patterns, indicating the occurrence of climate change in the study region. Thus, it is vital to regulate the water consumption in the region ideally with the changing condition and plan strategic climate change adaptation tactics, reducing all carbon emission mechanism, to improve the adaptive capability, by taking the decreasing and inconsistent nature of precipitation and the rise of temperature into consideration. Such controls are designed to use the available basin water resource rationally, and, as a result, they can help the ecology of the basin, to acquire an optimal stream flow, through allocating more water resource to the ecology.

The regulation of floodgates and dams on flow systems is crucial in understanding streamflow. Hence, some tangible actions should be commenced to guarantee the sustainability of water consumption and to nurture a healthy river ecology. The environmental and ecological streamflow must be preserved to avoid zero flow and meet the water demand. The current study has only attempted to address the variability of streamflow, temperature, and precipitation evolution. Because the upper part of the Huai river basin has a unique climatic feature, it is vital to conduct more climatic researches and study their impacts, on the hydrology and ecosystem in detail, using distributed hydrological simulation models. This study can be an inordinate resource to other researchers.

Data Availability

The data used to support the findings of this study are available from the first author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

Authors' Contributions

A. G. designed the project. D. Y. and X. S. delivered the overall guidance. B. D. and O. Y. performed analysis and software. T. Q., A. A., M. D., and J. W. finalized the manuscript and calculated the data. H. W. supervised the project. All authors revised the manuscript thoroughly.

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