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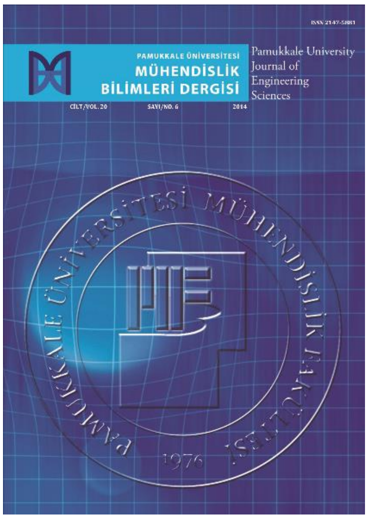

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Abstract

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Öz

Drought is a natural disaster developing secretly. In this study Standardized Precipitation Evapotranspiration Index (SPEI) has been applied for in Turkey's Mediterranean Region. Temperature and precipitation data were used for 8 meteorological observation stations. According to the data, 8 stations (Adana, Antalya, Burdur, Hatay/Antakya, Isparta, Kahramanmaraş, Mersin and Osmaniye) were observed between 1970-2018. Frequency analyzes of SPEI values of 1, 3, 6, 9 and 12 months were calculated for each station. Monthly (1, 3, 6, 9 and 12 months) frequency values between the distribution of ear and wetlands is intended to make a comparison. Comparisons were made how long the SPEI values were found in drought classes and on availability. As a result, the data obtained from all stations in the Mediterranean region are between mild dry and near to normal. Mersin has the maximum value both in near to normal and dry conditions. When the minimum values are considered, Adana has the least percentage values in both wetness and dryness conditions compared to other stations.

Keywords: + Õ Ò Á Ë Ì ą Ë ĥ 3 ą Ã Á Ë Ì ą Ë ĥ 9 Á ø ą ĥ ĥ Ó Ô Á Î Ä Á Ò Ô Ì Á ĥ Ô ą Ò ą Ì Í ą ĥ 9 Á ø ą ĥ % Ö Á Ð Ï Ô Ò Á Î Ó Ð É Ò Á Ó Ù Ï Î d Î Ä Å Ë Ó É ¡ 3 0

Anahtar kelimeler: Drought, Temperature, Precipitation, Standardized Precipitation Evapotranspiration Index (SPEI)

1 Introduction

Drought is a world-wide effect of climate change and climatic events including values below average precipitation [1], [2]. It is a time-dependent phenomenon that is affected by many parameters [3]. The parameter used varies according to drought varieties. In this reason there is no specific formula for drought. [4],[3]. In fact, it can be categorized as follows; (a) meteorological; it is defined as the precipitation falls significantly below normal values over a long period of time, (b) agricultural; it is a dry grounded period resulting from arid soils, low temperatures, more than expected precipitation events or more than normal evaporation, (c) hydrological; hydrological drought is associated with the effects of groundwater resources, surface waters or precipitation periods and (d) socio-economic; the drought stage in which the social and economic impacts of water scarcity are felt prominently and the supply in the economy falls below demand due to drought [5-8].

Each natural hazard varies in various forms. According to this definition, forms of diversity are divided into three groups [9]. The first one, drought is a continuing phenomenon. When it starts, it will not be known but it will not end. Although the effects belong to a certain region, the whole world is under the influence of this phenomenon [10]. The second one, there is no precise definition of drought. The third one is the state in which the solution can be obtained because the drought is not a sudden event. It can be controlled by appropriate monitoring and research [11-14].

As drought started to shape in a serious dimension in Africa, Alaska, Canada and Eurasia starting from 1950, scientists interested in this matter took notice and people started to find indices to minimize the drought [15]. Many indexes have been developed for the calculation of droughts. Some of these are Standardized Precipitation Index (SPI), Reclamation Drought Index (RDI), Effective Drought Index (EDI), Palmer Drought Severity Index (PDSI) and Standardized Precipitation Evapotranspiration Index (SPEI) [3], [16-19]. The purpose of all these indices is to detect and work on the arid regions that are now and in the future. It is necessary to investigate the detected regions and to minimize the risks that may occur.

Drought indices should include features such as determining drought and finding out how much the area is spreading. At the same time, they should not be same each other and be able to compare. SPEI uses both precipitation and temperature data to determine the region's drought. SPEI has emerged to prevent SPI problems. It is an advantageous drought index according to SPI [19].

The powerful feature of SPEI is that it allows for more accurate results with the help of numerical data. It is also affected by more than one factor, leading to more precise results [20]. Only precipitation and temperature values are sufficient for SPEI in climatic (meteorological) events. The results of time scales will be sufficient [21]. At the same time, we can say that SPEI covers the SPI because it considers the precipitation effect [1], [15]. In fact, SPEI includes parameters used to obtain other drought indices too. However, the main advantage compared to other indices is that a multi-scalar character combines the capacity of evapotranspiration affected by temperature and drought severity, end and start time [7].

Reference Evapotranspiration (ETo) value is needed to calculate SPEI. ETo can be obtained in more than one way [15], [20], [22-24]. In addition to these methods, hybrid models (ARIMA-ANN, Wavelet-ANN (WANN) and WANFIS), log-linear models can be used to find these indices [14].

In this study, the main objective is to assess of meteorological droughts in the Mediterranean region of Turkey. Many drought indices have been used in the past to present day Turkey. Examples of these are the Standardized Precipitation Index (SPI), the Percentage of Normal Precipitation and the Palmer Drought Severity Index (PDSI). However, in this study, applied in the world of but which for in Turkey will be applied drought index SPEI it is used. Frequency analyzes of SPEI values of 1, 3, 6, 9 and 12 months were calculated for each station.

2 Methodology

2.1 Study Area

There are 8 provinces of the Mediterranean Region in an area of 89.493 km². In this study, between 1970-2018 it was aimed to calculate the drought for 8 meteorological stations in the Mediterranean Region (Figure 1).

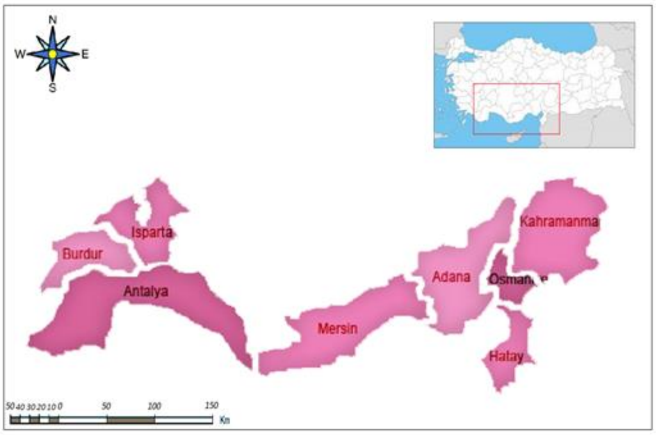

Figure 1: Mediterranean region.

Table 1 provides data for the region (altitude, average rainfall, etc.). Using this data, the operations in the method section were performed.

Table 1: Data on the Study Area

	Latitude (North)	Height (m)	Observation Time (year)	Average rainfall (mm/year)	Average temperature (mm)
Adana	37	23	49	656	19.2
Antalya	36.88	39	29	1119	18.6
Burdur	37.46	950	49	419	13.3
Hatay /Antakya	36.4	85	49	1113	18.4
Isparta	37.76	1035	49	534	12.2
Kahramanmaras	37.58	568	49	712	16.9
Mersin	36.8	6	49	588	19.4
Osmaniye	37.2	150	33	788	18.5

The evaluated monthly precipitation and temperature data were measured by the Turkish State Meteorological Services [DMI].

2.2 Methods

The SPEI is based on the Potential Evapotranspiration (PET) balance, which is the monthly climate balance. Precipitation and temperature values are taken into account when calculating the SPEI. This index can be calculated over several time periods. For this index benefit from the Table 2 created by [25]. Table 1 makes it easy to comment and monitor [26].

Table 2: Drought classification according to SPEI categories based on [25]

Categories	
Exceptionally wet	[illegible]
Severely wet	[illegible]
Mild wet	[illegible]
Near to Normal	[illegible]
Mild dry	[illegible]
Severely dry	[illegible]
Exceptionally dry	[illegible]

The following operations must be performed to obtain SPEI. The following steps must be taken to obtain SPEI. First of all, we start with PET calculation. PET calculation can be calculated with more than one method. For example, Thornwaite, Blaney Criddle etc. mentioned. However, Thornwaite (1948) method was preferred because it could be calculated more easily in this study.

$$PET = 16K\left(\frac{10T}{I}\right)^{m} \quad (1)$$

K is a function calculated by the correction coefficient of the latitude and month, T_{mm} is monthly-mean temperature (°C), I is a heat index and m [illegible]

Monthly precipitation and PET values are used in millimeters units.

$$D_i = P_i - PET_i \quad (2)$$

P and PET is calculated for the month. This difference shows a simple meteorological water balance [27].

$$X_{i,j}^{k} = \sum_{l=13-k+j}^{12} D_{i-1,l} + \sum_{l=1}^{j} D_{i,l} \quad (3)$$

For the different D series, k (month) is the time scale the cluster and n is the calculation number. The D valu [illegible]

The PWMs (probability-weighted moments) of order s are calculated as,

$$w_s = \frac{1}{N}\sum_{i=1}^{N}(1-F_i)^{s} D_i \quad (4)$$

The resulting w_s values are used to find a, b and g.

F_i is a frequency estimator, N is the number of data points. The probability distribution of series D is as follows;

$$F(x) = \left[1 + \left(\frac{\alpha}{x-\gamma}\right)^{\beta}\right]^{-1} \quad (5)$$

$F(x)$ formula, α, β and γ contain [illegible] parameters [illegible]. For the D [illegible]

As given in Equation 6, several scientists have suggested some approaches to the calculation of SPEI [29];

$$SPEI = W - \frac{C_0 + C_1 W + C_2 W^2}{1 + d_1 W + d_2 W^2 + d_3 W^3} \quad (6)$$

Where,

$$W = \sqrt{-2\ln(P)} \quad (7)$$

P is the probability of wear of a D value, $P = 1 - F(x)$. If $P > 0.5$, then then P is replaced by 1-P. Changes the SP value sign obtained. W is a tool used to obtain Constants used for SPEI;

$C_0 = 2.515517$, $C_1 = 0.802853$, $C_2 = 0.010328$,

$d_1 = 1.432788$, $d_2 = 0.189269$, $d_3 = 0.001308$

The cumulative probability for time scales is calculate The SPEI value is then obtained by converting t standard normal distribution to zero and to a varianc [30, 31].

3 Results and Discussions

The SPEI values were estimated on 1, 3, 6, 9 and 12-months time scale conditions for all stations. Thornthwaite, Penman-Monteith and Hargreaves methods can be used to calculate the SPEI. However, in this study, we decided to use the Thornthwaite method because we understood that these methods were simple and useful. As example, it was seen SPEI values graphs for Adana from Figure 2, dry and wet season periods are observed to increase from 1 to 12 months.

SPEI relative frequency results for all stations are given on Table 3-10.

The observed relative frequency of 1-month SPEI values for Adana was found to be near to normal and 67.47% maximum than other drought periods (Table 3). It was observed that the total of the data which is near to normal in the data of 6 months frequency is 52.94% minimum than the other drought varieties. Exceptionally dry period was observed in all time periods but not in other periods. However, throughout the arid interval, the frequency of 1-month SPEI viewing was generally lower than other frequencies. As it can be seen from Table 3, 1-month frequency values near to normal and exceptionally wet, 3, 6, and 9 months frequency values are observed in mild dry or mild wet intervals and 12-month frequency values are near to normal and exceptionally dry.

Antalya can be interpreted as taking place in the normal drought class. Near to normal, a maximum of 68.10 percent is available, and a minimum of 58.05 percent is obtained. Drought for Antalya has a minimum value of 16.73% and maximum value of 22.12%. Minimum 15.52% and maximum 20.40% values were obtained in wetness (Table 4). When the comparison is made according to Table 4, it is seen that 1-month frequency values are near to normal and exceptionally dry, 3-month frequency values are near to normal and mild dry, 6 and 9-month frequency values are mild dry, or mild wet and 12-month frequency values are exceptionally wet.

It can be said that the dryness for Burdur is between 25.95-16.78%. The wetness was observed to be between 19.91-16.78% (Table 5). However, it is concluded that the station is in near to normal condition. In the near to normal drought class, it is seen that 1-month frequency has a maximum value of 65.92%. According to Table 5, frequency values of 1 month were near to normal, frequencies of 3, 6 and 9 months were mild dry or mild wet and 12 months frequency was found to be severely dry.

According to all frequencies in Hatay / Antakya, dryness varies between 15.74% and 28.72%. The wetness is between 17.47% and 19.90% (Table 6). But the station near to normal has the highest percentage. This percentage is 66.61% in the 1-month frequency. It has been concluded that all frequencies in normal drought class exceed 50%. When compared with Table 6, it is seen that the frequency values of 1 month, 3, 6, and 9 months of the frequency values of 1 month were mild dry or mild wet and 12 months of frequency values of -1.5 < to < +1.5. Mild dry is very low compared to other frequencies in the 1-month frequency.

For Isparta, results were found between 66.15% and 57.51% in the near to normal drought class. However, if the Table 7 was placed in a general class, it was concluded that the dryness was between 16.58% and 24.18% and the wetness was between 15.72% and 18.31% (Table 7). As It can be seen from Table 7, 1-month of near to normal frequency values, 3, 6 and 9 months were mild dry or mild wet, 12 months frequency values were close to near to normal and severely dry.

When the Table 8 for Kahramanmaras is examined, it is concluded that the near to normal drought class has the highest percentage. Near to normal drought class has a minimum value with a 1-month frequency value (65.22%) and a maximum 6-month frequency value (51.73%). In addition, dryness and wetness of the station were divided into two, dryness between 16.26-25.61%, wetness resulted in values of 17.30-22.66% (Table 8). As It can be seen from Table 8, 1-month frequency values of near to normal and severely wet, 3-month and 6-month and 9-month frequency values of mild dry or mild wet and 12-month frequency values of near to normal and mild dry conditions were observed.

The maximum value for Mersin station was found in the near to normal drought class at 1-month frequency (68.17%). When the Table 9 is classified as dry and wet, the dry class takes a minimum of 15.74% and the maximum is 22.84%. The wet class was between 16.09% and 21.97% (Table 9). As it can be seen from Table 9, frequency values of 1 month are near to normal and frequencies of 3, 6 and 9 months are mild dry or mild wet and 12-month frequency values are near to normal or severely dry.

When the Table 10 for Osmaniye was examined, the maximum value in the near to normal drought class was found at the frequency of 12 months (68.06%). The minimum value was obtained at 1-month frequency (62.83%). The near to normal drought class is the highest in all frequencies. In addition, all frequencies in the near to normal drought class exceed 60%. Unlike other stations, the wetness at this station has the same percentage (15.97%) for frequencies 1, 3, 6, 9. Dryness also varies between 16.23% and 21.20% (Table 10). And unlike other illusions, the frequency values of 1 month were mild dry or mild wet, the frequency values of 3 and 9 months were near to normal, the frequency values of 6 months were exceptionally dry and 12 months frequency values were near to normal.

Figure 2: 1, 3, 6, 9 and 12-month SPEI values for Adana station

Table 3: Relative Frequency Percentage in Adana

ADANA	1	3	6	9	12
Exceptionally wet	1.73	1.90	0.87	1.90	1.73
Severely wet	7.27	3.29	4.15	3.11	3.98
Mild wet	8.48	11.07	15.40	11.42	9.34
Near to Normal	67.47	60.03	52.94	60.21	63.32
Mild dry	9.52	21.28	24.57	20.59	14.88
Severely dry	3.63	2.42	2.08	2.77	6.75
Exceptionally dry	1.90	0.00	0.00	0.00	0.00

Table 4: Relative Frequency Percentage in Antalya

ANTALYA	1	3	6	9	12
Exceptionally wet	2.30	2.01	1.44	2.59	2.87
Severely wet	5.17	4.60	5.75	4.02	3.16
Mild wet	8.05	10.63	13.22	11.49	12.07
Near to Normal	68.10	61.21	58.05	59.77	60.63
Mild dry	11.49	20.40	20.40	20.11	19.25
Severely dry	2.87	1.15	1.15	2.01	2.01
Exceptionally dry	2.01	0.00	0.00	0.00	0.00

Table 5: Relative Frequency Percentage in Burdur

BURDUR	1	3	6	9	12
Exceptionally wet	1.90	0.87	1.04	1.21	1.38
Severely wet	4.84	3.63	3.11	3.98	3.81
Mild wet	10.55	13.32	15.74	11.94	11.59
Near to Normal	65.92	58.48	54.15	59.69	60.73
Mild dry	11.07	17.13	22.84	16.78	13.67
Severely dry	4.84	6.57	2.94	6.40	8.82
Exceptionally dry	0.87	0.00	0.17	0.00	0.00

Table 6: Relative Frequency Percentage in Hatay/Antakya

HATAY/ANTAKYA	1	3	6	9	12
Exceptionally wet	1.90	1.21	1.04	1.21	1.21
Severely wet	5.88	4.84	5.02	4.84	5.19
Mild wet	9.86	12.11	13.84	11.76	11.07
Near to Normal	66.61	56.40	51.38	56.06	57.61
Mild dry	10.03	24.39	26.82	24.91	23.18
Severely dry	4.15	1.04	1.90	1.21	1.73
Exceptionally dry	1.56	0.00	0.00	0.00	0.00

Table 7: Relative Frequency Percentage in Isparta

ISPARTA	1	3	6	9	12
Exceptionally wet	2.25	1.73	1.04	1.73	1.73
Severely wet	5.70	4.49	5.70	3.97	4.32
Mild wet	9.33	10.02	11.57	10.36	9.67
Near to Normal	66.15	61.14	57.51	60.97	62.52
Mild dry	11.40	15.54	20.90	16.06	13.99
Severely dry	3.97	7.08	2.25	6.91	7.77
Exceptionally dry	1.21	0.00	1.04	0.00	0.00

Table 8: Relative Frequency Percentage in Kahramanmaras

KAHRAMANMARAS	1	3	6	9	12
Exceptionally wet	1.04	1.21	0.35	0.87	0.87
Severely wet	7.27	4.84	5.54	5.54	5.36
Mild wet	10.21	11.94	16.78	11.94	11.07
Near to Normal	65.22	57.79	51.73	56.92	58.82
Mild dry	9.52	21.97	24.57	22.32	20.42
Severely dry	5.71	2.25	1.04	2.42	3.46
Exceptionally dry	1.04	0.00	0.00	0.00	0.00

Table 9: Relative Frequency Percentage in Mersin

- % 2 3 d .	1	3	6	9	12
Exceptionally wet	2.25	1.21	1.21	1.21	1.38
Severelywet	4.84	3.81	4.15	5.02	3.63
Mild wet	9.00	14.36	16.61	12.63	12.11
Near to Normal	68.17	59.34	55.19	59.69	63.32
Mild dry	9.17	17.47	21.45	17.30	13.49
Severely dry	5.54	3.81	1.21	4.15	6.06
Exceptionally dry	1.04	0.00	0.17	0.00	0.00

Table 10: Relative Frequency Percentage in Osmaniye

/ 3 - ! . d 9	1	3	6	9	12
Exceptionally wet	3.14	2.62	2.88	2.36	2.09
Severely wet	2.62	4.19	4.45	4.19	4.97
Mild wet	10.21	9.16	8.64	9.42	8.64
Near to Normal	62.83	67.80	65.45	67.54	68.06
Mild dry	14.14	7.33	9.16	7.07	7.07
Severely dry	6.81	6.81	8.90	8.12	7.33
Exceptionally dry	0.26	2.09	0.52	1.31	1.83

Figure 3: Years where the region has the highest drought in all frequencies

Mediterranean Anatolia Region are the regions most affected by arid conditions in early 1970s and early 1990s.

If we accept Antalya as the starting point, the drought towards the northwest is turning to the previous year. Drought towards the northeast is also over the previous year. In other words, the same chart is displayed on the right side in both directions. Drought last for 3 years (Figure 3).

4 Conclusions

Drought is a natural disaster that causes significant problems in life. Drought analysis and management is very important in combating drought problems. Because drought is a very complex phenomenon, each drought is characterized by different properties. SPEI were used to determine drought and effective drought management in many countries [20]. The SPEI was applied for in Turkey by this study.

In the Mediterranean region between 1970 and 2018, mild, severely and exceptionally levels of drought were observed.

The remarkable drought interval at all stations is >1 to <+1. In other words, the country is located in the near-normal value range. In general, the near to normal drought percentage of the 1-month frequency is higher than the percentage of the 12-month frequency.

It was seen that dryness varies between 15.05% and 28.72% all stations. The wetness varies between 15.05% and 22.66%. Looking at the region in general, it can be concluded that the near to normal drought class has the highest percentages. Mersin has the maximum percentage with a 1-month frequency value (68.17%) in normal drought class. Hatay / Antakya has a minimum percentage with a frequency of 6 months (51.38%).

The Mediterranean region may also face the danger of agricultural and hydrological drought seen later than meteorological drought. Drought prevention plan can be created which to reduce the potential drought effects of the Mediterranean region. In addition, the use of water resources can be regulated.

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