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Research Article

Comparison of the meteorological drought indices according to the parameter(s) used in the Southeastern Anatolia Region, Turkey

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ABSTRACT

Southeast Anatolia Region, where Turkey's summer-winter differences were experienced as a region, was preferred in this study. Daily precipitation and daily temperature data for the 1950–2019 period were provided for analysis. However, due to data deficiencies, Adiyaman, Batman and Kilis stations were worked in the 1959–2019 period and Sirnak station in the 2000–2019 period. All data have been tested for homogeneity.
According to the parameters used in this study, comparisons were made between the indices. It is divided into 4 according to the parameters used. Although the parameter used is the same, each index has drawn different results due to time differences. Dry results were obtained across the entire station from the methodology of the EDI (as used daily rainfall data). In addition, due to the low precipitation in the index, dry results were obtained in the RAI. Normal results were obtained with other precipitation-based drought indices.
According to EDDI results, the driest month is April. During the 12-month seasonal period, only 5 months have passed in the form of no drought.
According to SPEI and RDI values, normal results were achieved at all stations. Moderately and severely dry conditions sometimes occur, extremely dry have rarely been seen. RDI has been identified to have a more drought duration than SPEI.
According to PCI and HTC (based on precipitation and temperature), EDI and RAI results (precipitation-based), the region is dominated by drought. When viewed on a station-by-station basis, drought has been observed at stations in the borders.

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INTRODUCTION

Drought is a natural disaster that causes the deterioration of hydrological, biological [1], economic [2], and social balance [3]. It is very difficult to indicate the beginning and end of the drought. Because drought gradually shows its effects and continues for long periods of time. It doesn't happen suddenly, like natural disasters like floods, storms, etc. It is one of the highest cost disasters in the world, with an average annual loss of $8–10 million [2].

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Although it is difficult to fully identify drought, it can be classified as a meteorological, agricultural, hydrological, and socioeconomic drought [4, 5]. 1) Meteorological drought occurs due to below-normal precipitation. 2) Agricultural drought occurs because of intense but less frequent precipitation or above-normal evaporation. All these harm plant production and plant development. 3) Then, hydrological drought occurs in aquifers, lakes, and reservoirs when river stream flow falls below long-term average levels. 4) Finally, socioeconomic drought occurs because of associating the supply and demand of some economic goods or services with meteorological, hydrological, and agricultural drought elements [6].

Drought indices provide comprehensive information for drought analysis. Drought indices are used to determine the beginning and end of the drought event, to monitor its change over time, to determine the severity of the drought, and to evaluate the drought.

Several drought indices have been developed to detect complex events such as droughts. Station-based drought models such as the Standardized Precipitation Index (SPI) [7], Aridity Drought Index (AI) [8], Percent of Normal Precipitation Index (PNPI) [9] and Reconnaissance Drought Index (RDI) [10] are among the most used models. Drought indecencies are markers that numerically and conceptually show information such as drought-related violence, duration, amplitude. These also categorize drought parameters.

Many research studies have conducted studies to compare drought indices. For example, there are many studies that compare index where only precipitation is used as parameters [11–13]. It is available in studies where indices with similar formulas are used [14]. There are also many studies comparing SPI and SPEI, where the same classification is used [15–18].

In this study, a drought study was conducted using meteorological data (precipitation, temperature and potential evapotranspiration). Southeast Anatolia Region, where the total annual rainfall in Turkey is low, the average annual evaporation is multi and the average annual temperature is high, has been selected. Meteorological data between 1950 and 2019 were used. The data were first tested for homogeneity. Meteorological droughts are important for monitoring drought and reducing its dangers because meteorological droughts occur first. For this purpose, China Z Index (CZI), Effective Drought Index (EDI), Percent of Normal Precipitation Index (PNPI), Rainfall Anomaly Index (RDI), Standardized Precipitation Index (SPI), Weighted Anomaly Standardized Precipitation (WASP), Z-Score Index (ZSI), Evaporative Demand Drought Index (EDDI), De Martonne Aridity Index (AI), Pinna Combinative Index (PCI), Hydro-Thermal Coefficient of Selyaninov (HTC), Standardized Precipitation Evapotranspiration Index (SPEI) and Reconnaissance Drought Index (RDI) in meteorological drought were used in the study. Comparisons were made between indices divided into four groups according to the parameters used.

MATERIALS AND METHODS

Study Area and Data

Southeastern Anatolia region, one of the 7 regions of Turkey, was selected as the field of study. The region is located within the 38° 6′ 22″ North and 41° 19′ 43″ East area. Southeast Anatolia Region is 8% of Turkey's territory. It is equivalent to an area of 59.176 km². It is found from the Southern Taurus Mountains in the north to Iraq and Syria in the South. Fig 1 shows the map where the boundaries are set.

In this study, 9 stations in Southeastern Anatolia region of Turkey were studied. Drought analysis was performed on stations from 1950–2019. Daily and monthly precipitation (mm) and monthly temperature (°C) data were used from meteorological data. This data was obtained from the General Directorate of Meteorology. Potential evapotranspiration (PET) was obtained using temperature data. Many methods are available to achieve potential evapotranspiration. In this study, Thornthwaite method (mm) was preferred. Due to their incomplete data at some stations, there are differences in the observation intervals at those stations. Adiyaman, Batman and Kilis stations 1959–2019 period and Sirnak station 2000–2019 period was worked. Diyarbakir, Gaziantep, Kilis, Mardin, Siirt and Sanliurfa stations were worked in 1950–2019 period.

The type of climate that dominates the region is the terrestrial climate. When looking at Fig 2, the station with the most rainfall is Adiyaman, while the station with the least rainfall is Sanliurfa. The highest annual temperature average station belongs to Sanliurfa station. June, July, and August are very dry in the region. When examined monthly, it can be said that the months with the most precipitation are December and January, and the month with the least rainfall is August.

In addition, it can be said that the average annual rainfall values of the stations belonging to the provinces that make up the borders of the country are lower than the stations inland. This can be attributed to the position of the stations on the parallels.

Homogeneity Test

The concept of variance analysis used in statistics is the general name of a group of methods that contain many statistical methods. The simplest form of variance analysis

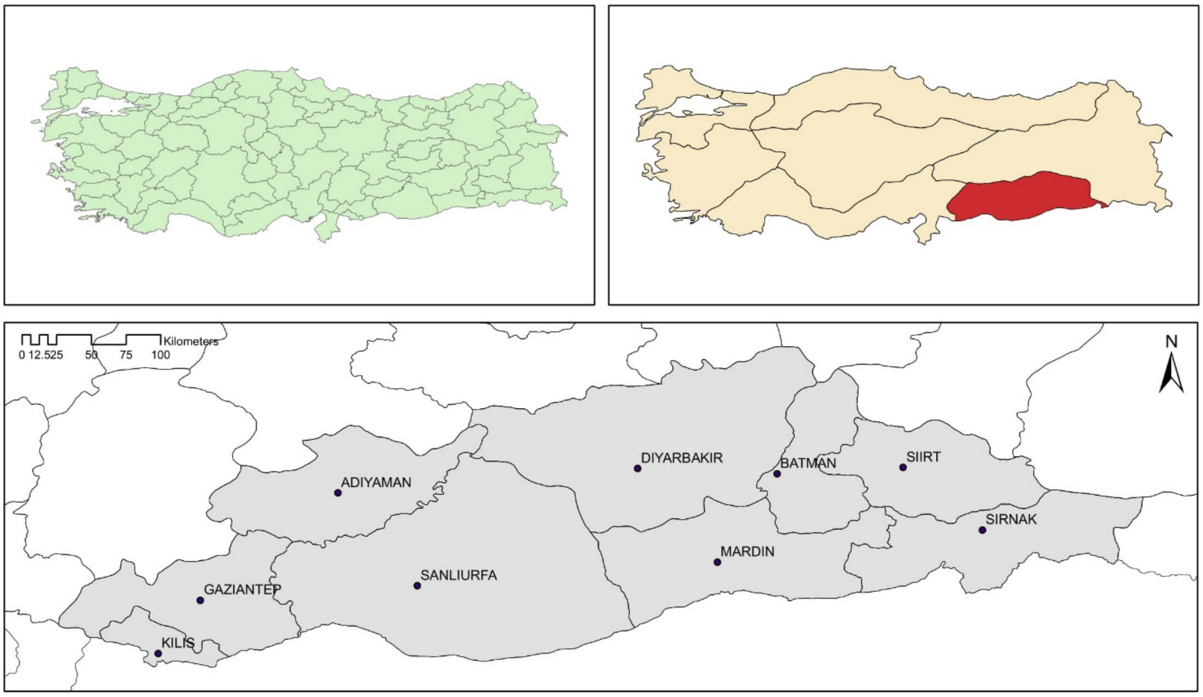

Figure 1. The location of Southeastern Anatolia Region in Turkey.

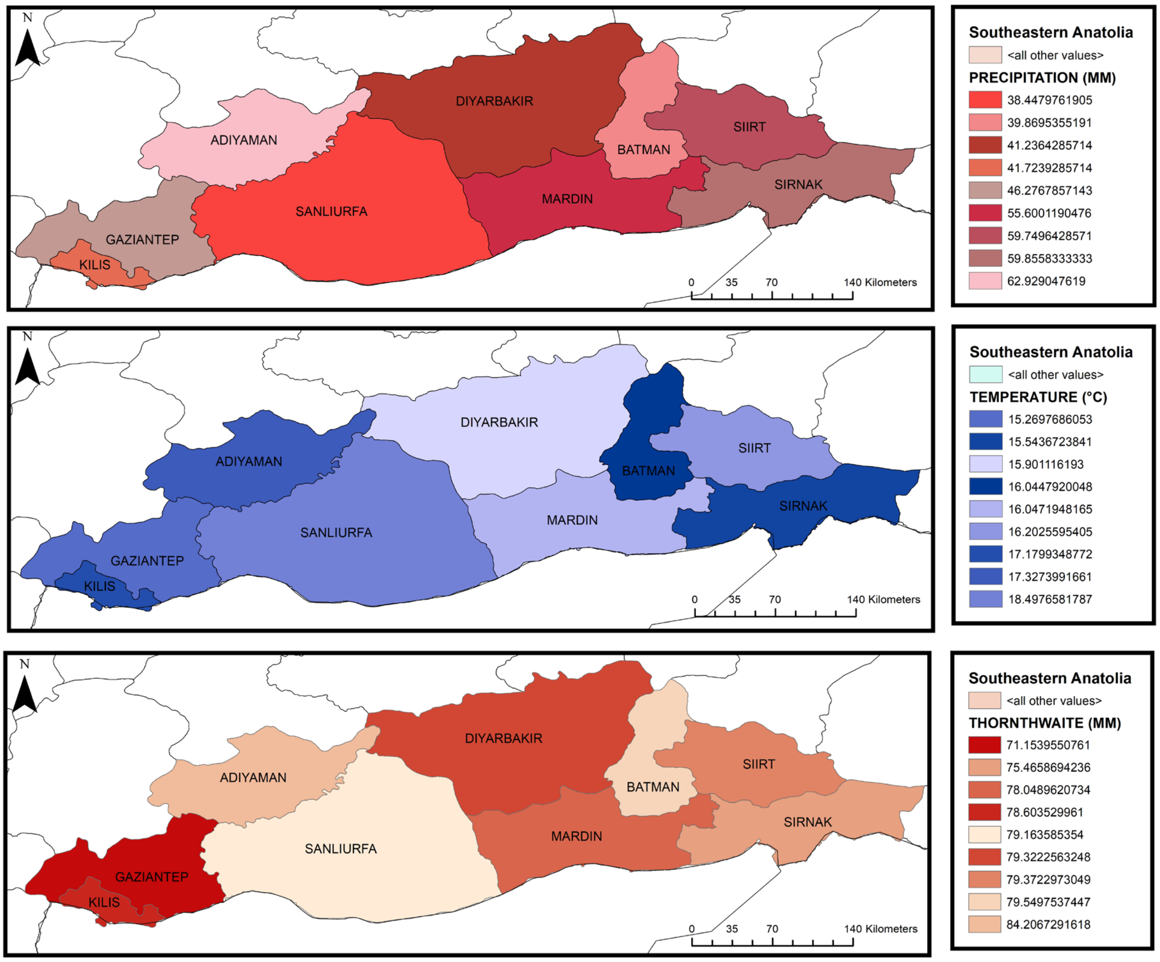

Figure 2. Average annual precipitation, average annual temperatures and average annual Thornthwaite distributions of stations.

Station		TEMPERATURE Sum of Squares	df	Mean Square	F	Sig.	THORNTHWAITE Sum of Squares	df	Mean Square	F	Sig.	PRECIPITATION Sum of Squares	df	Mean Square	F	Sig.
ADIYAMAN	Between Groups	421.064	57	7.387			23655.944	57	415.017			410092.846	69	5943.375		
	Within Groups	60603.541	629	96.349	0.08	1.00	4142969.955	629	6586.598	0.06	1.00	4357279.950	770	5658.805	1.05	0.37
	Total	61024.605	686				4166625.899	686				4767372.796	839			
BATMAN	Between Groups	1978.866	60	32.981			44902.218	60	748.370			89374.213	60	1489.570		
	Within Groups	70473.135	671	105.027	0.31	1.00	4132553.223	671	6158.798	0.12	1.00	1220215.838	671	1818.503	0.82	0.83
	Total	72452.001	731				4177455.440	731				1309590.051	731			
DIYARBAKIR	Between Groups	511.570	69	7.414			22358.895	69	324.042			91119.584	69	1320.574		
	Within Groups	88917.236	770	115.477	0.06	1.00	4910798.009	761	6453.085	0.05	1.00	1450440.282	770	1883.689	0.70	0.97
	Total	89428.806	839				4933156.905	830				1541559.865	839			
GAZIANTEP	Between Groups	692.245	69	10.033			22391.350	69	324.512			111298.123	69	1613.016		
	Within Groups	66888.874	770	86.869	0.12	1.00	3265329.080	761	4290.840	0.08	1.00	1972948.214	770	2562.270	0.63	0.99
	Total	67581.120	839				3287720.429	830				2084246.337	839			
KILIS	Between Groups	453.358	60	7.556			14375.063	60	239.584			113750.795	69	1648.562		
	Within Groups	48546.930	671	72.350	0.10	1.00	2988833.638	671	4454.298	0.05	1.00	1573426.514	770	2043.411	0.81	0.87
	Total	49000.287	731				3003208.701	731				1687177.309	839			
MARDIN	Between Groups	701.914	69	10.173			25853.939	69	374.695			259718.462	69	3764.036		
	Within Groups	78040.400	770	101.351	0.10	1.00	4339366.151	761	5702.189	0.07	1.00	3338206.028	770	4335.333	0.87	0.77
	Total	78742.314	839				4365220.091	830				3597924.490	839			
SIIRT	Between Groups	685.103	69	9.929			29241.164	69	423.785			207774.276	69	3011.221		
	Within Groups	82428.006	770	107.049	0.09	1.00	4670843.472	761	6137.771	0.07	1.00	3009762.344	770	3908.782	0.77	0.91
	Total	83113.109	839				4700084.636	830				3217536.620	839			
SANLIURFA	Between Groups	537.357	69	7.788			29062.570	69	421.197			123389.004	69	1788.246		
	Within Groups	74358.232	770	96.569	0.08	1.00	4630891.559	761	6085.271	0.07	1.00	1719719.133	770	2233.401	0.80	0.88
	Total	74895.588	839				4659954.129	830				1843108.137	839			
SIRNAK	Between Groups	98.192	19	5.168			3709.022	19	195.212			67750.850	19	3565.834		
	Within Groups	22123.601	220	100.562	0.05	1.00	1170987.977	220	5322.673	0.04	1.00	965041.042	220	4386.550	0.81	0.69
	Total	22221.792	239				1174696.998	239				1032791.892	239			

Figure 3. ANOVA test results of stations.

is one-way variance analysis, in other words, One-Way ANOVA. One-Way ANOVA is used to analyze how arguments interact between themselves and their effects on the dependent variable.

According to the ANOVA test, the H_0 hypothesis for homogeneity testing is accepted because the value "Sig." is Sig..>0.05 in all data groups (Fig 3). In other words, it can be said that "the variances of groups with 95% confidence are homogeneous."

Drought Indices Where Only Precipitation Data are Used

There are several indices in the meteorological drought, which has an input parameter precipitation. The calculation of these indices requires a specific classification (Table 1).

China Z Index (CZI) is based on Wilson–Hilferty's cube root transformation [22]. It has been observed that the precipitation data to be used in the index complies with the Pearson type III distribution. [11, 12]. China's National Climate Center developed CZI in 1995 as an alternative to the Standardized Precipitation Index (SPI) [21]. The CZI value is calculated as follows,

$$CZ_{ij} = \frac{6}{C_{si}}\left(\frac{C_{si}}{2}\varphi_{ij} + 1\right)^{1/3} - \left(\frac{6}{C_{si}}\right) + \left(\frac{C_{si}}{6}\right) \quad (1)$$

$$C_{si} = \frac{\sum_{i=1}^{n}(x_{ij} - \overline{x}_i)^3}{n \times \sigma_i^3} \quad (2)$$

$$\varphi_{ij} = \frac{x_{ij} - \overline{x}_i}{\sigma_i} \quad (3)$$

Where i is a time scale and can be equal to 1, 2, 3,..,72 months, and j is the current month. C_{si} = coefficient of skewness and n = the total number of months in the record, φ_{ij} = standardized variate, also called the Z-Score, and x_{ij} = precipitation of j month for period i, $\bar{x}_i$ = average of the precipitation of j month for period i, φ_{ij} = Standard deviation of the precipitation of j month for period i.

Effective Drought Index (EDI)

Unlike other drought indices, Effective Drought Index (EDI) uses data in the daily time period [23]. Initially, EDI was developed to monitor drought status in the daily time step [12, 24, 25]. It is suitable for the study of both meteorological and agricultural droughts, as the calculations include daily data. Calculate the EDI value:

$$EP_i = \sum_{n=1}^{i}\left[\frac{\sum_{m=1}^{n} P_m}{n}\right] \quad (4)$$

$$DEP = EP - MEP \quad (5)$$

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Table 1. Dry and wet categories of various drought indices where only precipitation data are used based on the index value [19–21]

Class	CZI	EDI	PNPI	RAI	SPI	WASP	Z–Score
Normal	–1 to +1	–0.7 to +0.7	>80	0 to 2	–1 to +1	–1 to +1	–1 to +1
Slight Dry	–	–	70 to 80	–	–	–	–
Moderately Dry	–1 to –1.5	–0.7 to –1.5	55 to 70	–2 to 0	–1 to –1.5	–1 to –1.5	–1 to –1.5
Severely Dry	–1.5 to –2	–1.5 to –2.5	40 to 55	–4 to –2	–1.5 to –2	–1.5 to –2	–1.5 to –2
Extremely Dry	≤–2.0	≤–2.5	<40	>–4	≤–2.0	≤–2.0	≤–2.0

China Z Index (CZI)

$$EDI = \frac{DEP}{SD(DEP)} \tag{6}$$

Where i is the period over which precipitation is summed. P_m shows the rainfall from m days ago (Eq. 4). Thus, the EP shows 365 days of precipitation. Mean EP (MEP) for each calendar day. Calculate the DEP, which is the difference between the EP and MEP (Eq. 5). The EDI account is obtained by dividing the DEP into the standard deviation of DEP [25, 26]. EDI and SPI use similar drought severity classification.

Percent of Normal Precipitation (PNPI)

Percent of Normal Precipitation (PNPI) was defined by [9] as a normal percentage of precipitation. It can be calculated in daily, weekly, monthly, seasonal, and annual time series. Precipitation data must be in accordance with the time series to be calculated. It is required to have at least 30 years of data to calculate the normal period. PNPI is calculated as following,

$$PNPI = \frac{P_i}{p} \times 100 \tag{7}$$

Where P_i is the precipitation in time increment *i* for in each year (mm), and P is average precipitation for the study period (mm) (Eq. 7) [27].

Rainfall Anomaly Index (RAI)

Rainfall Anomaly Index (RAI) was started by Van Rooy in the early 1960s [28]. This index is based on monthly or annual precipitation data.

$$\text{If } P > \overline{P} \text{ then } RAI = 3\left(\frac{P - \overline{P}}{\overline{\overline{m - P}}}\right) \tag{8}$$

$$\text{Else } P < \overline{P} \text{ then } RAI = -3\left(\frac{P - \overline{P}}{\overline{\overline{x - P}}}\right) \tag{9}$$

In Eq. 8 and 9, P is annual precipitation, $\overline{P}$ is average of 30 years of precipitation, the average of $\overline{m}$ 10 precipitation values occurring in $\overline{x}$ average of at least 10 precipitation values occurring during the period [29].

Standardized Precipitation Index (SPI)

The Standardized Precipitation Index (SPI) method, which converts the precipitation parameter into a single numerical value to describe the drought of regions with different climates, was first developed by [7]. SPI is obtained by dividing the difference between precipitation and the average in a selected time frame into standard deviation.

$$SPI = \frac{x_i - \overline{x}}{\sigma_x} \tag{10}$$

x_i the observed precipitation value, the average of the x_i precipitation series, and the standard deviation of series σ_x (Eq. 10). The resulting SPI values show a trend that increases and decreases linearly with the lack of precipitation [30]. To consider, the impact of precipitation deficiency on different water sources, different time periods such as 1..., 3, 24 months are determined in which changes in indices will be observed. SPI is one of the most studied drought indices among drought indices [31].

Weighted Anomaly Standardized Precipitation (WASP)

Weighted Anomaly Standardized Precipitation (WASP) was developed by [20] to monitor rainfall in the tropics within 30 degrees from the equator. Grilled uses monthly precipitation data at a resolution of 0.5° × 0.5°. It is based on 12-month overlapping totals of standardized monthly precipitation anomalies.

$$WASP_N = \frac{1}{\sigma_{WASP_N}} \times \sum_{i=1}^{N}\left(\frac{P_i - \overline{P_l}}{\sigma_i} \times \frac{\overline{P_l}}{\overline{P_A}}\right) \tag{11}$$

$\underline{Pi}$ and P_A monthly and annual precipitation here, $\overline{P_l}$ and $\overline{P_A}$ monthly and annual precipitation climatology, σ_i is the standard deviation of monthly precipitation and σ_{WASP_N} is the standard deviation of Weighted Anomaly Standardized Precipitation (WASP) (Eq. 11) [13].

Z-Score Index

Z-Score Index is compared to Standardized Precipitation Index (SPI). However, it is more similar to China Z Index (CZI). Precipitation data is not required to match gamma distribution or Pearson Type III distribution. It has been involved in many studies [12, 32].

$$ZSI = \frac{P_i - \overline{P}}{SD} \tag{12}$$

Here $\overline{P}$ average monthly precipitation (mm); P_i precipitation (mm) in the specific month and the SD shows the standard deviation at any time (Eq. 12) [33].

Drought Indices Where Only PET Data are Used

Evaporative Demand Drought Index (EDDI)

Since it is done via E_0, index results can be obtained by more than one method (Thornthwaite, Blaney-Criddle, Penman-Monteith, Hargreaves-Samani etc.) [14]. The calculation steps are similar to Standardized Precipitation Evapotranspiration Index (SPEI) [34].

$$P(E_{oi}) = \frac{i - 0.33}{n + 0.33} \tag{13}$$

$$EDDI = W - \frac{C_0 + C_1 W + C_2 W^2}{1 + d_1 W + d_2 W^2 + d_3 W^3} \tag{14}$$

Values of constants; C_0 = 2.515517, C_1 = 0.802853, C_2 = 0.010328, d_1 = 1.432788, d_2 = 0.189269, d_3 = 0.001308 (Eq. 14). If $P(E_{oi}) \leq 0.5$ then $W = \sqrt{-2In[P(E_{oi})]}$; $P(E_{oi}) > 0.5$ then $W = \sqrt{-2In[1 - P(E_{oi})]}$ [34]. EDDI within our climatology period (1950–2019), n = 70 (Eq. 13). The EDDI results obtained require a classification (Table 2).

Drought Indices Where Temperature and Precipitation Data are Used

De Martonne Aridity Index (AI)

De Martonne Aridity Index (AI) was found by [36]. Aridity is effective in climate and has emerged from a lack of humidity. It can also be calculated monthly or on an annual period. However, there are two different calculations.

$$I_{DM} = \frac{P}{T + 10} \tag{15}$$

$$I_M = \frac{12P'}{T' + 10} \tag{16}$$

Eq. 15 performs annual calculations, while eq. 16 performs monthly calculations. The drought values obtained because of these formulas are classified according to Table 3. P expresses the annual precipitation value (mm), T expresses the annual temperature value. P' and T' represent the average monthly precipitation and temperature [35, 37].

Pinna Combinative Index (PCI)

The Pinna combinative index (*Ip*) was developed by Pinna [35].

$$I_p = \frac{1}{2}\left(\frac{P}{T + 10} + \frac{12P'_d}{T'_d + 10}\right) \tag{17}$$

P and T represent the annual mean precipitation and temperature. P'_d and T'_d are the mean values of precipitation and air temperature of the driest month (Eq. 17). Many studies have been carried out on this index [35, 38].

Hydro-Thermal Coefficient of Selyaninov

The Selyaninov's hydrothermal coefficient (HTC), developed by [39]. Calculated using the following formula,

$$HTC = \frac{P}{\sum_{T>10} \frac{T}{10}} \tag{18}$$

where P is the sum of precipitation amounts (mm) and T is the sum of temperatures (°C) for the months (Eq. 18).

Table 2. Dry and wet categories of various drought indices where only PET data are used based on the index value [34].

USDM drought category	Description	EDDI percentiles
D_O	Abnormally dry	70–79
D_1	Moderate dry	80–89
D_2	Severe dry	90–94
D_3	Extreme dry	95–97
D_4	Exceptional dry	98–100

Table 3. Dry and wet categories of various drought indices where temperature and precipitation data are used based on the index value [35]

Climate classification	Values of IDM	PCI	HTC
Dry	<10	<10	<0.3
Semidry	10 to 20	10 to 20	0.30 to 0.6
Mediterranean	20 to 24	20 to 24	0.6 to 0.8
Semi-humid	24 to 28	24 to 28	0.8 to 1.0

Table 4. Dry and wet categories of various drought indices where PET and precipitation data are used based on the index value [10, 40]

Class	SPEI	RDI
Normal	–1 to +1	–1 to +1
Moderately Dry	–1 to –1.5	–1 to –1.5
Severely Dry	–1.5 to –2	–1.5 to –2
Extremely Dry	≤–2.0	≤–2.0

Drought Indices Where PET and Precipitation Data are Used

Standardized Precipitation Evapotranspiration Index (SPEI)

SPEI was originally developed by [40] to assess agricultural drought severity, considering plant evaporation and meteorological drought. SPEI is expressed as the difference (D_i) between monthly or weekly potential evapotranspiration (PET_i) and precipitation (P_i). This difference (D_i) is the surplus or lack of water for the analyzed month (i).

$$D_n^k = \sum_{i=0}^{k=1}(P_{n-i} - PET_{n-i}), \quad n \geq k \tag{19}$$

$$SPEI = W - \frac{C_0 + C_1 W + C_2 W^2}{1 + d_1 W + d_2 W^2 + d_3 W^3} \tag{20}$$

P and PET are calculated for i month. In different Dk series, k is the timescale for the month and n is the calculation number. D cannot be calculated in the case of $k > n$ (Eq. 19). Values of constants; C_0 = 2.515517, C_1 = 0.802853, C_2 = 0.010328, d_1 = 1.432788, d_2 = 0.189269, d_3 = 0.001308 (Eq. 20). If $P \leq 0.5$ then $W = \sqrt{-2In[P]}$; $P > 0.5$ then $W = \sqrt{-2In[1-P]}$. P is the probability of higher values of D. Many studies have been carried out on this index [41].

Reconnaissance Drought Index (RDI)

Reconnaissance Drought Index (RDI) was found by Tsakiris and Vangelis of the National Technical University of Athens / Greece [10]. There are two new expressions in the form of Normalized RDI and Standardized RDI.

$$\alpha_k^{(i)} = \frac{\sum_{j=1}^{k} P_{ij}}{\sum_{j=1}^{k} PET_{ij}} \tag{21}$$

$$RDI_n^{(i)} = \frac{\alpha_k^{(i)}}{\bar{\alpha}_k} - 1 \tag{22}$$

$$RDI_{st}^{(i)} = \frac{y_k^{(i)} - \bar{y}_k}{\sigma_{yk}} \tag{23}$$

Here, P_{ij} and PET_{ij} provide precipitation and potential evapotranspiration of the y-pearl month of the x-pearl year (Eq. 21). In the formula , $\alpha_k^{(i)}$'s value was found to be satisfactory able to track both lognormal and gamma distributions at different timescales and over a wide range of locations [42, 43]. The $\bar{\alpha}_k$ parameter is the average of $\alpha_k^{(i)}$ values calculated for n years of data. In eq. 23; , arithmetic means and σ_{yk} standard deviation.

The SPEI and RDI results obtained are divided into the same classification (Table 4). The results provide information about the region.

RESULT AND DISCUSSIONS

There are many drought indices in meteorological drought. However, many parameters such as precipitation and temperature vary from the location of each station. In addition, drought indices use different classifications due to the parameters used. As a result of the analysis, the obtained index values are divided according to drought categories. It has been tried to show which category the region is in.

Drought Indices Where Only Precipitation Data are Used

The result of frequency analyses of the CZI, EDI, PNPI, RAI, SPI, WASP, and Z-Score indices using the same drought classification are shown in Fig 4. Only classification by dry category was made. First, it can be said that similar results have been achieved in 9 stations. This shows that there is not much difference between the precipitation at the stations.

The index with extremely dry results is the EDI. This result may be due to the index's use of daily precipitation value, unlike other indices. RAI is the index where the severe dry category is maximum at each station. This result is due to the lack of precipitation in stations most of the time. Moderately dry, all stations have a certain percentage of drought. However, it belongs to Adiyaman and Gaziantep stations with a maximum value of 21%. At both stations, this value belongs to the RAI index. The sightly dry class contains only values for the PNPI index. This classification is available in Table 2.

The indices where normal results are lowest at all stations are EDI and RAI. From here, according to the RAI and EDI indices, it is the conclusion that the Southeast Anatolia Region is dry. According to these indices, the region can be said to be severely drought.

Drought Indices Where Only PET Data are Used

The EDDI values obtained monthly are averaged for each month and the value for that month was obtained. Fig 5 shows the mapping of the monthly averages of the EDDI at

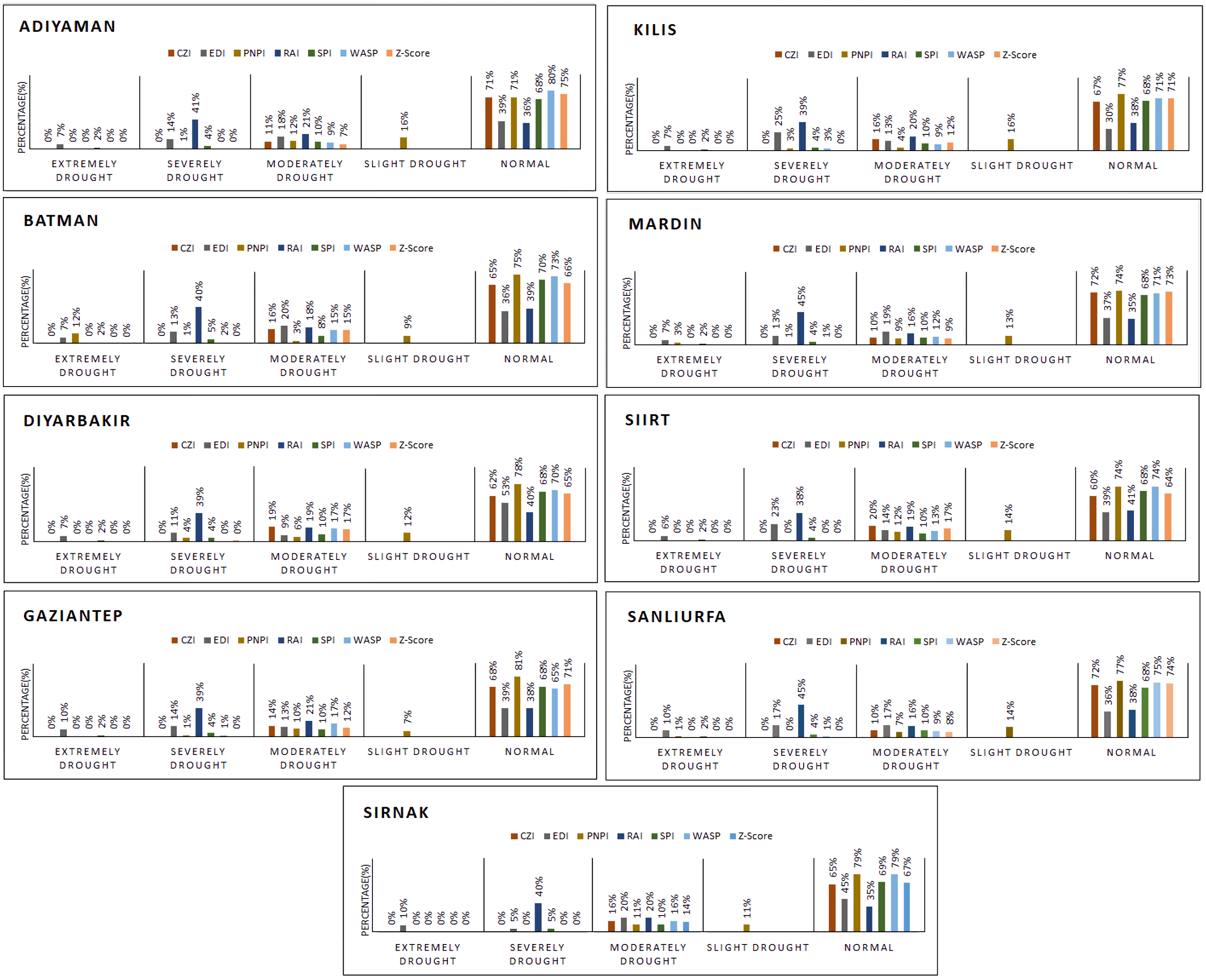

Figure 4. Frequency analysis of drought indices using only precipitation.

stations by Spline method (ARGCIS). Drought is observed from April to October, according to the results. Between December and February, minor variations were observed between the stations. It can be said that there are many seasonal differences on the border of the region.

November and March include a pass. The month dominated by Level 0 is January, while the month dominated by Level 4 is July.

Drought Indices Where Temperature and Precipitation Data are Used

The percentage results of the AI, PCI and HTC drought indices using the two parameters are seen in Fig 6. The results are based on annual formulas. According to the results, the Sanliurfa station is dry with a value of close to 90% in the maintenance of PCI and HTC indices. On a drought basis, it can be said that Batman came after Sanliurfa. The AI drought index showed lower results in drought across the region than the other two indices.

The AI drought index has more semi-humid values. According to the PCI and HTC indices, the region is a drought zone.

Drought Indices Where PET and Precipitation Data are Used

The RDI drought index is divided into Normalized RDI and Standardized RDI. However, because SPEI is a standardized value, comparing it to RDIs gives more accurate results. SPEI and RDI values were calculated at short (1 and 3 months), medium (6 months), and long (9 and 12 months) timescales, and drought analysis were performed. Fig 7 shows the results of the SPEI and RDIs drought indices of Diyarbakir station in graphs. There is also a more detailed representation of the values between 1950 and

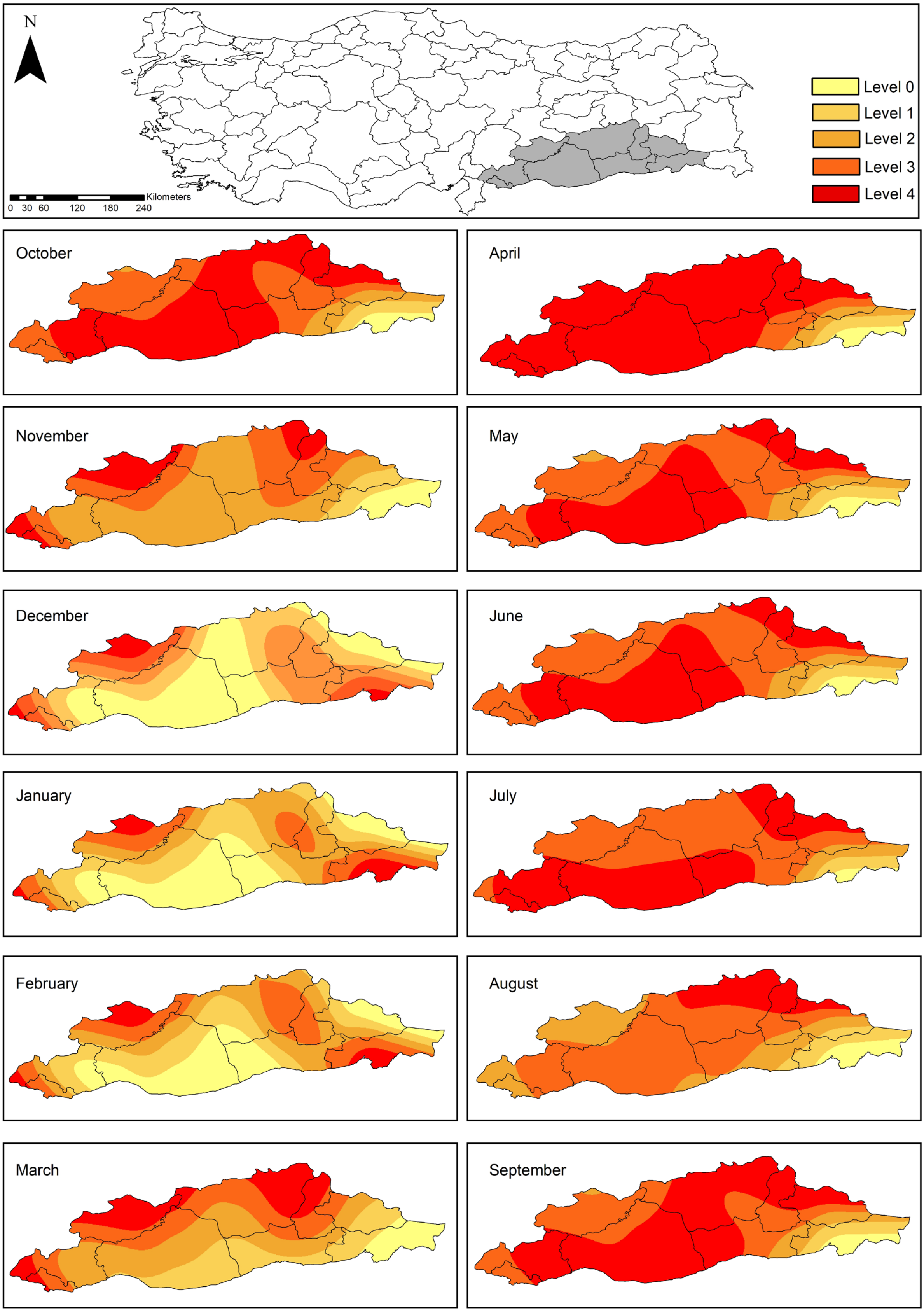

Figure 5. Monthly map of drought indices using only PET value by Spline method.

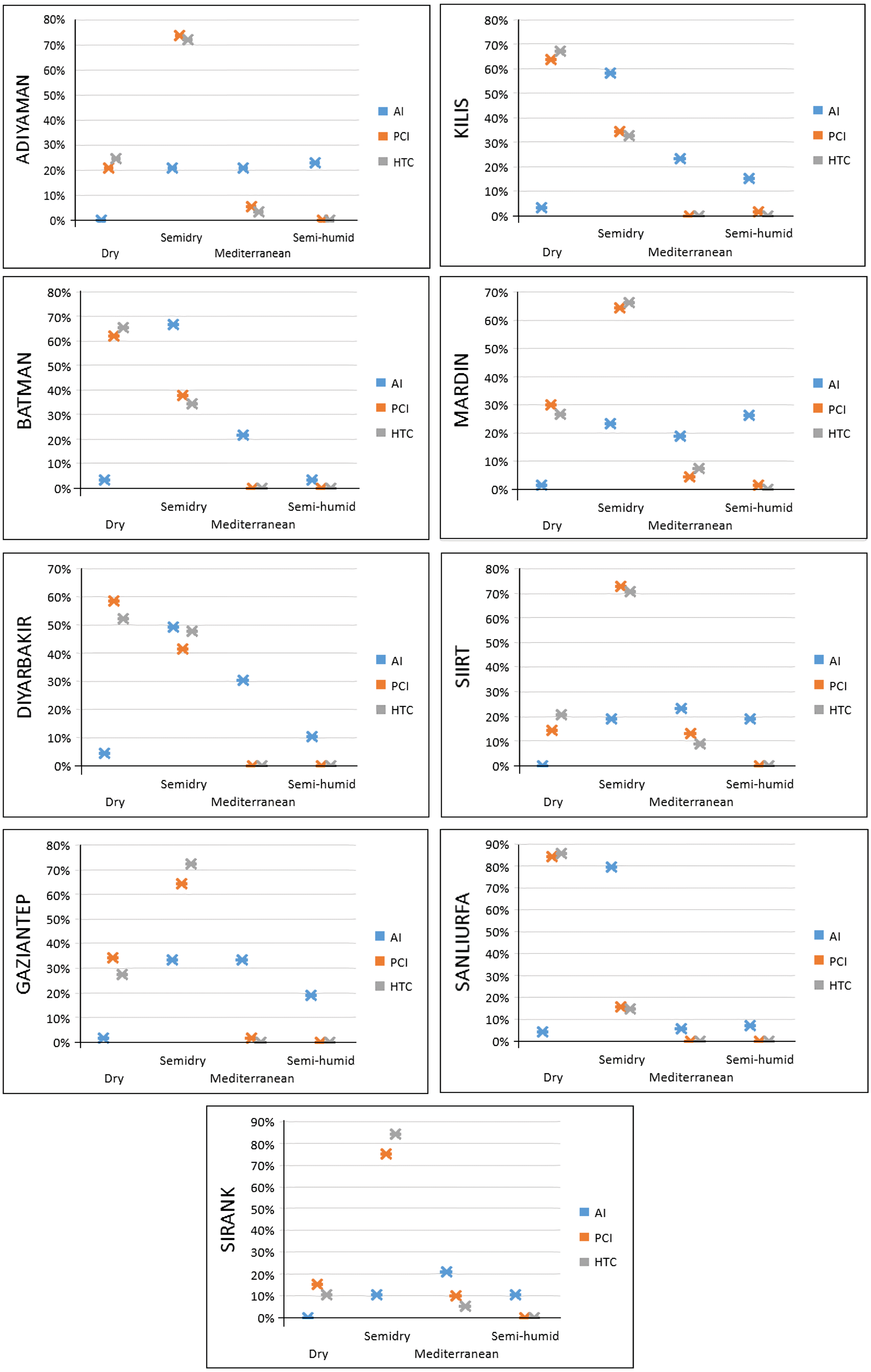

Figure 6. Frequency analysis of drought indices using precipitation and temperature.

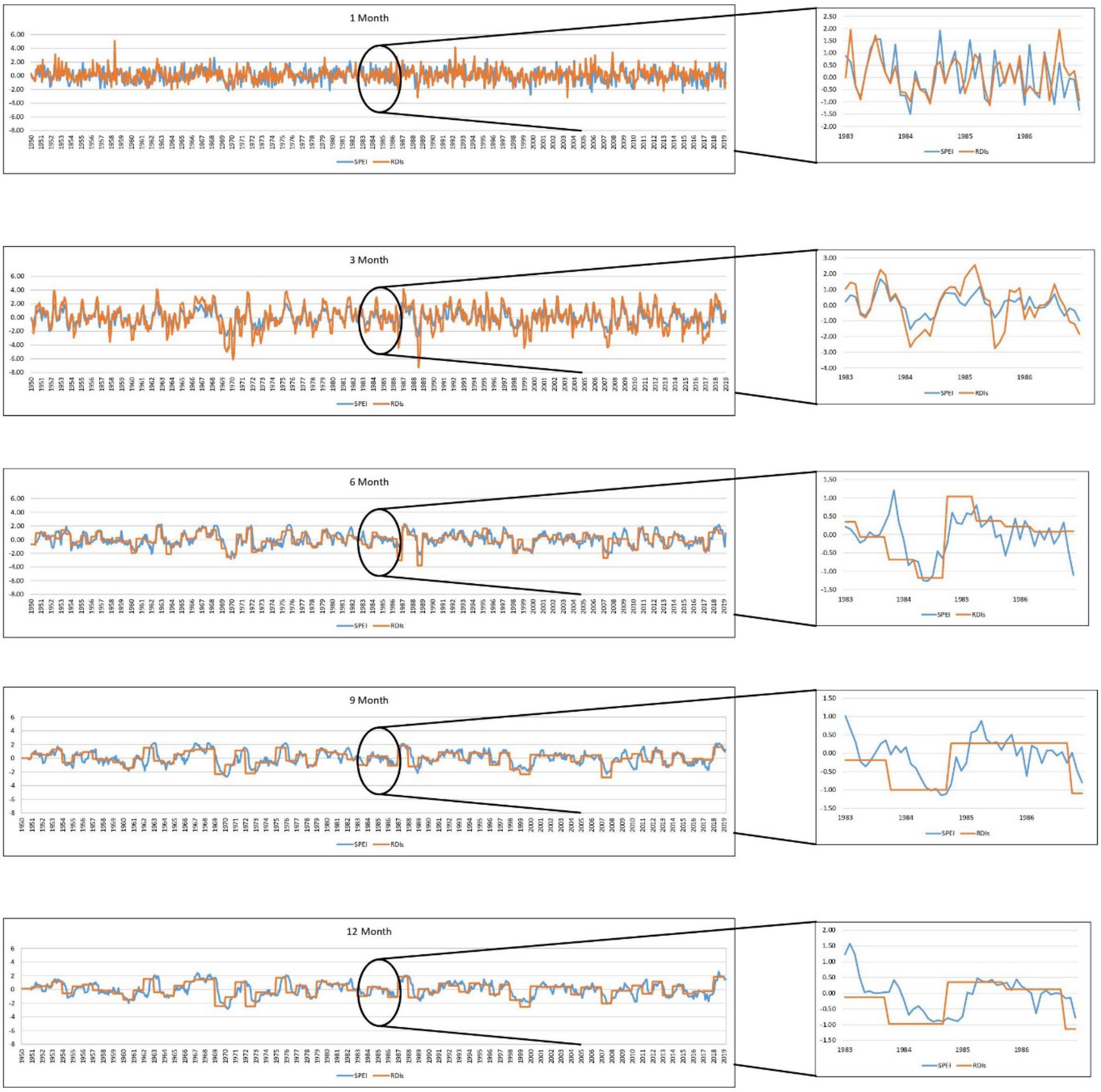

Figure 7. SPEI and RDI at different timescales in Diyarbakir.

2019 between 1983 and 1986 in the chart. According to the results, the frequentness of 1-month values and the frequentness of 12-month values vary.

CONCLUSION

Drought cannot be fully defined due to its mixed structure and effects. That is why it has been suffered for a long time. From simple approaches to mixed approaches, this has contributed to the development of the progressively evolving drought indices.

In this study, it covers a long period of 70 years between 1950 and 2019 for the Southeast Anatolia Region. Drought analysis was tried using meteorological drought indices. Given the drought indices, it can be concluded that there are differences between both seasonal variations and the parameters used. The objective is to sort the indices by separating the indices according to the parameters in which they are used. Thus, comparing the indices with each other gives more accurate results. In addition, the role of each method in drought detection will be determined. It is also intended to determine the most appropriate drought index for the region.

It is seen that the methods partially detect the drought that occurred in the period 2006 – 2009, which occurred throughout the country and caused large agricultural crop and economic loss, especially in the Southeastern Anatolia Region.

- Drought indices where only precipitation is used have high dry values on a percentage basis compared to normal values. According to the drought results applied for 70 years, normal values are currently prevailing in the region. However, it is observed that the dry values are increasing. RAI is the largest number of dry results between the indices. PNPI is also classified as 5 droughts, unlike other indices. As a result of these analyses, it was determined that SPI-originated indices (CZI, Z-Score and others) are reliable and accurate indices for drought analysis, and it was concluded that other indices may not yield very reliable results.
- In drought indices where only PET is used, it has been determined that dry months are more than normal months. Drought has an impact in most months. The months of April and July can be said in the months of the dry.
- Different results occur in drought instances where both precipitation and temperature are used. According to the PCI and HTC drought index, drought has been experienced, while AI says the drought may be just starting. In the indices in this drought classification, weedy results were achieved more dryly than others.
- Firstly, 5 different reference periods of 1, 3, 6, 9 and 12 months were determined for the total amount of rain per month. Potential evapotranspiration amounts were then obtained by Thornthwaite method by using monthly average temperatures, and these potential evapotranspiration amounts were divided into 5 different reference periods: 1, 3, 6, 9 and 12-month periods. In drought indices where both precipitation and PET are used, drought has generally been observed in both indices for at least 1 month. In SPEI, maximum drought was observed at all stations with a 3-month frequency. In RDI, maximum drought was observed at all stations with a 3-month frequency.

Differences are observed when looking at the drought rates obtained from the stations' annual and monthly drought indices. These differences are because the stations experience summer droughts, with rainfall falling mostly during the winter and spring months.

With this study, the approach created for the Southeast Anatolia Region is based on the meteorological drought index. Researchers tried to conduct spatial analysis of drought and determine the stations affected by drought in the study area, which is important for water resources and agriculture.

As a result, this study can be further expanded by including climate elements such as humidity, temperature, precipitation type, evaporation, wind, sunbathing intensity, etc. Relations between drought and these variables can be revealed. The effects of all climate elements on drought should be investigated and methods should be developed to fore-tell the drought.

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DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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