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Drought assessment of Yeşilırmak Basin Using Long-term Data

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Abstract: Drought is a prolonged period of inadequate rainfall, such as one season, one year or several years, on a statistical multi-year average for a region. Drought is a natural disaster effective on several socio-economic activities from agriculture to public health and leads to deterioration of the environment sustainability. The drought starts with meteorological drought, continues with agricultural and hydrological drought, and when it is in the socioeconomic dimension, the effects begin to be observed. Generally, drought studies are based on drought indices in the literature. This study applied long-term precipitation, temperature, and evaporation data from Samsun, Tokat, Merzifon, Çorum and Amasya meteorological stations from 1961 to 2022 to investigate the drought in the Yeşilırmak basin of Turkey. The present study applied Standardized Precipitation Index (SPI), and Effective Drought Index (EDI), China Z- Index (CZI) and Standardized Precipitation Evapotranspiration Index (SPEI) based on daily, monthly, seasonal, and annual time periods to evaluate drought. The Sen slope and Mann-Kendall test were employed for data analysis. The results revealed that the monthly drought indices for the study area were almost identical for the study area. Although dry and wet periods were observed.

Key words: Drought, EDI, Mann-Kendall, Sen slope.

Yeşilırmak Havzası'nın uzun vadeli veriler kullanılarak kuraklığının değerlendirmesi

Öz: Kuraklık, tarımdan halk sağlığına kadar birçok sosyo-ekonomik faaliyeti etkileyen ve çevrenin sürdürülebilirliğini bozulmasına neden olan doğal bir afettir. Kuraklık meteorolojik kuraklıkla başlar, tarımsal ve hidrolojik kuraklıkla devam eder, sosyoekonomik boyuta geçtiğinde ise etkileri görülmeye başlar. Literatürde genellikle kuraklık çalışmaları kuraklık indekslerine dayandırılmaktadır. Bu çalışmada, Türkiye'nin Yeşilırmak havzasındaki kuraklık özelliklerini incelemek için 1961-2022 yılları arasında Samsun, Tokat, Merzifon, Çorum ve Amasya meteoroloji istasyonlarından elde edilen uzun süreli yağış, sıcaklık ve buharlaşma verileri kullanılmıştır. Bu çalışmada, kuraklığı değerlendirmek için aylık, mevsimlik ve yıllık zaman dilimleri kullanılarak günlük verilere dayalı CZI, SPEI, SPI ve EDI değerleri elde edilmiştir. Veri analizi için Sen eğimi ve Mann-Kendall testi kullanılmıştır. Sonuçlar, çalışma alanı için aylık kuraklık indekslerinin neredeyse aynı olduğunu ortaya koymuştur. Özellikle şiddetli ve yağışlı dönemler gözlemlenmiş olmasına rağmen, genel olarak normal kuraklık seviyeleri gözlenmiştir

Anahtar kelimeler: Kuraklık, EDI, Mann-Kendall, Sen eğimi.

1. Introduction

Drought is a life-threatening natural disaster leading to several socio-economic activities such as agriculture, public health, and leads to deterioration the sustainability of environmental systems. There is not a precise definition of drought in the literature. However, drought effects are increasingly seen across the world. Humans usually feels drought when water scarcity begins [1]. There are four main types of droughts in the literature: meteorological, hydrological, socioeconomic, and agricultural droughts. The drought starts with meteorological drought, continues with agricultural and hydrological drought, and when it is in the socioeconomic dimension, the effects begin to be observed. Therefore, it is crucial to analyze the drought situation [2].

Generally, drought studies are based on drought indices in the literature. Several indices are employed in the literature to evaluate drought such as SPI (Standardized Precipitation Index, [3], CZI (China-Z Index), [4], EDI (Effective Drought Index), [5], PDSI (Palmer Drought Severity Index) [6], SPEI (Standardized Precipitation Evapotranspiration Index) [7], RDI (Reconnaissance Drought Index) [8], SDI (Streamflow Drought Index) [9], SWSI (Surface Water Supply Index) [10], SMDI (Soil Moisture Deficit Index) [11], ARI (Agricultural Rainfall Index) [12], ETDI (Evapotranspiration Deficit Index))[11]], etc.

The SPI has been commonly applied in Turkey ([13–15] and worldwide [16–19]

Morid et al. [18] used several drought indices for drought and compared them with each other. They concluded that EDI and SPI are better at identifying the start of drought, but EDI outperforms the SPI based on the sensitivity. Mishra and Singh [20] compared the strong and weak points of different indices against each other

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in their drought study. They stated that the best results are obtained with SPI when Gamma distribution is used since rainfall fits the Gamma distribution better than other distributions.

Yacoup and Tayfur [16] conducted a comparison of various meteorological drought indices for the Trarza Region of Mauritania for 1, 3, 6 and 12 months. They found that SPI values obtained from gamma and log-normal distributions can detect more severe droughts than SPI and CZI values obtained from normal distribution. Malik et al. [21] studied drought with the EDI for the Uttarkand State of India and used Mann-Kendall and the Innovative Sen Method for trend detection. It was determined that Innovative Şen method outperformed the MK method when different drought types are studied in the study. This advantage is due to the fact that the trend that cannot be studied with the MK method can be examined with the Innovative Şen method. Drought studies are widespread in Turkey as several parts of world.

Dogan et al. [22] performed a drought study in the Konya Closed Basin and performed a comparison of several drought indices and reported that EDI provides better performance than the others. Tugrul et al. [23] identified the droughts that are important for the region with EDI for the Southeastern Anatolia Region, studied the droughts occurring in the provinces in the region, and determined the percentages of drought events in total time. Gumus et al. [24] analyzed drought with monthly total precipitation data for the Southeastern Anatolia Project region and investigated the trend of drought with nonparametric MK and Mann-Kendall Rank Correlation tests. It was stated that a downward trend was determined in the majority of the region. Katipoglu et al. [25] analyzed SDI values with MK and Modified MK tests to detect trends in the hydrological drought of the Euphrates basin. It was reported that downward trends were determined in the Euphrates basin in summer and fall months.

Katipoglu et al. [26] applied Innovative Şen method and Mann-Kendall to detect the trend in the hydrological droughts of Yesilirmak basin. It was found that upward trends were dominant at monthly and annual scale. Şimşek et al. [27] analyzed meteorological drought for the Çoruh Basin using the SPI method. It was found that the longest dry time was observed after 2010 and drought increased with increasing time scale. Tuğrul and Hınıs [28] conducted meteorological and hydrological drought trend analysis in Konya Apa Dam Basin. Trend analysis demonstrated that there is an upward trend in all data in the findings obtained from ITA and in SPI-6, SPI-9 and SPI-12 in the findings obtained from MK at 0.01 significance level. Yuce et al. [29] analyzed drought in Samsun province with SPI and SPEI. Normal drought was observed more than the other drought types in Samsun while very severe drought was observed less. There is little difference between the two indices.

Değer et al. [30] analyzed hydrological drought using SDI and Innovative Trend Analysis (ITA) for 1, 3, 6, 9, 12-scale for the Kızılırmak Basin. The results show that mild drought was observed more. The Drought analysis in the Yeşilırmak Basin was studied with RDI and SPI indices by Hinis and Geyikli [31]. They show that the SPI and RDI methods generally indicate similar values for wet periods, whereas the RDI defines more extreme dry periods than the SPI during extreme dry periods. Zeybekoglu et al. [32] compared drought indices for Yeşilırmak Basin to assess the drought. They found that these indices yield similar results and SPI determines drought at an earlier stage than the other indices. Simsek et al. [33] evaluated the drought for the Black Sea region in Turkey. It was observed that the occurrence of severe and extreme droughts is nearly 15%. Yuce et al. [34] studied the hydrological drought analysis of Yeşilırmak Basin of with SDI and ITA. It was observed that drought categories are less than wet categories.

The drought indices, as given above, can be analyzed according to the drought type and the data to be used, as well as the function and the area of application of the indices. This study used SPI, CZI, SPEI and EDI compatible with the literature. The EDI, which is considered in this study, is frequently preferred as indices that provides satisfactory results because it can be calculated using daily temperature and precipitation values to assess drought [21–23].

This study was conducted using the most updated data (1961-2022) of Amasya, Çorum, Merzifon, Samsun and Tokat monitoring stations in Yeşilırmak Basin in Turkey. CZI, SPEI, SPI, and EDI values were used in the drought assessment of Yeşilırmak basin. It is seen in the literature that drought assessments have been made for the Yeşilırmak basin according to many different drought indices. Nevertheless, SPI, SPEI and CZI drought indices commonly used in the literature were used. In addition, the EDI was employed in the present study, which is different from the literature and adds originality to the study. In addition, Mann Kendall method and Sen slope were used to determine the trends in precipitation and mean temperature for 95% confidence interval.

2. Study area

Yeşilırmak Basin is located at 35° 49′ 52" East longitude and 40° 38′ 54" North latitude. It occupies an area of approximately 40.000 km², which is 5% of Turkey's total area (Fig. 1). The basin is bordered by the Seyhan, Kızılırmak, Western and Eastern Black Sea, Euphrates-Tigris basins [34].

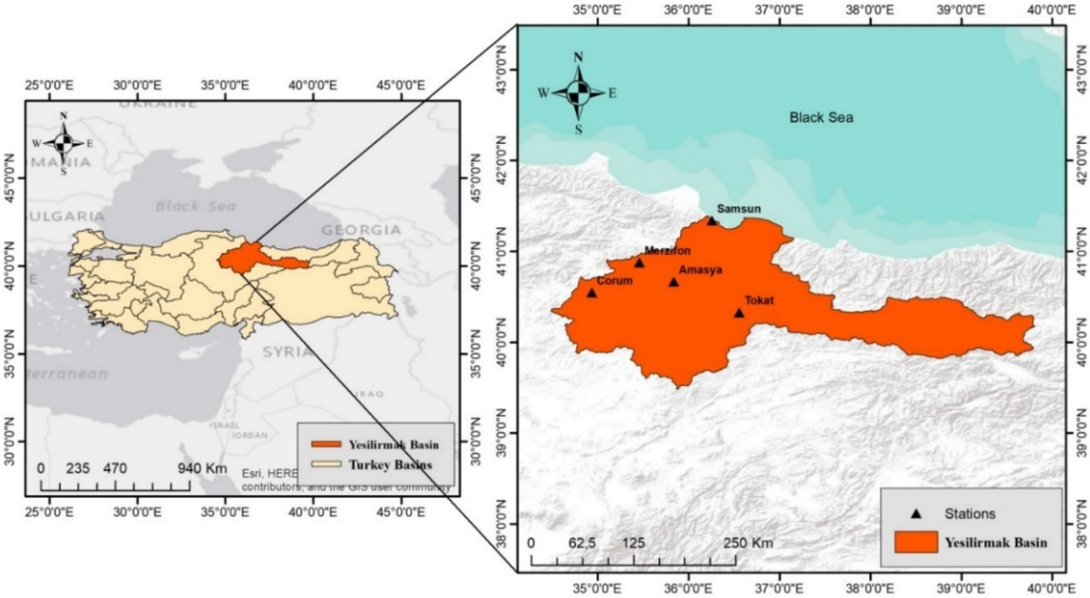

Figure 1. Location map of the present study

3. Methods and Materials

3.1. Data analysis

The meteorological data were provided from the General Directorate of Meteorology in daily average, maximum and minimum temperature, and daily precipitation data (P). In this study, homogeneity procedure was applied to complete the missing data. SPI, CZI, SPEI and EDI were calculated using daily values. Station details are shown in Table 1.

Table 1. Meteorological Monitoring Station

Station names	Latitude	Longitude	Altitude	Daily			
				T_{min} (C)	T_{ave} (C)	T_{max} (C)	P (mm)
17083-Merzifon	40.8793	35.4585	754	-21	11.5	42.6	1.17
17085-Amasya	40.6668	35.8353	409	-21	13.6	45	1.26
17086-Tokat	40.3312	36.5577	611	-22.1	12.5	45	1.17
17084-Çorum	40.5461	34.9362	776	-27.2	10.8	42.6	1.22
17030-Samsun	41.3442	36.2564	4	-7	14.6	38.7	1.95

3.2. Sen slope

It is a nonparametric test to detect the trend slope, developed by Sen [35]. Sen's slope is effective in large data errors and is employed to compute the trend in the time series data [36]. The magnitude of the trend is computed in (1) as follows [37,38]:

$$\beta = median\left(\frac{x_i - x_j}{t_i - t_j}\right) \quad (1)$$

in which x_i: value at time t_i and x_j: data value at time t_i (i> j). β indicates the magnitude of the trend.

3.3. Mann-Kendall test

Mann-Kendall test is employed commonly in the literature to detect the trend of meteorological and hydrological parameters in the hydrology [39–46]. The trend slope of time series can be computed using the Mann-Kendall test [47–49] as given in equations (2) to (5).

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \quad (2)$$

$$sgn(x_j - x_k) = f(x) = \begin{cases} 1, & if (x_j - x_k) > 0 \\ 0 & if (x_j - x_k) = 0 \\ -1 & if (x_j - x_k) < 0 \end{cases} \quad (3)$$

in which n is the data length. A downward trend refers to for S<0, but an upward trend refers to for S>0.

$$\sigma^2(s) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{p} t_i(t_i-1)(2t_i+5)}{18} \quad (4)$$

where p=number of groups, t_i=data number at p^{th} group. The Z value is calculated as below.

$$Z = \begin{cases} \frac{S-1}{\sqrt{\sigma^2(s)}}, & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sqrt{\sigma^2(s))}}, & if\ S < 0 \end{cases} \quad (5)$$

There has a tendency if $|Z|>Z_{1-\alpha/2}$, while there is no statistical trend if the condition $|Z|<Z_{1-\alpha/2}$. A significance level of 5% was used for the analysis.

3.4. Drought indices

3.4.1. Effective Drought Index (EDI)

The EDI is computed on a daily time scale and Byun and Wilhite [5] pioneered the development of the EDI, aiming to overcome some of the shortcomings observed in other indices such as the SPI. The EDI has a numerical range of -2.5 to 2.5. The EDI is calculated by applying the equations (6) to (8):

$$EP_i = \sum_{DS}^{n=1} \left[\frac{(\sum_{n}^{m=1} P_{i-m})}{n} \right] \quad (6)$$

$$DEP_i = EP_i - MEP \quad (7)$$

$$EDI_i = \frac{DEP_i}{\sigma(DEP)} \quad (8)$$

Here, DS is the number of days (usually 365 or 15) used for rainfall accumulation to compute drought severity, while σ is a standard deviation and MEP is the mean EP. The EDI ranges from -2.5 to 2.5. The drought range is different from SPI and SPEI (Table 2).

3.4.2. China Z Index (CZI)

CZI was developed by China International Climate Centre to evaluate drought in China [4,22,50]. CZI is calculated in the following equations (9) to (11) [4,22,50]:

$$CZI_j = \frac{6}{C_{st}} \left(\frac{C_{st}}{2} \varphi_j + 1 \right)^{\frac{1}{3}} - \frac{6}{C_s} + \frac{C_{st}}{6} \quad (9)$$

$$C_{st} = \sum_{j=1}^{N} \frac{(X_j - \bar{X})^3}{N \times \sigma^3} \quad (10)$$

$$\varphi_j = \frac{X_j - \bar{X}}{\sigma} \quad (11)$$

where t is the time (1, 2, 3, …9, 12, 24, 36, 48 months), C_{st} is a skewness coefficient for t, φ_j is a standard deviation, N is the total number of observation years, σ and $\bar{X}$ are the standard deviation and average of the rainfall X_j, respectively.

3.4.3. Standardized Precipitation Index (SPI)

The SPI is the dominant drought index on a global scale used for monitoring and comprehensive analysis [51–53]. As seen in the studies of [22,54,55], SPI has been recognized as an important tool for the identification of

meteorological drought patterns. The pioneering work of [3] has shown that the SPI can be measured at multiple temporal scales (1, 3, 6, 9, 12, 24, and 48 month scale). The SPI values vary from +2.0 to -2.0.
SPI is based only rainfall data that can be cumulated over different time scales, and can be computed as in (12):

$$g(x) = \frac{P^{\alpha-1} e^{\frac{-P}{\beta}}}{\beta^{\alpha} \Gamma(\alpha)} \tag{12}$$

In this context, the gamma function is denoted by Γ, where P is the rainfall, α is the shape parameter, and β is the scale parameter [22].

3.4.4. Standardized Precipitation Evapotranspiration Index (SPEI)

SPEI is employed to assess the meteorological drought considered rainfall and temperature in a region [7]. Firstly, the SPEI is computed using potential evapotranspiration (PET). The equation of water balance is applied to compute the monthly deficit (D_i) in the following equations (13) and (14).

$$D_i = P_i - PET_i \tag{13}$$

in which P_i is the total precipitation at i^{th} month. SPEI is computed by Eq. (14) [15,56].

$$SPEI_i = W_i - \frac{2.515517 + 0.802853W_i + 0.010328W_i^2}{1 + 1.432788W_i + 0.189269W_i^2 + 0.001308W_i^3} \tag{14}$$

$$W_i = \begin{cases} p < 0.5, & \sqrt{-2lnp} \\ p > 0.5, & \sqrt{-2\ln(1-p)} \end{cases}$$

where p is the exceeding probability of calculated D_i values.

In the computation of SPEI and SPI, the methodology of the studies of McKee et al. [3], Mersin et al. [15] and Vicente Serrano et al. [54] were employed. The drought classification calculated indices is shown in Table 2.

Table 2. Drought classification of CZI, EDI, SPI and SPEI [18,54,57]

Conditions	CZI, SPI and SPEI	EDI
Extremely wet	value ≥ 2.00	value ≥ 2.50
Very wet	1.50 ≤ value < 2.00	1.50 ≤ value < 2.50
Moderately wet	1.00 ≤ value < 1.50	0.7 ≤ value < 1.50
Near normal	−1.00 ≤ value < 1.00	−0.70 ≤ value < 0.70
Moderately dry	−1.50 ≤ value < −1.00	−1.50 < value < −0.70
Severely dry	−2.00 ≤ value < −1.50	−1.50 ≤ value < −2.50
Extremely dry	value ≤ −2.00	value ≤ −2.50

4. Results and Discussions

The present study was conducted by using monthly, seasonal, and annual time scales to compute the EDI, CZI, SPEI and SPI values to assess the drought of Yeşilırmak basin. In the present study, precipitation data for the Yeşilırmak basin for the years 1961-2022 were analyzed by applying the Sen slope and Mann-Kendall test and shown in Table 3. A downward trend was determined in rainfall data for all meteorological stations at 95% confidence interval based on Sen's slope. These trends were also evaluated with Mann-Kendall test.

Table 3. Mann-Kendall and Sen's slope results and descriptive statistics of rainfall

Station name	Descriptive statistics			Mann-Kendall		Sen's slope
	Maximum	Mean	Std. deviation	Kendall's tau	p-value	
Amasya	71.2	1.26	3.713	-0.001	0.770	-0.001
Çorum	58.4	1.22	3.635	-0.016	**0.002**	-0.001
Merzifon	95.8	1.17	3.464	-0.010	0.055	-0.001
Samsun	238.2	1.95	5.896	0.008	0.128	-0.001
Tokat	52.5	1.17	3.322	-0.001	0.805	-0.001

Figure 2 shows the variation of SPI-1, SPEI-1 and CZI-1 values derived between 1961 and 2022. In this date range, dry and wet periods were obtained for SPI-1, SPEI-1 and CZI-1. According to the findings, it is realized that especially SPI-1 values differ from the other indices. As seen in Fig. 2, the values below the -2 line represent an extremely dry situation, while the values above the +2 line represent an extremely wet situation. As seen in Fig. 2, for SPI-1, SPEI-1 and CZI-1, very severe, severe, and moderate drought and very severe, severe, and moderate wet periods were observed.

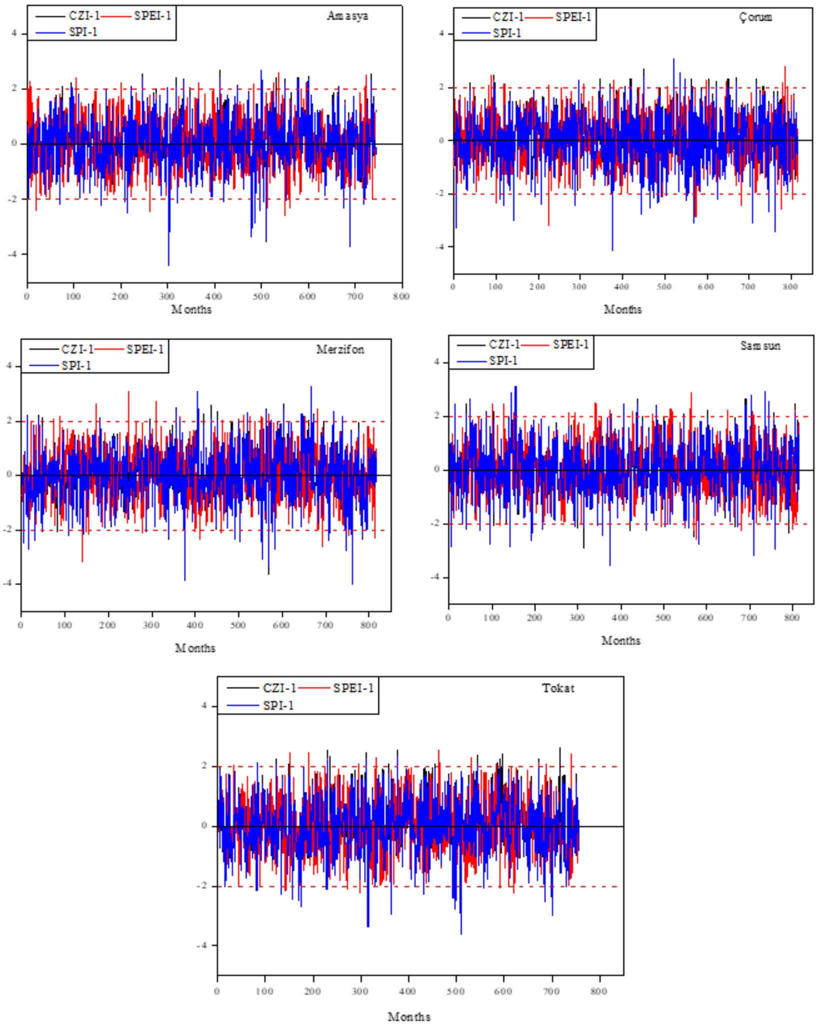

Figure 2. Monthly variation of CZI, SPEI and SPI values

Figure 3 presents the variation of SPI-3, SPEI-3 and CZI-3 values between the years 1961-2022. Dry and wet periods were obtained for SPI-3, SPEI-3, and CZI-3 between 1961-2022. The findings show that especially SPI-3 values are different from other indices. As mentioned above, values below the -2 line represent extremely dry conditions, whereas values above the +2 line represent extremely wet conditions. As shown in Fig. 3, there are very severe drought, severe and moderate drought and very severe, severe, and moderate wet periods for SPI-3, SPEI-3, and CZI-3. It was observed that droughts occurred in almost all seasons in Yeşilırmak basin, but extremely droughts generally occurred in the fall season.

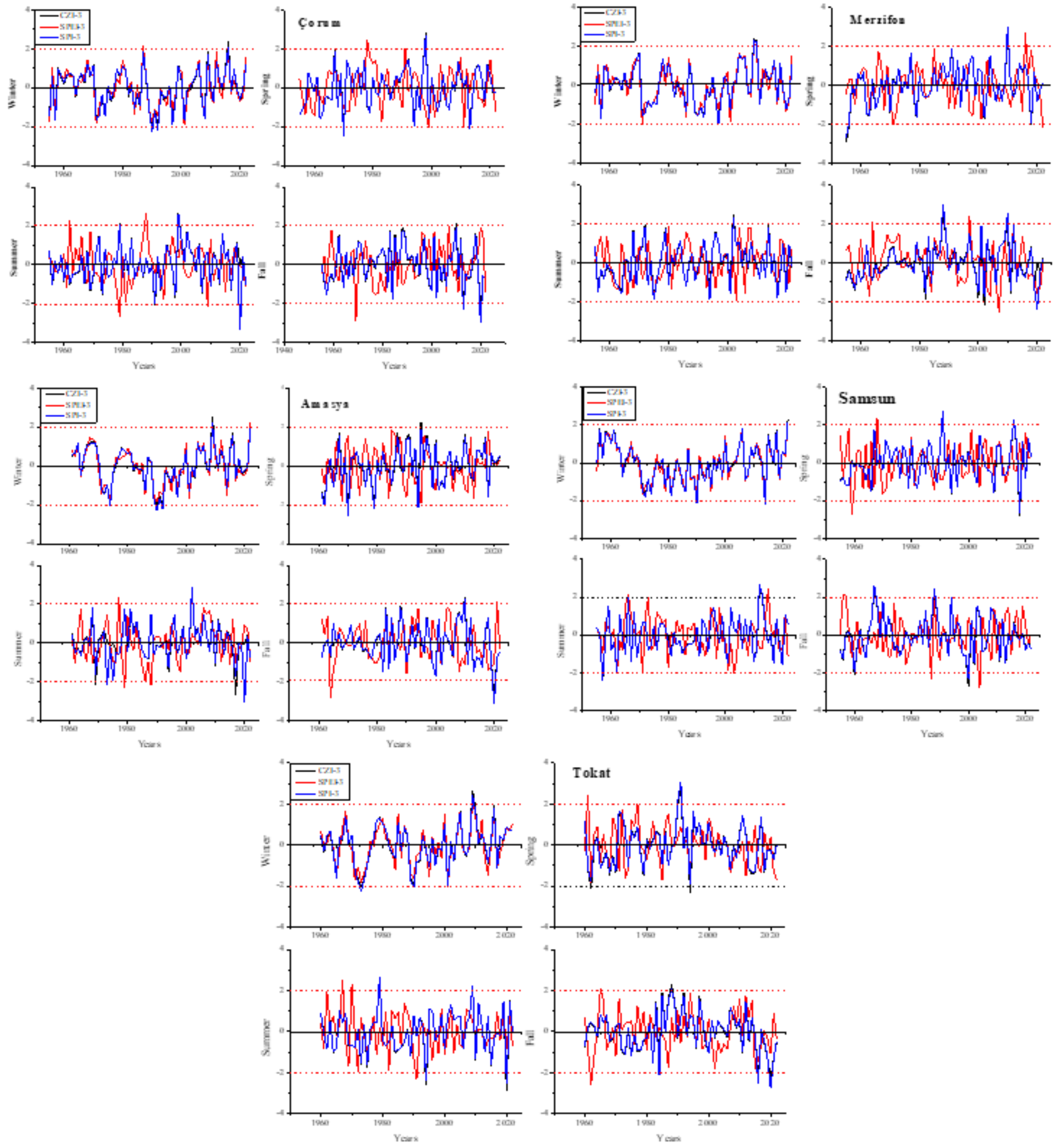

Figure 3. Seasonal variation of CZI, SPEI and SPI values

Figure 4 shows the variation of SPI-12, SPEI-12 and CZI-12 values obtained between 1961 and 2022. Wet and dry periods were observed for SPI-12, SPEI-12 and CZI-12 during this period. As seen in Fig. 4, extremely dry, severe and moderate drought and extremely wet, severe and mild wet periods were detected for SPI-12, SPEI-12 and CZI-12.

In general, the results of drought indices are compatible with each other. As seen in the Fig. 4, extremely dry periods occurred in Amasya in 2020s, in Çorum in 1960, 2010 and 2020s, in Merzifon in 1960 and 2020s, and in Samsun in 1980s. However, almost no extremely dry conditions were observed at Tokat station.

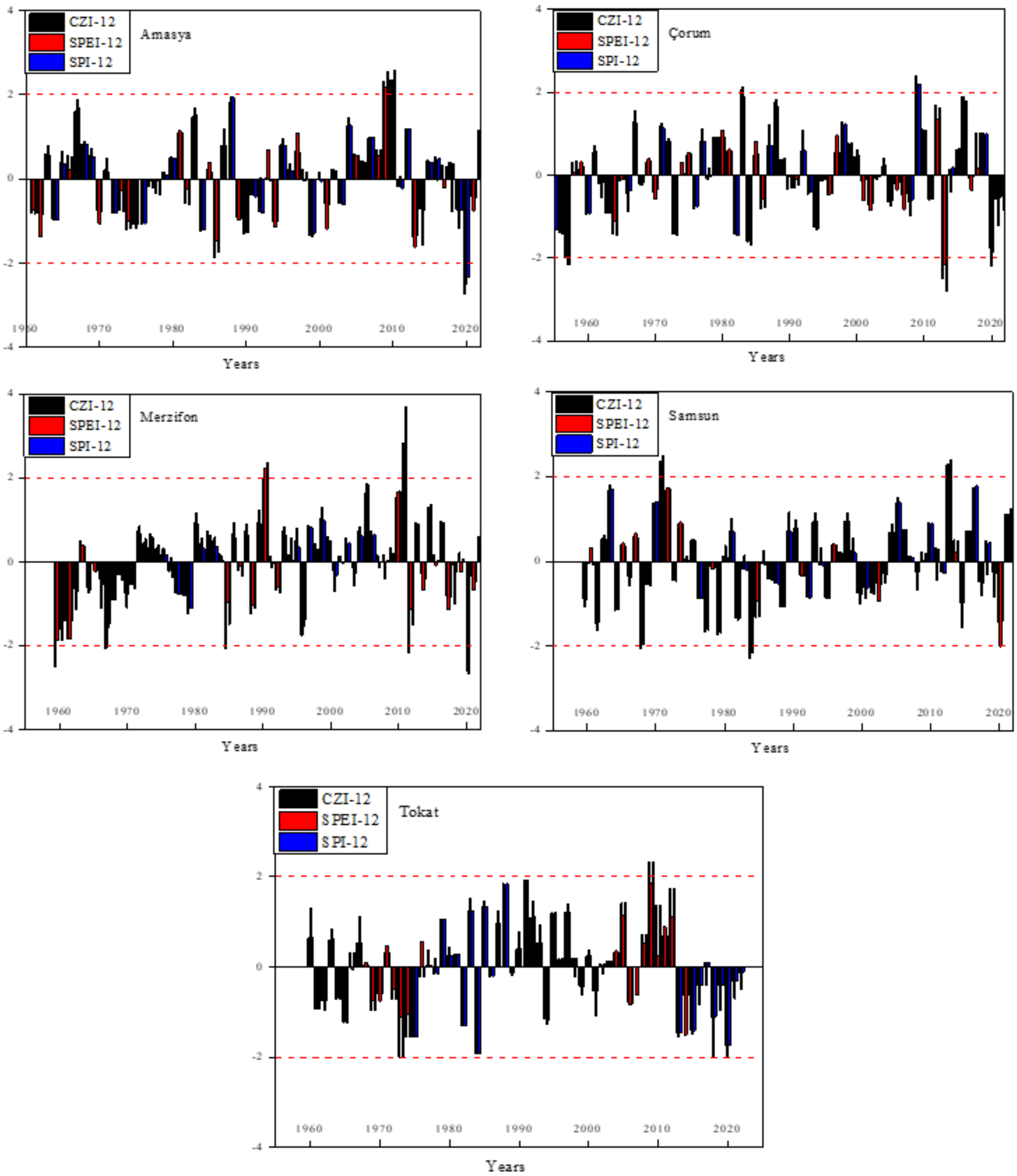

Figure 4. The variation of CZI, SPEI and SPI at annual time scale

Figure 5 shows the correlation between SPEI, CZI and SPI used for drought for Tokat. The linear correlation for SPEI, CZI and SPI shows a strong relationship. The R^2 values were used to analyze the correlation between SPEI, CZI and SPI ($\frac{\sum_{i=1}^{n}(o_i - o_{mean})^2 - \sum_{i=1}^{n}(o_i - p_i)^2}{\sum_{i=1}^{n}(o_i - o_{mean})^2}$). p is the predicted value and o is the observed value, o_i and p_i are the observed and predicted i^{th} values. R^2 values close to 1 mean that they have the most accurate prediction results possible [58]. As seen in Fig. 5, the lowest R^2 value was obtained between SPEI and SPI with 0.817 in the 1-month time scale. As shown in Fig. 5, consistent results were obtained between SPEI, CZI and SPI values at Tokat station. The results are more consistent between SPI and CZI.

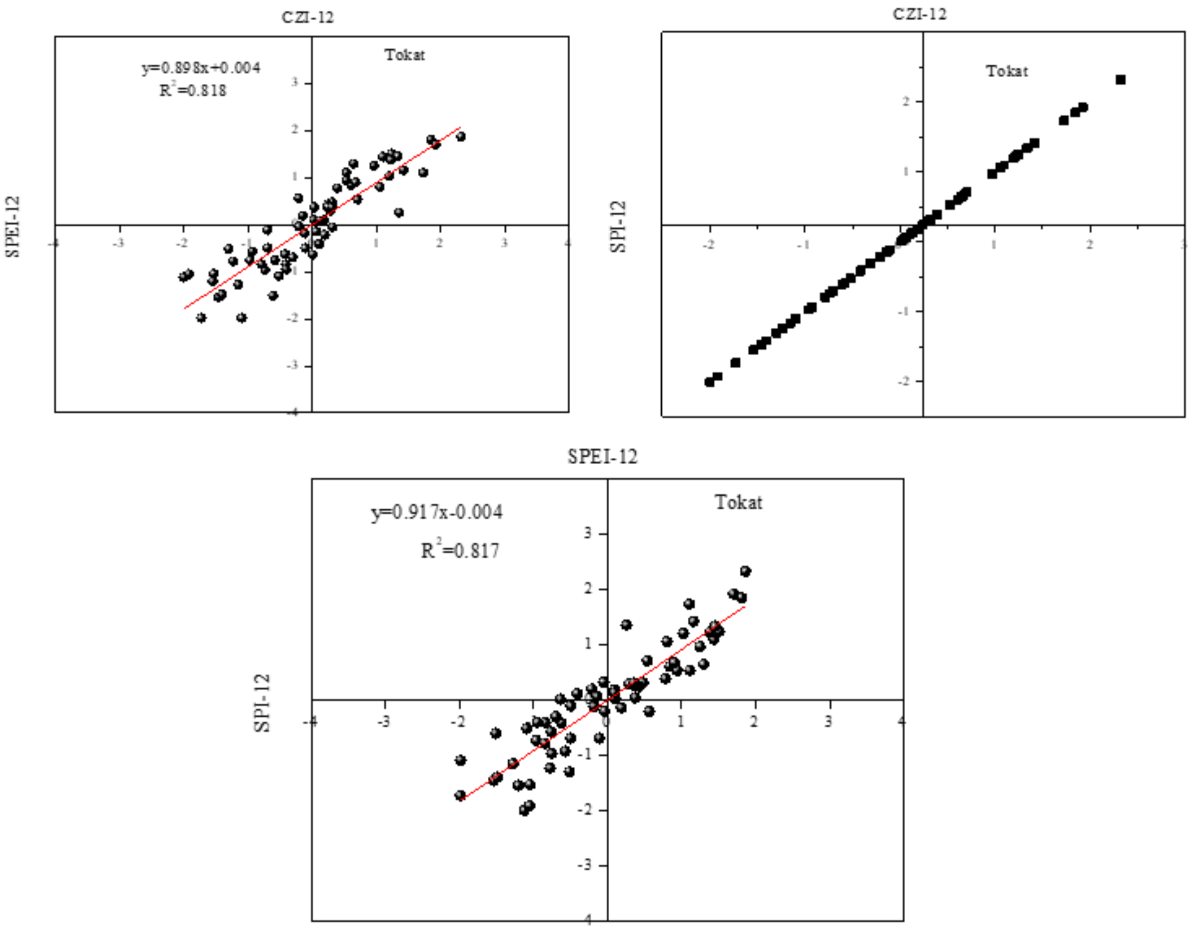

Figure 5. The comparisons of CZI-1, SPI-1 and SPEI-1

Figure 6 depicts the variation of EDI-1, EDI-3 and EDI-12 values obtained between 1961 and 2022. As seen in Fig. 6, the values below the -2.5 line represent an extremely dry situation, while the values above the +2.5 line represent an extremely wet situation. As shown in Fig. 6, for EDI-1, EDI-3 and EDI-12, extremely dry, severe and moderate drought and extremely wet, severe and moderate wet periods were observed. For EDI-1, extremely dry conditions occurred at all stations except Amasya station.
Moreover, Figure 6 shows that droughts occur in almost all seasons in Yeşilırmak basin in EDI-3. According to EDI-3 and EDI-12, no extremely dry condition occurred at any station.

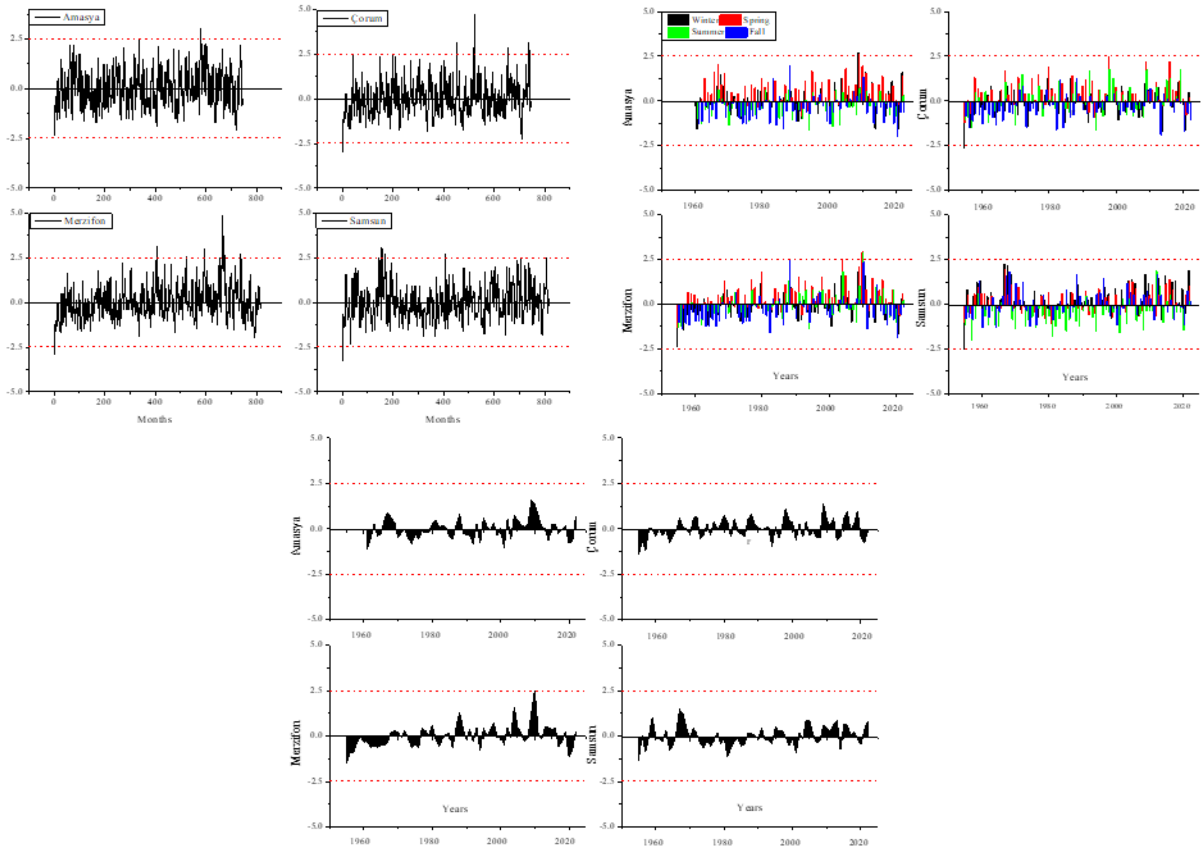

Figure 6. The variation of EDI-1, EDI-3 and EDI-12

The number of dry and wet months between 1961 and 2022 for the Yeşilırmak basin is given in Fig. 7. While SPEI, SPI and CZI are subject to the same drought classification, EDI is subject to a different drought class. Therefore, the number of dry and wet months obtained was used to make comparisons between the indices. For example, when SPI, SPEI and CZI<-2.00, extremely dry occurs, while the same is true for EDI<-2.5 in EDI (Table 2). Considering the 1-month time series, the normal condition occurred at most in all stations for CZI-1, SPEI, EDI-1 and SPI-1. When EDI-1 drought index is considered, extremely dry did not occur in any station. Extremely dry occurred 6, 6 and 19 times for CZI-1, SPEI-1 and SPI-1 for Amasya station, respectively. Extremely dry occurred 4, 8 and 21 times for Çorum, 9, 13 and 16 times for Merzifon, 14, 12 and 18 times for Samsun and 6, 8 and 21 times for Tokat.

Extremely dry occurred 14 times for Samsun according to CZI index, 13 times for Merzifon according to SPEI index, 21 times each for Tokat and Çorum according to SPI index and no extremely dry events occurred according to EDI. As seen in the Fig. 7, the highest number of extremely dry conditions was obtained according to SPI index. The driest month in Yeşilırmak basin occurred in Çorum in March 1986 with SPI-1=-4.12. The driest month according to CZI index was in Merzifon in May 2002 with CZI-1=-3.65, the driest month according to SPEI was in Çorum in October 1973 with SPE-1=-3.21 and the driest month according to EDI was in Çorum in January 2014 with EDI-1=-2.30.

Figure 7. The number of dry and wet months

The precipitation and temperature trend behaviors of the Yeşilırmak basin were reported by Serencam [59] using ITA. The downward trends at low, medium, and high levels, with an average of -3.4%, -3.8% and -2.4% were detected, respectively. They also indicated that temperature and precipitation records showed increasing (5-10%) and decreasing trends, respectively. Although the rainfall of the basin is higher than the national average, it has a decreasing trend. Katipoğlu et al. [26] found that many moderate droughts were observed and only a few extreme droughts were observed in the monthly and annual series using SDI in the hydrologic drought assessment of Yeşilırmak Basin. Katipoğlu et al. [26] applied the ITA method to trend analysis of hydrological droughts in the Yeşilırmak basin to classify wet (SDI > 0) and dry periods (SDI < 0) reported that, except for some stations, the trends in both dry and wet periods showed downward trends.

Aktürk et al. [14] conducted a meteorological drought assessment for 1967-2017 with SPI for the Kızılırmak River Basin, neighboring the Yeşilırmak Basin, and reported that thirty one years of the period were affected by drought categories and twenty eight of the thirty one years belonged to mild drought categories. Yuce et al. [29] analyzed drought in Samsun province with SPI and SPEI. Normal drought was observed more than the other drought types in Samsun while very severe drought was observed less. There is little difference between the two indices As seen in the study of Yuce et al. [29], they used the Mann-Kendall test to rainfall data of Samsun, the findings show that there is a relative decrease in this parameter in the trend of the rainfall based on the 95% confidence interval (-0.118). The degree of trend was measured by Sen's slope method for the rainfall (-0.102). The trend in the rainfall data for Samsun in the present study was detected 0.001 based on Mann-Kendall test and -0.001 was detected for Samsun based on Sen’s slope. The reason for the difference between the present study and Yuce et al. [29] can be due to the different period and data format. In this study daily data was used to assess the drought of Yeşilırmak

Basin. In the present study downward trends were determined in the rainfall data of Yeşilırmak Basin for all stations based on Sen's slope whereas an upward trend was determined in the rainfall data for Samsun based on Mann-Kendall test.

5. Conclusions

In this study, China Z Index (CZI), Standardized Precipitation Index (SPI) and Standardize Potential Evapotranspiration Index (SPEI) and Effective Drought Index (EDI) indices based on daily data were obtained by using rainfall, temperature and evaporation data measured by MGM between 1961 and 2022 for Samsun, Tokat, Merzifon, Çorum and Amasya stations located in Yeşilırmak basin. Drought analysis based on monthly, seasonal, and annual time scales was performed using different indices. According to CZI, SPI, SPEI and EDI indices, the number of dry and wet months at each station, as well as the seasonal and annual variations were obtained. The findings of the study were generally in parallel with each other. In addition, according to SPI, SPEI and CZI indices, extremely dry periods occurred in the same time periods. However, according to the EDI index, which is based on daily data, extremely dry periods never occurred at any station. The correlation between SPEI, SPI and CZI values showed that all three indices give similar results. Trend analysis of precipitation data by applying Sen and Mann-Kendall test showed that precipitation showed a decreasing trend. This study represents a step towards a comprehensive understanding of historical drought characteristics in the Yeşilırmak basin. Therefore, the following recommendations for future studies are made. The combination of meteorological drought with hydrological as well as agricultural and groundwater drought can be investigated to highlight the effects of climate change conditions.

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