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Türkiye'nin Güneydoğu Bölgesinde Kuraklık Şiddetinin Trend Analizi

İslam YAŞA[1*], Turgay PARTAL[1]

Öne Çıkanlar:

- SPI ile kuraklık analizi yapıldı
- SPI değerlerinden kuraklık şiddetleri hesaplandı
- Kuraklık şiddeti serisine MK ve ITA trend testleri uygulandı
- Mardin ilinde tüm dönemlerde kuraklık artışı tespit edildi

Anahtar Kelimeler:

- Kuraklık analizi
- Trend analizi
- Kuraklık şiddeti
- Standart Yağış İndeksi
- Yenilikçi Eğilim Analizi
- Mann-Kendall

ÖZET:

İklim değişikliğinin neden olduğu pek çok sorundan biri olan kuraklığın incelenmesi, su kullanımının ve su kaynaklarının planlanmasını sağlar. Kuraklık parametrelerinden biri olan kuraklık şiddetinin artışı veya azalışı kuraklıktan dolayı ortaya çıkabilecek sonuçların önceden tespiti açısından önemli bir bilgi kaynağıdır. Bu çalışmada, 1960'tan 2022'ye kadar Dicle Nehri havzasındaki dört istasyonun uzun süreli yağış verilerini kullanarak Standart Yağış İndeksi (SPI) ile 1-, 3-, 6-, 9- ve 12-aylık zaman periyotları için kuraklık analizi yapılmıştır. Kuraklık süresi ve şiddeti serileri kuraklık indeks değerlerinden elde edilmiş ve kuraklık şiddet serilerinin eğilimleri Mann-Kendall (MK) ve Yenilikçi Eğilim Analizi (ITA) testleri ile hesaplanmıştır. Sonuçlara göre ITA testi MK testine nazaran kuraklık şiddeti serilerindeki eğilimlerin tespitinde daha hassas olduğu görülmüştür. MK testine göre kuraklık önemli bir artış veya azalış göstermemiştir. Buna karşılık, ITA testine göre kuraklık Siirt ve Batman istasyonlarında sırasıyla 1-ve 12-aylık, Diyarbakır istasyonunda ise 1- ve 12 aylık ölçeklerde artış göstermiştir. Mardin istasyonunda tüm zaman dilimlerinde kuraklık artış göstermiştir.

Trend Analysis of Drought Severity in Southeast Region of Türkiye

Highlights:

- Drought analysed with SPI
- Drought severity was calculated from SPI values
- MK and ITA trend tests were applied to the drought severity series
- Increased drought was detected in all periods in Mardin

Keywords:

- Drought analysis
- Trend analysis
- Drought severity
- Standard Precipitation Index
- Innovative Trend Analysis
- Mann-Kendall

ABSTRACT:

The study of drought, one of the many problems caused by climate change, enables the planning of water use and water resources. The increase or decrease in drought severity, which is one of the drought parameters, is an important source of information in terms of predetermining the consequences that may arise due to drought. In this study, drought analysis was conducted for 1-, 3-, 6-, 9- and 12-month time periods with the Standard Precipitation Index (SPI) using long-term precipitation data of four stations in the Tigris River basin from 1960 to 2022. Drought duration and severity series were obtained from drought index values, and the trends of drought severity series were calculated with Mann-Kendall (MK) and Innovative Trend Analysis (ITA) tests. According to the results, the ITA test was found to be more sensitive in detecting trends in drought severity series compared to the MK test. According to the MK test, drought did not show a significant increase or decrease. On the other hand, according to the ITA test, drought increased at 1- and 12-month scales at Siirt and Batman stations, respectively, and at 1- and 12-month scales at Diyarbakır station. Drought increased in all time periods at Mardin station.

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INTRODUCTION

Drought is one of the extreme climatic conditions caused by extreme meteorological and hydrological events. There are many definitions for drought (McKee et al., 1993; Palmer, 1965; Redmond, 2002; Wilhite, 2000a, 2000b; Wilhite et al., 1985). Drought is generally defined as a long-term dry conditional that causes hydrological imbalance in a region (Eslamian et al., 2017). Predicting drought is vital for planning to combat it. For this reason, drought indices, of which there are many nowadays, are frequently used drought calculators by researchers. Drought calculators give certain parameters for drought: severity, peak, duration, and frequency (Xu, at al. 2015; Dikici, 2020). Changes in drought parameters are useful for monitoring drought.

Trend analysis is often used to analyses and interpret the evolution of hydro-meteorological data precipitation (Coşkun, 2020; Jain et al., 2012; Partal et al., 2006; Pastagia et al., 2022), temperature (Banda et al., 2021; Citakoglu et al., 2021; Ercan et al., 2017; Salami et al., 2014; Şen, 2014; Tokgöz et al., 2020), streamflow (Eriş et al., 2012; Şen, 2017; Umar et al., 2022), humidity (Gümüş et al., 2023; Vincent et al., 2007), evapotranspiration (Aksu et al., 2010; Katipoğlu, 2022; Phuong et al., 2020) data in Turkey and the world. The Mann-Kendall (MK) test is a widely used test in the literature for detecting a monotonic trend in a series. When identifying trends with low, medium, and high values from a data set, the Innovative Trend Method (ITA) is an even stronger instrument than the MK test. ITA, which is frequently used in hydro-meteorological data sets such as streamflow, temperature, solar radiation, and precipitation, is also used in trend detection of drought parameters (Caloiero, 2018; Deger et al., 2023; Gumus et al., 2023).

In recent years, the trends of drought index values and drought parameters in Turkey and the world have been analyzed using different trend techniques. Considering the most recent studies in 2023; Gumus (2023) divided the data between 1965-2020 in 8 stations in the Tigris basin of Turkey into three parts as the first, second and third periods. It calculated the trends of drought characteristics calculated in 3-, 6-, and 9-month time scales of their Standardized Precipitation Index with ITA. Achite (2023) investigated the temporal behavior of meteorological droughts with the Standardized Precipitation Index (SPI) index and hydrological droughts with the Standardized Runoff Index (SRI) index at different scales (1-, 3-, 6-, 9-, 12-, and 24-month) in the Wadi Ouahrane basin of northern Algeria with ITA, MK, Modified Mann–Kendall test (MMK), and Theil-Sen estimator (SS) tests. Their conclusion was that the SS test showed negative values, but the MK test did not show significant trends. This result explains the stable conditions of drought in that region. Deger (2023) computed hydrological droughts at 7 stations in the Kızılırmak basin at five different time scales (1-, 3-, 6-, 9-, and 12-month) with the SDI index and analysed the changes in index values series with the ITA method and concluded that a trend was observed at all time scales and this trend was mostly decreasing.

Analyses of drought parameters have gained significance due to the complex form of drought. Therefore, in this study, SPI drought index values were calculated from precipitation data of four meteorological stations located in the southeast of Türkiye, which is relatively drier than other regions. Drought severity series were obtained as the sum of the index values of dry months. Trend analysis of drought severity series was examined with Mann-Kendal (MK), which is widely used in the literature, and Innovative Trend Analysis (ITA), which is a relatively new method. The decreasing or increasing trend of drought series gives information about the temporal change of the severity of drought events. This represents the change of drought in the region.

MATERIALS AND METHODS

Study Area

This study includes the central stations of Batman, Diyarbakır, Mardin and Siirt, which are important agricultural cities of the Tigris River basin. These cities are also included in the scope of the Southeast Anatolia Project (GAP), which enables the development of the region through the utilization of resources and creates economic opportunities for the people living in the region by developing the region. The Tigris River originates in Turkey, passes through Iraqi territory, and flows into the Persian Gulf. The river has an approximate length of 1900 km and an average flow rate of 490 m^3/s (Zeybek, at al. 2016; Şen, 2019).

Figure 1 shows the study area. The stations are located as Siirt in the east, Diyarbakır in the west, Mardin in the south, and Batman between these three cities. Considering the altitudes of the stations above sea level, the highest station is Mardin (17275) with 1020 m and the lowest station is Batman (17282) with 620 m.

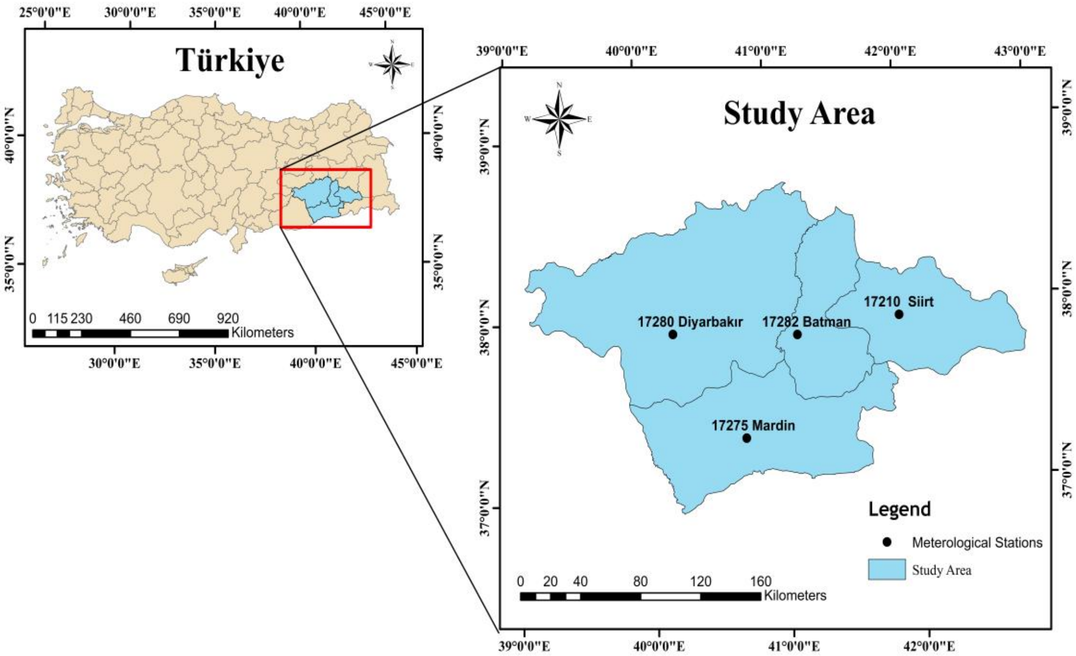

Figure 1. Study area

Table 1 contains information about the stations. The data in all stations are between 1960 and 2022. The station with the highest average annual total precipitation between these years is Siirt, with 690.04 mm, and the station with the lowest average annual precipitation is Batman, with 485.7 mm.

Table 1. Information of stations

Station	Earliest Record Year	Latest Record Year	Altitude above sea level (m)	Latitude	Longitude	Annual Mean Precipitation (mm)	Standard Deviation
17210-Siirt	1960	2022	895	37.9319	41.9354	690.04	171.18
17275-Mardin	1960	2022	1020	37.3103	40.7284	658.17	218.17
17280-Diyarbakır	1960	2022	675	37.9094	40.2133	487.28	128.94
17282-Batman	1960	2022	620	37.8636	41.1562	485.70	130.99

Figure 2 shows the change in the annual total precipitation of the stations according to years. While the maximum annual total precipitation in Siirt and Mardin stations reached up to 1200 mm, the maximum annual total precipitation in Diyarbakır and Batman stations reached approximately 750-800 mm. In 2021, it can be said that less precipitation was observed in the stations compared to other years.

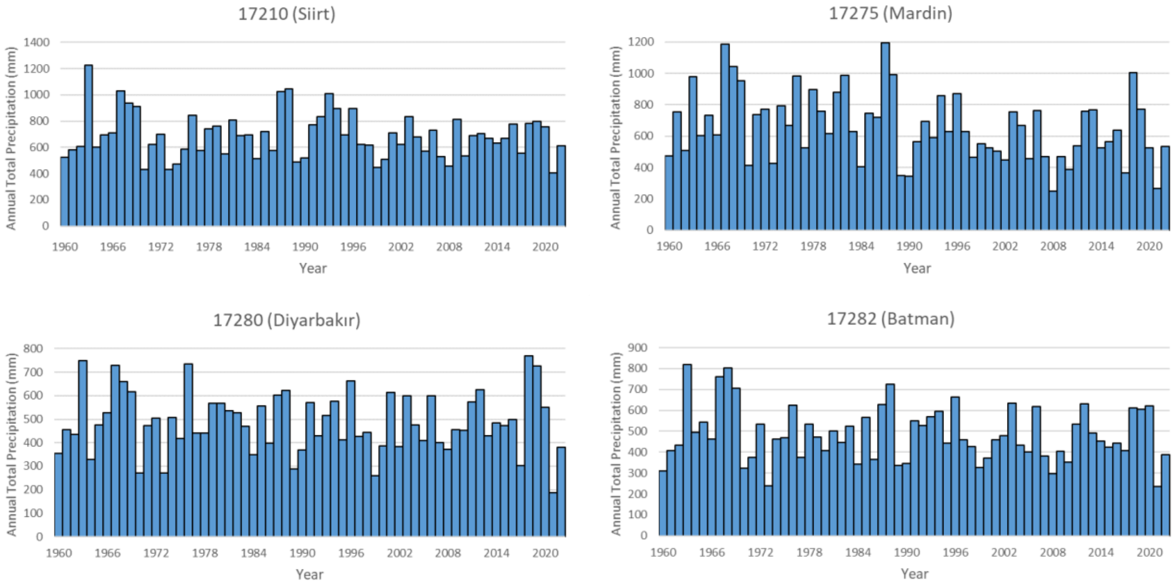

Figure 2. Change in the annual total precipitation of the stations

Homogeneity analysis

Homogeneity analysis is a data security check that is used to test two or more variables against the existing data set, to detect data that do not fit the data set, and to locate variables that do not fit the data set (Elzeiny et al., 2019; Yıldırım et al., 2022). Homogeneity analysis is essential before hydro-meteorological analyses and statistical analyses on meteorological data. In this study, Pettitt (Pettitt, 1979), Standard Normal Homogeneity (SNHT) (Alexandersson, 1986), Buishand (Buishand, 1982) and Von-Neuman (Von-Neumann, 1941) tests, commonly used in climate studies and known as absolute methods, were used to investigate homogeneity. With the help of these studies (Aksu at al. 2022; Kocaoğlu, E., & Çağliyan, 2022), which include the details and formulation of these methods, information about the methods can be obtained. The confidence interval of these tests used in the study was accepted as 95%.

Standard precipitation index (SPI)

A common drought index used in drought calculations is SPI, which was established by (McKee et al., 1993). It bases its estimations only on long-term precipitation data. Both short-term (1- and 3-months) and long-term (6-,9-, and 12-months) drought predictions can be generated via it. The value of each month in the dataset is determined by a new average value from previous months for these scales. The formula 1 defines the SPI method's formulation.

$$SPI = (P_{ij} - \mu)/\sigma \tag{1}$$

Where, P_{ij} represents the monthly precipitation at the ith at the jth observation, μ represents the mean of long-term precipitation, and σ represents the standard deviation.

Thom (1958) showed that the gamma function fits precipitation. Gamma distribution frequency $g(x)$ as given by the equation 2.

$$g(x) = \frac{x^{\alpha-1} e^{-x/\beta}}{\beta^{\alpha}\Gamma(\alpha)}, \quad where\ x, \alpha, \beta > 0 \tag{2}$$

(3)

$$\Gamma(\alpha) = \int_0^\infty y^{\alpha-1} e^{-y} dy$$

Where α is the shape parameter, β is the scale parameter, x is the amount of rainfall, and $\Gamma(\alpha)$ is Gamma function.

As following formulas, the optimal values of α and β are estimated. where n is the total number of observations of precipitation, the precipitation amount, x, and the average precipitation, x.

$$\alpha = \frac{1 + \sqrt{1 + \frac{4A}{3}}}{4A}$$
$$\beta = \frac{\overline{x}}{\alpha} \tag{4}$$
$$A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n}$$

The cumulative probability for a specific month can be calculated using the following equations (Alsanjar, at al. 2022).

$$G(x) = \int_0^x g(x)\, dx = \frac{1}{\beta^\alpha \Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{-x/\beta}\, dx \tag{5}$$

$$H(x) = q + (1-q)G(x)$$
$$q = m/n \tag{6}$$

$$SPI = S(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3} \quad ,$$
$$\begin{Bmatrix} c_0 = 2.515517, c_1 = 0.802853, c_2 = 0.020328 \\ d_1 = 1.432788,\ d_1 = 0.189269,\ d_1 = 0.001308 \end{Bmatrix} \tag{7}$$

$$t = \begin{Bmatrix} \sqrt{\ln\left(\frac{1}{H(x)}\right)^2} & , & 0 < H(x) \leq 0.5 \\ \sqrt{\ln\left(\frac{1}{1-H(x)}\right)^2} & , & 0.5 < H(x) \leq 1 \end{Bmatrix} \tag{8}$$

Where m is numbers of zero precipitations, c_0, c_1, c_2 and d_0, d_1, d_2 are the constants, and $H(x)$is cumulative probability. If $H(x) > 0.5$ then S is 1, else S is -1. $H(x)$ is then converted into a standard normal random variable Z, with mean zero and variance one. which is the value of the SPI.

Negative index values in SPI represent drought and positive index values represent humidity. Figure 3 shows the change of index values over time. Dry periods are when the index values go below zero. The time from the beginning to the end of the dry period is called drought duration, and the cumulative sum of the index values during this period is called drought severity (McKee et al., 1993; Mishra et al., 2010).

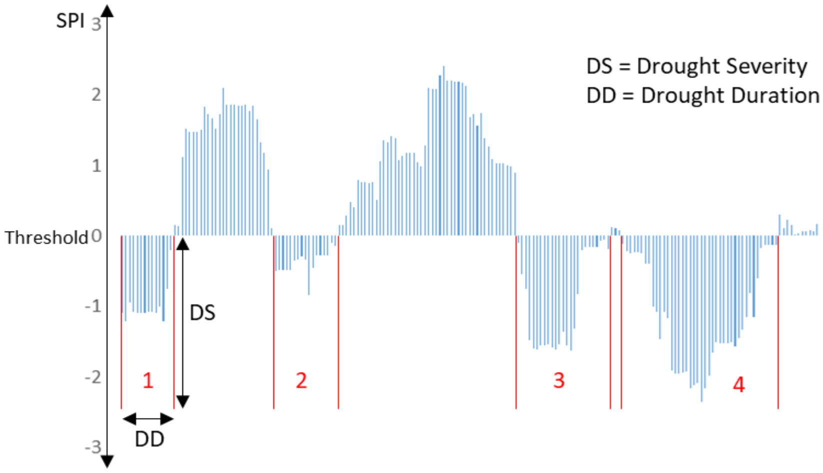

Figure 3. Definition of drought characteristic

Mann-Kendall (MK) test

A nonparametric test Mann-Kendall (MK), also known as the Kendall tau statistic, was developed by x and y. This test, also proposed by World Meteorological Organization (WMO), checks for a trend in a series. The time series to be checked for the trend is $x_1, x_2, x_3 \ldots . x_n$, pairs x_i and x_j are divided into two groups and the test statistic S is calculated as follows;

$$S = P - M \tag{9}$$

Where for $i < j$, P is the number of $x_i < x_j$ pairs and M is the number of $x_i > x_j$ pairs.

$$\tau = S/[n\left(n - \frac{1}{2}\right)] \tag{10}$$

Equations 10 represents the Kendall correlation coefficient. For $n \geq 10$ variance (σ_S);

$$\sigma_S = \sqrt{\frac{n(n-1)(2n+5)}{18}} \tag{11}$$

Since z is the Mann-Kendall standard test parameter;

$$Z = \begin{Bmatrix} \frac{(S-1)}{\sigma_S} & s > 0 \\ 0 & s = 0 \\ \frac{(S+1)}{\sigma_S} & s < 0 \end{Bmatrix} \tag{12}$$

The z-test statistic is the standard normal distribution. if there are equal observations, σ_S is calculated as follows;

$$\sigma_S = \sqrt{[n(n-1)(2n+5) - \sum_i (t_i - 1)(2t_i + 5)]/_{18}} \tag{13}$$

t_i is the number of observations that are equal.

Innovative trend analysis

The innovative trend analysis developed by Şen (2012) has been widely used in trend analysis of hydro-meteorological observations in recent years. In this approach, the data set is divided in the middle to form two equal data sets and these series are ordered from smallest to largest on the x-axis and y-axis. These data sets are represented by a 1:1 line with an angle of 45 degrees in the Cartesian coordinate system. Figure 4 represents the sample graphical results for the ITA approach. According to

ITA, the area above the 1:1 line is the increasing trend area, and the area below it is the decreasing trend area. The 1:1 line is the no-trend area.

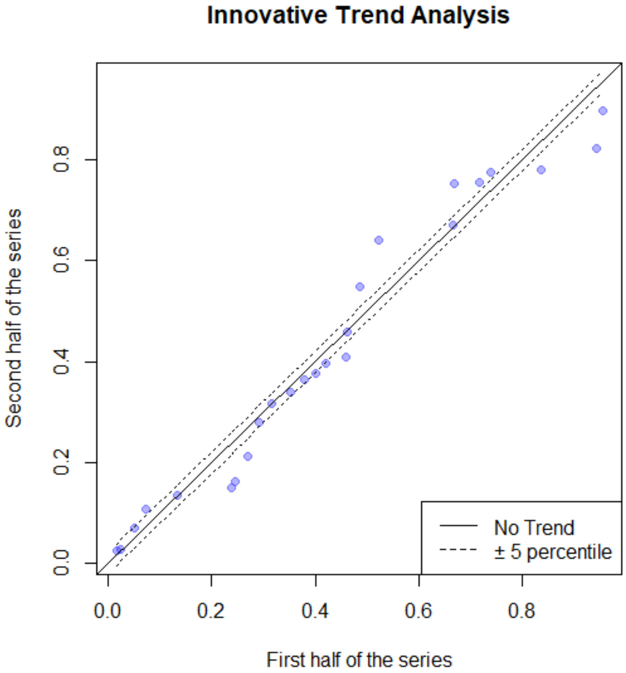

Figure 4. The innovative trend analysis method (ITA)

The statistical significance test introduced by Şen (2017) divides the time series into two equal parts and finds their arithmetic average. The trend slope is found by the following formulas.

$$E(s) = 2\frac{[E(\bar{y}_2) - E(\bar{y}_1)]}{n} \tag{14}$$

$$\sigma_s^2 = 8\frac{[E(\bar{y}_2^2) - E(\bar{y}_1\bar{y}_2)]}{n^2} \tag{15}$$

$$\rho_{\bar{y}_1\bar{y}_2} = \frac{E(\bar{y}_1\bar{y}_2) - E(\bar{y}_2) - E(\bar{y}_1)}{\sigma_{y_1}\sigma_{y_2}} \tag{16}$$

$$\sigma_s^2 = \frac{8}{n^2}\frac{\sigma^2}{n}(1 - \rho_{\bar{y}_1\bar{y}_2}) \tag{17}$$

$$\sigma_s = \frac{2\sqrt{2}}{n\sqrt{n}}\sigma\sqrt{(1 - \rho_{\bar{y}_1\bar{y}_2})} \tag{18}$$

Where n is data set length, $E(s)$ is the first-order moment of slope value, σ_s^2 trend slope variance and the SD of the trend slope.

$$CL_{(1-\alpha)} = 0 \mp s_{cri}\sigma_s \tag{19}$$

The formula 19 represents the trend slope confidence interval calculation. s_{cri} is the value of z obtained from the standard normal distribution with a specific level of confidence. No statistically significant trend occurs when the trend slope is between the confidence level, increasing trend when it is higher than the upper confidence level and decreasing trend when it is less than the lower confidence level. The confidence interval of these tests used in the study was according to 0.05.

RESULTS AND DISCUSSION

Homogeneity Analysis

Quality control of hydro-meteorological data sets before statistical analyses provides information about the data set. Homogeneity analysis is one of these control tools. Since SPI drought index was used in this study, the homogeneity of rainfall data sets was analysed by four homogeneity analysis as Pettitt, SNHT, Buishand, Von-Neuman tests. Homogeneity analysis results are given in Table 2. Ho hypothesis indicates the homogeneity of the series while Ha indicates the rejection of the hypothesis. While homogeneity was found in 3 out of 4 tests in Siirt, Diyarbakır, and Batman stations, rejection of the Ho hypothesis was found in all tests in Mardin station. The deterioration of homogeneity in data sets may give information about the presence of a trend. As a matter of fact, at the end of the study, the increase in drought at Mardin station means a decrease in precipitation, which may explain the deterioration of homogeneity here.

Table 2. The results of the homogeneity analysis for the rainfall data set (Ho= Homogenous, Ha= Non- homogenous)

Station Number	Meteorological Variables	SHNT	Pettitt	Buishand Range	Von Neumann
Siirt	Annual total precipitation (mm)	Ho	Ho	Ho	Ha
Mardin	Annual total precipitation (mm)	Ha	Ha	Ha	Ha
Diyarbakır	Annual total precipitation (mm)	Ho	Ho	Ho	Ha
Batman	Annual total precipitation (mm)	Ho	Ho	Ho	Ha

Drought characteristics

In this study, the standardized precipitation index was first obtained from Diyarbakır, Batman, Siirt, and Mardin stations. Then, the drought severity series were obtained for these stations.

Figure 5. Drought characteristic of 17210-Siirt

Since negative values in the SPI drought index represent drought periods, the drought severity series consists of the cumulative sum of these negative values. drought duration shows the sum of the months during which the index values fall below zero and then rise above zero again. As an example, Figure 5 shows the graph of drought duration and severity series of 17210-Siirt station for 1-, 3-, 6-, 9-, and 12-months.

Considering the drought duration and severity of the stations, the drought severity increases as the drought period increases. It is also clear from the graph that drought severities are at negative values. therefore. when it is decided that there is a decreasing trend in trend analysis, this means that drought is increasing. On the contrary, drought is decreasing if drought intensity shows an increasing trend.

Mann-Kendall test

For the Mann Kendal test to have a significant trend in the 95% confidence interval, the z value must be more than 1.96 or less than -1.96. Table 3 shows the test results of drought severity of four stations according to five different time scales (1-, 3-, 6-, 9-, and 12-month). Siirt and Mardin stations showed decreasing tendency in all periods, Diyarbakır station showed decreasing trend in 6- and 12-month periods, and Batman station showed a decreasing tendency in 1- and 9-month periods. It is seen that there is a significant trend only in Mardin station according to the 1-month time scale.

Table 3. The results of the Mann-Kendall for 1-, 3-, 6-, 9-, and 12-month drought severity

Station	SPI1	SPI3	SPI6	SPI9	SPI12
Siirt	-1.123	-0.423	-0.332	-0.398	-0.944
Mardin	**-2.417**	-0.285	-0.471	-0.379	-0.108
Diyarbakır	0.172	0.261	-0.209	0.415	-0.605
Batman	-1.277	0.377	1.063	-0.280	0.540

In fact, a decreasing trend in drought severity data shows an increase in drought. In contrast, Diyarbakır and Batman stations show an increasing trend in drought according to 6- and 12-month and 1- and 9-month time periods, respectively. A statistically significant increase in drought was observed only in the Mardin station at the 1-month time scale.

Innovative trend results

In the study, graphical and statistical analyses were made for innovative trend analysis. The graphs (Figure 6- 9) of the innovative trend analysis for four stations in the study area are shown below.

Statistical significance tests of innovative trend analysis of drought severity series obtained from SPI five different time scale index values of the stations were performed, and trend slopes and upper and lower values at 95% confidence level were determined. When the trend slope is between the confidence levels, it is concluded that there is no trend, when it is lower than lower confidence level, there is a decreasing trend, when it is higher than upper confidence level, there is an increasing trend.

Table 4 indicates the Innovative trend significance test results of drought severity series in 1-, 3-, 6-, 9-, and 12-month time periods of four stations according to 0.05 significant level. When the table is analysed, it is seen that Mardin station has a statistically significant decreasing trend in all periods. In Siirt Diyarbakır and Batman, the decreasing trend is observed in 1-month, 12-month, 1- and 12-month periods, respectively. On the other hand, the increasing trend is detected in Siirt (9-month), Diyarbakır (3-, 6- and 9-month), and Batman (9-month) stations.

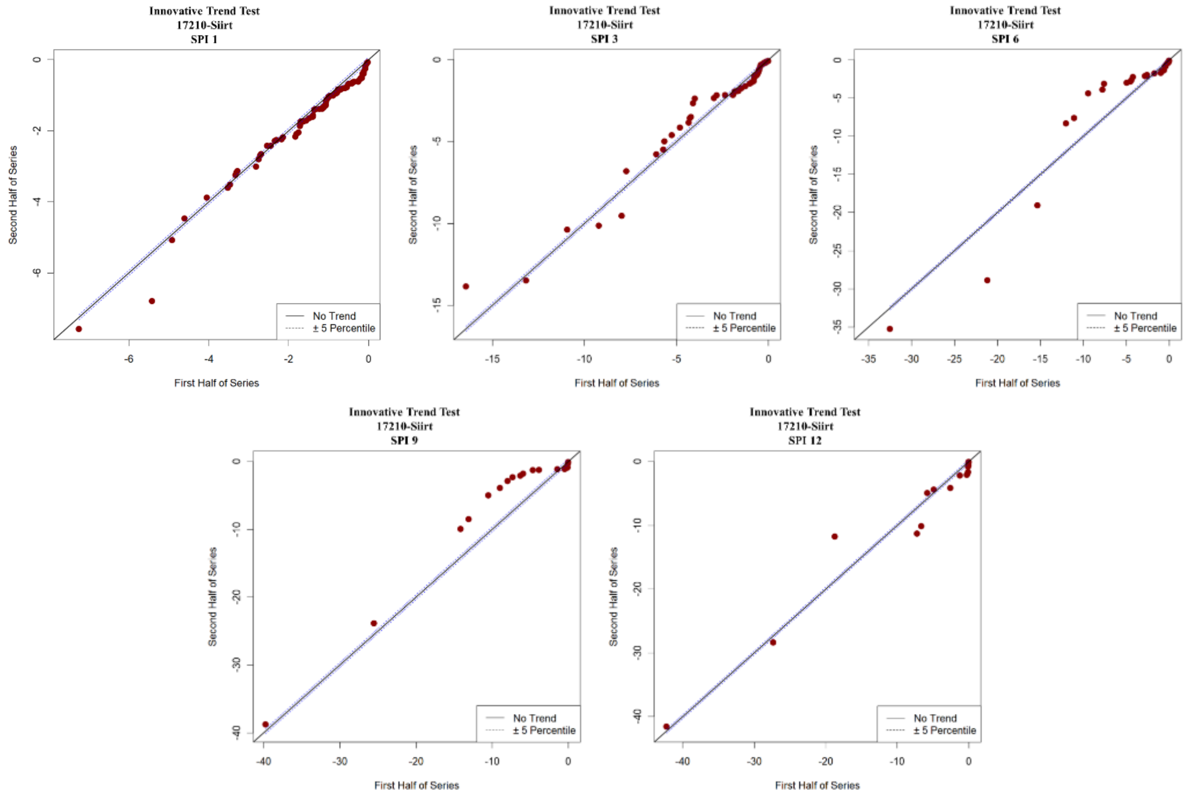

Figure 6. ITA of drought severity of Siirt (1-, 3-, 6-, 9- and 12-month)

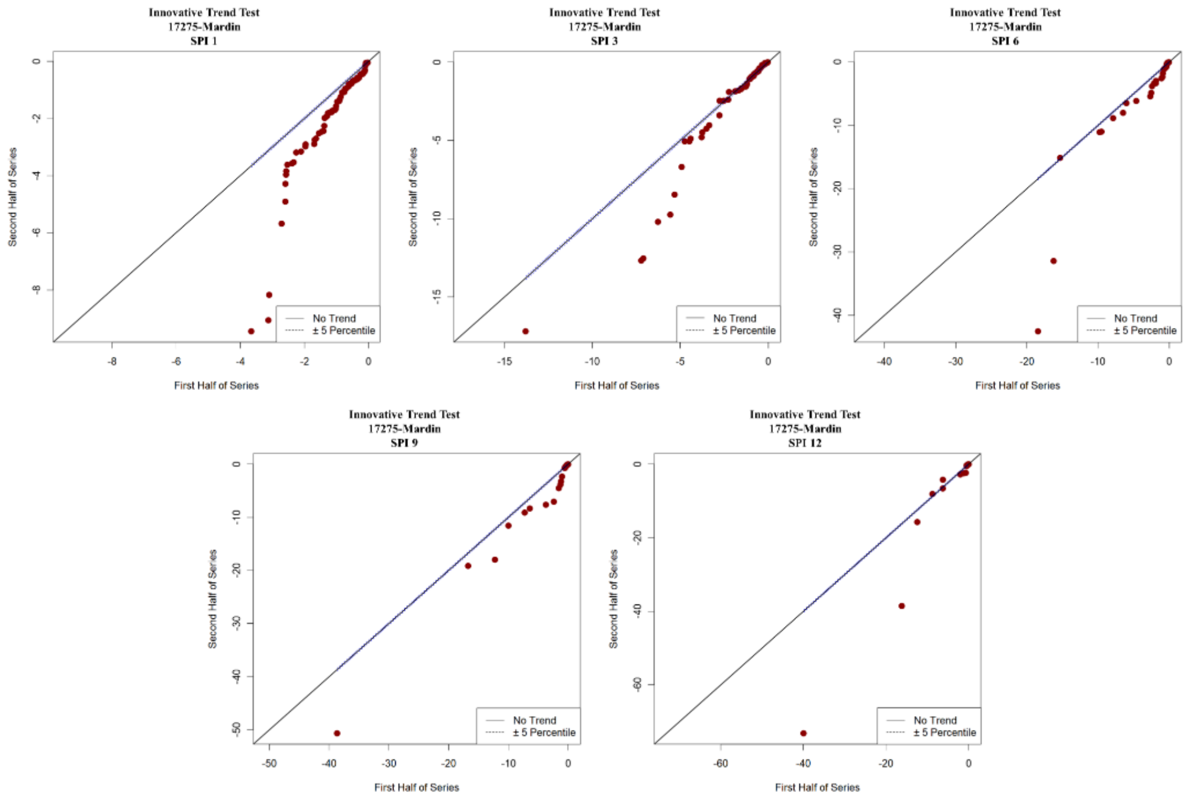

Figure 7. ITA of drought severity of Mardin (1-, 3-, 6-, 9- and 12-month)

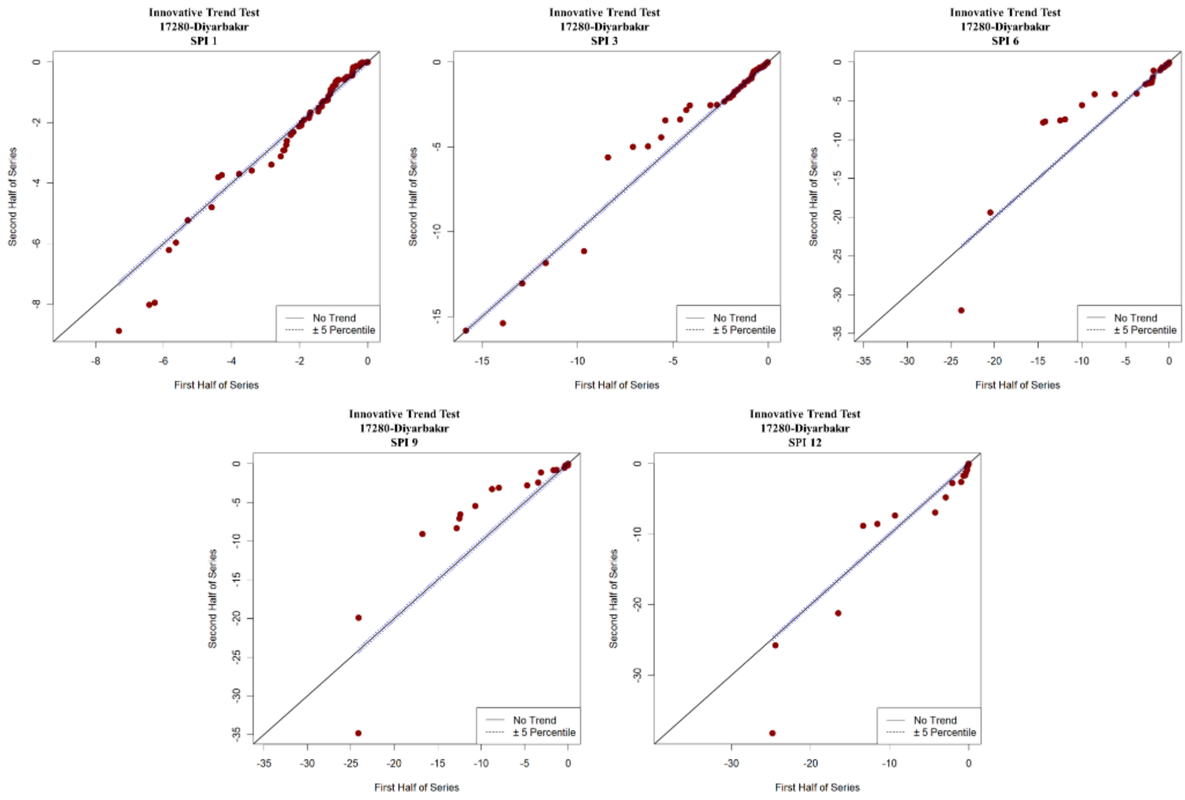

Figure 8. ITA of drought severity of Diyarbakır (1-, 3-, 6-, 9- and 12-month)

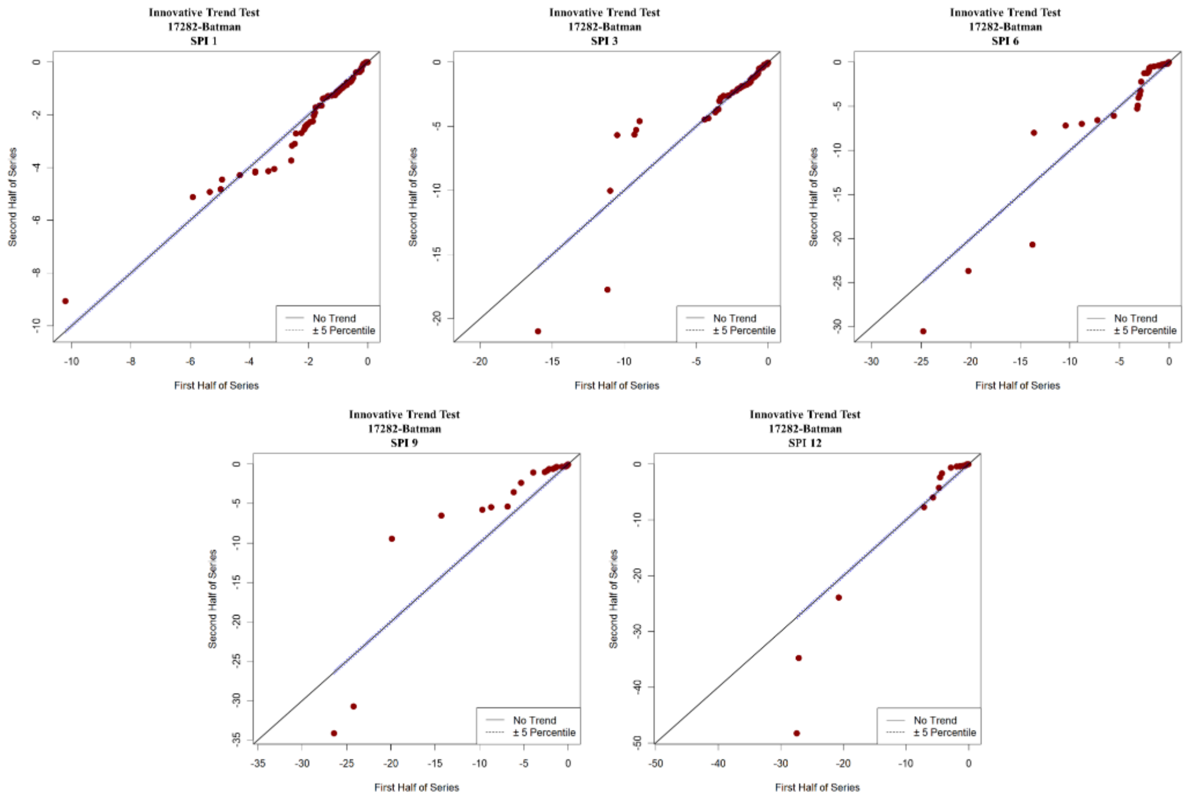

Figure 9. ITA of drought severity of Batman (1-, 3-, 6-, 9- and 12-month)

This explains that drought increased in all time periods in Mardin station, while drought increased in some time periods in Siirt (1-month), Diyarbakır (12-month) and Batman (1- and 12-month).

Table 4. Statistical significance test result of ITA

Station	Time Scale	Slope	Intercept	Slope of SD	Correl.	Lower CL	Upper CL	Decision
Siirt	SPI 1 DS	-0.0019	1.0716	0.0002	0.9908	-0.0003	0.0003	Downward
	SPI 3 DS	0.0022	-0.3645	0.0012	0.9845	-0.0024	0.0024	No Trend
	SPI 6 DS	0.0094	-0.6751	0.0082	0.9573	-0.0161	0.0161	No Trend
	SPI 9 DS	0.0954	-2.8582	0.0167	0.9692	-0.0327	0.0327	Upward
	SPI 12 DS	-0.0243	0.7646	0.0174	0.9810	-0.0341	0.0341	No Trend
Mardin	SPI 1 DS	-0.0090	7.0637	0.0005	0.9388	-0.0010	0.0010	Downward
	SPI 3 DS	-0.0102	2.7020	0.0012	0.9747	-0.0023	0.0023	Downward
	SPI 6 DS	-0.0533	5.3056	0.0096	0.9315	-0.0189	0.0189	Downward
	SPI 9 DS	-0.0818	4.0942	0.0081	0.9918	-0.0160	0.0160	Downward
	SPI 12 DS	-0.2270	6.2885	0.0338	0.9782	-0.0662	0.0662	Downward
Diyarbakır	SPI 1 DS	-0.0004	0.1968	0.0002	0.9892	-0.0005	0.0005	No Trend
	SPI 3 DS	0.0039	-0.7940	0.0012	0.9822	-0.0024	0.0024	Upward
	SPI 6 DS	0.0234	-1.6770	0.0118	0.9126	-0.0232	0.0232	Upward
	SPI 9 DS	0.0805	-2.6490	0.0255	0.8886	-0.0499	0.0499	Upward
	SPI 12 DS	-0.0577	1.9047	0.0240	0.9493	-0.0470	0.0470	Downward
Batman	SPI 1 DS	-0.0012	0.7138	0.0003	0.9837	-0.0005	0.0005	Downward
	SPI 3 DS	0.0016	-0.3174	0.0029	0.9057	-0.0058	0.0058	No Trend
	SPI 6 DS	0.0016	-0.1619	0.0053	0.9610	-0.0103	0.0103	No Trend
	SPI 9 DS	0.0324	-2.1069	0.0130	0.9187	-0.0254	0.0254	Upward
	SPI 12 DS	-0.0664	1.7669	0.0247	0.9757	-0.0484	0.0484	Downward

Table 5 shows the trends detected in the MK and ITA tests. When compared, no contrasting results were obtained at any station between the two methods. However, it is seen in the table that the trends not detected in MK are detected in ITA. The 1-month drought intensity of the Mardin station, which was detected as a downward trend in MK, was also a downward trend in ITA.

Table 5. The comparison of tests used in trend analysis (→=No Trend, ↓= Downward, and ↑= Upward)

Stations	Trend Tests	SPI 1 DS	SPI 3 DS	SPI 6 DS	SPI 9 DS	SPI 12 DS
Siirt	MK	→	→	→	→	→
	ITA	↓	→	→	↑	→
Mardin	MK	↓	→	→	→	→
	ITA	↓	↓	↓	↓	↓
Diyarbakır	MK	→	→	→	→	→
	ITA	→	↑	↑	↑	↓
Batman	MK	→	→	→	→	→
	ITA	↓	→	→	↑	↓

When the studies conducted by Sezen (2020), Muratoglu (2012) and Gumus (2022) in the Tigris basin, where the stations used in this study are located, are examined, it is seen that precipitation and flow show a decreasing trend throughout the basin. In contrast to these, temperature shows an increasing trend (Hadi and Tombul, 2018). It is usual that drought, which occurs when the meteorological and hydrological water availability falls below normal, is negatively affected by the decrease in precipitation and flow in the region and the increase in temperatures. In all 4 stations, as a result of the negative change in drought severity, it can be shown among the reasons for the increase in short- and long-term drought events.

CONCLUSION

Drought analyses were calculated for 1-, 3-, 6-, 9-, and 12-month periods using the SPI method. The trends of drought severity were calculated by applying MK and ITA to the drought severity series, which is one of the drought parameters. According to the results obtained from drought analysis in the study area, it was determined that high severity droughts were observed in high time periods and the duration of these droughts was high in proportion to their severity. In the results obtained, according to the MK test, no significant trend in drought severity was detected in all time periods of all stations except for Mardin (1-month). According to ITA, which captures more trends than the MK test, drought severity shows an increase in Siirt and Batman in the 1-month period, Diyarbakır and Batman stations in the 12-month period, where there is an increase in drought severity in all periods of Mardin station.

As a result, drought increases according to the SPI drought severity index in the Southern-east Region of Turkey. Identification of drought characteristics and analyses of their temporal variations contribute to the water use action plans of administrations and legislators in the region. Because of that, in the future studies, it is considered to make a more detailed analysis of drought using different drought indices and trend analysis methods. Trend analysis of drought indices will give us more explicit information in determining drought.

Conflict of Interest

The article authors declare that there is no conflict of interest between them.

Author's Contributions

The authors declare that they have contributed equally to the article.

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