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Analysis of temperature and precipitation series of Hirfanli Dam Basin by Mann Kendall, Spearman's Rho and Innovative Trend Analysis

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Abstract

In this study long-term trend analysis of precipitation and temperature series are determined in the Hirfanli dam basin of Turkey. Data is obtained from the Turkish State Meteorological Service for the period of 1968 to 2017 for Gemerek, Kayseri, Kirsehir, Nevsehir, Sivas and Zara. Mann-Kendall, Spearman's Rho and Innovative Trend Analysis are used for trend analysis with 95% confidence levels. According to the results of the temperature series upward trend were determined. The results of all methods are similar but increasing significant trends were determined by Mann Kendall and Spearman's Rho except Zara. According to the precipitation series results, with decreasing trends in Gemerek, Kirsehir, Nevsehir and Zara, increasing trends were determined in Kayseri and Sivas. The results of Mann Kendall and Spearman's Rho methods show parallelism with each other. Contrary to other methods, Innovative Trend Analysis determined a decreasing trend in Kayseri. As a result of the analysis, the trends in the precipitation series are not significant at the 95% confidence level. In addition to statistical analyzes, evaluations were made in terms of integrated disaster management for drought disaster in the basin with arid climate characteristics.

1. Introduction

Along with the global climate change, the causes of the events that adversely affect the climate are the irregularities in the precipitation regimes with the increase in temperatures. It is observed that global climate change affects hydrological and climatological parameters, such as the decrease in glacial masses in the world, changes in sea water levels and irregularities in precipitation [1].

As can be seen in the literature, the effects of global climate change on various hydro-meteorological parameters are being investigated [2-10].

Global climate change has become an important problem affecting civilization around the world. Global climate change manifests itself to different degrees in various geographies in Turkey. These effects were investigated using hydro-meteorological climate parameters [11–21].

Studies on climate and climate components have reported that temperatures have increased and precipitation has decreased in recent years [22].

Keskin et al. [23] examined the effects of global climate change on the Eastern Anatolia region by using precipitation and temperature parameters. Toros [24] evaluated low and high temperature data and precipitation data of 18 stations. Altin et al. [25] conducted trend analysis using rainfall and temperature series of 33 stations in the Central Anatolia region between 1975 and 2007 using the Mann Kendall test.

Drought disaster, which emerged with the oscillations in hydro-meteorological parameters with the effect of global climate change, is one of the main subjects of researchers today. This disaster, which is examined on a global and local scale, is also evaluated in terms of countries [26-36].

In this study, Hirfanli Dam basin, which is located in the semi-arid climate region where climate change can be seen due to its location, was chosen as the study area. The drought situation in the basin and the Central Anatolia region, where it is geographically located, has been examined with different methods in the literature [37-42]. Temperature and precipitation series analyzes were made by using Mann Kendall (MK), Spearman's Rho (SR) and Innovative Trend Analysis (ITA). In addition, evaluations were made from the perspective of integrated disaster management for the basin's fight against drought.

2. Integrated Disaster Management

Disasters are events that affect every geography and every society. Disasters encountered in the developing and changing world have revealed the importance of the concept of integrated disaster management. Disaster management is one of the main areas of activity under the responsibility of the public administration. It is an interdisciplinary, transdisciplinary and transdisciplinary field of study that covers all processes from detection of risks, control of natural, social, human and technological conditions, education of decision makers and all stakeholders, creation of disaster awareness and disaster culture, and planning to control in management. The management model, which is called integrated disaster management today, is a strategic management system that aims to identify risks before disaster or emergency occurs, to prevent or minimize damages, to respond effectively and quickly when disaster occurs, and to carry out post-disaster recovery efforts by providing integration. The phases of this strategic management system are mitigation, preparedness, response and recovery phases [43-45].

3. Material and Methodology

3.1. Study area and data

The sub-basin containing the Hirfanli Dam Basin, which is located between 33.3°E and 38.7°E longitudes and 38.3°N and 40.1°N latitudes, is within the Kizilirmak River Basin, and has a surface area of approximately 26700 km^2. In the basin, the altitude varies between 799 and 3880 m (Figure 1). The east part of the basin is the hilliest region of the basin, which consists of high peaks and is bordered by mountainous areas. Plateaus, wide plains, and meadows are more common in the west part of the basin [38–40].

Temperature and precipitation data between 1968 and 2017 were obtained from the Turkish State Meteorological Service. The mean temperature of the basin is 10.03 °C, and the mean annual precipitation value is 424.82 mm. In addition, geographical and meteorological details of the stations are given in Table 1. The temperatures in the basin decrease from west to east, and the distribution of precipitation increases from west to east contrary to temperatures. The spatial distribution of temperature and precipitation is given for the basin in Figures 2-3, respectively.

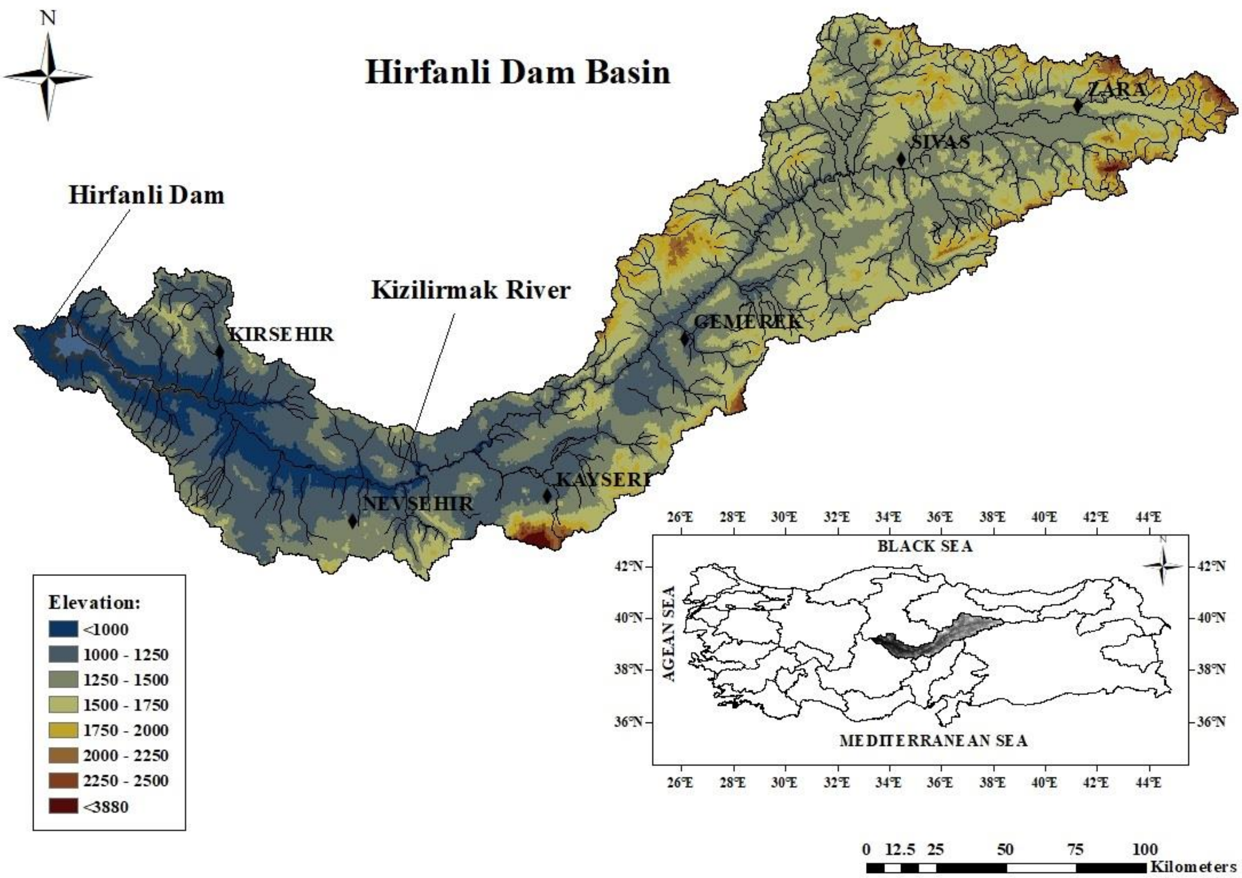

Figure 1. The geographical and topographical situation of the study area [41].

Table 1. Geographical and meteorological information of the stations.

Stations	Latitude (N)	Longitude (E)	Elevation (m)	P_{mean}(mm/year)	T_{mean} (°C/year)
Gemerek	39.11	36.04	1173	403.31	9.64
Kayseri	38.44	35.29	1093	390.13	10.54
Kirsehir	39.09	34.10	1007	383.49	11.47
Nevsehir	38.35	34.40	1200	413.20	10.70
Sivas	39.45	37.01	1285	443.70	9.19
Zara	39.54	37.45	1348	515.11	8.66

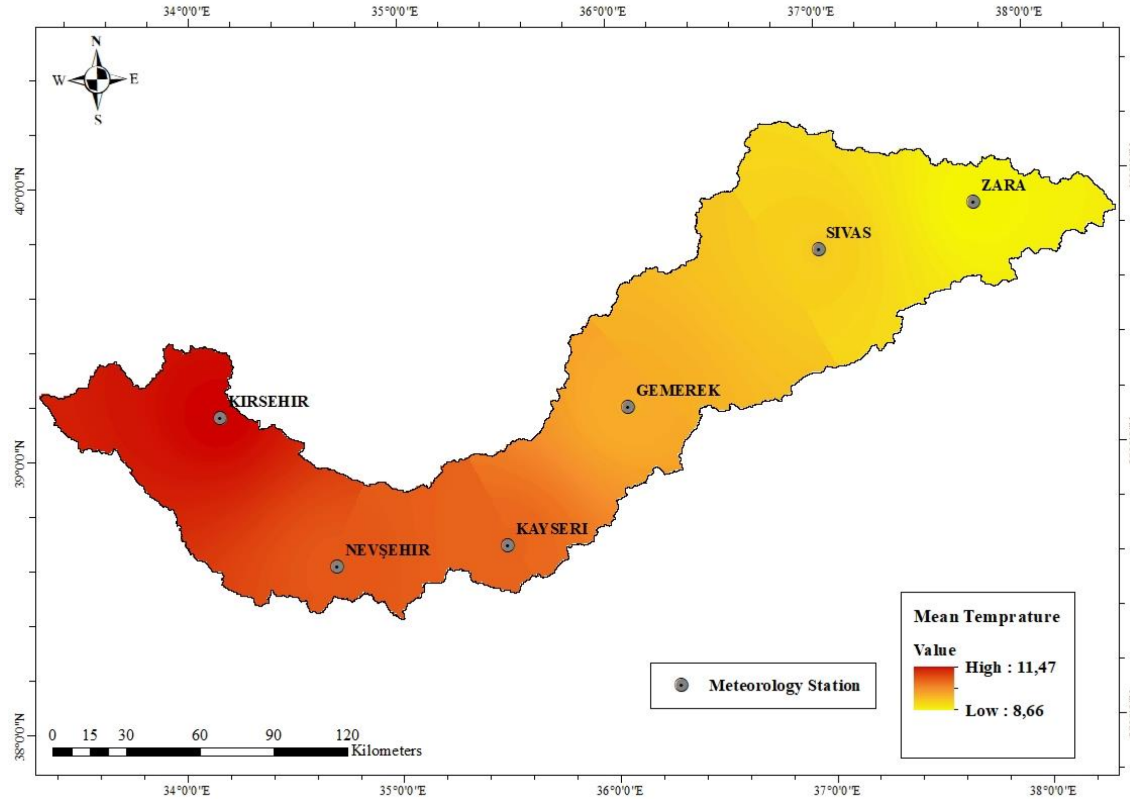

Figure 2. Spatial distribution of temperatures [42].

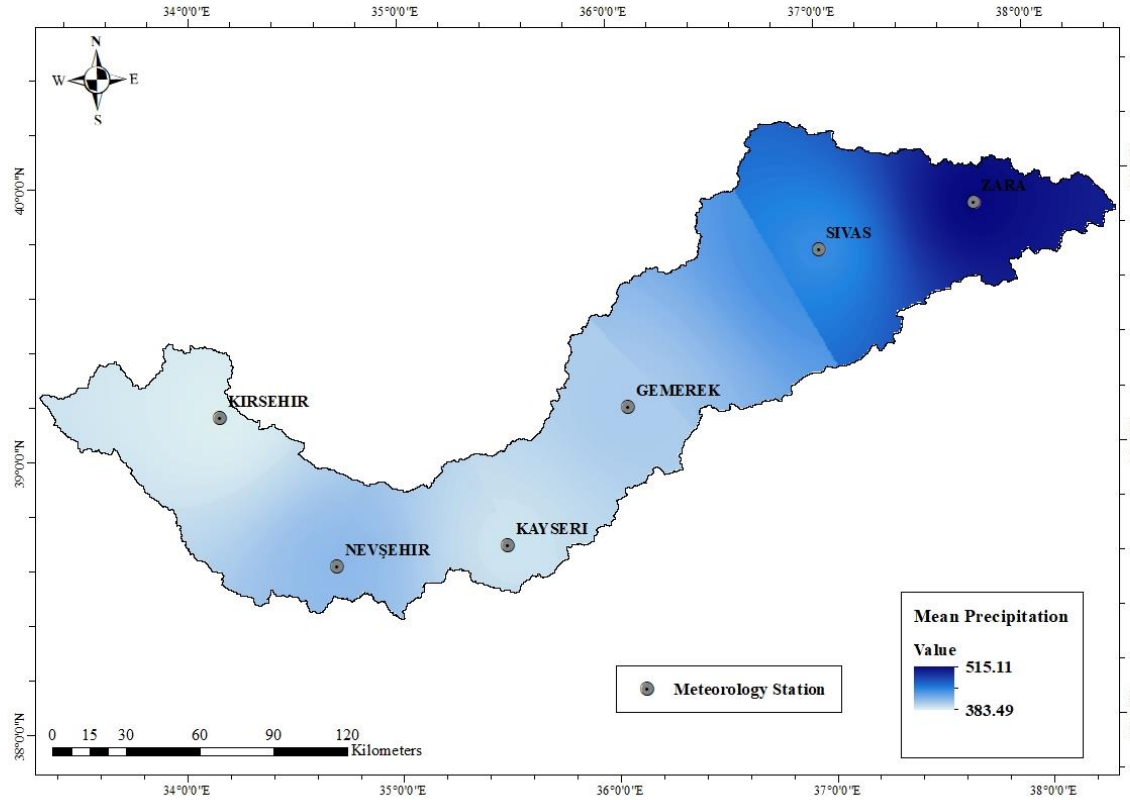

Figure 3. Spatial distribution of precipitation [42].

3.2. Mann Kendall (MK) trend test

The MK test is independent of the distribution of variables [46-47]. Whether there is a tendency in the time series is tested by the null hypothesis (H_0: no trend) [2, 48-49]. The pairs x_i, x_j in the series x_1, x_2, ..., x_n are divided into two groups. The test statistic (S) is expressed by Equation (1), where for i <j the number of pairs with $x_i < x_j$ is P and the number of pairs with $x_i > x_j$ is M. Kendall correlation coefficient with Equation (2); variance is calculated by Equation (3). If there are equal values in observations in the series, the variance value is calculated using Equation (4).

$$S = P - M \tag{1}$$

$$\tau = \frac{S}{\left[{}^{n(n-1)}/_{2}\right]} \tag{2}$$

$$\sigma_s = \sqrt{\frac{n(n-1)(2n+5)}{18}} \tag{3}$$

$$\sigma_s = \sqrt{\frac{n(n-1)(2n+5)-\sum t_i(t_i-1)(2t_i+5)}{18}} \tag{4}$$

Standardized MK test statistics are calculated by Equation (5).

$$\begin{matrix} \frac{(S-1)}{\sigma_s} & ; & S > 0 \\ 0 & ; & S = 0 \\ \frac{(S+1)}{\sigma_c} & ; & S < 0 \end{matrix} \tag{5}$$

If the absolute Z obtained by Equation (5) is less than the critical Z of the normal distribution corresponding to the selected α significance level, the H_0 is accepted; otherwise, the existence of the trend is determined. Positive values indicate the presence of an increasing trend, while negative values indicate a decreasing tendency [50].

3.3. Spearman's Rho (SR) trend test

SR method is a simple and fast method used to investigate whether a linear trend exists. The purpose of the SR test is to investigate the existence of a linear relationship between the two-observation series [51-52]. Using Equation (6), the r_s value for the SR test statistic is calculated [53-54].

$$r_s = 1 - \frac{6\left[\sum_{i=1}^{n}(R(x_i)-i)^2\right]}{(n^3-n)} \tag{6}$$

If the observation period (n) exceeds 30 years, the Z value is calculated using Equation (7) [11, 55].

$$Z = r_s\sqrt{n-1} \tag{7}$$

If the Z value at a selected α significance level is greater than the $z\alpha$ value determined from the standard normal distribution table, the H_0 (No trend) hypothesis based on the fact that the observation values do not change over time is rejected and it is concluded that there is a certain trend.

3.4. Innovative trend analysis (ITA)

According to this approach proposed by Sen, the recorded set of hydrometeorological data is divided into two equal halves from the median year [56]. The trend was not observed above the 1:1 line, and it was observed that decreasing trend is observed when the data 1: 1 line is located in the lower triangular region, and there is an increasing trend when it is located in the upper triangular region [56]. Sen [57] provided statistical control of the statistical process and results with this method. The steps of the stated statistical process are given in Equations (8-13) [57-60].

$$E(s) = \frac{2}{n}\left[E(\overline{y_2}) - E(\overline{y_1})\right] \tag{8}$$

$$\sigma_s^2 = \frac{4}{n^2}\left[E(\overline{y_2})^2 - 2E(\overline{y_2}\,\overline{y_1}) - E(\overline{y_1})^2\right] \tag{9}$$

$$\rho_{\overline{y_2}\,\overline{y_1}} = \frac{E(\overline{y_2}\,\overline{y_1}) - E(\overline{y_1}) - E(\overline{y_2})}{\sigma_{\overline{y_2}}\sigma_{\overline{y_1}}} \tag{10}$$

$$\sigma_s^2 = \frac{8}{n^2}\frac{\sigma^2}{n}\left(1 - \rho_{\overline{y_2}\,\overline{y_1}}\right) \tag{11}$$

$$\sigma_s = \frac{2\sqrt{2}}{n\sqrt{n}}\sigma\left(1 - \rho_{\overline{y_2}\,\overline{y_1}}\right) \tag{12}$$

$$CL_{(1-\alpha)} = 0 \pm S_{critical}\sigma_s \tag{13}$$

In equations: $\overline{y_1}$ average of first data, $\overline{y_2}$: the average of the second data, ρ: correlation between the first and second data, s: slope value, n: number of data, σ: standard deviation of all data, σ_s : slope standard deviation, $S_{critical}$: In the one-way hypothesis (for example 95% confidence level) Z shows critical values. The critical upper and lower limit values calculated by Equation 6 were established to determine the limits of the hypothesis test. Each station has a trend in the time series when the slope value s is outside the upper and lower confidence limits. The trend direction s depending on the sign. Slope value (s) can be positive or negative. This means that there is an increasing (+) or decreasing (-) trend in the time series [57-62].

4. Results

The MK, SR and ITA were applied to identify the tendency in the Hirfanli Dam Basin stations recorded by TSMS in the period of 1968-2017. The results of the analyzes performed at 95% confidence levels are shown in the Tables 2 and 3 respectively. Graphical results of ITA also shown Figures 4-5.

According to temperature results (Table 2 and Figure 4), increasing trends were determined at all stations. Statistically significant trends of upward ($Z>Z_{Cr}$) were designated in the Gemerek, Kayseri, Kirsehir, Nevsehir and Sivas pursuant to MK and SR. On the other hand, the ITA results of stations, a significant upward trend could not be determined but stations have upward trend. The findings of this results, obtained by MK, SR and ITA methods for the Hirfanli dam basin, show parallelism for temperature series.

According to Table 3 and Figure 5, MK, SR and ITA results of the stations. According to the MK and SR results, a significant trend could not be determined. An upward trend detected Kayseri and Sivas. Gemerek, Kirsehir, Nevsehir and Zara have downward trend. For ITA results, Gemerek Kayseri, Kirsehir, Nevsehir and Zara have downward trend. There is just Sivas has upward trend. The findings of precipitation results, obtained by MK, SR and ITA methods for the Hirfanli dam basin, show parallelism except Kayseri. The results of Kayseri have upward for MK and SR but ITA show downward trend.

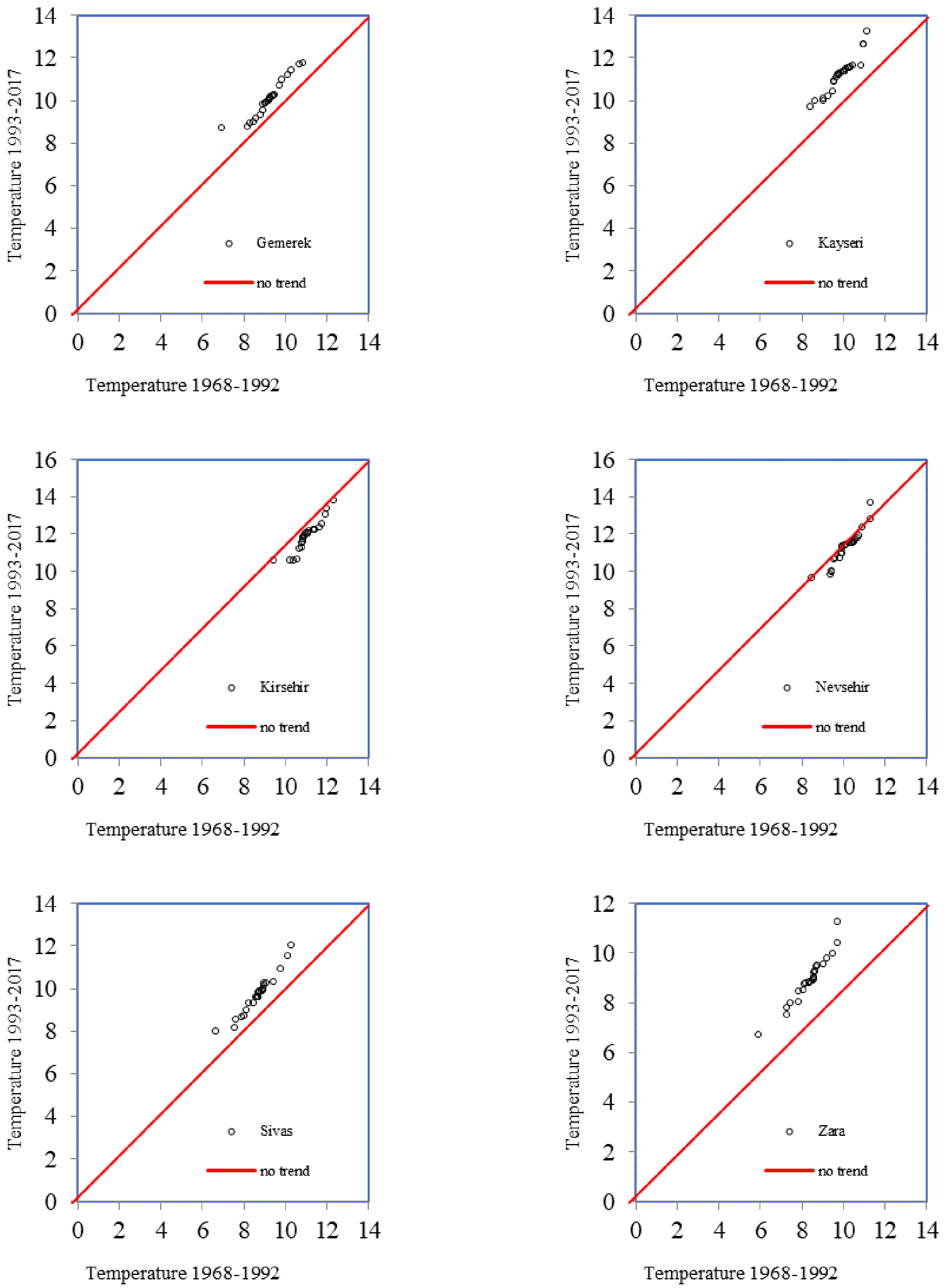

Figure 4. Graphical ITA results of temperature series.

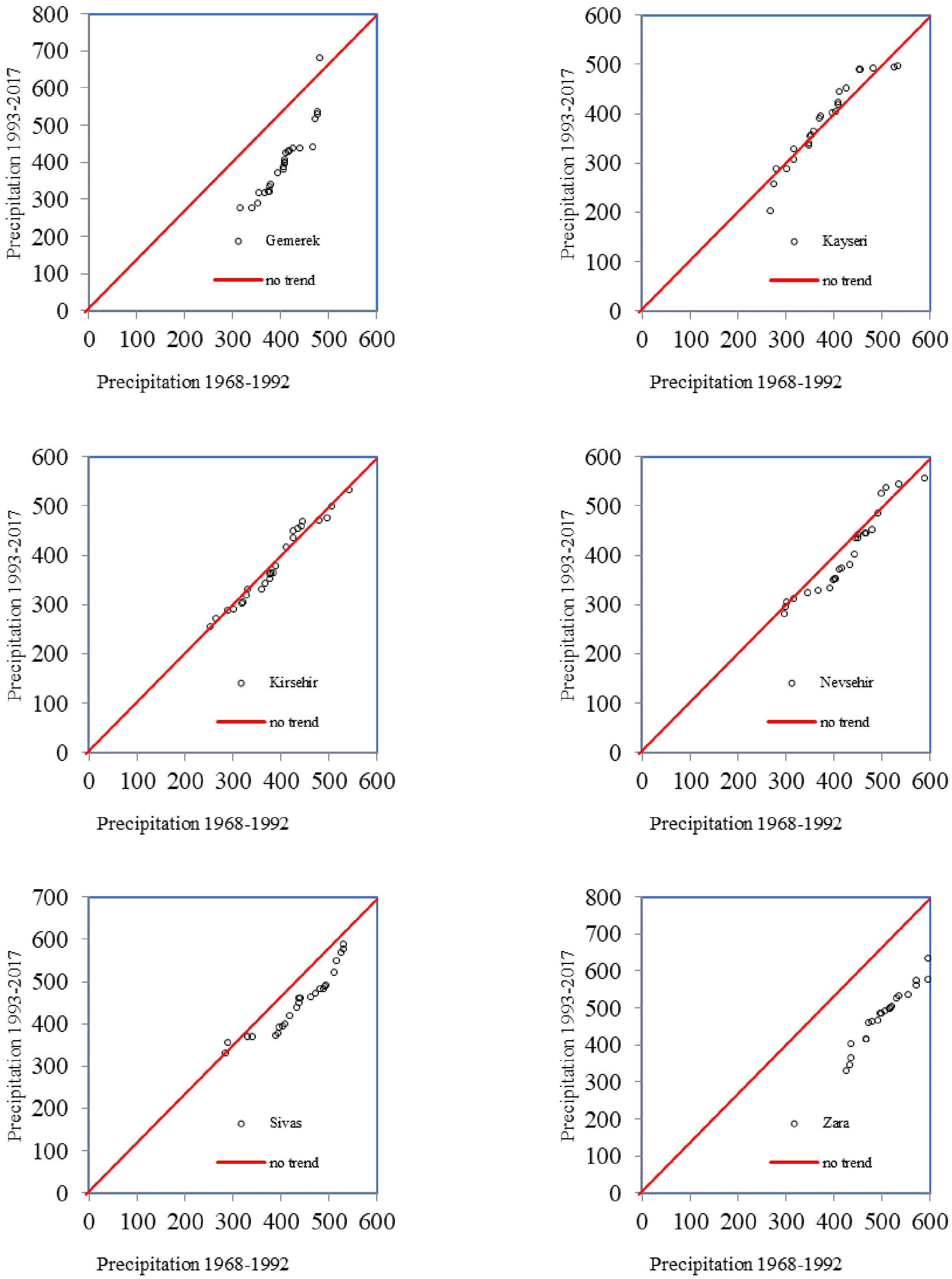

Figure 5. Graphical ITA results of precipitation series.

Table 2. MK, SR and ITA results of temperature series.

Stations	Z_{Cr}	Z_{MK}	Trend	Z_{SR}	Trend	CL_{ITA}	s	Trend
Gemerek	±1.96	**2.46**	**Significant upward**	**2.53**	**Significant upward**	±0.0568	0.0341	Upward
Kayseri	±1.96	**4.80**	**Significant upward**	**4.55**	**Significant upward**	±0.0695	0.0526	Upward
Kirsehir	±1.96	**3.35**	**Significant upward**	**3.40**	**Significant upward**	±0.0645	0.0337	Upward
Nevsehir	±1.96	**4.02**	**Significant upward**	**4.06**	**Significant upward**	±0.0673	0.0457	Upward
Sivas	±1.96	**3.36**	**Significant upward**	**3.36**	**Significant upward**	±0.0581	0.0413	Upward
Zara	±1.96	1.77	Upward	1.80	Upward	±0.0508	0.0225	Upward

Table 3. MK, SR and ITA results of precipitation series.

Stations	Z_{Cr}	Z_{MK}	Trend	Z_{SR}	Trend	CL_{ITA}	s	Trend
Gemerek	±1.96	-0.08	Downward	-0.03	Downward	±1.1895	-0.2965	Downward
Kayseri	±1.96	1.14	Upward	1.05	Upward	±1.3414	-0.0810	Downward
Kirsehir	±1.96	-0.36	Downward	-0.25	Downward	±1.2302	-0.2707	Downward
Nevsehir	±1.96	-0.23	Downward	-0.19	Downward	±1.2699	-0.9218	Downward
Sivas	±1.96	0.86	Upward	0.79	Upward	±1.1621	0.5354	Upward
Zara	±1.96	-1.70	Downward	-1.72	Downward	±1.4146	-0.7675	Downward

5. Conclusion

In this study, the effect of global climate change on the temperature and precipitation series in the Hirfanli Dam Basin was investigated. The temperature and precipitation records measured by TSMS in the period 1968-2017 were used. An upward trend has been determined in the temperature values throughout the basin. For precipitation series downward and upward trends have been determined.

As a result of global climate change, drought in the basin is expected to increase even more in the future. In line with this expectation, it is important to identify risks and hazards, take all necessary precautions, take responsibility for disasters and to raise awareness in order to prevent and reduce damages within the scope of the modern disaster management approach [63]. In line with the disaster management approach, for the drought disaster and other possible disasters in the basin:

- Strategic disaster action plans should be prepared with a participatory understanding.
- Disaster management policies should be established with a culture of cooperation between central and local governments, non-governmental organizations, professional chambers and the private sector.
- In this context, all stakeholders, governorships, local governments, public institutions, development agencies, universities, city councils, professional chambers and non-governmental organizations should come together to prepare plans and share them with the public, knowing their responsibilities within the framework of cooperation.
- Short films and public service announcements should be created to inform about disasters.
- Disaster education issues should be reviewed and new topics should be strategically added. Disaster education should be given starting from primary school age and education should be repeated at regular intervals.

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Author contributions

Utku Zeybekoglu: Conceptualization, Methodology, Analysis, Validation, Visualization, Writing-Original draft preparation, Editing. **Fatma Gunduz:** Conceptualization, Analysis, Investigation, Writing-Original draft preparation, Writing-Reviewing and Editing

Conflicts of interest

The authors declare no conflicts of interest.

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