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Drought Assessment of Siirt using SPI and SPEI

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Abstract Turkey is in the semi-arid semi-humid mid-latitude region. Therefore, drought, one of the destructive effects of climate change, is a fundamental problem for the country, part of which is in the semi-arid climate zone. To evaluate the drought of Siirt province in Turkey, a total of 792 time series were evaluated. In this study, meteorological drought analysis was carried out in Siirt province, located in the Southeastern Anatolia region, monthly and annual periods using the Standardized Precipitation Index (SPI) method and SPEI. Meteorological data (temperature, evaporation, and precipitation) from Siirt province between 1957-2022 were used. The results showed that the monthly and annual values of SPI and SPEI showed almost similar results at the selected stations for annual time scales. Although there were periods of severe drought, normal drought levels were observed in the overall average. The wet and dry periods were identified, and the results were presented graphically. As a result, the trend results in the region will contribute to the water resources planning management.

Keywords – Siirt, SPI, SPEI, Drought, Rain

I. INTRODUCTION

Water is one of the most important elements for living things to survive and is essential for their vital needs. The water needs of living things are met by surface and underground water resources. For the allocation of water resources, it is necessary to determine their efficiency. Historical changes in river flows are vital for water management and water resources planning. The concept of drought is one of the most important issues related to water availability in the context of climate change. Therefore, the measurement of hydrometeorological parameters is very important in the development and planning of the region to assess drought. Changes in hydro-meteorological parameters (precipitation, temperature, runoff, evaporation, etc.) affect climate change in the region. Drought is regarded as a major natural disaster that humanity has faced since ancient times, but it has affected more people than any other hazard and has among the most complex structure of all natural disasters. [1,2]. Unlike other extreme events (cyclones, hurricanes, floods, etc.) drought evolves in slow and steady progression, and its onset and end are not easy to determine [3]. Droughts are particularly more common and severe in arid and semi-arid regions and can last for weeks, months, years, decades or even centuries. The frequency and intensity of drought events are on the rise and have a significant effect on the continued warming of the global climate, human survival, and the sustainable development of society [4]. Wilhite and Glantz, (1985) stated that drought generally forms when a region does not get enough precipitation for a long period of time, leading to water scarcity. Researchers such as Degefu and Bewket (2014) and Sheffield and Wood (2008) have shown in different ways that the causes of drought and its effects on the environment, which are spatially or temporally dependent, are determined by their characteristics such as frequency, magnitude, and intensity. In recent years, drought studies have been common [8–13]. Furthermore, studies have been carried out to compare different methods and indices for drought assessment. Several drought-related indices have been proposed so far to accurately characterize and assess drought events (magnitude, severity, duration, etc.). The standard precipitation index (SPI) is widely used to describe and compare drought in various climatic zones [14,15]. However, numerous studies have agreed on the increasing global temperature, causes the increasing of water need due to evapotranspiration [16]. Therefore, SPEI was improved by considering precipitation and potential evapotranspiration (PET) [17,18]. In the study, drought analysis of Siirt was carried out by using monthly precipitation, temperature and evaporation data, SPI and SPEI indices recorded between 1957 and 2022 from the Siirt meteorological station, considering monthly and yearly time scales.

This study aimed: (1) to obtain SPI and SPEI drought indices at different time scales (1 and 12-month scale), (2) to compare the performances of SPI and SPEI for Siirt province.

II. Study Area

Located at the northeastern end of the Southeastern Anatolia Region, Siirt is surrounded by Şırnak and Van from the east, Batman and Bitlis from the north, Batman from the west, Mardin and Şırnak from the south. The region rises suddenly after the plains of Southeastern Anatolia, and the eastern and northern parts receive abundant rainfall. For this reason, the province is surrounded by the Muş South Mountains from the north and the Siirt East Mountains from the east and constitutes one of the important catchment areas of the Tigris River. The entire territory of the province falls within the Tigris Basin. Siirt is surrounded by highlands covered with rich meadows receiving abundant rainfall in summer and winter.

The continental climate prevails in Siirt and the four seasons are experienced with their most distinctive features. Winters are harsher and rainy in the eastern and northern regions and mild in the southern and southwestern regions. Summers are hot and dry. The study area is shown in Fig. 1

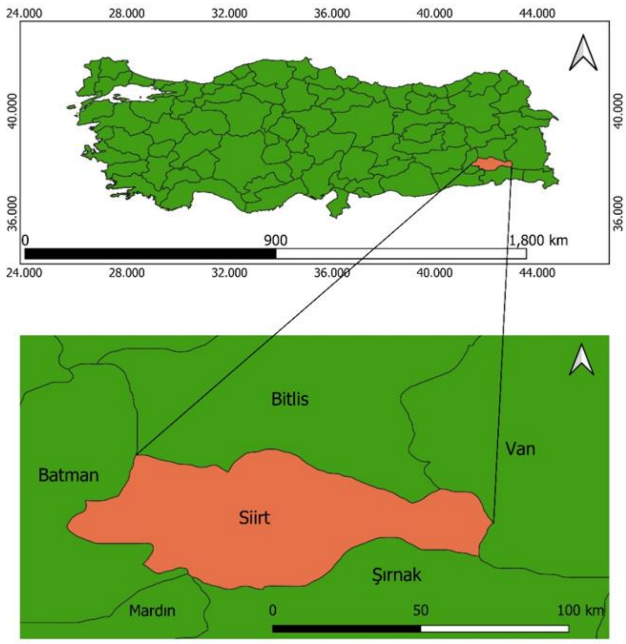


Fig. 1 Study area

III. Materials and Method

3.1. Data Analysis

Meteorological data were obtained from the General Directorate of Meteorology (MGM) as daily data and converted into monthly data. Meteorological data are complete (temperature, precipitation) at the station in Siirt province. Time series of daily data were converted into monthly format. Station name, altitude (m), latitude (°) and longitude (°) are shown in Table 1. The data of the meteorological station used in the study were selected between 1957 and 2022.

Table 1 Locations

St. Name	Latitude (°)	Longitude (°)	Altitude (m)
Siirt	379319	419354	895

3.2 Drought Indices

3.2.1. SPI

SPI values are affected applying different statistical distribution types since SPI is mainly dependent on the distribution fitting to rainfall time-series. As SPI can be calculated for one month, it also calculated for 3, 6, 9, 12, etc. month SPI values. A longer SPI (i.e., 18-, 24-, and 48-month SPIs) are utilized to assess climate, groundwater stage, and the water resources in the region [3]. Gamma distribution was applied to precipitation data as below [19]:

$$(x) = \frac{p^{\alpha-1} e^{\frac{-p}{\beta}}}{\beta^{\alpha} T(\alpha)} \quad (1)$$

$$\propto = \frac{1}{4A}\left(1+\sqrt{\frac{4A}{3}}\right) \quad (2)$$

$$\beta = \frac{\bar{x}}{\alpha} \quad (3)$$

$$A = \ln(\bar{x}) - \frac{\ln(\bar{x})}{n} \quad (4)$$

Where n:the number of observations, β:scale parameter, α:shape parameter T:Gamma-function by integration, P:precipitation amount.

3.2.2. SPEI

SPEI is a drought index related to meteorological drought that considers temperature and precipitation variability to evaluate drought in a region. The first step in calculating the SPEI is to obtain the monthly potential evapotranspiration (PET). Usually, when more data are available, a more complete accounting of drought variability is possible by calculating PET with a more complex method. Then, the equation of water balance is applied to calculate the monthly deficit (D_i) as follows.

$$D_i = P_i - \mathrm{PET}_i \quad (5)$$

where P_i is the total rainfall at i^{th} month.

At last, the fitted explicit values are normalized and fitted to a log-logistic distribution function. The SPEI values for the i^{th} month are the normalized values of the probability (p) of a given D_i value being exceeded and are computed by Eq. (6) [20], while Table 2 defines the drought classification for SPEI.

$$\mathrm{SPEI}_i = W_i - \frac{2.515517+0.802853W_i+0.010328W_i^2}{1+1.432788W_i+0.189269W_i^2+0.001308W_i^3} \quad (6)$$

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

In which p is the exceeding probability of for computed values of D_i

Table 2 Drought classification of CZI, SPI ve SPEI indices Barua et al. (2011)

Condition	SPI and SPEI
Extremely wet	$value \geq 2.00$
Very wet	$1.50 \leq value < 2.00$
Moderately wet	$1.00 \leq value < 1.50$
Near normal	$-1.00 \leq value < 1.00$
Moderately dry	$-1.50 \leq value < -1.00$
Severely dry	$-2.00 \leq value < -1.50$
Extremely dry	$value \leq -2.00$

IV. Results

4.1 Analysis of Climate Data for Siirt

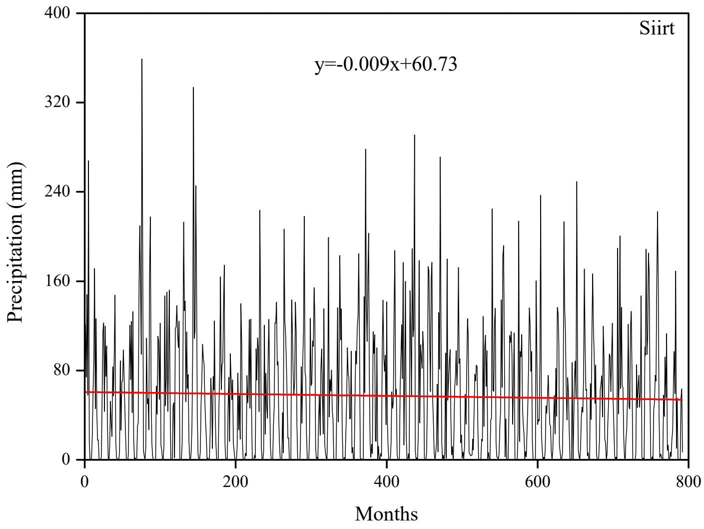
In the study, monthly temperature (max, min, mean), precipitation, and evaporation data for Siirt were analyzed for 1957-2022 and descriptive statistics of data was shown in Table 3. The precipitation data for all stations were not randomly distributed.

Table 3 Descriptive Statistics of data

	Tot.	Av.	St. Dev.	Min	Median.	Max
Min T	792	5.98	9.344	-15.6	5.4	23
Av T		16.326	9.939	-4.0	16.28	33.481
Max T		27.56	10.177	4.5	28.6	46
Rain		57.32	59.269	0	43.8	359.2

Figure 2 shows the graph of the linear trend analysis, where the X-axis represents the time in a month and the Y-axis represents the monthly daily total precipitation in mm.

Firstly, the climate change effects on temperature, precipitation, and evaporation parameters were analyzed. A decreasing trend was detected in precipitation data, while an increasing trend was detected in temperature and evaporation data based on 95% confidence interval. Secondly, the relationship between the two indices was analyzed in detail for Siirt province.



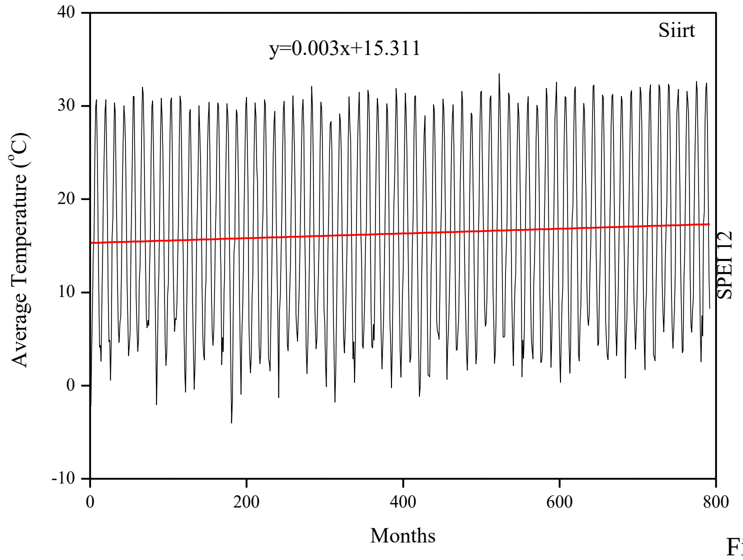
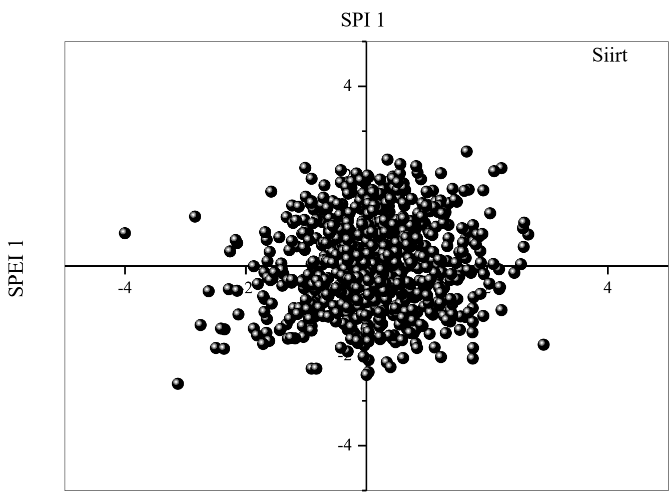


Fig. 2. The trend analysis of precipitation and Temperature data for Siirt

4.2 The comparison of SPEI and SPI

By applying SPI and SPEI drought indices, Siirt province was analyzed for 1- and 12-month time series. These time series are shown in Fig. 3. The months below 0 represent the dry period, while the months above 0 represent the humid months. While SPI is calculated using only monthly precipitation data, SPEI considers both precipitation and temperature data. Both drought indices show a similar relationship between 1957 and 2022. To compare the results obtained with SPI and SPEI drought indices for monthly and yearly, they are plotted in Fig. 3 for Siirt station. As shown in Fig. 4, SPI and SPEI drought indices are generally consistent with each other (R^2=0.952) annual time series. However, the relationship with SPI and SPEI has not consistent for monthly time scales.



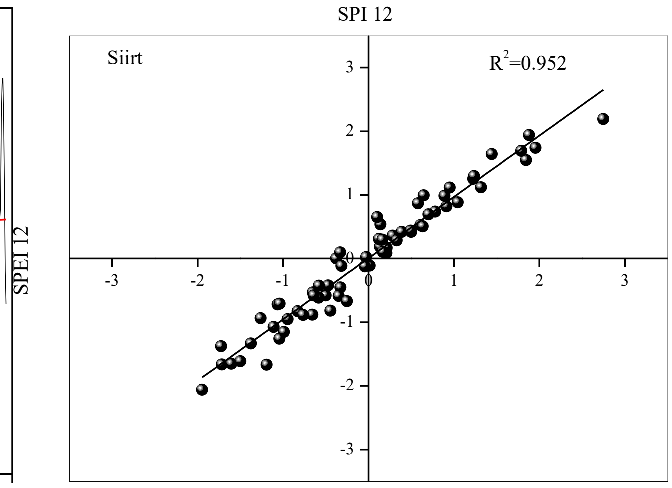
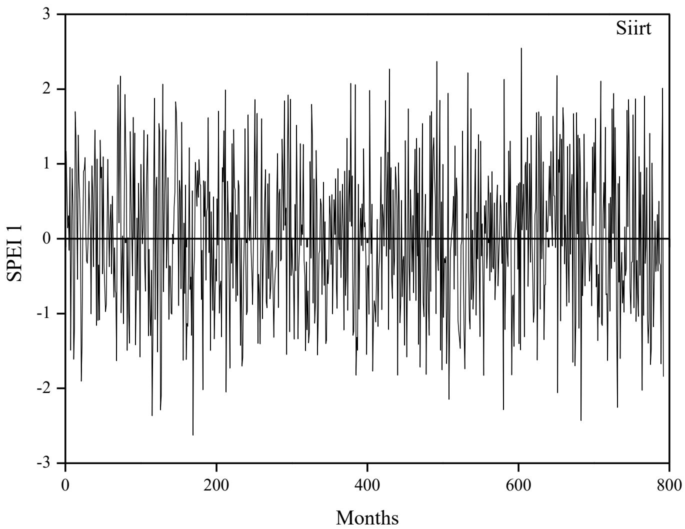


Fig. 3. The comparisons of SPI and SPEI indices for Siirt

4.3. SPI and SPEI drought indices

By applying the SPI and SPEI drought indices for Siirt province, analyses were conducted for monthly and annual time series. These time series are shown in Fig. 4. If the drought values of the month are below zero, they represent the dry period, while the drought values are above zero, they represent the humid period. While SPI is calculated using only monthly precipitation data. SPI values were calculated for each month and evaluated by considering the precipitation of each month. To reach a general conclusion for a one-month period (SPI-1), drought values were plotted for SPI-1 and SPI-12 values in Fig. 4. Finally, dry and wet periods were observed at Siirt between 1957 and 2022 both SPI-1 and SPI-12.



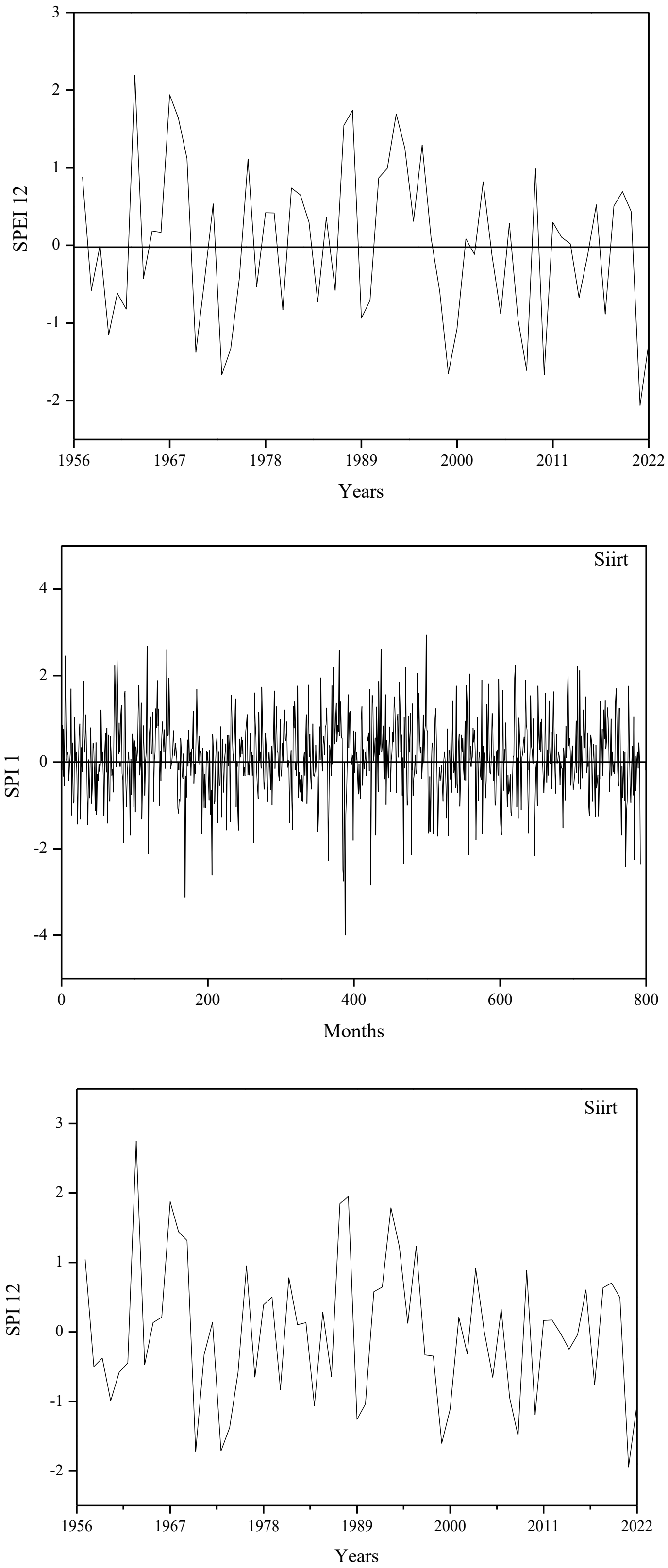


Fig. 4. The SPI and SPEI indices for Siirt

V. CONCLUSION

The general objective of this study is to make a detailed drought analysis for Siirt in monthly and annual time scales by SPI and SPEI. For this reason, drought analysis was performed by considering the period between 1957-2022 with SPEI and SPI indices. The effects of climate change on temperature (max, min, average), precipitation, and evaporation parameters were examined in detail. An increase trend was detected in temperature and evaporation data based on 95% confidence, while a decreasing trend was detected in rainfall data. Although normal drought has the highest share among drought categories, very severe drought has the lowest share. it is determined that SPI gives more sensitive results in the very severe drought category than SPEI index. It is expected to shed light on the drought analyses to be made in the field for Siirt

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Declarations

Funding**:** There is no funding.

Conflicts of interest**:** The authors declare no conflicts of interest.

Data availability: The datasets used and/or analyzed in the present study are available from the corresponding author on reasonable request.

Ethics approval: Not applicable.

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