MCBÜ SOSYAL BİLİMLER DERGİSİ Cilt:16, Sayı:1, MART 2018

Geliş Tarihi:05.04.2017 Doi:10.18026/cbayarsos.411475 Kabul Tarihi:27.03.2018

CLIMATE CLASSIFICATION AND DROUGHT ANALYSIS OF MERSIN

Mehmet Ali ÇELİK[1]

Ali Ekber GÜLERSOY[2]

ABSTRACT

Studies show that the southern regions of Turkey, within which also Mersin is located, would be greatly affected by possible climate change. According to a report published by NASA, the most severe droughts of the last 900 years are being witnessed in the Eastern Mediterranean Basin. In this context, the study of the drought of Mersin in the Eastern Mediterranean Basin is of great importance.

In this study, the drought analysis on, and the Thornthwaite climate classification for Mersin and the surrounding area was carried out (1965-2014). The Standardized Rainfall Index (SPI), Normal Percentage Index (PNI) and Erinç Drought Index were used in our study. Drought analyses on monthly, annual and seasonal scales were carried out. According to the Erinç drought index, extreme climatic conditions have been experienced frequently over the past 15 years. For example, the results of the SPI analysis show that there was a lack of precipitation in Mersin across all months of the year 2008. Again, 2009 became the driest year of the last 55 years. After 1968, the years 2001 and 2012 represent the most humid climatic conditions in Mersin. However there is a significant negative trend, especially throughout the winter months. 2001 and 2012 have been the most humid periods in recent years. If the monthly SPI values of these periods have been examined, it can be seen that the humidity of 2001 originated from heavy rainfalls which had occurred in December. The precipitation which fell in December 2001 was the highest rainfalls the last 55 years. Another drought index used in our study is PNI. The PNI was calculated using monthly rainfall data of 1965-2014 belonging to the Mersin station. It is seen that PNI results were consistent with those obtained from Erinç and SPI models. The year 2008 is recorded as being arid according to the PNI analysis. According to the PNI analysis, the year 2008 was observably arid while moist conditions for the year 2012 are worthy of note.

Keywords: *Mersin, Drought, PNI, SPI, Erinc Index.*

[1] Kilis 7 Aralık Üniversitesi, Fen- Edebiyat Fakültesi, Coğrafya Bölümü mail: mehmet.ali.celikk@gmail.com

[2] Dokuz Eylül Üniversitesi Buca Eğitim Fakültesi Sosyal Bilgiler Eğitimi Anabilim Dalı öğretim üyesi, gulersoy74@gmail.com

MERSİN'İN İKLİM SINIFLANDIRMASI VE KURAKLIK ANALİZİ

ÖZ

Yapılan çalışmalar, Mersin'in de içerisinde bulunduğu Türkiye'nin güney bölgelerinin olası iklim değişiminden oldukça etkileneceğini göstermektedir. NASA'nın yayınladığı rapora göre, Doğu Akdeniz Havzası'nda son 900 yılın en şiddetli kuraklıkları görülmektedir. Bu bağlamda Doğu Akdeniz Havzası içerisinde yer alan Mersin'in kuraklığının çalışılması büyük önem kazanmaktadır.

Bu çalışmada, Mersin ve çevresinin Thornthwaite iklim sınıflandırması ve kuraklık analizi yapılmıştır (1965-2014). Çalışmamızda Standart Yağış İndisi (SPI), Normalin Yüzdesi İndisi (PNI) ve Erinç Kuraklık İndisi kullanılmıştır. Aylık, yıllık ve mevsimlik ölçekte kuraklık analizleri yapılmıştır. Erinç kuraklık indisine göre, son 15 yılda ekstrem iklim olayları sıklıkla yaşanmıştır. Örneğin, SPI analizi sonuçları, Mersin'de, 2008'de yılın tüm aylarında yağış eksikliği olduğunu göstermektedir. Yine 2009 yılı son 55 yılın en kurak yılı olmuştur. 2001 ve 2012 yılları ise 1968'den sonra Mersin'de yaşanan en nemli iklim koşullarını temsil etmektedir. Fakat bilhassa kış aylarında önemli bir negatif trend vardır. 2001 ve 2012 yılları son yıllarda yaşanmış en nemli dönemlerdir. Bu dönemlere ait aylık SPI değerleri incelenecek olursa, 2001 yılına ait nemliliğin Aralık ayında meydana gelen şiddetli yağışlardan kaynaklandığı görülmektedir. 2001 yılı Aralık ayında düşen yağış miktarı son 55 yılın en yüksek yağışlarıdır. Çalışmamızda kullanılan bir diğer kuraklık indisi ise PNI'dir. Mersin istasyonuna ait 1965-2014 yıllarına ait aylık yağış verileri kullanılarak PNI hesaplanmıştır. PNI sonuçları ile Erinç ve SPI modellerinden elde edilen sonuçların uyuştuğu görülmektedir. PNI analizinde 2008 yılının kurak olduğu gözlenmiştir. PNI analizine göre, 2012 yılında ise nemli koşullar dikkati çekmektedir.

Anahtar Kelimeler: *Mersin, Kuraklık, PNI, SPI, Erinç İndisi.*

Introduction

Although drought is a type of natural disaster in and of itself, it differs from other natural disasters in certain aspects. First of all, drought is a process with a slow onset (Tosunoğlu, 2014: 1). Therefore, its effects are seen cumulatively over a prolonged period of time (Doğan, 2013: 1). Secondly, since drought does not have an absolute and commonly accepted definition, both its existence and severity are ambiguous. Lastly, the effects of drought are not structural. In other words, drought has a wider geographical distribution than other natural disasters such as landslides, earthquakes, flooding, or overflows. This makes it difficult to measure the impact of drought and disaster management as drought is potentially more difficult when compared to other forms of natural disasters (Akbaş, 2014: 102).

Meteorological drought manifests itself in the form of a lack of precipitation. The amount and duration of that lack of precipitation as well as a lack of humidity stand out at this point. Meteorological drought comes before and triggers other types of drought. While the detection of meteorological drought is difficult, it is possible to mention an onset of drought in cases where the drop in precipitation in a given region is greater than 25%. This rate varies between regions and the duration may be a single season, or it may even be several years (Zaidman et al., 2002: 734; Kıymaz et al., 2011: 91; Tatlı and Türkeş, 2011: 982; Yetmen, 2013: 5).

It is essential to predict dry conditions in advance so that their devastating effects can be diminished. In areas where the risk of drought is high, predicting drought in advance ensures that the devastation sustained by vegetation, agriculture, society and economy are reduced. It is necessary to conduct studies on drought using advanced techniques.

Several drought indices have been developed in order to detect complex events such as drought. Station-based drought models such as the Palmer Drought Severity Index (PDSI), the Standardized Precipitation Index (SPI), the Aridity Index (AI), the Percent of Normal Index (PNI) and Erinç Index are among the most frequently used models. These indices were used in many previous studies and tested for reliability. Multiple indices were used in our study to monitor drought (Çiçek, 1995; Türkeş and Tatlı, 2008; Türkeş et al., 2009; Doğan et al., 2012; Tatlı, 2015).

In this context, the province of Mersin, which is located in Mediterranean Region and which is an area with one of the highest drought risks in Turkey, was selected as the study area as drought has caused major damages in this area in the past years (Türkeş, 1996: 18; Bahadır, 2011: 374). Mersin is located between the 30th and the 40th northern latitudes. The typical ecosystems of Mersin are described as Mediterranean-type ecosystems. Mersin has a sub-arid climate. Summers are dry whereas winters are mild and wet (Tavşanoğlu and Gürkan, 2004: 120). The purpose of our study is to determine Mersin's dry periods (Figure 1) where precipitation variability is about 25% and consequently drought is frequently experienced, and to emphasize drought severity using various indices.

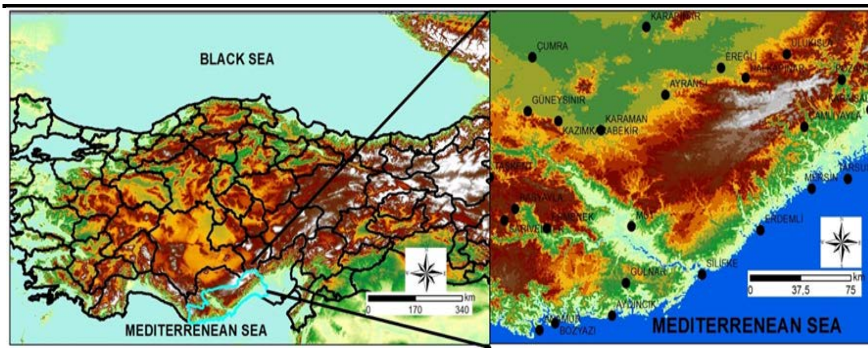

Figure 1. Location map of study area.

Material and Method

The climate data of Mersin was received from the Turkish State Meteorological Service (TSMS). The daily and monthly total precipitation and average temperature data, as well as the daily maximum and minimum precipitation and temperature data from stations in the districts of Mersin, Erdemli, Anamur and Silifke cover a time period of more than 40 years (Table 1). Thus, meteorological drought indices were established through climate classification.

Table 1. Data used in the study

Mersin	Monthly and daily temperature data (average, maximum and minimum) Monthly and daily precipitation data (average, maximum and minimum)	1965-2014
Erdemli	Monthly and daily temperature data (average, maximum and minimum) Monthly and daily precipitation data (average, maximum and minimum)	1965-2014
Silifke	Monthly and daily temperature data (average, maximum and minimum) Monthly and daily precipitation data (average, maximum and minimum)	1965-2014
Anamur	Monthly and daily temperature data (average, maximum and minimum) Monthly and daily precipitation data (average, maximum and minimum)	1965-2014

The most common means of scientifically address drought is to examine the decrease in precipitation amount and number of wet days. However, models and methods such as the Palmer Drought Severity Index, the Standardized Precipitation Index, and the Aridity Index are used to determine, describe, and monitor different cases of drought. Whereas some drought indices (e.g. SPI) depend on precipitation series and pertain to meteorological drought, others are aimed at describing hydrological (e.g. PDSI) or agricultural droughts (e.g. CMI) and water shortages in urban water supplies. There are a number of indices (e.g. PDSI and SPI) that are widely used in order to assess and monitor regional-global droughts. Drought indices gather a large sum of information such as precipitation amount, snow cover, stream flow, and other reserve indicators in order to observe the severity of drought comprehensively and to measure the climate deviation over a certain period of time from normal conditions (Narasimhan and Srinivasan 2005: 70). Station-based drought analyses allow for the revealing of the onset, severity, and duration of drought in detail. Table 2 shows advantages and disadvantages of commonly used meteorological drought indices. First, we will mention the advantages as well as the limitations of PDSI, as it is the most frequently used model in station-based drought analysis. PDSI is one of the most widely used drought indices (Palmer 1965; Alley, 1984) and the only index that uses readily available monthly precipitation amount and temperature inputs in order to assess temperature (Heim, 2002). PDSI was originally developed to assess drought in sub-arid climates-specifically, the Great Plains of the United States (Palmer, 1965). For this reason, some parameters may not apply well for other regions (Heim, 2002; Keyantash and Dracup, 2002). In spite of these limitations, Dai et al. (2004) note that PDSI correlates with soil moisture in hot climates (Table 2).

Other widely used drought indices include PNI (Werick et al.,1994), Deciles (Gibbs and Maher, 1967), SPI (McKee et al., 1993), Palmer Hydrological Drought Index (Palmer, 1965), Crop Moisture Index (Palmer, 1968), Surface Water Supply Index (Shafer and Dezman, 1982; Wilhite and Glantz, 1985; Doesken et al.,1991) and Reconnaissance Drought Index (Tsakiris and Vangelis, 2005; Tsakiris et al., 2007). The relative strengths and weaknesses of these indices are summarized in Table 2. Most of these indices are designed to detect meteorological and/or hydrological drought excluding their impact on vegetation.

Table 2. Advantages and disadvantages of commonly used meteorological drought indices.

Index	*Definition*	*Advantages*	*Disadvantages*
PNI	A simple calculation that divides the precipitation over 30 years by the average precipitation and multiplies by 100 for a result in percentage.	Effective for a single region or season.	Precipitation does not have a normal distribution. PNI depends on location and season. PNI cannot determine specific drought effects.
SPI	A simple concept-based calculation pertaining to effects of precipitation deficiencies over various time scales on groundwater, reservoir volume, soil moisture, snow cover, and stream flow.	Flexible, calculates various time scales, allows for early warning related to drought, and helps with assessment of drought severity.	Precipitation is only an input value. SPI value based on long-term precipitation may vary. A 24 month-long time scale is unreliable.
PDSI	Calculated using precipitation, temperature, and soil moisture data. A soil moisture algorithm is calibrated for relatively homogeneous regions.	The first comprehensive drought index commonly used to detect agricultural drought.	PDSI may delay resulting droughts. It has frequent climatic extremes and is ineffective for mountainous areas during the winter and spring.
PhDI	Derived from PDSI in order to measure the long-term effects of hydrological drought.	Similar to PDSI in terms of advantages, but more effective in detecting drought after it ends.	PhDI may change more slowly compared to PDSI.
CMI	A derivative of PDSI. CMI reflects the moisture requirement in the short-term.	More effective than PDSI in the early detection of short-term agricultural drought.	CMI cannot observe long-lasting droughts well.
SWSI	Derived from the Palmer index by combining hydrological and climatic properties.	SWSI takes reservoir volume, stream flow, snow cover, and precipitation into consideration Effective under snow cover conditions.	Difficult to compare SWSI results between different basins. Cannot detect extreme cases effectively. It is an inappropriate indicator for agricultural drought.

RDI	Based on precipitation rate and PET and similar to SPI.	Drought detection is based on both precipitation and PET. Suitable for climate change scenarios.	It contains uncertainties in input data related to calculation of PET. RDI results in different basins are calculated seasonally and cannot be compared.
USDM	Depends on a number of basic indicators such as PDSI, SPI, PNI, soil moisture model percentiles, daily stream flow percentiles, remote sensing-based Vegetation Health Index, and many other indicators.	Combines the remote sensing-based Vegetation Health Index with other drought indices.	USDM mostly depends on precipitation and soil moisture in short-term. USDM considers weaknesses of other indices that it uses.

Drought indices, which are widely used in station-based drought analysis studies such as Erinç, SPI and PNI, were used in this study. These indices were employed to determine the onset, duration, and severity of drought. Multiple station-based drought indices were used, and the results obtained from these methods were compared. Thus, the months showing dry conditions were detected using each one of these three methods.

The first station-based drought model used in our study was the Erinç Index. This index takes the ratio of precipitation to maximum temperature. The Erinç Index is frequently used by many researchers at various times in order to demonstrate Turkey's dry/humid areas and periods, as well as its overall drought problem (Şaylan, 1997; Bacanlı and Saf, 2005). This index shows above-normal humid conditions than that actually exist in regions where a continental climate is observed. For this reason, Erinç uses the average maximum temperature instead of the average temperature in index calculations. However, months with an average maximum temperature below 0 °C are ignored in this assessment due to a lack of evapotranspiration (GDM, 2013:8). The Erinç Index is calculated with the following formula (Erinç, 1965):

$$Im = P/Tom$$

Where, P is the total annual precipitation and Tom is the annual average maximum temperature. The index values obtained are classified under 6 categories. Each index value also provides information about the vegetation type (Table 3).

Table 3. Classification of the results of the Erinc Index

Climate Classification	Index value	Vegetation
Severe arid	<8	Desert
Arid	8-15	Desert-Steppe
Semi-arid	15-23	Steppe
Sub-humid	23-40	Dry forest
Humid	40-55	Humid forest
Perhumid	>55	Perhumid forest

Another drought index used in our study is SPI. It is an effective method to determine, assess, and monitor droughts, as well as to develop drought management, drought-fighting skills, and national and regional opportunities therewithin (Türkeş et al., 2009: 130). The Standardized Precipitation Index method was developed by Mckee et al. (1993), and converts the precipitation parameter into a single numerical value in order to define drought in regions with varied climatic properties. In this method, the index value is the precipitation in a selected period of time (X_i) minus the average precipitation (X_i^{avg}) divided by standard deviation (σ) as in Equation 1 below. SPI is calculated using the following formula (Mckee, 1993):

$$SPI= (X_i - X_i) / \sigma$$

A SPI value of -2 and below indicates exceptionally dry climatic conditions. An SPI value of 2 and above indicates that exceptional moisture is observed in the climate (Table 4).

Table 4. Classification of the results of the SPI

SPI value	*Classification*
2 and higher	Exceptionally Humid
1.60 to 1.90	Extremely Humid
1.30 to 1.59	Very Humid
0.80 to 1.29	Moderately Humid
0.51 to 0.79	Abnormally Humid
0.50 to -0,50	Normal
-0.51 to -0.79	Abnormally Dry
-0.80 to -1.29	Moderately Dry
-1.30 to -1.59	Severely Dry
-1.60 to -1.99	Extremely Dry
-2 and below	Exceptionally Dry

Another drought index used in our study is the Percent of Normal Index. PNI is the simplest one among drought indices. In this method, the result is obtained as a percentage by dividing the amount of precipitation within a certain period of time with the average precipitation. PNI is calculated via the following formula (Werrick et al., 1994):

$$PNI=(P_i / P_i)*100$$

In PNI calculations, precipitation periods of 12 months or below can also be used. In a drought analysis carried out by taking PNI values into consideration, the period with an index value continuously below a threshold value is defined as being a dry period. The first value below the threshold is accepted as the onset of drought, and the first value above the threshold after the onset is accepted as being the end of drought. In this method, the severity of drought is classified as follows (Table 5):

Table 5. Classification of the results of the PNI

Period	Normal and over (No risk)	Slightly Dry (Start monitoring)	Moderately Dry (Warning)	Severely Dry (Emergency)
1	More than 75%	65% - 75%	55% - 65%	Less than 55%
3	More than 75%	65% - 75%	55% - 65%	Less than 55%
6	More than 80%	70% - 80%	60% - 70%	Less than 60%
9	More than 83.5%	73.5% - 83.5%	63.5% - 73.5%	Less than 63.5%
12	More than 85%	75% - 85%	65% - 75%	Less than 65%

Thornthwaite climate classification was used to better understand climates of study areas examined in the study. Thornthwaite's climate classification depends on the relationship between precipitation-evaporation and temperature-evaporation parameters. According to Thornthwaite, the soil is saturated in places and at times when evaporation is less than precipitation and there is an excess of water. The climate of this area is thus humid. When the opposite is the case, water does not accumulate in the soil in places where the precipitation is less than evaporation, thus leaving the soil being unable to provide the water needed by plants. There is a shortage of water in such places. The climate is such arid. Climate types in Thornthwaite's classification are determined between these two extreme values. Thornthwaite's climates are firstly divided into 2 large groups: humid and arid climates, based on the relationship between precipitation and evaporation. Humid climates are divided into 6, and arid climates into 3, based on their degrees (GDM, 2013: 9). These letters represent the first letters of the climate types in Thornthwaite's classification (Table 6):

Table 6. Classification of the results of the Thornthwaite

Humid Climates	A	Perhumid
	B4	Humid
	B3	Humid
	B2	Humid
	B1	Humid
	C2	Sub-humid
Dry Climates	C1	Dry Sub-humid
	D	Semi-arid
	E	Arid (desert)

Also, Thornthwaite divides the 9 climate types given in the table above into thermal characters based on the relationship between temperature and evaporation. The classification according to thermal character is represented using letters. Thornthwaite classifies thermal characters of these 9 climate types as Megathermal (climates with high temperatures), Mesothermal (climates with mild temperatures), Microthermal (climates with low temperatures), Tundra (climates with very low temperatures), and Frost.

The third letter of the Thornthwaite analysis results represents the seasonal distribution of precipitation. The fourth letter of Thornthwaite results is classified according to evaporation in summer. The Thornthwaite precipitation efficiency index used in our study for climate classification and drought detection in study areas is calculated with the following formula (Thornthwaite, 1948):

lm=(100s-60d)/ETP

In this formula; s: water surplus, d: annual water deficiency, and ETP: annual potential evapotranspiration. Values obtained from the Thornthwaite precipitation efficiency index represent the following (Table 7):

Table 7. Climatic characteristic represented by Thornthwaite results

>100	A	Perhumid
100-80	B4	Humid
80-60	B3	Humid
60-40	B2	Humid
40-20	B1	Humid
20-0	C2	Sub-humid
(0)-(-20)	C1	Dry Sub-humid
(-20)-(-40)	D	Semi-arid
(-40)-(-60)	E	Arid (desert)

Findings and Discussion

According to GDM data, Mersin has a warm and mild climate. The precipitation in Mersin is higher in winter than in summer. Mersin’s long-term annual average temperature is 19.0 °C. The annual average precipitation is 655 mm. August is the region’s the hottest month of the year at 27.6 °C. The average temperature in January is 10.4 °C, which is the lowest average temperature of the year. Temperature and precipitation diagrams for Mersin and a number of its districts, as well as regional temperature-precipitation can be found below (Figure 2 and 3).

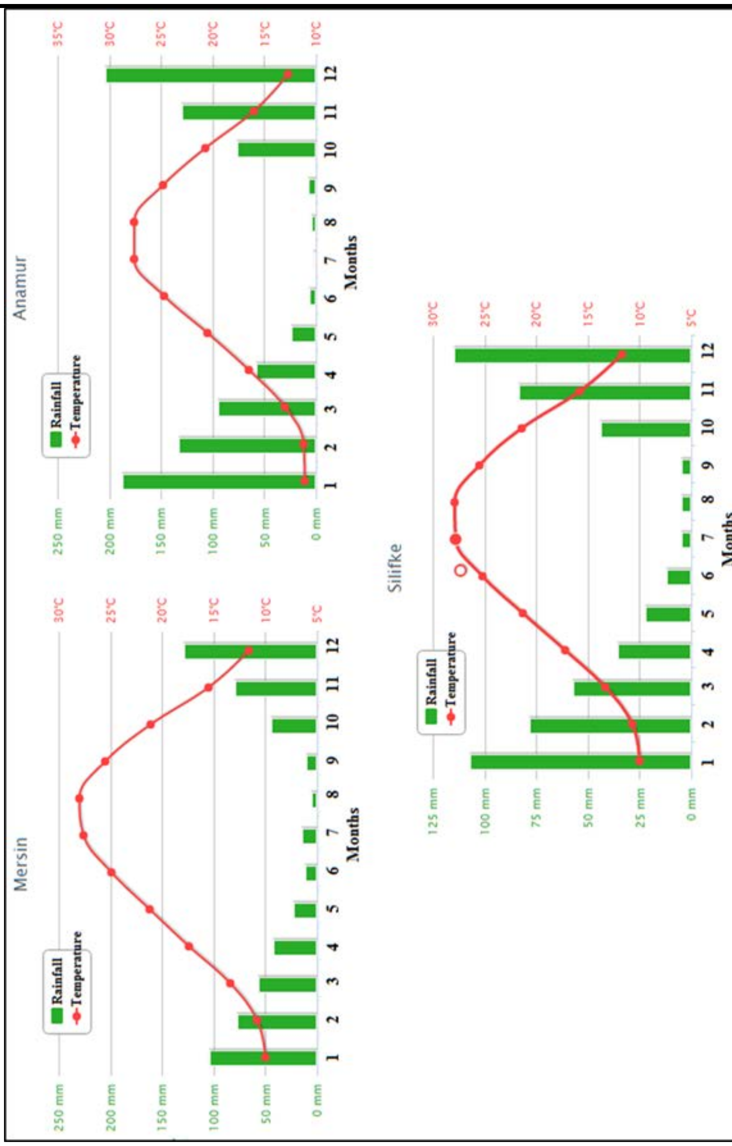

Figure 2. Temperature and precipitation diagrams of Mersin and districts.

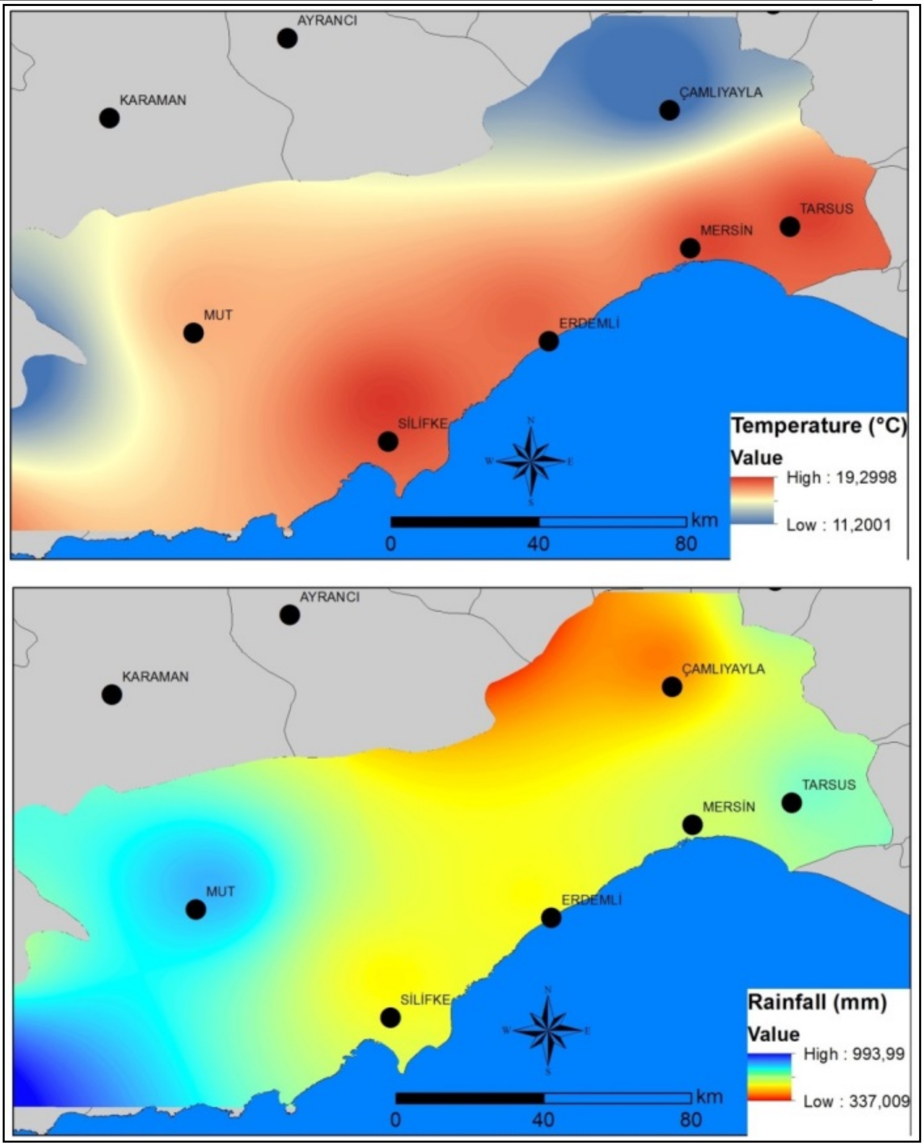

Figure 3. Temperature and precipitation maps of the study area.

According to Thornthwaite climate classification, Mersin's climate values are represented with C1, B'3, s2, and b'4. Here, C1: Dry Sub-humid, B'3: Mesothermal, s2: large winter water surplus, and b'4: Summer evaporation rate of 50%. According to these values, Mersin seems to have dry (arid-humid) climatic conditions (Table 8).

Table 8. Thornthwaite climate classification of Mersin and nearby stations.

Station	*Classification of Climate*	*Climate Type*
Mersin	C1, B'3, s2, b'4	Dry sub-humid, mesothermal, large winter water surplus, summer evaporation rate of 50%.
Anamur	C2, B'3, s2, b'4	Sub-humid, mesothermal, large summer water deficiency, summer evaporation rate of 51%.
Silifke	C1, B'3, s2, b'4	Dry sub-humid, mesothermal, large winter water surplus, summer evaporation rate of 50%.
Adana	C1, B'4, s2, a'	Dry sub-humid, mesothermal, large winter water surplus, summer evaporation rate of 42%.
Antalya	B1, B'3, s2, b'3	Humid, mesothermal, large winter water surplus, summer evaporation rate of 53%.

Large water deficiency is observed in Mersin during the months of June, July, August and September. The maximum water deficiency is observed in July with 181 mm. The largest ground water surplus is observed during winter when precipitation increases. Water surplus is at its highest peak in December, January and February. The average water surplus during these months is 72 mm. Surface water surplus is high in December, January and February, with January having the highest water surplus.

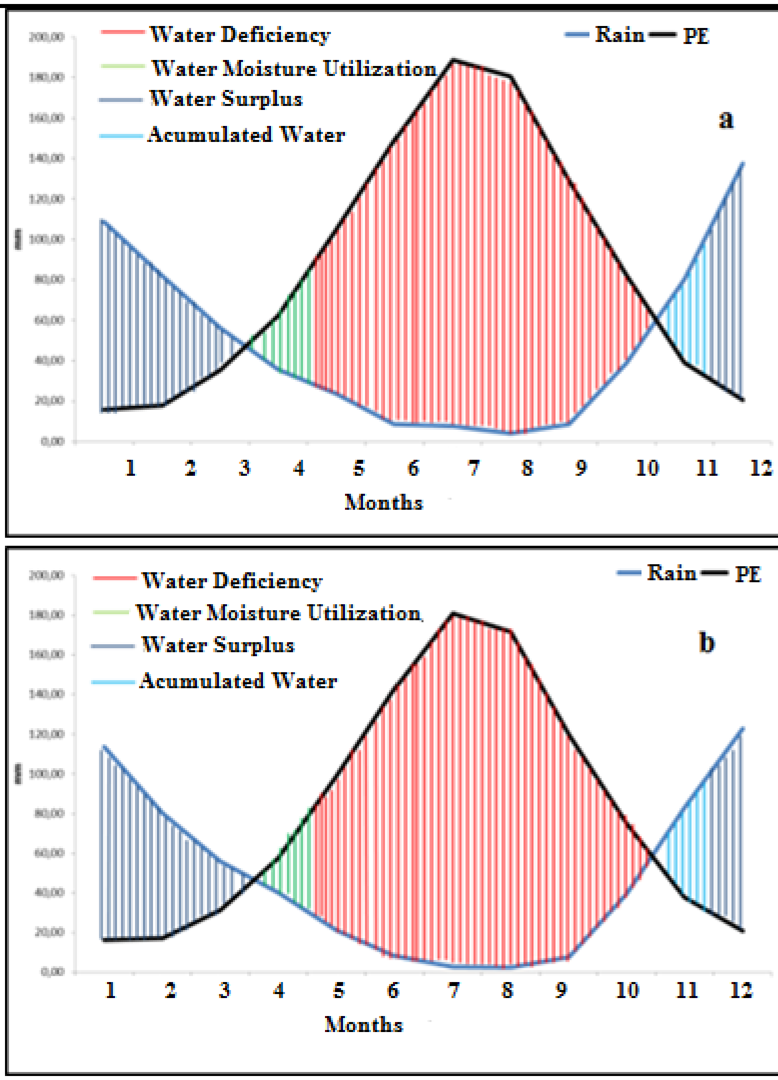

Figure 4. Water balances of Mersin (a) and Erdemli (b) (According to Thornthwaite's method)

Erinç Drought Index

Data from the Mersin meteorology station were examined in this stage of the study. The Erinç drought index was established using monthly maximum temperature and total precipitation data. Thus, arid and humid years were detected. Extreme climatic conditions have been frequently experienced over the last 15 years. For example, 2009 was recorded as being the driest year within the last 55 years. On the other hand, Mersin had also experienced the most humid climatic conditions since 1968 in 2001 and 2012.

Studies show that extreme climatic conditions are experienced in the Mediterranean Region every 10 years (Ölgen, 2010). Indeed, similar results were obtained for Mersin using the Erinç index as well. According to the results obtained, Mersin experienced extreme climatic conditions in 5 of the last 15 years. This indicates that extremely humid and dry climatic conditions are experienced in Mersin every 5 years. Extreme climatic conditions were experienced in 12 of the 55-year period between 1960 and 2014 (Figure 5). This shows that extreme cases are observed more frequently in Mersin when compared with the the Mediterranean Region on whole.

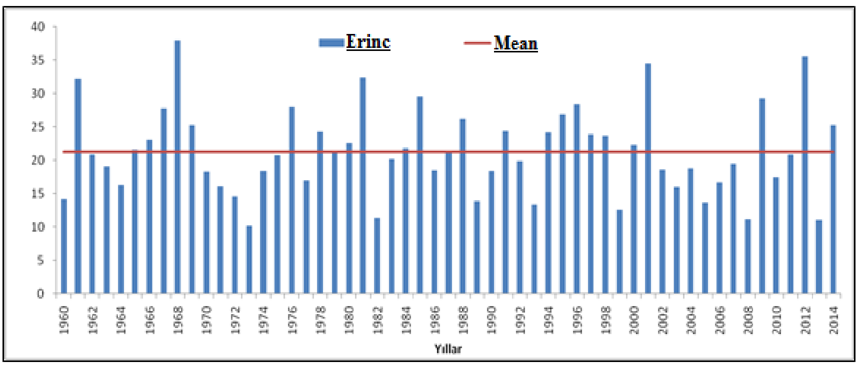

Figure 5. Dry and humid years in Mersin (According to Erinç's method).

The Erinç Drought Index was applied to the meteorological data of the district of Erdemli, located west of Mersin. Studies report that the Mediterranean Region will be one of the most severely affected regions from climate change as it has been experienced in recent years (Karabulut and Çelik, 2012; Kum and Çelik, 2013). The Erinç Drought Index findings derived from GDM data of the district of Erdemli are similar to results of other studies conducted in the Mediterranean Region. In other words, it is seen that dry climatic conditions are dominant in the Mediterranean Region over recent years. Examining the Erinç Drought Index results in terms of periods, the average Erinç Index value was 21.9 between 1963 and 1982, whereas it has dropped to 19.5 over the last 15 years (Figure 6).

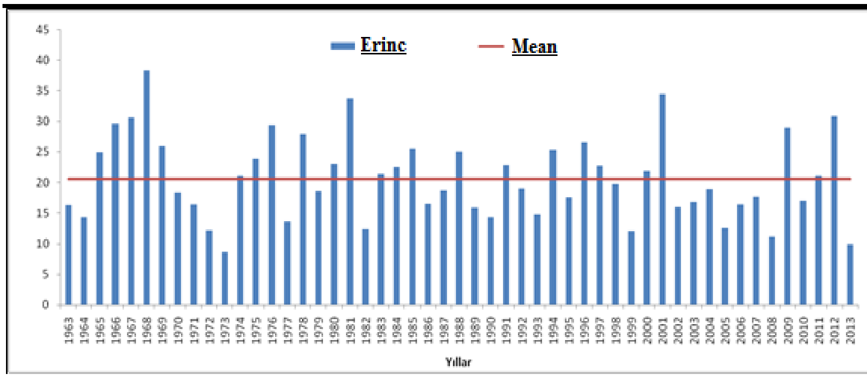

Figure 6. Dry and humid years in Erdemli (According to Erinc's method).

Standardized Precipitation Index (SPI)

The SPI method was applied to the annual precipitation data in this section. This method was applied to selected test areas in the Mediterranean Region. Humid and dry periods in the last 15 years determined using the Erinç Index were examined by being comparing with monthly SPI results. 2008, the driest year observed in Mersin recent years according to Erinç Model, was examined on a monthly scale. Accordingly, an attempt was made to answer, "Which month did show the highest precipitation deficiency and cause the drought observed in 2008?" and other similar questions.

The SPI analysis results for 2008 show that precipitation deficiency had been experienced in almost all of periods of the year. However, there was a negative trend in especially winter months. 2001 and 2012 were the most humid periods observed in recent years. Considering monthly SPI values for these periods, it is seen that the humidity in 2001 resulted from the severe precipitation in December. The precipitation in December of 2001 was the highest of the last 55 years. In addition to December, humid climate conditions were observed in August 2001 as well.

No significant positive trend was present in the other months. October, December and January were humid during 2012. 2014 was also a year with humid climate conditions. The humid periods of 2014 included March, May, August, September, and November. March of 2014 was the most humid month of March between 1988 and 2014 (Figure 7).

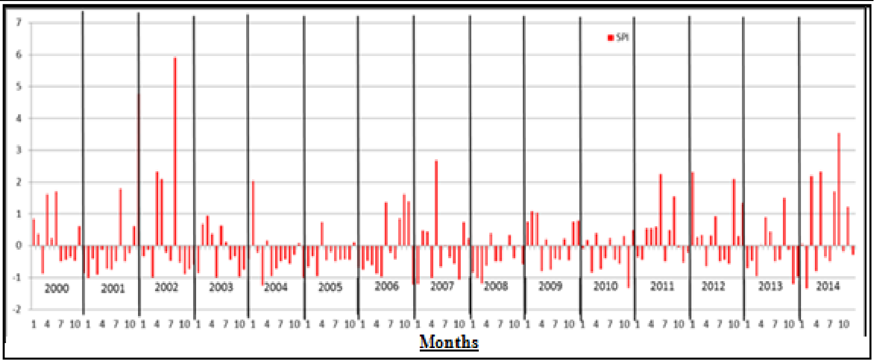

Figure 7. Dry and humid years in Mersin (According to SPI method).

The results of the SPI analysis performed using the monthly precipitation data of the district of Erdemli between 1965-2013 and the results of the SPI analysis performed for Mersin are similar. Monthly drought results of 2008, which stand out as the district of Erdemli's dry period, show that there was a drop in winter precipitation in particular. Dry climate conditions were observed in the period between December and May. A precipitation deficiency in winter usually results in drought for the district of Erdemli as the highest level of precipitation is observed in winter. This leads to stress conditions for plants, which need atmospheric water to grow. As in Mersin, 2001 and 2012 were also humid years for the district of Erdemli. December 2001 was an exceptionally humid period for Erdemli. The severe precipitation in this period increased the total precipitation in 2001 and caused the entire year to appear humid. There were no humid months in 2001 with the exception of August, November, and December. The humidity in 2012, on the other hand, was observed in almost all of the months of that year. It is noted that winter months were especially humid during that year. Since the humidity in 2012 had been distributed across all of the months of that year, it was had a greater impact on plant growth. It is expected that the vegetation index values for 2012 are higher than those of 2001 for the district of Erdemli. There was no exceptionally humid or extremely humid month in 2001 except for June. However, moderately humid climate conditions were observed nearly in all months of the year (except for March, August and September) (Figure 8).

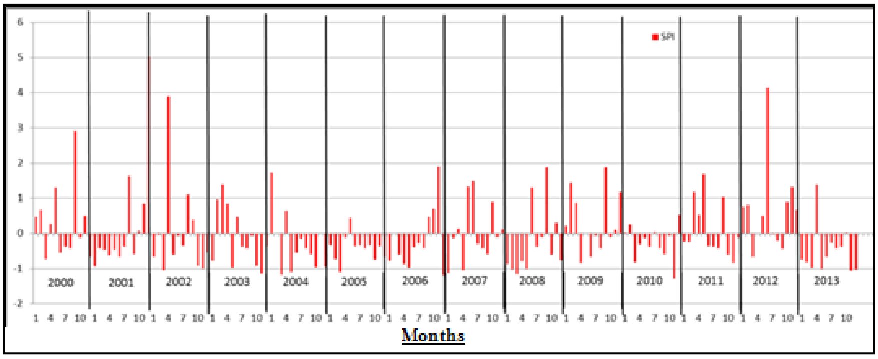

Figure 8. Dry and humid years in Erdemli (According to SPI method).

The SPI drought analysis was applied to selected stations in the Mediterranean Region in this section of the study. Drought analysis was conducted in 3-month periods. 2001, 2006 and 2010 stand out as dry years in SPI analysis results for Mersin during the spring. The spring of 2008 stands out as a dry period across all stations except for the Mersin station. The spring of 2010 seems to be a dry period throughout the region as well. The spring of 2011, on the other hand, was found to be a humid period throughout the region (Table 9).

Table 9. Seasonal SPI analysis results of Mersin

Year	***Spring***	***Summer***	***Winter***	***Autumn***
2000	Normal	Abnormally Humid	Abnormally Humid	Normal
2001	Moderately Dry	Normal	Extremely Dry	Normal
2002	Moderately Humid	Extremely Humid	Abnormally Dry	Moderately Dry
2003	Abnormally Humid	Normal	Normal	Moderately Dry
2004	Moderately Humid	Severely Dry	Moderately Humid	Normal
2005	Normal	Abnormally Dry	Moderately Dry	Normal
2006	Severely Dry	Abnormally Humid	Moderately Dry	Extremely Humid
2007	Moderately Humid	Normal	Normal	Normal
2008	Moderately Dry	Abnormally Dry	Extremely Dry	Normal
2009	Abnormally Humid	Moderately Dry	Very Moist	Abnormally Humid
2010	Abnormally Dry	Normal	Normal	Moderately Dry
2011	Moderately Humid	Moderately Humid	Normal	Normal

2012	Normal	Normal	Extremely Humid	Moderately Humid
2013	Normal	Normal	Severely Dry	Normal
2014	Extremely Humid	Normal	Normal	Moderately Humid

Percent of Normal Index (PNI)

The PNI was calculated using the monthly precipitation data from the Mersin station between 1965-2014. PNI results seem to be consistent with those obtained from the Erinç and SPI models. The PNI shows that 2008 was a dry year. Severe drought was observed across 6 months of 2008 (January, February, March, April, June and July), i.e. half of the year. Humid conditions were observed in 2012. The humidity in Mersin in 2012 was detected in the Erinç and SPI models as well. In addition to 2012, another remarkable year was 2009. The humidity was above normal in January, February, March, September, November, and December of 2009. Another similarity between 2009 and 2012 is that the humidity was experienced especially during winter (Figure 9).

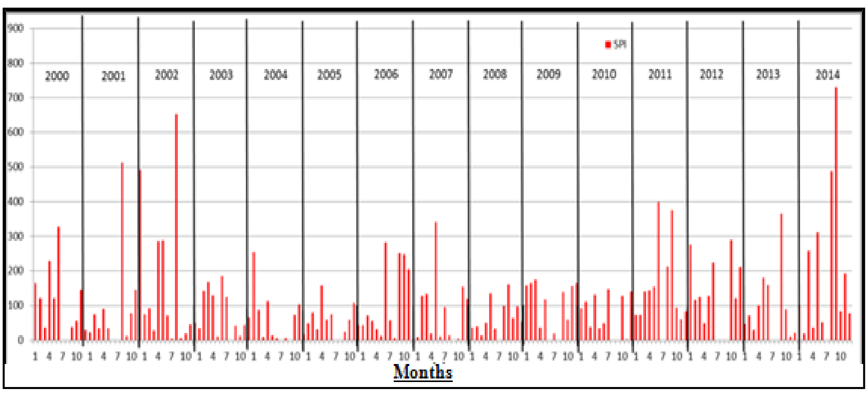

Figure 9. Dry and humid years in Mersin (According to the PNI method).

PNI analysis was applied to the precipitation data from the Erdemli station between 1965-2013. Accordingly, dry conditions in 2008 seem to be reflected in the PNI results as well. With the exception of 3 months, nearly all of months in 2008 were dry. According to the Erinç Drought Index results, 2001 was more humid compared to other years in the district of Erdemli. However, SPI and PNI results show that this not to be case. To clarify, the humidity observed in 2001 mainly stems from a single month: December. Humid conditions were observed in almost all of the months of 2009 and 2012. Indeed, PNI results demonstrate the same. With the exception of 4 months in 2009 and 3 months in 2012, nearly all months were humid during both years. In 2001, on the other hand, only 4 months were humid. However, the severity of humidity in these months was high in 2001. The severity of humidity particularly in the month of December indicates that December 2001 was the single most humid December in recent years (Figure 10).

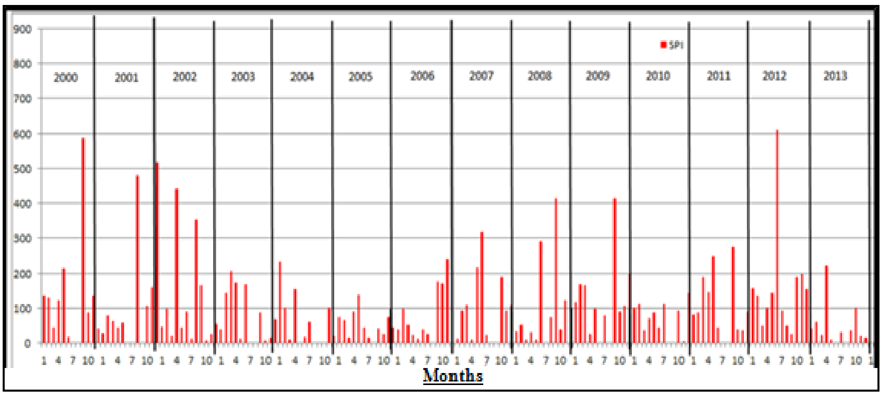

Figure 9. Dry and humid years in Erdemli (According to PNI method).

Conclusion

The SPI, PNI, and Erinç indicies were used to conduct drought analysis for the region of Mersin. Findings show that Mersin has a risk of drought. All of the indices used in the study show that severe droughts have been experienced in Mersin over recent years. Several dry periods were detected, especially within the last 15 years. 2009 proved to be Mersin's driest year within the past 55 years. In addition, 2008 also stands out as a period in which a severe drought was observed. In contrast, 2001 and 2012 were found to be periods with humid climate conditions. Findings obtained from the PNI, SPI and Erinç indices are consistent with one other. This increases the reliability of dry and humid periods detected in our study.

Our study shows similar results with other studies pertaining to various stations in Turkey's Mediterranean region. Previous studies show that the severity of drought is increasing in this region. It has been observed in this study that the severity as well as the duration of drought is gradually increasing in Mersin.

The Mediterranean Region including Mersin is among important vegetation zones for Turkey and contain fertile farmland. Drought has adverse effects on a broad scale spanning agriculture and irrigation to vegetation cover and food supply. Given that, it is seen that drought experienced in Mersin has negative effects. Therefore, it is necessary to take measures against drought. As a initial step, drought-monitoring centers need to be built in cities across the Mediterranean Region. Experts recruited in these centers need to be able to use modern techniques for the early detection of drought on a sufficient scale. Considering that drought occurs in Mersin every 10 years, farmers must be informed and trained on this subject. Additionally, good management of water resources in case of drought is of vital importance as drought shows its severest impact on wetlands.

Drought-related studies should focus on the Mediterranean Region as this region is faced with major drought-related problems. It is both vitally important and very difficult to identify the severity and duration of drought in advance. Thus, studies on drought must also develop facilitating methods for determination of drought severity as well as for the early detection of dry periods.

BIBLIOGRAPHY

AKBAŞ, A. 2014. "Türkiye Üzerindeki Önemli Kurak Yıllar" Coğrafi Bilimler Dergisi, 12 (2), 101-118.

ALLEY, W.M., 1984. "The Palmer drought severity index: limitations and assumptions". Journal of Application Meteorology 23 (7), 1100–1109.

BACANLI, Ü. G. ve SAF, B. 2005. "Kuraklık Belirleme Yöntemlerinin Antalya İli Örneğinde İncelenmesi", Antalya Yöresinin İnşaat Mühendisliği Sorunları Sempozyumu, http://www.e-kutuphane.imo.org.tr/pdf/11138.pdf, (Erişim Tarihi:14.03.2017).

BAHADIR, M. 2011. "Akdeniz Bölgesi'nde Sıcaklık ve Yağışın Gelecekteki Eğilimleri ve Olası Sonuçları", The Journal Of International Social Research, 4, (19), ss. 364-378.

ÇİÇEK, İ. 1995. "Türkiye'deki Kurak Dönemin Yayılışı ve Süresi (Thornthwaite Metoduna Göre)" Ankara Üniversitesi, Türkiye

Coğrafyası Araştırma ve Uygulama Merkezi Dergisi, S:4, s:77-101, ANKARA,

DAI, A.,K. E. TRENBERTH, and T. QIAN, 2004. A global dataset of Palmer drought severity index for 1870–2002: Relationship with soil moisture and effects of surface warming. J. Hydrometeor.,5, ss.1117–1130.

DOĞAN, S. 2013. Konya Kapalı Havzası Kuraklık Karakterizasyonunun Zamansal Konumsal Analizi. Selçuk Üniversitesi Fen Bilimleri Enstitüsü Yayınlanmamış Doktora Tezi, Konya.

DOĞAN, S., BERKTAY, A., SİNGH, V.P., 2012. Comparison of multi-monthly rainfall-based drought severity indices, with application to semi-arid Konya closed basin, Turkey. J. Hydrol. 470–471, ss. 255–268.

DOESKEN, N. J., T. B. MCKEE, and J. D. KLEİST, 1991. Development of a surface water supply index for the western United States: Final report. Climatology Rep. 91-3, Colorado State University, ss. 1-76.

ERİNÇ, S., 1965. Yağış Müessiriyeti Üzerine Bir Deneme ve Yeni Bir İndis. İstanbul Üniversitesi, Edebiyat Fakültesi, Coğrafya Enstitüsü Yayınları (41), İstanbul.

GIBBS, W. J., and J. V. MAHER, 1967. “Rainfall Deciles as Drought Indicators”, Bureau of Meteorology Bulletin,No. 48, Commonwealth of Australia, ss. 1-33.

HEIM, R. R., Jr., 2002. “A review of twentieth-century drought indices used in the United” States.Bull. Amer.Meteor. Soc.,83, ss. 1149–1165.

KEYANTASH, J., and J. A. DRACUP, 2002. The quantification of drought: An evaluation of drought indices.Bull.Amer. Meteor. Soc.,83, 1167–1180.

KIYMAZ, S, GÜNEŞ, V. ve MURAT A. 2011 "Standartlaştırılmış Yağış İndeksi İle Seyfe Gölünün Kuraklık Dönemlerinin Belirlenmesi." Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi 28 (1), ss.91-102.

MCKEE, T.B., DOESKEN, N.J., KLEIST, J. 1993. “Drought Monitoring with Multiple Time Scales”, January 15-20, American

Meteorological Society, Proceedingof The 9th Conference on Applied Climatology, Boston, ss. 233-236.

MGM, 2013. İklim sınıflandırmaları, Klimatoloji Şube Müdürlüğü Çalışanları, url: http://www.mgm.gov.tr/FILES/iklim/iklim_siniflandirmalari.pdf

NARASIMHAN, B., and R. SRINIVASAN, 2005. Development and evaluation of soil moisture deficit index (SMDI) and evapotranspiration deficit index (ETDI) for agricultural drought monitoring. Agric. ForestMeteorology, 133**,** ss. 69–88.

PALMER, W. C., 1965. Meteorological drought. U.S. Weather Bureau Research Paper 45, ss. 1-65.

SHAFER, B. A.,and L. E. DEZMAN, 1982. “Development of a surface water supply index (SWSI) to assess the severity of drought conditions in snowpack runoff areas”, Proc. 50th Annual Western Snow Conf.,Reno,NV, Western Snow Conference, ss. 164–175.

SVOBODA, M. and COAUTHORS, 2002. “The drought monitör”, Bull. Amer. Meteor. Soc.,83, ss. 1181–1190.

ŞAYLAN, L., DURAK, M., ŞEN, O., 1997. “Kuraklık ve Etkileri”, Meterolojik Karakterli Doğal Afetler Sempozyumu, Bildiriler Kitabı, ss.433-444, Ankara.

TATLI ve TÜRKEŞ 2011. “Empirical Orthogonal Function analysis of the palmer drought indices”. Agricultural and Forest Meteorology 151, ss. 981–991.

TATLI, H., 2015. "Detecting Persistence of Meteorologıcal Drought Via Hurst Exponent ", Meteorological Applications, 22, ss. 763-769.

TAVŞANOĞLU, Ç., GÜRKAN, B. 2004. “Akdeniz Havzasında bitkilerin kuraklık ve yangına uyumları”. Ot Sistematik Botanik Dergisi 11: ss. 119-132.

THORNTHWAITE, 1948. “An approach toward a rational classification of climate”Geographical Review”, 38, ss. 55–94

TSAKIRIS, G., and H. VANGELIS, 2005. “Establishing a drought index incorporating evapotranspiration”, Eur. Water, 9–10, ss. 3–11.

TSAKIRIS, D. PANGALOU, and H. VANGELIS, 2007. "Regional drought assessment based on the reconnaissance drought index (RDI)", Water Resour. Manage.,21**,** ss. 821–833.

TOSUNOĞLU, F. 2014. Türkiye'deki Meteorolojik Ve Hidrolojik Kuraklıkların Atmosferik Salınımlarla Olan İlişkilerinin İncelenmesi, Atatürk Üniversitesi Fen Bilimleri Enstitüsü Yayınlanmamış Doktora Tezi, Konya.

TÜRKEŞ, M. 1996. "Meteorological drought in Turkey: A historical perspective, 1930-1993", Drought Network News, University of Nebraska, 8.

TÜRKEŞ, M., AKGÜNDÜZ, A. S., DEMİRÖRS, Z. 2009. "Palmer Kuraklık İndisi'ne göre İç Anadolu Bölgesi'nin Konya Bölümü'ndeki kurak dönemler ve kuraklık Şiddeti". Coğrafi Bilimler Dergisi 7, ss. 129-144.

TÜRKEŞ, M. ve TATLI, H. 2008. "Türkiye'de kuraklık olasılıklarının standartlaştırılmış yağış indisi (SPI) Kullanılarak Saptanması Ve İklimsel Değişkenlik Açısından Değerlendirilmesi", Ormanlar Sempozyumu , Bildiriler Kitabı (Ed., Ünal Akkemik), ss. 55-62. İÜ Orman Fak, 13-14 Aralık 2007, Bahçeköy – İstanbul.

WERICK, W. J., G. E. WILLEKE, N. B. GUTTMAN, J. R. M. HOSKING, ve J. R. WALLIS, 1994. "National drought atlas developed", Eos, Trans. Amer. Geophys. Union,75, 89.

WILHITE, D. A.,and M. H. GLANTZ, 1985. "Understanding the drought phenomenon: The role of definitions", Water Int.,10, ss**.**111–120.

YETMEN, H. 2013. Türkiye'nin Kuraklık Analizi, Ankara Üniversitesi Sosyal Bilimler Enstitüsü Yayınlanmamış Doktora Tezi, ss. 1-194.

ZAIDMAN, M. D., REES, H. G., and YOUNG, A. R., 2002. "Spatio-temporal development of streamflow droughts in north-west Europe", Hydrol.Earth Syst. Sci., 5(4), ss. 733–751.