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Homogeneity and Trend Analysis of Temperature Series in Hirfanli Dam Basin

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Abstract: Climates are constantly changing on a temporal and spatial scale, so they are not static. In recent years, global warming and changes in climate have shown more and more effects on the hydrological cycle and water resources, and their effects have become so noticeable that they hinder sustainable life. For this reason, the studies on the investigation of the main causes of the observed changes in the climate, the evaluation of climate change as a process and the determination of the effects that will emerge, have increased over time. In the present study, the homogeneity of annual and seasonal temperature series in Hirfanli Dam basin were examined by using the Pettitt Test (PT), and the trends were examined with the Spearman's Rho (SR) test and Mann Kendall (MK) test. 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 temperature data of the Gemerek, Kayseri, Kirsehir, Nevsehir, Sivas and Zara meteorological stations in the basin between 1965 and 2017 were analyzed. It was noted that summer temperatures increased throughout the basin. Significant trends to increase were also detected in spring and autumn. The trend to increase was statistically significant at a 95% confidence level in all stations except for the Zara in terms of annual temperatures. Trend maps were prepared for the basin by using the results obtained here and the Geographical Information Systems. It was reported that the tendency to increase in annual temperature series was because of the increase in summer temperatures at intense levels throughout the basin.

Hirfanlı Baraj Havzasında Sıcaklık Serilerinin Homojenlik ve Eğilim Analizleri

Anahtar Kelimeler
Trend analizi, Homojenlik analizi, Spearman's Rho Test, Mann Kendall Test, Hirfanlı Baraj havzası

Öz: İklimler durağan olmamakla beraber zamansal ve mekânsal ölçekte sürekli değişim halindedir. Son yıllarda küresel ısınma ve iklimde gözlenen değişimler, hidrolojik çevrim ve su kaynakları üzerinde gün geçtikçe daha fazla etkisini göstererek, günümüzde sürdürülebilir yaşamı engelleyecek boyutlarda hissedilebilir hale gelmiştir. Bu sebeple, iklimde gözlenen değişimlerin temel sebeplerinin araştırılması, iklim değişikliğinin süreç olarak değerlendirilmesi ve ortaya çıkacak etkilerin belirlenmesine yönelik yapılan çalışmaların sayısı zamanla artmaktadır. Çalışmada, Hirfanlı baraj havzasındaki yıllık ve mevsimlik sıcaklık serilerinin homojenlikleri Pettitt Testi (PT), eğilimleri ise Spearman's Rho (SR) ve Mann Kendall (MK) testleri kullanılarak araştırılmıştır. Yarı kurak iklim bölgesinde yer alan ve konumu gereği iklim değişiminin görülebileceği Hirfanlı Baraj havzası çalışma alanı olarak seçilmiştir. Havzada içerisinde bulunan Gemerek, Kayseri, Kırşehir, Nevşehir, Sivas ve Zara meteoroloji gözlem istasyonlarına ait 1965-2017 yılları arasındaki sıcaklık verileri analiz edilmiştir. Havza genelindeki yaz sıcaklıklarının arttığı dikkat çekmektedir. İlkbahar ve sonbahar mevsimlerinde de anlamlı artma eğilimleri belirlenmiştir. Yıllık ortalama sıcaklıklarda ise Zara dışındaki bütün istasyonlardaki artma eğilimleri istatistiki olarak %95 güven düzeyinde anlamlıdır. Elde edilen sonuçlar ve coğrafi bilgi sistemleri kullanılarak havzaya ait trend haritaları hazırlanmıştır. Yıllık sıcaklık serilerindeki artma eğiliminin havza genelinde yoğun bir şekilde yaz sıcaklıklarından artmasında kaynaklandığı ifade edilmiştir.

1. INTRODUCTION

Different climatic conditions occurred in Turkey due to global warming, as it is the case in other countries in the world. Due to being surrounded by seas on three sides, has a fragmented topography and orographic features, the effects of global climate change occur differently in various regions of our country [1]. Climate parameters need to be analyzed in order to determine the effects of climate change and to take necessary measures [2, 3]. Hydro-meteorological parameters were investigated during the observation periods in order to investigate the effects of global climate change on our country [4-20]. Partal and Kahya [21] examined the trends of precipitation from 1929 to 1993 of 96 stations. Ucgun [22] conducted trend analysis of precipitation, temperature, evaporation and flow data obtained from stations in the Kızılırmak basin. Yerdelen [23] investigated the trends of Susuruluk basin flows using the Sequential MK. It is stated that there is a downward trend in river flows in the basin. Simsek et al. [24] investigated the seasonal and annual trends of temperature, humidity, wind speed and precipitation data of Hatay. In Antakya, they determined an increase in temperature, a decrease in wind speed, an increase in temperature and precipitation and a decrease in humidity values for the Iskenderun. Zeybekoglu and Karahan [25] investigated the trends of annual maximum rainfall intensity series for 206 stations using the MK, SR and Innovative Trend Analysis.

Southeast, Central Anatolia, Aegean and Mediterranean Regions, which have the characteristics of arid and semi-arid climates under the threat of desertification and which are expressed as semi-humid regions due to their lack of sufficient water resources, are expected to be affected more by the increase in temperature [26, 27]. From the past to the present, research has been carried out for seven geographical regions using temperature data, which is the subject of this study also. Toros [28] evaluated low and high temperature data and precipitation data of 18 stations. When daytime and nighttime temperatures are compared, they determined that there are significant increases in night temperature. Kadioglu [29] used temperature data measured at 18 stations between 1929 and 1990 and investigated local and regional trend analysis with the MK. Altin et al. [30] conducted trend analysis using rainfall and temperature series of 33 stations in the Central Anatolia region between 1975 and 2007 using the MK test in the analysis, and observed that the precipitation decreases in the winter and spring months and tends to increase in the summer and autumn months. Kizilelma et al. [31] determined that there were significant increases in the maximum and minimum temperature trends for the central Anatolia region, and that there were increases in the values of the mean temperatures at all stations, except the Ürgüp. Dogan et al. [32] reported in their study that the trends achieved a milestone in the 1950-2006 period based on the analysis of trends in temperature series in Turkey. Ulke and Ozkoca [33] investigated the changes in temperature series of Sinop Ordu and Samsun provinces located in the central Black Sea Region over time using the MK Test and Sen's Trend Slope Test. As a result of their findings, they stated that the temperatures in the region are in an increasing trend. Gumus [34] investigated precipitation and temperatures in the Seyhan-Ceyhan river basin. As a result of annual and seasonal scale evaluations, it has been determined that temperatures tend to increase throughout the basin.

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. Seasonal and annual temperature series analyzes were made by using PT, SR and MK Tests.

2. MATERIALS AND METHHOD

2.1. Study Area

The Hirfanli Dam basin, which is a sub-basin of the Kizilirmak River basin, is about 27,092 km^2 in areal size (Fig.1.) and located between 33.3-38.7ºE longitudes and 38.3-40.1ºN latitudes. The Hirfanli Dam, which was built on the Kizilirmak River in 1959 for flood control and hydropower purposes, has a surface area of 263 km^2 and reservoir volume of 5,980 hm^3 at normal water surface level. The Hirfanli Dam basin has a high and mountainous plateau with the altitude varying between 799-3880 m. 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. Agriculture is a major economic sector in the study area where wheat, barley, potato and sugar beet are the main agricultural products [35, 36].

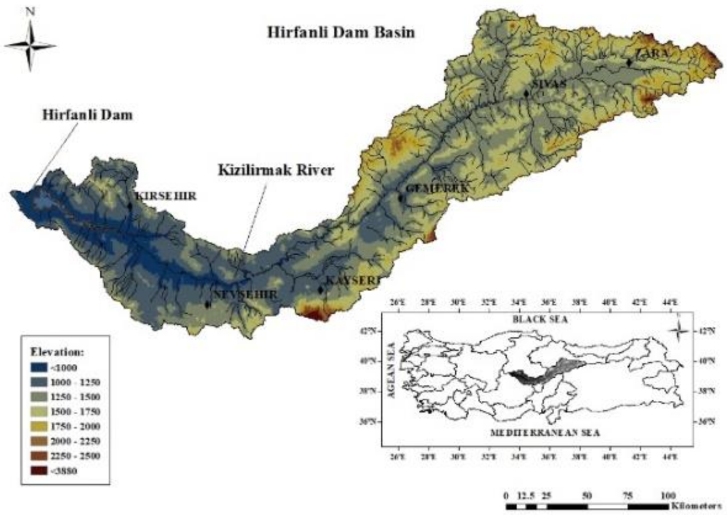

Figure 1. Hirfanli Dam basin

Annual and seasonal mean temperature data between 1965 and 2017 were obtained from the Turkish State Meteorological Service. Table 1 gives the geographical details of the six meteorological stations used in the study. Statistical characteristics of annual and seasonal mean temperature (minimum, maximum and mean) are shown in Table 2.

Table 1. Geographical information of the meteorological stations in the Hirfanli Dam basin

Station Name	Station ID	Latitude (N)	Longitude (E)	Elevation (m)
Gemerek	17162	39.11	36.04	1173
Kayseri	17196	38.44	35.29	1093
Kirsehir	17160	39.09	34.10	1007
Nevsehir	17193	38.35	34.40	1260
Sivas	17090	39.45	37.01	1285
Zara	17716	39.54	37.45	1348

Table 2. Statistical information of temperature series in the Hirfanli Dam basin (ºC)

		Gemerek	Kayseri	Kirsehir	Nevsehir	Sivas	Zara	Basin
Annual	Min.	6.94	8.41	9.43	8.49	6.64	5.94	7.64
	Max.	11.77	13.23	13.78	13.64	11.99	11.27	12.61
	Mean	9.63	10.52	11.46	10.69	9.17	8.63	10.02
Winter	Min.	-7.63	-6.87	-3.80	-4.73	-7.93	-9.03	-6.39
	Max.	2.47	4.13	4.70	5.40	2.87	2.60	3.67
	Mean	-1.66	-0.46	0.93	0.71	-1.89	-2.30	-0.78
Spring	Min.	6.80	8.17	7.70	7.13	6.37	5.23	7.38
	Max.	11.63	13.07	12.73	12.40	11.10	10.83	13.36
	Mean	9.20	10.23	10.52	9.83	8.67	7.96	9.40
Summer	Min.	17.90	18.73	19.83	17.73	16.90	16.03	17.86
	Max.	22.20	23.70	24.30	23.03	21.93	20.90	22.59
	Mean	20.15	21.07	21.95	20.50	19.29	18.61	20.26
Autumn	Min.	8.30	8.87	10.37	9.37	8.33	7.73	8.94
	Max.	13.63	13.67	15.00	14.63	12.90	12.30	13.36
	Mean	10.81	11.24	12.44	11.70	10.60	10.26	11.18

The basin is dominated by convective and frontal precipitation in general. The mean temperature is around 10.02ºC and also the annual temperature decreases from the upstream to the downstream due to the increase in altitude. In the basin the hottest months are July and August, and the coldest months are January and February, and the difference between the highest temperature value and the lowest temperature value is over 10ºC. While the temperature is around 21~22ºC in July and August, the temperature drops to around -2~-1ºC in January and February. As can be seen, the mean temperature drops below 0ºC in winter months.

According to Table 2, the maximum temperature is during the summer at 20.26ºC; the minimum temperature is seen in the winter at -0.78ºC. In addition, the mean temperature values of basin in autumn and spring were 11.18ºC and 9.40ºC, respectively. The spatial distribution of seasonal and annual temperature in the basin was given in Figure 2.

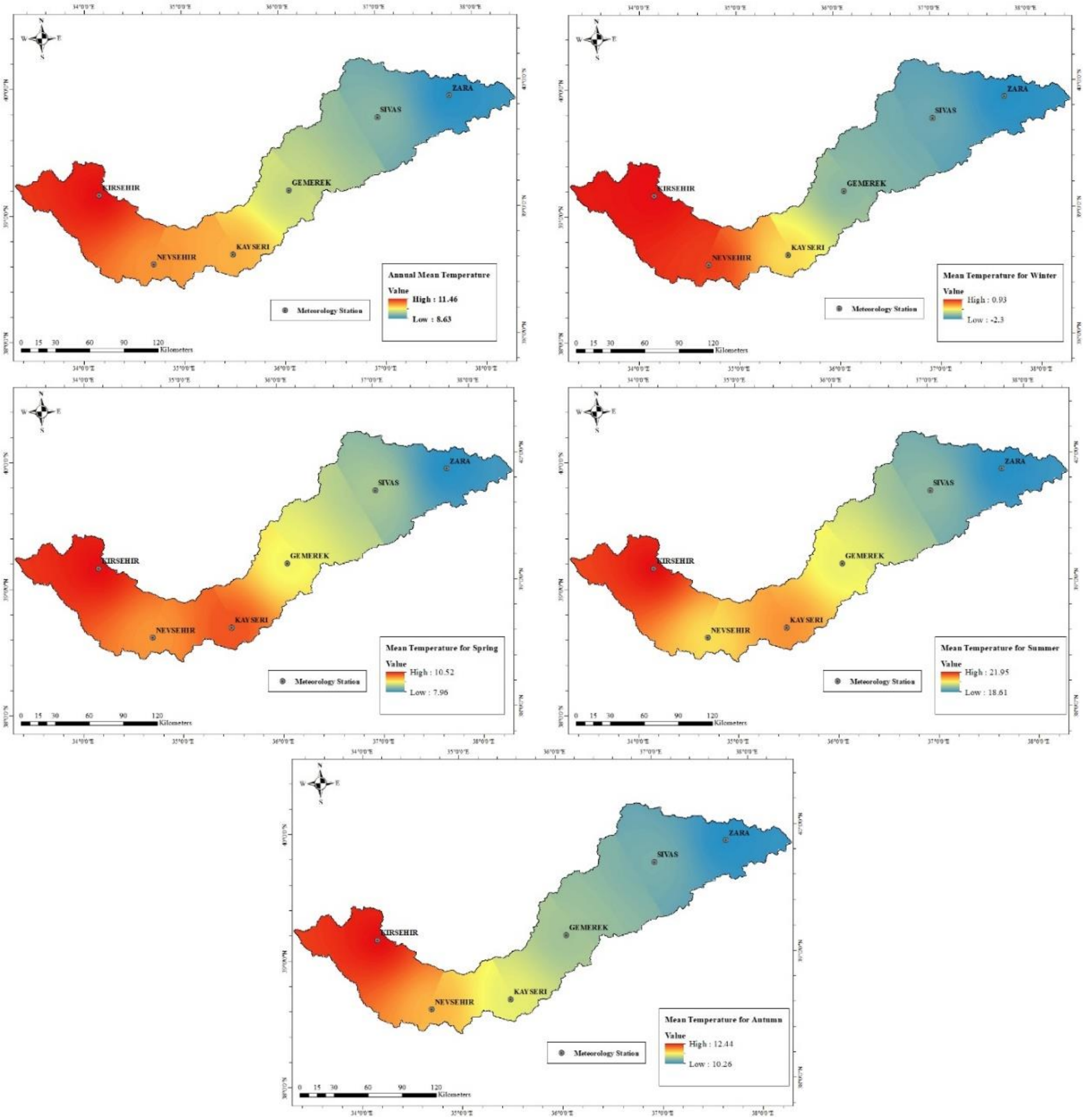

Figure 2. Spatial distribution of annual and seasonal temperature series

2.2. Pettitt Test (PT)

This non-parametric method developed by Pettitt [37] to determine the change point in a time series can find the change point on a monthly or annual scale [37]. The null hypothesis (H_0) states that the series has an independent and random distribution, the alternative hypothesis states that there is a sudden change. The test statistic is associated with the Mann-Whitney statistic [38]. The critical values of this test are given in Table 3 [37].

Table 3. Critical values of X_E

N	20	30	40	50	70	100
%95	57	107	167	235	393	677
%99	71	133	208	293	488	841

Observation values Y_1, ..., Y_n values are listed as r_1, ..., r_n.

$$X_k = 2\sum_{i=1}^{k} r_i - k(n+1)\,; k = 1, \ldots\ldots, n \tag{1}$$

Xk values are plotted graphically by means of Equation 1. In Equation 2, the absolute maximum value of X_k determines the change point.

$$X_E = max_{1\le k\le n}^{|X_k|} \tag{2}$$

If the result of the homogeneity test is smaller than the value determined as the critical value, that data set is called homogeneous. The confidence level was chosen as 95% in the study. The critical value at this level of confidence was calculated as 256.

2.3. 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 [39, 40]. Using Equation 3, the r_s value for the SR test statistic is calculated [41, 42].

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

If the observation period (n) exceeds 30 years, the Z value is calculated using Equation 4.

$$Z = r_s\sqrt{n-1} \tag{4}$$

If the Z value at a selected α significance level is greater than the Z_α 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.

2.4. Mann Kendall (MK) Trend Test

The MK test is independent of the distribution of variables [43, 44]. Whether there is a tendency in the time series is tested by the null hypothesis (H_0: no trend) [21, 45, 46]. The pairs x_i, x_j in the series $x_1, x_2, \ldots, x_n$ are divided into two groups. The test statistic (S) is expressed by Equation 5, 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 5; variance is calculated by Equation 7. If there are equal values in observations in the series, the variance value is calculated using Equation 8.

$$S = P - M \tag{5}$$

$$\tau = \frac{S}{\left[{n(n-1)}/{2}\right]} \tag{6}$$

$$\sigma_s = \sqrt{\frac{n(n-1)(2n+5)}{18}} \tag{7}$$

$$\sigma_s = \sqrt{\frac{n(n-1)(2n+5) - \sum t_i(t_i-1)(2t_i+5)}{18}} \tag{8}$$

Standardized MK test statistics are calculated by Equation 9.

$$\begin{array}{ll} \frac{(S-1)}{\sigma_s} & ; \quad S>0 \\ 0 & ; \quad S=0 \\ \frac{(S+1)}{\sigma_s} & ; \quad S<0 \end{array} \tag{9}$$

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 [47].

3. RESULTS AND DISCUSSION

The homogeneity of annual and seasonal temperature series was tested by the PT at the significance level of 0.05 across the Hirfanli Dam basin. Six meteorological stations for the period 1965-2017 were analyzed, with the test results and break years given in Table 4.

Table 4. Results of PT

	Annual	Winter	Spring	Summer	Autumn
Gemerek	**358 (1994)**	124	**310 (1994)**	**394 (1985)**	172
Kayseri	**466 (1998)**	222	**384 (1999)**	**596 (1995)**	**462 (1988)**
Kirsehir	**424 (1992)**	104	252	**494 (1995)**	**360 (1991)**
Nevsehir	**456 (1996)**	146	**294 (1993)**	**598 (1989)**	**336 (2000)**
Sivas	**408 (1993)**	166	**286 (1998)**	**448 (1991)**	**328 (1986)**
Zara	**276 (1994)**	164	172	**358 (1994)**	150

According to Table 4, it was determined that the annual, spring and summer temperatures of Gemerek were not homogeneous. The years when the break occurred were determined as 1994, 1994 and 1985, respectively. For Kayseri, annual, spring, summer and autumn temperature values are not homogeneous and the breaking years are 1998, 1999, 1995 and 1988, respectively. In the Kirsehir temperature data, non-homogeneous values belong to the annual, summer and autumn temperature results. While the deterioration in the annual temperature values started in 1992, the deteriorations in the mean temperature values of summer and autumn began in 1995 and 1991. It was seen that the annual, spring, summer and autumn temperature values for Nevsehir were not homogeneous and the breaking years were 1996, 1993, 1989 and 2000, respectively. In the Sivas mean temperature data, non-homogeneous values belong to the annual, spring, summer and autumn mean temperature results. While the deterioration in the annual temperature values started in 1993, the deteriorations in the mean temperature values of spring, summer and autumn began in 1998, 1991 and 1986. It is concluded that the annual and summer temperatures of Zara are not homogeneous. Breakings in the annual and summer temperature values occurred in 1994.

Annual and seasonal temperature results of SR and MK of the Hirfanli Dam basin are shown in Table 5. In this study, the critical Z value was chosen as 1.96, which corresponds to 0.05 significance level.

Table 5. Results of SR and MK Trend Tests

		Annual		Winter		Spring		Summer		Autumn	
		Z	Trend	Z	Trend	Z	Trend	Z	Trend	Z	Trend
Gemerek	SR	**2.42**	**Δ**	0.68	-	**2.18**	**Δ**	**3.91**	**Δ**	0.68	-
	MK	**2.43**	**Δ**	0.69	-	1.91	-	**3.90**	**Δ**	0.63	-
Kayseri	SR	**4.13**	**Δ**	1.46	-	**2.78**	**Δ**	**5.41**	**Δ**	**3.81**	**Δ**
	MK	**4.48**	**Δ**	1.53	-	**2.70**	**Δ**	**5.64**	**Δ**	**3.93**	**Δ**
Kirsehir	SR	**3.12**	**Δ**	0.50	-	1.83	-	**4.71**	**Δ**	**2.96**	**Δ**
	MK	**3.18**	**Δ**	0.47	-	1.62	-	**4.86**	**Δ**	**3.14**	**Δ**
Nevsehir	SR	**3.72**	**Δ**	0.74	-	**2.43**	**Δ**	**4.94**	**Δ**	**2.47**	**Δ**
	MK	**3.82**	**Δ**	0.83	-	**2.45**	**Δ**	**4.92**	**Δ**	**2.45**	**Δ**
Sivas	SR	**3.21**	**Δ**	1.23	-	**2.39**	**Δ**	**4.52**	**Δ**	**2.68**	**Δ**
	MK	**3.32**	**Δ**	1.16	-	**2.31**	**Δ**	**4.62**	**Δ**	**2.62**	**Δ**
Zara	SR	1.88	-	0.82	-	1.15	-	**3.18**	**Δ**	0.64	-
	MK	1.90	-	0.75	-	1.03	-	**3.14**	**Δ**	0.63	-

According to Table 5, significant increasing trends in annual, spring, summer and autumn temperatures were determined at Kayseri, Nevsehir and Sivas. Statistically significant trends of increase in annual, spring and summer temperatures in the Gemerek temperature series. On the other hand the MK result of the Spring for Gemerek, a significant trend could not be determined. Significant positive trends were found in the annual, summer and autumn temperature series in the results of Kirsehir. In Zara, a significant increasing trend was identified for just summer temperatures.

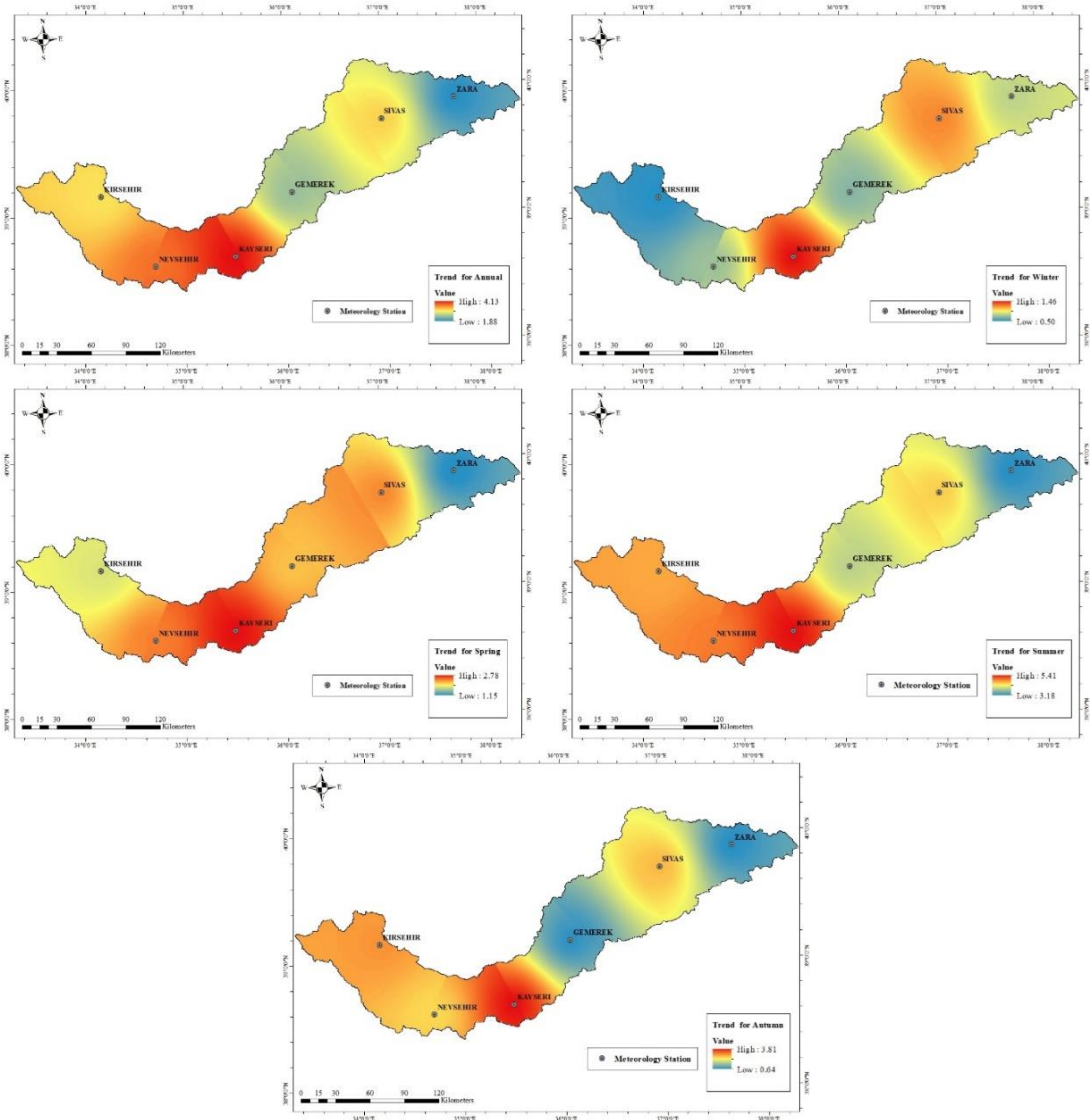

Figure 3. Annual and seasonal trend maps for SR Results.

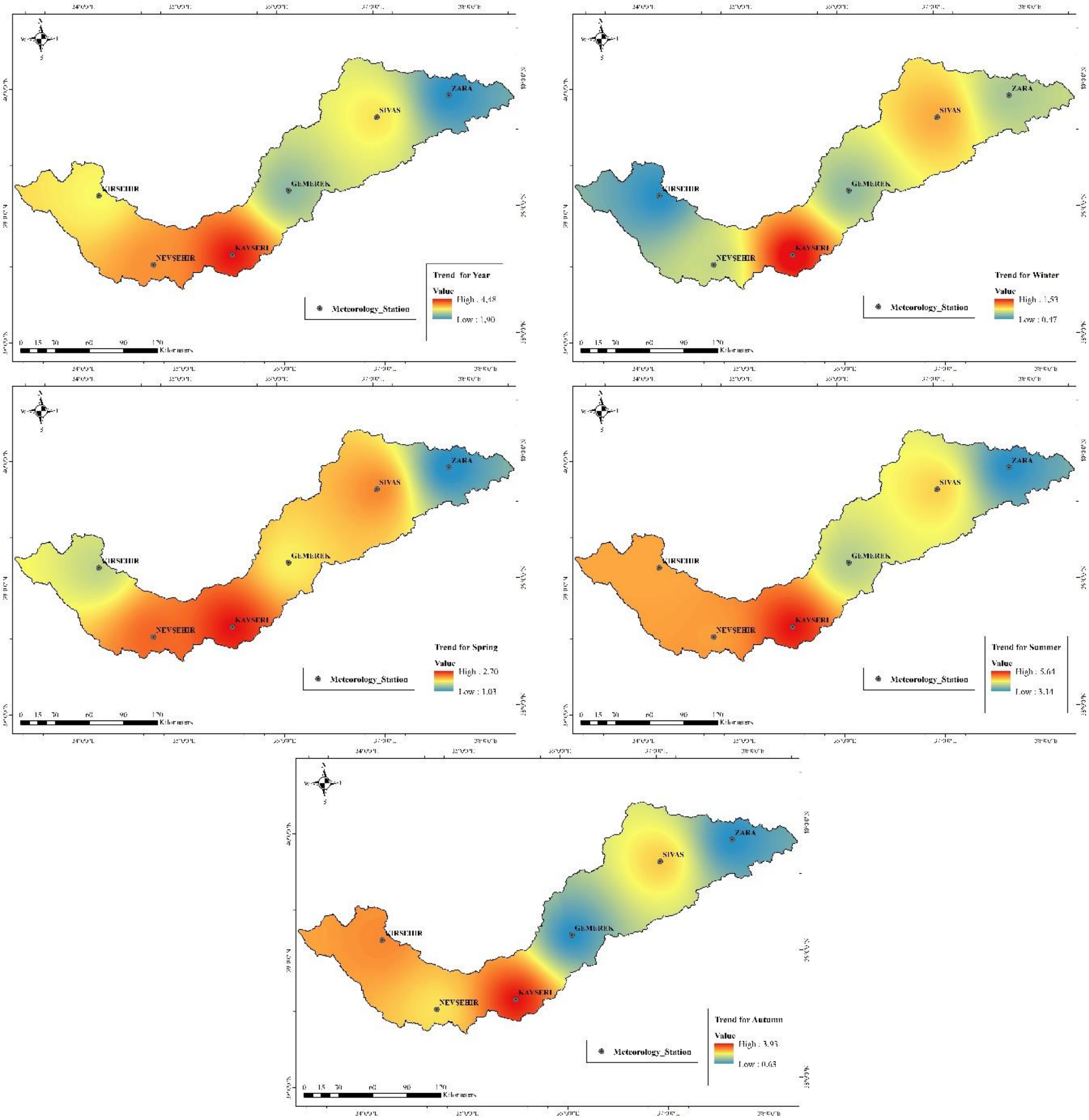

Figure 4. Annual and seasonal trend maps for MK Results.

The increasing trend in spring and summer temperatures determined in Gemerek will cause an increase in the annual temperatures. The increasing trend in annual temperatures in Kirsehir is due to the increasing trend in summer and autumn. In addition, the reason for the increase in annual temperatures of Kayseri, Nevsehir and Sivas is due to the significant increases in spring, summer and autumn temperatures.

In the studies carried out for Turkey, an increasing trend was reported in the temperature series [48-51]. The existence of an increasing trend in annual and seasonal temperature series has been revealed by various trend analysis methods in the Central Anatolia region and the Kizilirmak River basin [31, 52-55]. The findings of this study, obtained by SR and MK methods for the Hirfanli dam basin, show parallelism with the studies carried out for the Kizilirmak River basin, of which it is a sub-basin, and the Central Anatolian region. In addition, annual and seasonal trend maps of the basin were prepared using geographic information systems and Z scores of SR and MK (Figs. 3-4).

4. CONCLUSION

In this study, the annual and seasonal temperature series of the Hirfanli Dam basin in the period 1965-2017 were investigated using the PT, SR and MK. According to the homogeneity test results, deterioration was detected in the annual and summer mean temperatures of all stations in the basin. All stations in the basin showed homogeneous characteristics in the winter temperature series. In the trend analysis results, the significant increase trend in the annual temperature series, except for Zara, is remarkable in the basin. Another remarkable point is that significant increase trends were detected in all stations in summer temperatures throughout the basin. Also, significant increases were determined in the spring and autumn temperature series at the several stations in the basin. There is no significant trend in winter temperature series for all stations. In addition, the results of trend analysis methods (SR and MK) are generally compatible with each other.

Homogeneity analysis and trend analysis results support each other at all stations, other than the Zara. In other words, the reason for the deterioration of homogeneity may be the increasing trend. However, it is thought that this situation determined at the Zara is due to its highest altitude in the basin and being under the influence of the climate of the Eastern Anatolian region.

In the Hirfanli Dam basin, which has a semi-arid feature, it is possible that severe drought events will be seen as a result of the temperature increase caused by global climate change. For this reason, it is of great importance to evaluate the basin in terms of climatic parameters, drought and water resources.

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