PALMER DROUGHT ANALYSIS OF NORTH CYPRUS

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ABSTRACT

PALMER DROUGHT ANALYSIS OF NORTH CYPRUS

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As one of the most important results of climate change; drought has become to be the most pervasive problem that causes water scarcity and shortage in North Cyprus. The rainfall is the only source of the natural water resources in this country which has semi-arid climate with dry and hot summer and moderate winter seasons. Owing to the reduction in precipitation and increase in evaporation, the level of water in aquifers, reservoirs, and streams of North Cyprus has dropped considerably and it is certain that the water scarcity will be more difficult problem to overcome in the future. Accordingly, it is needed to study the level of the drought in this region. In this study, the main target is to identify the major drought events and their duration and severity by using Palmer Drought Severity Index (PDSI) for 33 stations in North Cyprus between 1978 and 2015. In order to find PDSI values of each station, in addition to monthly precipitation and temperature, soil available water capacity (AWC) is also required. AWC values were calculated based on soil characteristics of each station. After evaluating monthly PDSI values, the historical drought events are identified and the Mann Kendall Trend test is applied. As a result, it has been found that there are mainly 6 dry periods occurred from the September 1978 to August 2015. The drought occurred between 2004 and 2005 was remarkable severe. Generally, North Cyprus is 28% near normal, 45% drought and 27% wet. However, statistically significant downward trend is evident in almost all stations.

Keywords: Drought, PDSI, Mann Kendall Trend Test, North Cyprus

ÖZ

KUZEY KIBRIS PALMER KURAKLIK ANALİZİ

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İklim değişikliğinin en önemli sonuçlarından biri olarak; kuraklık, Kuzey Kıbrıs'ta su kıtlığı ve sıkıntısına neden olan en yaygın sorun haline gelmiştir. Kurak ve sıcak yaz mevsimi ve ılık kış mevsimi ile yarı kurak bir iklime sahip olan bu ülkede, yağış doğal su kaynaklarının tek kaynağıdır. Yağışta görülen azalma ve buharlaşmada görülen artış, Kuzey Kıbrıs'ta bulunan akifer, rezervuar ve derelerde su seviyesinin önemli ölçüde azalmasına neden olmuştur. Bu da gelecekte su kıtlığını ciddi bir problem olarak önümüzde bulacağımızın bir göstergesidir. Bu nedenle, bölgede kuraklık şiddetini incelemek gerekmektedir. Bu çalışma, 1978 ve 2015 yılları arasında Kuzey Kıbrıs'ta bulunan 33 meteorolojik istasyon için Palmer Kuraklık Şiddeti İndeksi (PKŞİ) kullanarak geçmişte meydana gelen kuraklık olaylarının süresini ve şiddetini belirlemeyi hedeflemektedir. İstasyonlar için PKŞİ değerlerinin bulunmasında, aylık toplam yağış, aylık ortalama sıcaklık ve toprağın Mevcut Su Kapasitesi girdi olarak gereklidir. Bu nedenle, öncelikli olarak, istasyonların Mevcut Su Kapasitesi değerleri her istasyonun temsil ettiği bölgeye ait toprak özellikleri esas alınarak hesaplanmıştır. Aylık PKŞİ değerleri değerlendirildikten sonra, Mann Kendall Trend testi uygulanarak, trend analizleri yapılmıştır. Sonuç olarak, Eylül 1978 ve Ağustos 2015 arasında esas olarak 6 kez kurak dönemin yaşandığı tespit edilmiştir. Bu dönemlerden 2004 ve 2005 yılları arasında meydana gelen kuraklığın bu zamana kadar yaşanan en şiddetli kurak dönem olduğu ortaya çıkmıştır. Genellikle, Kuzey Kıbrıs yüzde 28 oranında normale yakın, yüzde 45 kurak ve yüzde 27 nemli olarak değerlendirilmiştir. Bununla birlikte, yapılan trend analizi sonucunda istasyonların PKŞİ değerlerinde genel bir düşüş olduğu belirgindir.

Anahtar kelimeler: Kuraklık, PKŞİ, Mann Kendall Trend testi, Kuzey Kıbrıs

To my parents

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TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF SYMBOL and ABBREVIATIONS

ASWC	Available soil water capacity
AWC	Available Water Capacity
C	Improvement coefficient
CAFEC	Climatically Appropriate For Existing Conditions
CMI	Crop Moisture Index
D	Water deficiency
$\overline{d_J}^{-1}$	The average of monthly recorded absolute d values for all years
d_i	The distance between the target and the closest station
ET	Real Evapotranspiration
I	Period
ID	Inverse Distance Method
j	Monthly heat index
J	Annual heat index
K	The weighting factor
L	Total evapotranspiration loss
L_s	Evaporation Loss from the surface layer
L_u	Evaporation Loss from the underlying layer
MedPDSI	PDSI for Mediterranean conditions

n	# of variables
NCDC	National Climatic Data Center
NR	Normal Ratio Method
PDI	Palmer Drought Index
PDSI	Palmer Drought Severity Index
PE_{ad}	Adjusted potential evapotranspiration
PE_x	Potential evapotranspiration
PHDI	Palmer Hydrological Drought Index
P_i	Rainfall depth
PL	Potential Loss
PL_s	Potential Evapotranspiration Loss from the surface layer
PL_u	Potential Evapotranspiration Loss from the underlying layer
PNI	Percent of Normal Index
PR	Potential Recharge
PRO	Potential runoff
RDI	Recoinnaissance Drought Index
RMSE	Root Mean Squared Error
RO	Runoff
SC-PDSI	Self-calibrated PDSI
S_i	Stored soil moisture

SPEI	Standardized Precipitation Evapotranspiration Index
SPI	Standardized Precipitation Index
S_s	Soil moisture stored at the beginning of the month in the surface layer
S_u	Soil moisture stored at the beginning of the month in the underlying layer
SWSI	Surface Water Supply Index
TRNC	Turkish Republic of Northern Cyprus
V_0	Predicted value of the target station
V_i	The value of the i^{th} closest station
Weighted PDSI	Modified Palmer Drought Severity Index
X_j	PDSI value
Z-index	Palmer Moisture Anomaly Index

CHAPTER 1

INTRODUCTION

As one of the most dangerous result of the global climate change, recently drought has become to occur more frequently and intensely and it causes global and local water problems in the world (Ryan, 2011; IPCC,2007). According to The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (2007); most probably drought events will also be an extensive issue in the near future owing to the variability in temperature and precipitation trends and rapid snowmelt which are the most effective factors that induce the droughts to exist more often.

Drought is one of the costliest and deadliest hazard which affects great number of people. Usually the properties of drought depend on meteorological, agricultural, hydrological, ecological and socio-economic situations and accordingly, it can be classified into five types as meteorological, agricultural, hydrological, ecological and socio-economic droughts. Agricultural drought is related with soil moisture and generally has a negative effect on the farm production. Hydrological drought is involved with streamflow and runoff. It causes a decrease in streamflow levels. Meteorological drought is a kind of drought that balances precipitation and evapotranspiration and it also measures the availability of soil moisture during average conditions. Ecological drought is the shortage of available natural water supplies for extended periods within variability in natural and controlled hydrology. It causes a lot of difficulties across ecosystems. Socio-economic drought deals with the amount of water for the supply and demand issues (Horstmeyer, 2011; SNAPP, 2016).

A drought is defined as an extreme climate phenomena happening when precipitation level falls below-normal over a period of months to years. It is known as a temporary prolonged dry period and intensity of the precipitation, soil moisture, and water storage deficit, duration and spatial coverage are three major aspects that affect drought (Dai, 2011b). Drought is a kind of slow developing phenomenon having complicated structure and consequences that demonstrate regional differences. In addition, it is difficult to forecast the starting and ending point, duration, severity, and frequency of drought. Thus, it can be more harmful than other hazards and also it may affect water resources, agriculture and famine, social, economic, and environmental conditions of a country (Tatli and Türkeş, 2011). Hydrological and thermal properties of a region have a major impact on the water budget because the input and output elements of the water balance are directed by these properties. In order to illustrate these properties, a lot of "drought indices" have been defined and studied. Palmer Drought Severity Index (PDSI), Recoinnaissance Drought Index (RDI), Standardized Precipitation Index (SPI), Crop Moisture Index (CMI), Palmer Hydrological Drought Index (PHDI), and Surface Water Supply Index (SWSI) are the most important drought indices which are used world-wide. By using drought indices, the quantity of a drought for a region can be defined with a single number (Mika et al., 2005). Drought indices are required for the prediction of the future dry years and for the detection of the return period of a drought event, and also the frequency, duration, and severity of the drought for a specific region (Tatli and Türkeş, 2011).

1.1 Problem Statement

Water resources sustainability is the ability of consuming water properly to meet the needs of living things and environment for the present and leave sufficient amount of water for future generations to sustain life. In addition, water resources sustainability is making the freshwater always available during the long dry periods, extreme floods and rapid population growth. Water planning and management is the one of the main requirement of water sustainability (Mays, 2007). Therefore, in order to make the water sustainable in North Cyprus, the analysis of drought, flood and other natural hazards that affect the quantity and quality of water should be performed.

Gökçekuş (1997), states that the demand of water has increased in North Cyprus since 1960. Currently, as a result of rising population rate, developing tourism industry, poor water management and climate change, water scarcity becomes more serious problem for North Cyprus (Elkiran and Ongul, 2009). Although, according to the annual total rainfall data of recent years; there has not been a significant trend variation in the annual total rainfall, the seasonal disparity in rainfall is obvious (Agboola and Egelioğlu, 2012; Seyhun and Akıntuğ, 2013). Moreover, there had been a lot of drought events from 1971 to present and due to the continuous dry winter seasons; most of the streams were dry during the past two decades (Pashiardis and Michaelides, 2009). Therefore, some precautions should be taken immediately because of the increase in population and life standard in island. As the rainwater is the only source for the water resources of the island which has semi-arid climate, the water scarcity could be more difficult problem to overcome in the future (Agboola and Egelioğlu, 2012).

Although Turkish Republic of Northern Cyprus (TRNC) Department of Meteorology has been using some drought indices to determine drought in North Cyprus, a more effective and complex drought monitor index should be used to obtain more reliable results. Some of the drought's damaging effects and results can be reduced by using early warning systems and monitoring implements. Therefore, investigating the relationship between drought and ocean atmosphere circulations such as Pacific Decadal Oscillation (PDO), North Atlantic Oscillation (NAO), El Nino Southern Oscillation (ENSO) should be beneficial to forecast coming dry years. However, first a reliable drought index is needed to analyze the time series of past years before studying their relationship.

The AWC is a problematic issue in the hydrological studies. Most of the time the knowledge of AWC is required to examine the physical structure and quality of soil. Since, it can be used for the development of new models to solve agricultural and environmental issues. Therefore, the AWC values for the soil regions of North Cyprus should be identified to perform more studies to build a well-managed ecosystem, environment, region and food system.

1.2 Objective of the study

Due to the climate change, the frequency of extreme events has increased in the country. Accordingly, besides the floods, it is required to study the level of the drought in this region and compare its condition with other drought events taking place in other countries around the world. In order to analyze the drought condition, a drought index is required.

In this study, the main target is:

- To obtain AWC values for the regions of North Cyprus.
- To determine the historical drought periods,
- To find the severity of the drought events in North Cyprus between 1978 and 2015 by using monthly Palmer Drought Severity Index (PDSI),
- To analyze the PDSI time series in order to identify whether the drought conditions in the country have upward or downward trends,

1.3 Organization of the Thesis

The rest of this thesis is organized as follows. Chapter 2 gives general information about drought, drought indices, trend analysis and available water capacity including the studies of related issues. Chapter 3 includes the meteorological data used for the calculation of monthly PDSI. Chapter 4 describes the method of prediction of missing meteorological data, calculation of Available Water Capacity, methodology of monthly PDSI and trend tests. Chapter 5 gives the results and discussions and finally Chapter 6 provides the conclusions drawn from the results of the study.

CHAPTER 2

LITERATURE SURVEY

Global climate change impacts different kinds of factors related with drought. Drought is usually related with other hydrologic factors and their relationship is another important point to research. Nowadays, there is high confidence that because of the climate change there is an obvious raise in temperature. In addition to temperature, the climate change has also caused increase in evapotranspiration and change in prepicitation type. All of these impacts of climate change that have significant effects on drought are world-wide meteorological popular issues.

The drought analysis has been studied in almost all countries. Since, the drought is a complex phenomenon which has various effects for different regions. Generally, meteorological department of a country is responsible for executing drought analysis monthly or weekly using a suitable drought index for the country. However, applying only one index may not be sufficient to obtain accurate results, because the drought indices have various limitations. Therefore, different drought indices have been developed and studied for different regions to find the most appropriate index showing consistent results over the years.

2.1 Extreme Drought Events in Different Countries

There have been number of drought conditions that have been experienced in the world for the last years. Because of the global warming and increase in greenhouse gases in the atmosphere, these events have been occurring more frequently. Almost all parts of the world become familiar with drought events in recent years.

Syria experienced 3-year drought between the years of 2007 and 2010. It was the worst disaster in this region which had happened mainly due to the decrease in groundwater supply and also the human forcing activities (Kelley et al., 2015).

In FAOLAND&WATER (2013), a lot of drought events, their effects and results all around the world have been discussed. The countries that have experienced severe drought periods have been given with the amount of damage that they have suffered from these events. For instance; many drought events have occurred frequently in Africa for twelve years. In recent years, the Horn of Africa suffered from the unbearable drought periods. Droughts also had a serious impact on daily life in 2009 and 2011 in Kenya. Especially, agriculture was influenced dramatically based on the crop data. Since the yields of wheat in 2009 was 45% less than the yield in 2010.

In Australia several drought events took place from 2002 to 2010. According to the statistical data, in 2006 the total wheat yield of this country decreased by 46% and this was the lowest yield during the period of 1960 -2010.

In 2010, Russia had the most severity drought events in the last 38 years. The duration of drought was too long and it covered considerable region of the country. The drought also had adverse impact on environment, economy and human health.

Texas, Oklahoma, and New Mexico located at the southern parts of the US, affected seriously from the drought in 2011. In addition to southern states; Arizona, Kansas, Arkansas, Georgia, Florida, Mississippi, Alabama, South and North Carolina were also experienced severe drought in 2011.

The drought in US known as great grain belt drought lasted for almost one year. It started in 2012 and ended in spring 2013. The extreme drought extended over the most parts of the US. Accordingly; due to high prices, livelihood becomes more difficult and also safety of food was influenced seriously. In addition to the 3 or 4 percent incline in the retail food prices of US, the food prices had also a sharp increase owing to the drought in the world.

A deadly drought had happened in the southwestern China’s Yunnan province for 3 years. It started in 2009 and at least 6.3 million people suffered from the drought and

2.4 million people could find drinking water hardly. The agriculture of this region was affected considerably by losing nearly 317 million USD. Farmers were also fighting against drought and they started to grow more resistant crops. However; despite these preventions, the effect of drought could not be decreased effectively. Even though desertification already influenced the northern and western parts of the China, it was not that much serious in southwestern region of the country (FAOLAND&WATER, 2013).

2.2 Drought Indices

Hydrological and thermal properties of a region have a major impact on the water budget because the input and output elements of the water balance are directed by these properties. In order to illustrate these properties, a lot of drought indices have been defined and studied. Palmer Drought Severity Index (PDSI), Recoinnaissance Drought Index (RDI), Standardized Precipitation Index (SPI), Crop Moisture Index (CMI), Palmer Hydrological Drought Index (PHDI), and Surface Water Supply Index (SWSI) are the most important drought indices which are used world-wide (Dai, 2011b; Tsakiris et al., 2007). Using drought indices, the quantity of a drought for a region can be defined with a single number (Mika et al., 2005). Drought indices are required for the prediction of the future dry year and for the detection of the return period, duration and severity of the drought event for a specific region (Tatli and Türkeş, 2011).

Each drought index has different requirements and properties. For that reason, in order to apply the most appropriate index for a specific region, before using the index, the acceptability of it for the region should be checked. For instance; if the required data for the calculation of the index is not available, then different index should be chosen in order to detect the drought periods. To overcome these problems, several drought indices have been developed. These indices have both limitations and superiorities over each others as it can be seen from Table 2.1 (Tsakiris et al., 2007). For instance; by using Palmer Moisture Anomaly Index (Z-index), the current precipitation deficit can be determined quickly. However, this index does not include conditions in the previous years. Accordingly, the most suitable index for a region can be chosen with taking these limitations and superiorities of the drought index into consideration (Dai, 2011b).

Table 2.1 Most common drought indices with their limitations and advantages (Tsakiris et al., 2007).

Index Name	Advantage	Disadvantage
Palmer Drought Severity Index(PDSI)	Contains water supply and demand (soil moisture).	Re-norrmalization needed in mountainous and snow-covered areas.
Standardized Precipitation Index (SPI)	Evaluated for several time series. Evaluation of drought severity.	Utilization of only precipitation as an input. Does not consider evaporation.
Percent of Normal	Calculation procedure is simple.	Values are based on region and season.
Palmer Hydrological Drought Index(PHDI)	Considers the impact of precipitation and temperature by using water balance model.	Re-normalization needed in mountainous and snow-covered areas.
Surface Water Supply Index (SWSI)	Includes storage of reservoir.	Does not assess the extreme facts properly.

2.3 Studies of Drought Indices in Cyprus

In recent years, drought has started to become a serious problem in Cyprus owing to its negative effects on the economy, social life, and also environment. There have been a lot of drought events between 1971 and present. The last drought event in 2008 was the most severe one, since the amount of water that flew into dams was lower than in the previous years (Pashiardis and Michaelides, 2009).

The drought situation in southern Cyprus between 1971 and 2008 was analyzed by Pashiardis and Michaelides (2009) using the SPI and the RDI. As a result, both of these indices demonstrate that there were nine drought periods during 38 years and the return period of the drought varies between 4 and 5 years.

Papakonstantinou et al. (2011) examined the impact of climate change on especially drought and other natural disasters such as forest fires from 1979 to 2009 for some regions that are found in the southern part of Cyprus. The Average Maximum Drought Index (AMDI) and the Average Actual Values of Drought Index (AAVDI) are the drought risk indices that were used to measure the potential risk of drought in eight stations (Chrysochous, Pafos, Prodromos, Platania, Lemesos, Athalassa, Larnaka, Paralimni) which are in the south part of the island. It was found that Athalassa is the most arid region among eight stations owing to having more population and CO_2 emission and less forested area than other stations and also it was concluded that the drought has been rising significantly in all studied regions.

Griggs et al. (2014), analyzed the yearly precipitation and a 250-year drought period from four Pinus brutia tree-ring chronologies across the four regions with different heights in west-central Cyprus. As a result of the study, it is concluded that, there is not a considerable change in the number of droughts and extreme level of yearly precipitation during these periods, whereas there is a significant decrease in the number of moderate to wet years. According to the results, generally, the annual droughts have repeated every 5 years and the duration of dry periods has been changing from 2 to 6 years.

The study of Akıntuğ (1997) examined the level of drought in northern part of Cyprus from 1976 to 1995 with Palmer Drought Severity Index. Seven meteorological stations (Alevkaya, Ercan, Girne, Lefkoşa, Gazimağusa, Yeni Erenköy, Güzelyurt) were selected that distributed all over North Cyprus. As a conclusion, the results showed that the most drought station is Güzelyurt located along the West Mesarya Plain, the drought events had occurred both in summer and winter times and based on the Palmer classification some of the regions were near normal; whereas the others were mild to moderate drought.

Beside these studies, The South Cyprus Department of Meteorology uses SPI and the Water Development Department uses five additional indices; Wet Season Runoff Index, Hydrological Year Runoff Index, Monthly River Runoff Index and Dam Storage Index as drought indices to monitor drought condition in the southern part of Cyprus (Republic of Cyprus, Water Development Department, 2015). Turkish Republic of Northern Cyprus (TRNC) Department of Meteorology uses SPI, De Martonne, Aydeniz and the Percent of Normal Index (PNI) to analyze drought for 1-

month, 3-month, 6-month, 9-month and one year for the assessment of drought in northern part of the island (TRNC Department of Meteorology, 2015).

2.4 Palmer Drought Severity Index (PDSI)

The Palmer Drought Severity Index (PDSI) is one of the most commonly employed drought index in which is universally used to measure the duration and severity of drought events or dry and wet spell using monthly or weekly time series. It was developed by Palmer (1965), for the measurement of the deficiency of moisture and gained importance particularly in the USA (Dai, 2011a). The Palmer Drought Severity Index (PDSI) varies based on the weather conditions. It changes significantly when conditions have been extremely dry or extremely wet (Szép et al., 2005).

In the PDSI method, the principles of the balance between moisture supply and demand are used as an approach. The change in the precipitation and temperature, evapotranspiration, moisture of the soil, and runoff influence the water balance. The monthly or weekly precipitation and temperature data and soil Available Water Capacity (AWC) of the location are used for the calculation of the PDSI values. Then the calculated values are evaluated according to the Palmer classification. Generally, negative PDSI values illustrate dry periods and positive PDSI values indicate wet periods. Nearly average conditions are usually indicated around zero (Mika et al., 2005).

As other indices, PDSI has also some superiorities and shortcomings. Unlike the other drought indices which use precipitation as an input, the PDSI uses both precipitation and average surface air temperature. Therefore, PDSI can account the basic influence of surface warming. This index measures the cumulative departure in surface water balance and almost all of the fundamental concepts of the water balance equation containing evapotranspiration, soil recharge, runoff, and the surface moisture loss can be identified with this index. However, this index only depends on the inputs without considering human impacts such as the usage of water for irrigation and industries and construction of new reservoirs on the water balance (Dai, 2011b; Karl, 1983) and also it is sensitive to only specific types of soil. Therefore, the application of this index for a climate division may be too general in order to obtain accurate values. The estimation of potential evapotranspiration is determined by using the Thornthwaite method. Despite wide acceptance of this technique, it is still only an approximation and causes problems in some locations (Alley, 1984; Dai, 2011a).

Although PDSI was developed for the characterization of drought in United States, it has been using widely for the other regions in the world as well. It was tested for the climates of US which shows variation from region to region and then standardized for the climates by using supply-demand approach including available water content. A great number of PDSI studies in different regions can be found in the literature. For instance: Dai et. al, (1998) analyzed the decadal meteorological droughts and wet spells changes and also their correlation with streamflow in four stations. These stations are Slack for the U.S., Simpson for S.E. Australia (River Murray and Darling), Barnes for Europe and mid-latitude Canada. The PDSI values were computed from 1900 to 1990 by using monthly air temperature and precipitation data based on the moisture balance on the ground. According to the results, it was obvious that due to climate change which has been triggered by greenhouse gases, there was a sharp increase in the number of wet and dry regions since 1970s.

Dai et al., (2004) acquired PDSI values over Illinois, Mongolia, and different regions of China and the former Soviet Union which are on a 2.5^{o} grid. The dataset of precipitation and temperature were available from 1870 to 2002 for these regions. It was concluded that the number of areas having PDSI value less than 3 increased dramatically since 1970 whereas the number of areas having PDSI value more than 3 had decreasing trend since 1980s. It was also found out that the anthropogenic activities of global warming caused incline in temperature and drying and it was obvious that the potential of drought was increased.

Vasiliades and Loukas (2009) investigated the convenience of the PDSI, PHDI, the Palmer Z-index and the Modified Palmer Drought Severity Index (Weighted PDSI) for seven watersheds which were chosen in the region of Thessaly, Greece; Mouzaki, Pili, Mesdani, Ali Efenti, Larissa, Mesohora and Sykia in order to observe droughts and its relationship with river discharge and soil moisture for the analysis period from

1960 to 2002 and as a result, it was concluded that the Palmer indices were good in order to identify the severity of drought. However, they were not useful for the determination of duration of the drought.

In order to monitor climate change, droughts, the influence of drought on crop yield and choose the best appropriate drought index in the western part of Turkey, Durdu (2013) used PDSI and its moisture anomaly index, Self-calibrated PDSI (SC-PDSI) and its moisture anomaly index, and the SPI. Aydın, Denizli, Afyon and Uşak were selected as crop regions since the long year precipitation and temperature data of these regions were available for the analysis period between 1963 and 2007. As a conclusion of this study, the drought years were determined and according to the crop yield models, it was found that the SC-PDSI was the best performer index in Aydın region whereas the PDSI was the most appropriate index for the identification of the drought years in Denizli, Afyon and Uşak.

Rosa et al., (2012) investigated the performance of the SPI, the Palmer PDSI, PDSI for Mediterranean conditions (MedPDSI) and the Standardized Precipitation Evapotranspiration Index (SPEI) over 27 weather stations in Portugal between 1941 and 2006. The determination of drought years and specification of drought severity has been useful for this region in order to identify water shortage. It was obtained from the results that PDSI and MedPDSI performed better than other indices for these regions and the usage of soil moisture balance approach in these indices has been helpful for the prediction of droughts.

Rhee and Carbone (2007), checked the method that was developed by the National Climatic Data Center (NCDC) to enable monitoring of drought weekly by using the PDI (Palmer Drought Index). It was analyzed for the Kansas Northwest Climate Division and five weather stations in the South Carolina Southern between 1961 and 2000. It was found out that, the weekly monitoring sometimes gave better results than the monthly monitoring, but in general the monthly and weekly PDI results showed similarity.

2.5 Available Water Capacity (AWC)

World-wide, there is a high demand for the knowledge of soil data and information. Mainly, in order to build a well-managed ecosystem, environment, region and food system, a contemporary and proper data of soil properties are necessary for the scientist and governments. In order to define the physical structure and quality of soil, firstly available water capacity (AWC) of the soil should be characterized (Hong et al., 2013).

AWC or in other words available soil water capacity (ASWC) is a water balance determinative soil factor that affects the rate of photosynthesis, plant growth, carbon distribution and nutrient cycle in the ecosystem. Furthermore, the evaporation and transpiration rates and groundwater recharge, infiltration and most of the other hydrologic processes that have an important role on climate are also controlled by AWC. It is the total water capacity of surface soil layer and underlying layer. Therefore, it is reasonable to say that it should be the most important variable in order to develop local and regional model for an ecosystem (Hong et al., 2013; Zheng et al., 1996).

In Palmer method, the recorded values of precipitation and temperature are used to calculate water capacity monthly or weekly. In addition to water capacity, soil moisture storage is also required where the soil is considered to consist of two layers. One of them is surface layer which is assumed that it can store 25 mm water. The second one is underlying layer. The soil property of the site affects the available capacity of underlying layer. Evapotranspiration occurs on the surface layer and before starting to remove moisture from the underlying layer, all of the available moisture must be removed from the surface layer. Therefore, after the surface layer is saturated, the moisture begins to be recharged from the underlying layer (Alley, 1984).

From hydrological perspective, mostly droughts in Mediterranean region are caused by the low precipitation levels and large amounts of evaporation. Therefore, due to this reason, the drought index should include the water availability of soil in addition to climatic variables (Sousa et al., 2011). This is one of the main reason of choosing PDSI as a drought index in this study. Since as mentioned above; the AWC is one of the major components in this method. In this study, before the computation of PDSI, firstly AWC is calculated for better results.

Soil structure, ingredients of the soil, bulk density and depth of the soil are the most known parameters for the forecast of AWC (Hong et al., 2013; Zheng et al., 1996). There are a lot of studies and methods in the literature that were developed for the evaluation of AWC.

Briggs and Shantz (1912) studied the soil charachteristic of 104 different soil types in order to evaluate the wilting coefficient from the moisture retentivity of soil which was found according to the physical measurements. As a result, a linear equations were developed between the wilting coefficient, and the moisture equivalent, the hygroscopic coefficient and the moisture holding capacity. The definitions related with the soil properties such as wilting point, field capacity, moisture holding capacity were given in this study and still the some of the same definitions have been using in the soil studies. Hence, this study gained importance and used in a lot of studies which investigate soil properties. The studies of Blair et al. (1950), Amonette (2013), Twarakavi et al. (2009), Pachepsky and Rawls (2004) and Kirkham (2005) are only some examples which mentioned the study of Briggs and Shantz (1912).

In order to estimate the available soil water capacity (ASWC) of the Seeley-Swan Valley and Montana state which are found in the U.S., Zheng et al. (1996) used topographic wetness index instead of the traditional methods that are derived from soil series data. The topographic index is represented as ln ($\alpha/\tan\beta$). In this equation α refers to the upslope area draining past a certain point per unit width of slope whereas β is the regional surface slope angel. As a result of the comparison between their findings and the available soil water capacity (ASWC) evaluated by Soil Conservation Service, U.S. Department of Agriculture, it was found that they have linear correlation that means this index is also convenient to find AWC in this region.

Hong et al. (2013) derived a soil AWC map of Korea by applying digital soil mapping methods. The conventional soil survey was integrated with the soil map to perform this technique. It was found out that the new developed map can demonstrate the physical quality of soils in Korea precisely.

For the development of AWC, maps of Canadian proviences; Alberta, Saskatchewan and Manitoba; Jong and Shields (1988) utilized from the Soil landscape maps. AWC classes were substituted for soil textural groups. Textural classes that hold huge part of the polygons are the data used for the improvement of AWC maps. As a result, they obtain AWC values in mm for different textural groups. For instance; AWC value for sand and loamy sand type of soil, for a 120-cm-deep, is 50 mm.

Cazemier et. al (2001) performed a study for the prediction of available water capacity for the part of Plain of Languedoc which is situated in the south of France. The possibility theory was applied in order to convert the imprecise soil data found in the soil databases to reliable prediction. It was confirmed that this approach can be used for regional applications.

Groenendijk (1989) developed a project in order to determine the AWC of soils in Europe. Soil texture classes and the effective rooting depth were two parameters needed for the calculation of AWC. For the estimation of AWC in the regions where stones and gravels are highly found, a specific reduction factor was also used that was calculated based on the properties of the region to calculate the AWC properly.

2.6 Trend Tests

In order to detect whether there is an important statistical trends for observations in series with time, trend analysis is applied. Although, parametric trend tests have superiorities over nonparametric tests, the outliers in the data can be reconciled easily and the independent data can be used in nonparametric trend tests. Thus, nonparametric tests are more common. For the better understanding of the climate change and the effect of greenhouse gases on the hydrological cycle, identification of trends in long term historical data are the major issue to improve management of water resources (Rahmat et al., 2012).

In recent years, several analyses have been devoted in order to determine if there is a continuous trend taking place in environmental variables or not. Accordingly, observational series of water cycle variables mostly precipitation, temperature, drought and flood, ground water and salinity trend analysis have been performed (Gudmundsson and Seneviratne, 2015; Helsel and Frans, 2006).

In this study, the trend analysis is performed to assess the patterns of change in PDSI for North Cyprus. In the most part of the world, there are a lot of studies about trend analysis of drought. For example; Rahmat et al. (2012), analyzed the trends of drought in SPI by using non parametric trend methods for five chosen meteorological location in Victoria, Australia. Mann-Kendall and Spearman's rho tests were used in this study to detect the trends during the period 1977-2010. It was found out that generally decreasing trend prevailed over whole regions.

Gudmundsson and Seneviratne (2015) examined the drought frequency trends applying SPI from 1961 to 1990 for Europe. The Theil-Sen trend test and Mann-Kendall test were used. The results showed that the drought frequency had downward trend in northern Europe while it had upward trend in southern stations.

Yusof et al. (2013), used Standardized Precipitation Index in order to quantify drought level during 33 years over 69 stations in Peninsular Malaysia. Then, Mann-Kendall test was applied and the trend values indicated that there is an increasing trend in the drought events which has occurred in the eastern and western regions of Peninsular Malaysia.

Sousa et al. (2011), performed trend analysis for precipitation and drought levels during the 20th century in the Mediterranean. The self-calibrated Palmer Drought Severity Index was used to identify the drought conditions and Mann-Kendall test was employed. It was verified that the most western and central Mediterranean regions have tendency to have increasing trends in the number of drought event.

CHAPTER 3

DATA

The monthly PDSI values are identified in this study from September 1978 to August 2015. In the methodology of PDSI, temperature, precipitation and AWC values are essential inputs. In this study, 33 meteorological stations across North Cyprus that are shown in Figure 3.1 are selected to determine the drought condition. The information about these stations are given in Table 3. and Table 1.2 The representation of whole North Cyprus including different types of soil types which are provided in the soil map and having long term data are considered as basic criteria while choosing these stations. In order to obtain more accurate results which illustrate the drought condition, having long term data is the most significant parameter. Moreover, this method include available soil water capacity. Therefore in order to measure the drought, the soil types should be taken into consideration. The monthly temperature and rainfall data of these 33 stations starting from September 1978 to the ending of August 2015 were provided by Meteorological Office of North Cyprus. The percentage of sand, silt and clay belong to different soil series that are used to calculate AWC values are taken from the soil map which is provided by the Agriculture Office of North Cyprus (Dinç et al., 2000).

Figure 3.1 The Meteorological stations across North Cyprus

Table 3.1 Information of the temperature stations

Number of Stations	**Stations**	**Latitude**	**Longitude**	**Elevation(m)**	**Annual Average Temperature (ºC)**
1	Alevkaya	33^{0}32'05"	35^{0}17'09"	623	16.6
2	Beyarmudu	33^{0}42'31"	35^{0}02'43"	82	19.5
3	Boğaz	33^{0}16'54"	35^{0}16'47"	232	19.3
4	Çamlıbel	33^{0}04'14"	35^{0}18'58"	277	18.3
5	Ercan	33^{0}30'07"	35^{0}09'33"	119	19.3
6	Esentepe	33^{0}35'03"	35^{0}20'10"	213	19
7	Geçitkale	33^{0}43'25"	35^{0}15'36"	58	19.4
8	Girne	33^{0}19'53"	35^{0}20'31"	10	20.4
9	Güzelyurt	32^{0}58'55"	35^{0}11'20"	52	18.3
10	Lapta	33^{0}10'29"	35^{0}20'27"	73	19.9
11	Lefkoşa	33^{0}21'07"	35^{0}11'47"	134	19.2
12	Gazimağusa	33^{0}56'34"	35^{0}07'40"	8	19.8
13	Yenierenköy	34^{0}11'22"	35^{0}32'08"	119	19.9
14	Akdeniz	35^{0}17'59"	32^{0}57'54"	89	384.1
15	Çayırova	35^{0}21'53"	34^{0}01'11"	49	389

Table 3.1 Information of the temperature stations (con't)

Number of Stations	Stations	Latitude	Longitude	Elevation(m)	Annual Average Temperature (ºC)
16	Değirmenlik	$35^0$14'40"	$33^0$28'46"	146	332.2
17	Dipkarpaz	$35^0$35'56"	$34^0$22'45"	136	497.9
18	Esentepe	$35^0$20'10"	$33^0$35'03"	213	445.7
19	İskele	$35^0$17'10"	$33^0$53'04"	39	339.8
20	Kantara	$35^0$24'02"	$33^0$54'49"	480	558.5
21	Lefke	35^0 46'48"	$32^0$50'59"	129	312.5
22	Mehmetçik	$35^0$25'20"	$34^0$04'42"	99	420.8
23	Salamis	$35^0$11'21"	$33^0$54'12"	10	321
24	Serdarlı	$35^0$14'50"	$33^0$36'28"	95	326.6
25	Yeşilırmak	$35^0$09'59"	$32^0$44'13"	20	376

Table 1.2 Information of the rainfall stations

Number of Stations	Stations	Latitude	Longitude	Elevation(m)	Annual Average Rainfall (mm)
1	Akdeniz	$35^0$17'59"	$32^0$57'54"	89	384.1
2	Alayköy	$35^0$11'05"	$33^0$15'24"	166	286.1
3	Alevkaya	$35^0$17'09"	$33^0$32'05"	623	485.2
4	Beyarmudu	$35^0$02'43"	$33^0$42'31"	82	349.0
5	Boğaz	$35^0$16'47"	$33^0$16'54"	232	412.2
6	Çamlıbel	$35^0$18'58"	$33^0$04'14"	277	453.8
7	Çayırova	$35^0$21'53"	$34^0$01'11"	49	389.0
8	Değirmenlik	$35^0$14'40"	$33^0$28'46"	146	332.2
9	Dipkarpaz	$35^0$35'56"	$34^0$22'45"	136	497.9
10	Dörtyol	$35^0$10'44"	$33^0$45'31"	54	273.1
11	Ercan	$35^0$09'33"	$33^0$30'07"	119	313.6
12	Esentepe	$35^0$20'10"	$33^0$35'03"	213	445.7
13	Geçitkale	35 14'00"	33 43'43"	45	329.7
14	Girne	$35^0$20'31"	$33^0$19'53"	10	470.0
15	Gönendere	$35^0$15'51"	$33^0$39'39"	75	324.2

Table 2.2 Information of the rainfall stations (con't)

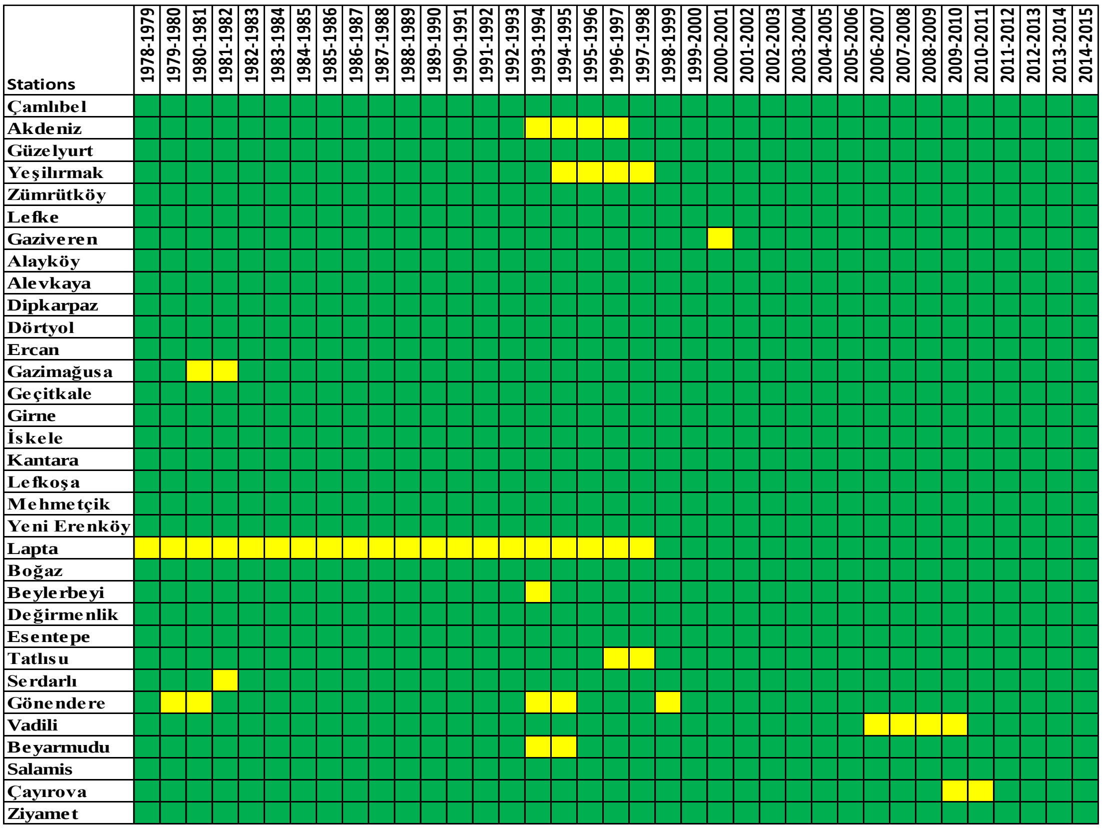
Number of Stations	Stations	Latitude	Longitude	Elevation(m)	Annual Average Temperature (ºC)
16	Güzelyurt	35⁰11'20"	32⁰58'55"	52	286.7
17	İskele	35⁰17'10"	33⁰53'04"	39	339.8
18	Kantara	35⁰24'02"	33⁰54'49"	480	558.5
19	Lapta	35⁰20'27"	33⁰10'29"	73	561.9
20	Lefke	35⁰ 46'48"	32⁰50'59"	129	312.5
21	Lefkoşa	35⁰11'47"	33⁰21'07"	134	306.6
22	Gazimağusa	35⁰08'11"	33⁰56'08"	7	339.3
23	Mehmetçik	35⁰25'20"	34⁰04'42"	99	420.8
24	Salamis	35⁰11'21"	33⁰54'12"	10	321
25	Serdarlı	35⁰14'50"	33⁰36'28"	95	326.6
26	Tatlısu	35⁰22'47"	33⁰45'06"	168	482.9
27	Yenierenköy	35⁰32'08"	34⁰11'22"	123	453.8
28	Yeşilırmak	35⁰09'59"	32⁰44'13"	20	376
29	Ziyamet	35⁰28'11"	34⁰08'24"	131	431

3.1 Precipitation

The monthly precipitation values are obtained for 33 stations between September 1978 and August 2015 from the Meteorological Office of TRNC. However the data came with missing parts. In Table, the years which have missing data are indicated in yellow (light) and the years which have complete data are shown in green (dark) for each meteorological stations. The missing values are filled by using Inverse Distance Method or Normal Ratio Method. Before completing the missing data, the statistical indicators are used to find the most suitable method amongst the two methods for each stations. In

Table the closest station or stations that are used to fill the missing rainfall data of candidate stations are shown.

Table 3.3 Name of the station and the missing monthly rainfall values



: The years which have missing data
: The years which have complete data

Table 3.4 Name of the station that has missing rainfall data and neighbor stations of this station.

	Station Name	**Closest Station 1**	**Closest Station 2**	**Closest Station 3**
1	Akdeniz	Çamlıbel	Kozanköy	
2	Lapta	Girne	Kozanköy	
3	Beylerbeyi	Girne	Alevkaya	Boğaz
4	Tatlısu	Kantara	Esentepe	
5	Gaziveren	Güzelyurt	Lefke	
6	Yeşilırmak	Lefke	Gaziveren	
7	Serdarlı	Değirmenlik	Geçitkale	
8	Vadili	Dörtyol	Margo	Beyarmudu
9	Gönendere	Geçitkale	Değirmenlik	
10	Beyarmudu	Vadili	Dörtyol	Çayönü
11	Çayırova	İskele	Mehmetçik	
12	Gazimağusa	Dörtyol	Salamis	

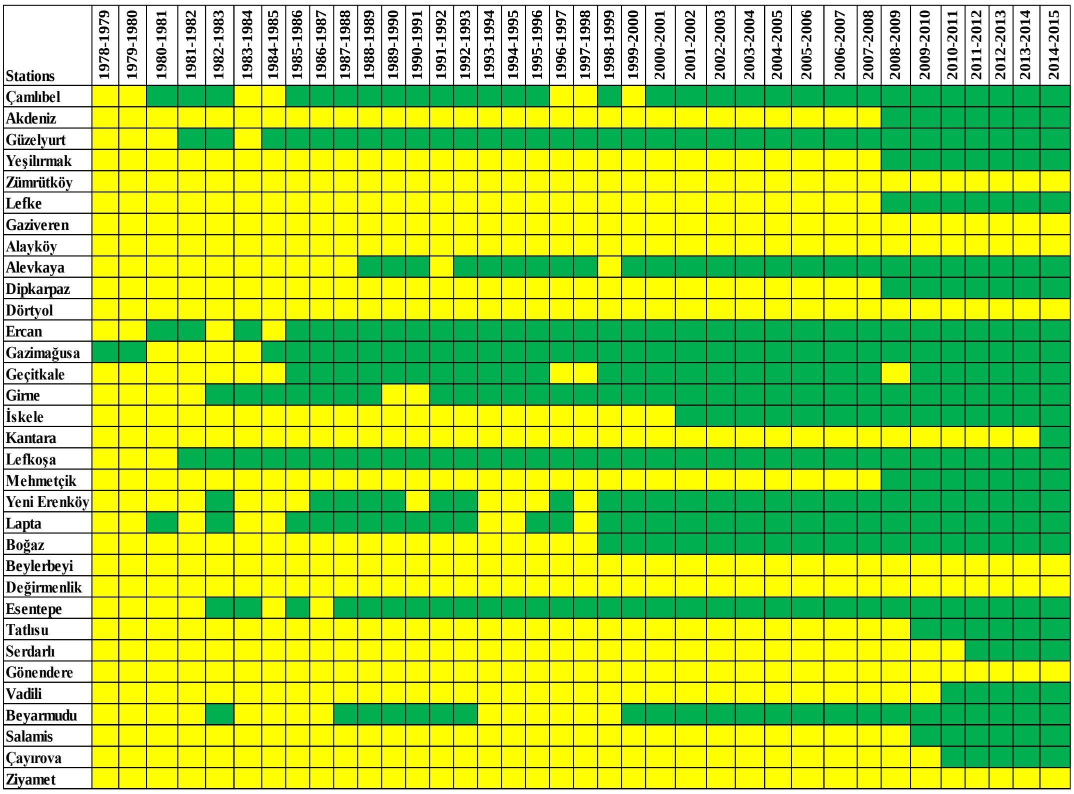
Figure 3.2 The stations that have missing precipitation data.

3.2 Temperature

In addition to rainfall data, the monthly measured average temperature values are also obtained from the Meteorological Office of TRNC. The Meteorological Office currently measures temperature in 24 stations as indicated in Table. Among these 24 stations, 10 of them have very short data that represents last seven years. On the other hand, other 14 stations have also missing values.

In the island, the variability in rainfall is much more significant than variability in temperature. In this drought analysis, in order to consider variability in rainfall across the country (33 stations), the number of the temperature stations are also extended to the number of the rainfall stations. Since the change in temperature is not considerable when the distance between the stations are close to each other. It is belived that this is an acceptable assumption. Moreover, if only 24 stations were used, the knowledge of rainfall data for 33 stations could not be used. Thus, all of the obtained rainfall data has been used by using estimation methods, and the number of temperature station which shows low variability, relative to rainfall, has been increased to 33 stations.

Table 3.5 Name of the station and missing temperature values



: The years which have missing data

: The years which have complete data

Table 3.6 Name of the temperature station that has missing data and closest stations to this station.

	Name of the Station	**Closest Station1**	**Closest Station 2**	**Closest Station 3**	**Closest Station4**
1	Çamlıbel	Girne	Lapta	Güzelyurt	
2	Akdeniz	Çamlıbel	Güzelyurt		
3	Lapta	Çamlıbel	Girne		
4	Boğaz	Alevkaya	Girne	Lapta	
5	Girne	Çamlıbel	Lapta	Alevkaya	
6	Beylerbeyi	Girne	Alevkaya	Lefkoşa	
7	Değirmenlik	Ercan	Alevkaya	Lefkoşa	
8	Alevkaya	Esentepe	Girne	Lapta	
9	Esentepe	Alevkaya	Girne	Lapta	
10	Tatlısu	Esentepe	Alevkaya		
11	Kantara	Alevkaya	Esentepe	Erenköy	
12	Zümrütköy	Güzelyurt	Çamlıbel		

Table 3.6 Name of the temperature station that has missing data and closest stations to this station (con't)

	Name of the Station	Closest Station1	Closest Station 2	Closest Station 3	Closest Station4
13	Lefke	Güzelyurt	Çamlıbel		
14	Gaziveren	Güzelyurt	Çamlıbel		
15	Güzelyurt	Çamlıbel	Lapta	Lefkoşa	
16	Yeşilırmak	Güzelyurt	Çamlıbel		
17	Alayköy	Lefkoşa	Çamlıbel		
18	Lefkoşa	Ercan			
19	Ercan	Lefkoşa			
20	Serdarlı	Ercan	Alevkaya	Esentepe	
21	Gönendere	Ercan	Alevkaya	Esentepe	
22	Geçitkale	Beyarmudu	Ercan	Mağusa	
23	Vadili	Ercan	Beyarmudu	Mağusa	
24	Dörtyol	Ercan	Beyarmudu	Mağusa	
25	Beyarmudu	Mağusa	Ercan	Lefkoşa	Geçitkale
26	Salamis	Magusa	Yeni Erenköy		
27	İskele	Magusa	Yeni Erenköy		
28	Çayırova	Erenköy	Mağusa		
29	Mehmetçik	Erenköy	Mağusa		
30	Ziyamet	Erenköy	Mağusa		
31	Erenköy	Mağusa	Ercan	Girne	Geçitkale
32	Karpaz	Erenköy	Mağusa		
33	Magusa	Yeni Erenköy	Geçitkale	Ercan	

The missing monthly temperature data of 33 meteorological stations are filled in three steps. As shown in Table, all the meteorological stations have missing temperature data, but among the 33 stations; Çamlıbel, Güzelyurt, Alevkaya, Ercan, Gazimağusa, Geçitkale, Girne, Lefkoşa, Yeni Erenköy, Lapta, Esentepe and Beyarmudu have small amounts of missing values. First of all, the missing values of these twelve stations are filled by using neighbor stations as shown in

: The years which have missing data
: The years which have complete data

Table. Then after completing the missing data of these stations, the missing months of remaining 12 stations that have only few months of data are completed by using the stations having long-term data. For the final step, the missing values of 9 meteorological stations; Zümrütköy, Gaziveren, Alayköy, Dörtyol, Kantara, Beylerbeyi, Değirmenlik, Gönendere and Ziyamet that do not have any measured temperature data are filled. In Table, the years which have missing temperature data are demonstrated in yellow (light) and the years which have complete data are shown in green (dark) for each meteorological station. In

: The years which have missing data
: The years which have complete data

Table the closest station that are used for the filling the missing data of the candidate stations are given.

3.3 Available Water Capacity

The knowledge of AWC of a region is significant in order to use the soil property to improve new models for the agriculture and environmental management. There are a lot of studies and methods in the literature that were developed for the calculation of AWC. Applying topographic wetness index, digital soil mapping methods and using soil structure, ingredients of the soil, bulk density and depth of the soil are only few examples of methods using in order to forecast AWC. Although, in order to obtain the available water of the soil; using drying-oven and measuring the value in the laboratory experimentally is one of the best estimation method, due to the variability of soil properties, measurement and analysis of the soil characteristic usually takes too much time and needs large amount of money. In this study, a regression equation that was developed by Briggs and Shants (1912) using only texture type of soil to determine AWC of a lot of soil samples was applied. In this equation, only sand, silt and clay percent of the soil type are needed to obtain AWC.

The soil texture including sand, silt and clay content of soil is used to calculate the AWC of 33 meteorological stations. As shown in Table (Appendix B), there are 108 soil series that are distributed uniformly along North Cyprus. The organic matter of the regions are also given in this table. The soil including high amounts of organic matter usually has higher water holding capacity and conductivity due to aggregation of soil and the distribution of pore space (Saxton and Rawls, 2006). However, as it can be seen, the amount of organic matter is generally below 2 which means that it is too small to affect the AWC of soil. Therefore it is negligible for this study.

CHAPTER 4

METHODOLOGY

4.1 Methods used for the Estimation of Missing Data

Both in this study and other climatological and environmental studies, knowledge of long term weather data is major parameter of the study. However, due to the random errors or systematic errors in instrumentation, lack of the observer and failure in communication, some gaps are occurred during the observation of the data. Therefore, the first step of these studies is generally filling the incomplete data with reliable estimation methods (Kashani and Dinpashoh, 2012).

Completing the missing data is different from the predicting weather. In predicting weather, the data has been recorded instantly. However, the data has been gathered both before and after the missing data, the missing values should be consistent with the past data in order to obtain more accurate results in the study. Hence, first the relation between the missing and known data should be found by using statistical indicators. Then according to the result, the best interpolation technique should be chosen. Some of the most common statistical indicators are Root Mean Squared Error, Correlation Coefficient, and Mean Absolute Error (Kotsiantis et al, 2006)**.**

4.1.1 Estimation Methodology for Missing Data

There are a lot of different interpolation methods for the estimation of missing data. Before deciding the suitable interpolation method, the topography, elevation, the dispersion of observations of the closest stations and microclimate of the target area should be taken into consideration, because these parameters are significant for the weather condition of the station and may affect the choice of the methods (Eischeid et al., 2000). Simple Arithmetic Averaging, Inverse Distance Method (ID), Normal Ratio Method (NR), Single Best Estimator, Multiple Regression Analysis, Least

Absolute Deviations Criteria, Closest Station Method are the empirical methods that are known widely (Xia et al., 1999). In this study, ID and NR are used to fill the missing parts of temperature and rainfall data.

4.1.1.1 Inverse Distance Method (ID)

The convenience of the inverse distance method makes it one of the most commonly used methods among the other interpolation methods. According to this method, the distance between the stations is considered as weighting function on estimating the missing data. However, the distance between stations should not be more than 100 km to obtain more accurate results. The missing values are predicted by,

$$V_0 = \frac{\sum_{i=1}^{n}(V_i/d_i)}{\sum_{i=1}^{n}\left(\frac{1}{d_i}\right)} \qquad (1)$$

where V_0 is the predicted value of the target station, V_i is the value of the i^{th} closest station and d_i is the distance between the target and the closest station. As it can be seen from Equation 1, the distance between the target and surrounding station affects the value inversely (De Silva et al., 2007; Xia et al., 1999).

4.1.1.2 Normal Ratio Method (NR)

In this method, annual average values of candidate and closest stations are used as weights. The weights of closest stations affect the predicted data. Therefore, the estimated data is the combination of these weights. If the difference between the annual average of the target and closest station is more than 10%, this method is appropriate for estimating the incomplete data. The missing data are predicted according to,

$$V_0 = \frac{1}{n}\sum_{i=1}^{n}\left[\frac{N_0}{N_i}\right]V_i \qquad (2)$$

where n is the number of closest stations, V_0 is the predicted value of the target station, V_i is the value of the i^{th} closest station, N_i is the normal annual data of i^{th} closest station and N_0 is the normal annual data of target station (De Silva et al., 2007; Xia et al., 1999).

4.1.2 Comparison of Methods for the Estimation of Missing Data

There are different types of statistical indicators. Mean Absolute Error, Root Mean Squared Error (RMSE), Coefficient of Efficiency, Correlation Coefficient and Standard Deviation are the most common statistical indicators of error. (Kashani and Dinpashoh, 2012; Kotsiantis et al., 2006; De Silva et al., 2007). Before choosing the most suitable method for each station to fill the missing data, some statistical indicators are used to find the best correlation between predicted and observed values. RMSE is a measure of the error between the predicted and observed values. Thus, in order to prefer a method, the difference should be smaller. In this study, RMSE is used to decide the suitability of methods.

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(p_i - a_i)^2}{n}} \quad (3)$$

where p_i is the predicted value, a_i is the actual value, and n is the number of missing values. The method with a smaller RMSE is selected in the estimation of missing data.

4.2 Calculation of Available Water Capacity

4.2.1 Divison of North Cyprus into polygons

Before calculation of AWC of each region, North Cyprus is split into polygons to obtain the areas of 33 stations. Thiessen Polygon Method is used in the determination of the boundary of the stations. First, a distance line is drawn between a candidate station and its neighbor stations. For instance; the neighbor stations of Lefkoşa are; Değirmenlik, Boğaz, Beylerbeyi, Alayköy, and Ercan as shown in the Figure.1

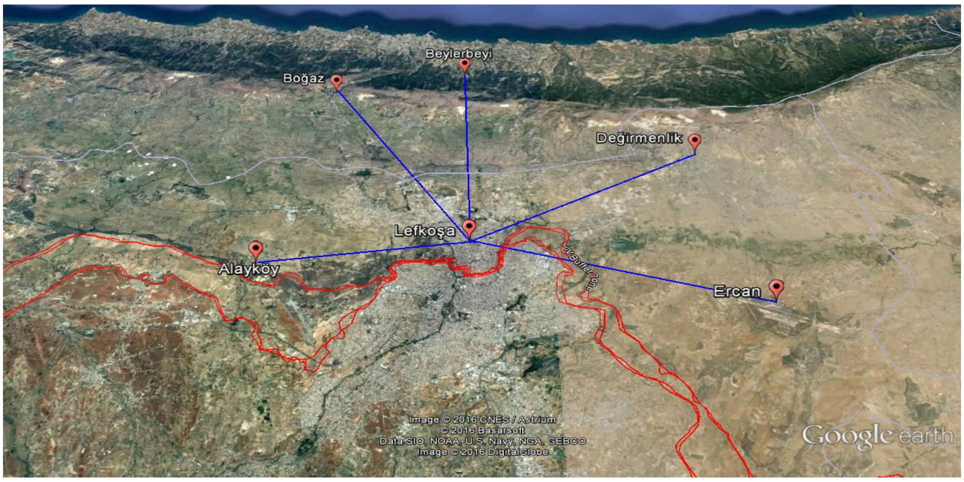


Figure 4.1 The neighbor stations of Lefkoşa

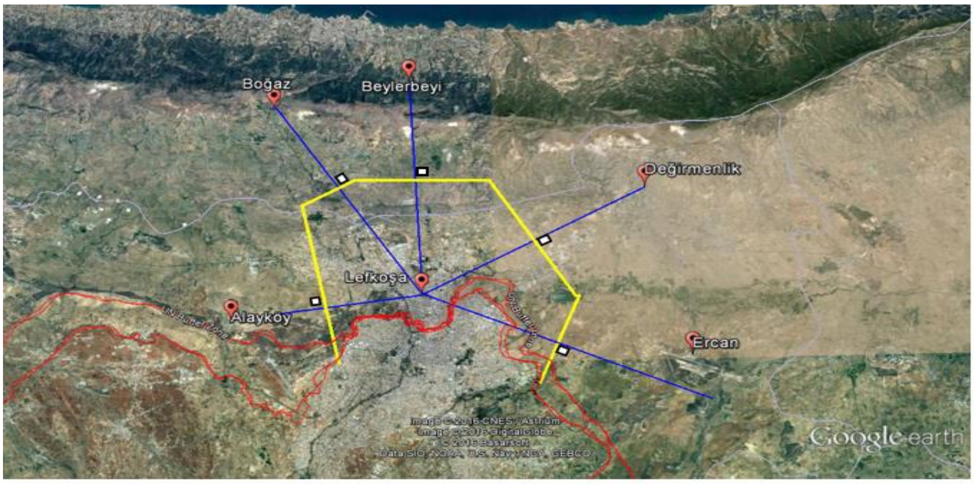


Figure 3.2 The boundaries of Lefkoşa

Figure 4.3 The boundaries of all regions

Then from the midpoint of these lines, perpendicular lines to these lines are drawn as given in Figure 3.2 Then, the boundary of the Lefkoşa station is formed. This is repeated for all 33 meteorological stations and polygons are obtained for 33 stations as shown in Figure. The area of all polygons are found using Google Earth Pro.

4.2.2 Available water capacity (AWC)

AWC of each station is required for the determination of PDSI. Therefore, before calculating PDSI, AWC values of all stations are calculated.

Nowadays, there is a high demand for the determination of soil processes. Since, it can be used for the development of new models to solve agricultural and environmental issues. Formerly, to measure the available water of the soil; gravimetric soil content of water was determined in the laboratory by using drying-oven experimentally. However, due to the variability of soil properties, measurement and analysis of the soil characteristic usually takes too much time. In addition to taking time, it is highly-priced process and limits the usage of measurements for large samples (Reichert et al., 2009; Minansny et al., 1999).

There are a lot of physical properties that influences the water holding property of soil. Soil texture and structure are only two examples of the properties that may change the water holding content of the soil. Thus, establishing an empirical relation between water availability and these properties that named as pedotransfer functions or equations is a feasible way to obtain water availability of soil(McBratney et al., 2002; Reichert et al., 2009).

In 1912, Briggs and Shants used a lot of soil samples and developed a regression equation by using only texture type of soil to determine AWC of soil. In the recent studies, in addition to soil texture that includes sand, silt and clay content of soil, organic matter and bulk density of the soil are the other pedotransfer parameters using to establish multiple linear regression for the evaluation of the water availability (McBratney et al,2002; Reichert et al., 2009).

For instance; Reichert et al. (2009) determined the water retention curves and water availability for the soils of Rio Grande Do Sul by using organic matter, organic carbon, bulk density and silt, sand, and clay content of soil.

Saxton and Rawls (2006) predicted the soil water characteristics of the soil taken by United States Department of Agriculture soil database by using organic matter and soil. However, although the Agriculture Office of TRNC have studied the percentage of sand, silt and clay ratios for 108 soil serials, the bulk density of the soil has not been studied for all regions of North Cyprus. Furthermore, the soil regions in North Cyprus does not contain considerable amount of organic matter as shown in TableB1 (Appendix B). Therefore, instead of using pedotransfer equations including soil texture, bulk density and organic matter, the empirical equation developed by Briggs and Shants (1912) has been used in this study to calculate AWC of the 108 soil serials.

The soil texture differs from depth to depth. Therefore, first of all the depth of each horizon is multiplied with the percentage of the sand, silt and clay of that horizon and the values found for each horizon are summed up. Then the AWC values are calculated for the 108 soil serial.

The calculated AWC values of soil serials are multiplied by the area of each region, and weighted average method was applied to find the AWC values of 33 meteorological stations. The mathematical model that was generated by Briggs and Shants(1912) is used in this study for the evaluation of AWC:

The plant can draw water from the soil and decrease the water amount of the soil continuously until it wilts permanently when the roots of it accomplish to be organized and outstretched completely in the soil. After the wilting point of the plant, the water which is remained in the soil can not be used, so it is called non-available in the earlier studies. However, according to the study of Briggs and Shantz (1912), even after the wilting point, the tissues of the plant still continue to draw water from the soil until a balance is set up between the soil and air. Therefore, instead of wilting point, they used the term of ‘wilting coefficient’ which refers the percentage of water that the soil has when the plants start to wilt and cannot recover itself unless water is added to the soil. The formula of wilting coefficient in terms of sand, silt, and clay percent which they found is as follow:

$$\text{wilting coefficient (mm)} = 0.01\text{sands} + 0.12\text{ silt} + 0.57\text{ clay} \qquad (4)$$

Identifying the amount of available soil moisture needed for plant to continue its growth is the essential parameter in the plant research, since generally the demand for water is greater than the supply and this makes the water supply a limiting agent. Thus, Briggs and Shantz (1912) studied the relation between wilting coefficient and moisture holding capacity of the soil. The moisture holding capacity of the soil refers to the percentage of water that soil can hold against to the gravity force on free drainage condition. Then the relation between the wilting coefficient and moisture holding capacity is obtained as follows:

$$\text{wilting coefficient (mm)} = \frac{\text{Moisture Holding Capacity} - 21}{2.90(1 \pm 0.021)} \qquad (5)$$

In this study, it was noted that the equation of the wilting coefficient which has been found as a result of a lot of experimental studies might not give the exact calculated value; some experimental errors that have been named as probable error might limit the accuracy of the results. Therefore, a probable error showing the degree of accuracy was determined and given in the Equation 5 as $\pm$ 0.021.

Using Equation 4 and 5, the relation between soil texture and moisture holding capacity is established as:

$$\text{Moisture Holding Capacity (mm)} = (0.03\text{sand} + 0.35\text{ silt} + 1.65\text{ clay}) + 21 \qquad (6)$$

The maximum available moisture is defined as the maximum amount of available moisture that can be retained by a soil type. In other words, it is the difference between wilting coefficient and moisture holding capacity. Therefore, it is same as AWC which is one of the required input data to calculate PDSI. The relationship of maximum available moisture between moisture holding capacity and wilting coefficient are shown in Equation 7 and 8. These relationships were found in the study of Briggs and Shantz (1912) according to the soil column that is in 1 cm height in the laboratory and the coefficients are improved as a result of further studies.

$$\text{Max. Available Moisture (mm)} = (\text{Moisture Holding Capacity} \times 0.65) + 7 \quad (7)$$

$$\text{Max. Available Moisture (mm)} = (\text{wilting coefficient} \times 1.9) + 21 \quad (8)$$

When Equation 7 and 8 are rearranged, than Equation 9 that shows the relationship between soil texture and the maximum available moisture that can be hold by the soil is obtained.

$$\text{Max Available Moisture (mm)} = (0.02\text{sand} + 0.23\text{ silt} + 1.08\text{ clay}) + 21 \quad (9)$$

The established equations of maximum available moisture (Equation 7, 8 and 9) were performed with a soil column having 1 cm height. Thus, it was assumed that the amount in drained soils under field conditions was found abundantly.

In all these equations, sand indicates the percentage of particles which have diameters between 2 and 0.05 mm, silt indicates the percentage of particles which have diameters between 0.05 and 0.005 mm and clay indicates the percentage of particles which have diameters smaller than 0.005 (Briggs and Shantz, 1912).

4.3 Calculation of Palmer Drought Severity Index (PDSI)

In this study, Palmer Drought Severity Index (PDSI) is chosen as an index to analyze drought and its statistical characteristic in North Cyprus. In order to calculate monthly PDSI, monthly precipitation and temperature values of each station are required. The required data of precipitation and temperature from 1978 to 2015 are obtained from the Meteorological Office of the government of North Cyprus. In addition to monthly precipitation and temperature values, available water capacity (AWC) of each region which is calculated according to the soil characteristics of stations is used for the determination of PDSI. The latitudes of stations are also important for the calculation of PDSI.

There are six basic steps for the computation of PDSI:

Step 1. Calculation of Potential Evapotranspiration by Thornthwaite Method

Palmer used the water balance approach that includes moisture supply and demand. For the prediction of the soil moisture storage, the soil is considered to be consist of two layers. One of them is surface layer which is assumed that it can store 25 mm water. The second one is underlying layer. The soil property of the site affects the available capacity of underlying layer. Evapotranspiration occurs on the surface layer and before starting to remove moisture from the underlying layer, all of the available moisture must be removed from the surface layer. Therefore, after the surface layer is saturated, the moisture begins to be recharged to the underlying layer. For the determination of the potential evapotranspiration (PE), Palmer used the Thornthwaite method. In 1948, Thornthwaite developed this method to find the maximum amount of water that is needed for a region and also to categorize the local climate of regions (Güner, 1997). In order to calculate PE, average temperatures, total precipitation and latitude of the station are required. (Alley, 1984; Mika et al., 2005; Güner, 1997). The computation steps are shown below:

1.1 Calculation of monthly heat index (j)

Befor calculating annual heat index, monthly heat index is evaluated as:

$$j_i = \left(\frac{t_i}{5}\right)^{1.514} \quad (10)$$

where i defines the period and it is 12 for the calculation of monthly and, j_i is calculated for each month in a year; t_i defines the average temperature for month i (Tatli and Türkeş, 2011; Bacanlı et al., 2005).

1.2 Calculation of annual heat index (J)

Annual heat index (J) is the summation of 12 heat indices (Tatli and Türkeş, 2011; Bacanlı et al., 2005)

$$J = \sum_{i=1}^{n} \left(\frac{j_i}{5}\right)^{1.514} \quad (11)$$

where n is the number of the periods in a year.

1.3 Calculation of potential evapotranspiration (PE_x)

PE_x is mainly calculated according to the temperature. As shown in Eqution 12, the equation includes an adjustment based on the number of daylight hours. Estimation of PE_x, calculated on a monthly basis:

$$PE_x = 16 . \left(\frac{10 * t_i}{J}\right)^a \text{ mm} \quad (12)$$

where a is an exponential which was derived as a function of J_i (Bacanlı et al., 2005) as

$$a = (675x10^{-9} . J^3) - (771x10^{-7} . J^2) + (1.79x10^{-4} . J) + 0.492 \quad (13)$$

where J is the annual heat index calculated using Equation 11.

1.4 Calculation of adjusted potential evapotranspiration (PE_{ad})

According to the latitude PE_{ad} is calculated as:

$$PE_{ad} = PE_x * c \quad (14)$$

where c is the improvement coefficient that is determined regarding to the latitude of the meteorological station. For each station, c was calculated by Thornthwaite and as a result a chart was arranged based on average back periods which were under the sun (Tatli and Türkeş, 2011). For North Cyprus which is 35^0 latitude, it is 0.97 given in Table (Appendix F) (Botkin, 1993; Thornthwaite, 1948).

1.5 Computation of stored soil moisture (S_i) and runoff (RO_i)

When the stored soil moisture (S_i) which is equal to the sum of the soil moisture of underlying and surface layer of the soil at the end of previous month, and rainfall depth (P_i) of that month are added and this value is higher than the PE_{ad} for the first time, then this month is defined as first wet month. The stored soil moisture of the first wet month is zero. Then, after the first wet month the other months are calculated.

Runoff (RO_i) of that month depends on S_i, P_i and AWC. When the amount of moisture found in the soil is greater than the maximum amount of moisture that the soil can storage, RO occurs. Otherwise, if the soil still has moisture capacity, RO is equal to zero for that month (Erinç, 1984; Dönmez, 1984).

Therefore;

If $S_{i-1} + P_i - PE_{adi} > 0$ (15)

Then;

If $S_{i-1} + P_i - PE_{adi} \geq AWC$,

$$S_i = AWC, \quad (16)$$

$$RO_i = S_{i-1} + P_i - PE_{adi} - AWC \quad (17)$$

If $S_{i-1} + P_i - PE_{adi} < AWC$,

$$S_i = S_{i-1} + P_i - PE_{adi} \quad (18)$$

$$RO_i = 0 \quad (19)$$

and also it is assumed that maximum capacity of surface soil layer is 25 mm. Thus;

If $S \geq 25$ mm, $S_s = 25$ mm, $S_u = S - 25$ mm (21)

If $S < 25$ mm, $S_s = S$, $S_u = 0$ (22)

If $S_i + P_i - PE_{adi} \leq 0$, (23)

Then;

$$S_i = 0, \quad (24)$$

$$RO_i = 0 \quad (25)$$

1.6 Calculation of Real Evapotranspiration (ET)

Evapotranspiration for the first wet month is calculated as follows (Erinç, 1984; Dönmez, 1984):

If $PE_1 \geq P_1$, $ET_1 = P_1$ (26)

or

If $PE_1 < P_1$, $ET_1 = P_{ad1}$ (27)

and for the following months:

If $S_i + P_i - PE_{adi} \leq 0, \qquad ET_i = S_i + P_i$ (28)

If $S_i + P_i - PE_{adi} > 0, \qquad ET_i = PE_{adi}$ (29)

Step 2. Hydrologic Calculations

By using these inputs, as a part of water balance, in addition to PE, potential recharge (PR), potential loss (PL) and potential runoff (PRO) are also calculated.

PR (Potential Recharge) is the amount of moisture which is needed to provide a saturated moisture content of the soil.

$$PR = AWC - (S_s + S_u) \tag{30}$$

PL (Potential Loss) is the amount of moisture lost which is caused by evapotranspiration when there is no precipitation (Tsakiris et al., 2007; Alley, 1984; Mika et al., 2005; Güner, 1997).

$$PL\ (\text{Potential Loss}) = PL_s + PL_u \tag{31}$$

where;

$$PL_s = \min(PE, S_s) \tag{32}$$

and

$$PL_u = \frac{(PE - PL_s) * S_u}{AWC}, PL_u \leq S_u \tag{33}$$

PRO (Potential Runoff) is the difference between potential precipitation and potential recharge where potential precipitation is equal to AWC (Tsakiris et al., 2007; Alley, 1984; Mika et al., 2005; Güner, 1997).

$$PRO = AWC - PR = S_s + S_u \tag{34}$$

Step 3. Climatic Coefficients

In order to calibrate the water balance model to normal levels, four climatic coefficients are used. These climatic coefficients depend on the climate of the region which is studied and it is determined according to the historical data of temperature and precipitation.

The potential values; PE, PR, PL and PRO calculated in the upper steps are used to compute these coefficients for each month or week. For each month or week, different sets of coefficients are computed with average values (Tsakiris et al., 2007; Alley, 1984; Mika et al., 2005; Güner, 1997).

$$a_j = \frac{\overline{ET_j}}{\overline{PE_{ad_j}}}, \quad b_j = \frac{\overline{R_j}}{\overline{PR_j}}, \quad c_j = \frac{\overline{RO_j}}{\overline{PRO_j}}, \quad d_j = \frac{\overline{L_j}}{\overline{PL_j}} \tag{35}$$

Step 4. CAFEC Values

The Climatically Appropriate For Existing Conditions (CAFEC) values are calculated by using climatic coefficients for the determination of moisture amount needed to meet normal weather condition for each month**.** Then the difference between actual precipitation and the CAFEC value gives the 'D' value. 'D' indicates water deficiency or excess for certain months at the analyzed station (Tsakiris et al., 2007; Alley, 1984; Mika et al., 2005; Güner, 1997).

$$\widehat{ET_j} = a_j * PE_j \tag{36}$$

$$\widehat{R_j} = b_j * PR_j \tag{37}$$

$$\widehat{RO_j} = c_j * PRO_j \tag{38}$$

$$\widehat{L_j} = d_j * PL_j \tag{39}$$

By using calculated CAFEC Values, CAFEC precipitation amount is evaluated in order to find the precipitation amount for the water resources supply of an area to execute effective economic activity (Tsakiris et al., 2007)

$$\dot{P_j} = \widehat{ET}_j + \widehat{RO_j} + \left(\widehat{R_j} - \widehat{L_j}\right), \qquad \dot{P_j} \geq 0 \tag{40}$$

Step 5. Moisture Anomaly Index (Z-index)

In order to determine moisture anomaly index which is also known as Palmer Z-index, departure (D) value which is an indicator of water deficiency for each month must be converted into Z-index. Therefore, in this step weighting factor (K) is needededas a conversion factor. The aim of using this factor is to regulate departures (D) from normal precipitation because of the fact that the departures may vary from area to area and also it may vary for different months (Tsakiris et al., 2007; Alley, 1984; Mika et al., 2005; Güner, 1997).

$$D_j = P_j - \dot{P}_j \quad (41)$$

$$Z_j = K_j * D_j \quad (42)$$

where the weighting factor (K) depends on the properties of climate of an area and the value varies from region to region. Thus, the regional extension of drought is affected significantly from this factor (Tsakiris et al., 2007; Alley, 1984; Mika et al., 2005; Güner, 1997).

$$K_j = \frac{17.67 * \widehat{K_j}}{\sum_{i=j}^{12} \widehat{d_j K_j}} \quad (43)$$

where

$$\widehat{K_j} = \left(1.5 * \log_{10}\left(\frac{(\overline{PE_j} + \overline{R_j} + \overline{RO_j})}{\overline{P_j} + \overline{L_j}}\right) + \left(2.8 * \overline{d_j^{-1}}\right) + 0.5\right) \quad (44)$$

where $\overline{d_j}^{-1}$ is the average of monthly recorded absolute d values for all years .

Step 6. Palmer Drought Severity Index

For the determination of the starting and ending of the drought periods, in last step Z-index time series are studied. X_j is the PDSI value and X_i is the PDSI value for the initial month (Tsakiris et al., 2007; Alley, 1984; Mika et al., 2005; Güner, 1997).

$$X_j = \left(0.897 * X_{j-1}\right) + \left(\frac{Z_j}{3}\right) \quad (45)$$

$$X_i = \frac{1}{3} . Z_i \quad (46)$$

After the calculation of monthly PDSI values according to the precipitation, temperature and soil moisture content, recent weather conditions can be classified by using these values based on the Palmer classification as shown in

Table.1. Generally, if PDSI values are negative, they will illustrate dry periods and if they are positive, wet periods will be indicated. Nearly average conditions are usually indicated around zero values (Mika et al., 2005).

Table 4.1 The values for Palmer Classifications (Palmer, 1965)

Palmer Classifications	
Palmer values	**Possibilities**
4.0 or more	extremely wet
3.0 to 3.99	very wet
2.0 to 2.99	moderately wet
1.0 to 1.99	slightly wet
0.5 to 0.99	incipient wet spell
0.49 to -0.49	near normal
-0.5 to -0.99	incipient dry spell
-1.0 to -1.99	mild drought
-2.0 to -2.99	moderate drought
-3.0 to -3.99	severe drought
-4.0 or less	extreme drought

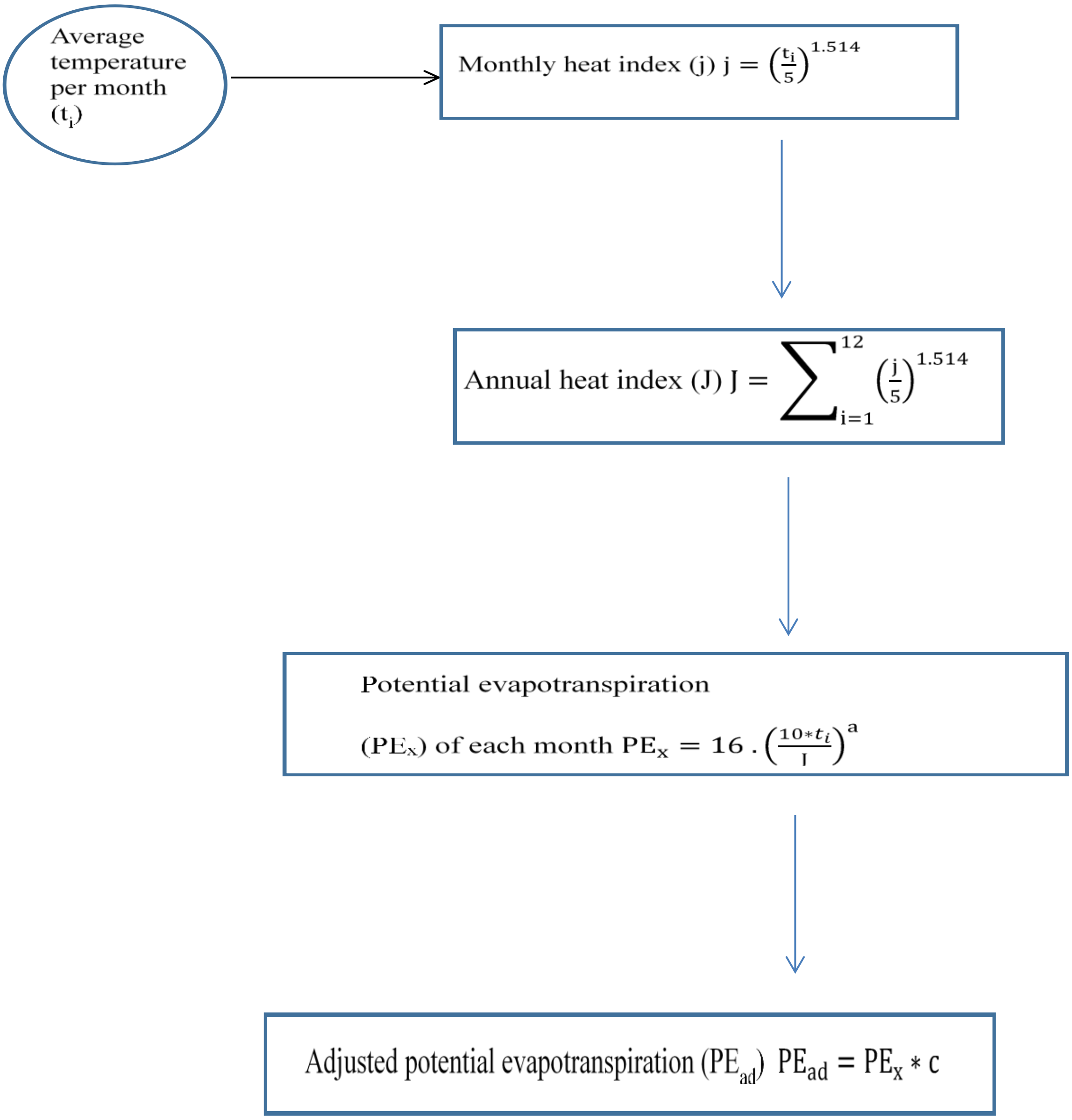
4.3.1 Summary of PDSI Method

Palmer (1965) developed PDSI according to a water balance model between soil moisture supply and demand. This index uses a monthly time series of precipitation and temperature as inputs to create a single value for the indication of wet and dry spells. In this index, soil moisture storage is determined separating the soil into two layers. The upper layer of the soil is surface soil layer and it is assumed to have 25 mm of moisture capacity. The lower layer of the soil is underlying layer. It has an available moisture capacity related with the soil properties of the region. AWC is also used as an input showing the maximum amount of moisture that can be stored in the soil. According to this model moisture can not flow to the underlying layer until all of the available moisture has been removed from the surface layer. RO occurs when both layers of the soil reach the amount of AWC. Four potential values; PE, PR, PL and PRO are calculated in PDSI method in order to find the climate coefficients. Then by using these potentials, the climate coefficients are evaluated as a proportion between averages of actual and calculated potential values for each month. The climate coefficients are used to find the amount of precipitation required for the CAFEC. The d value is the difference between the actual P and CAFEC precipitations showing the water deficiency for each month. The Z index is calculated and then the PDSI is computed monthly. Finally the PDSI values are evaluated according to the Palmer Classification. (Tsakiris et al., 2007; Alley, 1984; Mika et al., 2005; Güner, 1997, Palmer, 1965).

4.3.2 Flow chart of Palmer Drought Severity Index (PDSI)

In the flow chart, each step is shown which is used for the calculation of PDSI in MATLAB program. Following these steps, MATLAB computer program for PDSI is formed as given in Appendix B.

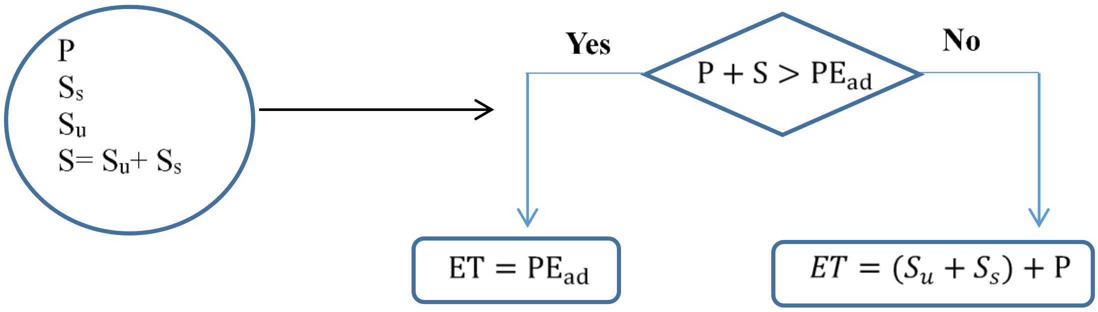
Calculation of Potential Evapotranspiration by Thornthwaite Method:



c = latitude of the meteorological station

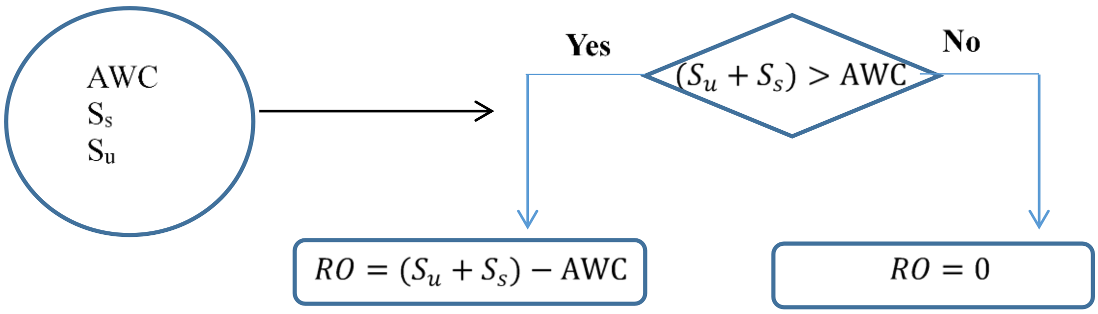
$a = (675x10^{-9} . J^3) - (771x10^{-7} . J^2) + (1.79x10^{-4} . J) + 0.492$

Calculation of Real Evapotranspiration (ET)



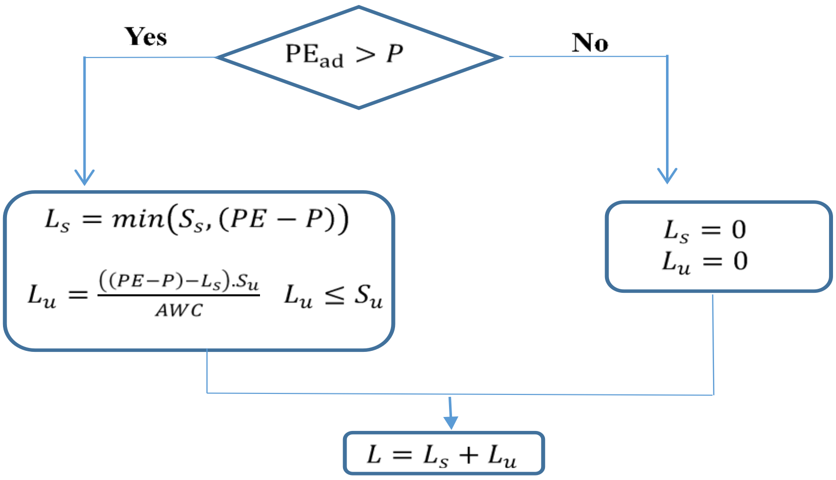
P: Monthly total precipitation
S_s: soil moisture stored at the beginning of the month in the surface layer
S_u: soil moisture stored at the beginning of the month in the underlying layer

Calculation of Runoff (RO)



AWC: Available Water Capacity of soil

Calculation of Evapotranspiration Losses from the soil:



L: Total evapotranspiration loss
L_s: Evapotranspiration Loss from the surface layer
L_u: Evapotranspiration Loss from the underlying layer

Hydrologic Calculations:

Potential Recharge (PR):

$$PR = AWC - (S_s + S_u)$$

Potential Loss (PL):

$$P = 0$$

$$PL_s = min(PE, S_s)$$

$$PL_u = \frac{(PE - PL_s) * S_u}{AWC},$$

$$PL_u \leq S_u$$

PL (Potential Loss) $PL = PL_s + PL_u$

PL_s: Potential Evapotranspiration Loss from the surface layer
PL_u: Potential Evapotranspiration Loss from the underlying layer

Potential Runoff (PRO):

$PRO = AWC - PR = S_s + S_u$

Climatic Coefficients

PE_{ad}
PR
PRO
PL

→

$$a_j = \frac{\overline{ET_j}}{\overline{PEad_j}},\ b_j = \frac{\overline{R_j}}{\overline{PR_j}},\ c_j = \frac{\overline{RO_j}}{\overline{PRO_j}},\quad d_j = \frac{\overline{L_j}}{\overline{PL_j}}$$

a: Evapotranspiration coefficient
b: Recharge coefficient
c: Runoff coefficient
d: Loss coefficient

- The overbars indicate that the coefficients are calculated based on the average values for each month.

Calculation of Climatically Appropriate For Existing Conditions (CAFEC) Values:

CAFEC Values

$$\widehat{ET_j} = a_j * PE_j$$

$$\widehat{R_j} = b_j * PR_j$$

$$\widehat{RO_j} = c_j * PRO_j$$

$$\widehat{L_i} = d_i * PL_i$$

CAFEC precipitation amount

$$\dot{P}_j = \widehat{ET}_j + \widehat{RO_j} + (\widehat{R}_j - \widehat{L}_j), \qquad \dot{P}_j \geq 0$$

Calculation of Moisture Anomaly Index (Z-index)

d (departures) $d_j = P_j - \dot{P}_j$

↓

Weighting factor (K) $K_j = \frac{17.67 * \widehat{\widehat{K_j}}}{\sum_{i=j}^{12} \overline{d_i}\, \widehat{K_j}}$

$$\widehat{K}_j = \left(1.5 * \log_{10}\left(\frac{(\overline{PE_j} + \overline{R_j} + \overline{RO_j})}{\overline{P_j} + \overline{L_j}}\right)\right) + \left(2.8 * \bar{d}_j^{\,-1}\right) + 0.5$$

↓

Moisture Anomaly Index (Z-index) $Z_j = K_j * d_j$

P_j: Actual precipitation value for month j.
$\dot{P}_j$: CAFEC precipitation value for month j.
$\overline{d}_j$: Monthly average of the absolute values of d
$\overline{P_j} + \overline{L_j}$: Average water supply
$\overline{PE_j} + \overline{R_j} + \overline{RO_j}$: Average water demand

Calculation of Palmer Drought Severity Index (PDSI):

Z_j → **Palmer Drought Severity Index (PDSI)**

$$X_j = (0.897 * X_{j-1}) + \left(\frac{Z_j}{3}\right)$$

For initial month: $X_i = {}^{1}/_{3}\, Z_i$

4.4 Trend Test

One of the main goal of this study is to detect trends in PDSI series by using non parametric trend analysis methods.

4.4.1 Mann-Kendall test:

The Mann-Kendall test, which has been used generally in hyrology and climatology order to test for randomness against trend in time series is known as Kendall's tau statistic (Kahya and Kalaycı, 2003; Partal and Kahya, 2006). The calculation of this method is started with the test statistic S and it is calculated using the following equations:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \mathrm{sgn}(x_j - x_k) \quad (45)$$

where the data values are indicated as x and n is the length of the data set.

$$\mathrm{sgn}(x_j - x_k) = \begin{cases} +1, & \text{if } x_j - x_k > 0 \\ 0, & \text{if } x_j - x_k = 0 \\ -1, & \text{if } x_j - x_k < 0 \end{cases} \quad (46)$$

The sign of S is decided and when the value is positive, it illustrates an 'upward trend', however negative value points out 'downward trend' in the time series. Based on these computation, if there is a trend, then the standardized test statistic Z should be found to obtain the rank of the trend.

For the cases when $n \geq 8$, the test statistic S is approximately normally distributed, has mean zero and variance is computed as follows:

$$E(S) = 0 \quad (47)$$

$$\mathrm{Var}(S) = \frac{[(n(n-1)(2n+5)) - (\sum_{i=1}^{n} t_i i(i-1)(2i+5))]}{18} \quad (48)$$

where t_i is the number of extent i and if there is not any tie, the variance of the test statistic S will be calculated by:

$$\mathrm{Var}(S) = \frac{[(n(n-1)(2n+5)]}{18} \quad (49)$$

After the computation of variance of the test statistic, the standardized test statistic Z is calculated.

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} \text{ if } S > 0 \\ 0 \quad \text{if } S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} \text{ if } S < 0 \end{cases} \quad (50)$$

In a two sided-test, H_0 or the null hypothesis which indicates there is not any trend in the time series should be accepted when $|z| \leq \frac{z\alpha}{2}$ at the level of α significance. Otherwise, H_1 (alternative hypothesis) indicating existence of trend in the data set should be accepted (Yue et al, 2002).

Chapter 5

RESULTS AND DISCUSSION

5.1 Filling in Missing Data

Before calculating the PDSI values, the missing values in temperature and rainfall series should be filled. In the filling in missing data, as given in Section 4.1, two commonly used missing data estimation methods are considered. In the decision of the most appropriate estimation method, first of all observed data in the station have been estimated using NR and ID methods. Then using RMSE, estimated and measured data have been compared. The method that gives smaller error is selected in the filling in missing data for this station. The RMSE results for rainfall stations with missing data are given in Table.1.

Table 5.1 The candidate rainfall station and the selected method

	Station Name	**The neighbouring stations**	**RMSE-NR**	**RMSE-ID**	**Selected Method**
1	Akdeniz	Çamlıbel, Kozanköy	5.1	5.3	NR
2	Lapta	Girne, Kozanköy	4.9	5.0	NR
3	Beylerbeyi	Girne, Alevkaya, Boğaz	5.6	5.7	NR
4	Tatlısu	Kantara, Esentepe	5.5	5.5	ID
5	Gaziveren	Güzelyurt, Lefke	5.2	5.4	NR
6	Yeşilırmak	Lefke, Gaziveren	6.1	6.2	NR
7	Serdarlı	Değirmenlik, Geçitkale	5.4	5.4	NR
8	Vadili	Dörtyol, Ercan, Beyarmudu	5.7	5.7	ID
9	Gönendere	Geçitkale, Değirmenlik	5.5	5.5	NR
10	Beyarmudu	Vadili, Dörtyol, Çayönü	6.1	6.3	NR
11	Çayırova	İskele, Mehmetçik	5.7	5.7	NR
12	Mağusa	Dörtyol, Salamis	6.2	6.1	ID

As seen from Table, although RMSE values for both methods are not significantly differ from each other, the method that gives smaller RMSE has been selected in the estimation of missing rainfall data for that particular station.

In the calculation of PDSI values, both monthly rainfall and monthly temperatures are required. However, as mentioned in Chapter 3, the number of the rainfall stations across North Cyprus is more than temperature stations.

As given in Chapter 4, the annual average values of candidate and closest stations are used to complete the missing data in NR method. However, the distance between the candidate and neighbouring station is considered in the ID method. In Table, the name of the station and the selected method to fill the missing temperature data are given for five stations. As shown in Table, the difference between RMSE values of NR and ID method is not considerable for temperature data and also the results show that NR method is better for the stations which have long year data. Therefore, for the stations which have long year data NR method is chosen whereas for the stations which do not have any data and the stations which have only few years of data, ID method is employed. The selected method for all temperature stations are given in Table (Appendix A).

Table 5.2 The candidate temperature station and the selected method

	Station Name	**The neighbouring stations**	**RMSE -NR**	**RMSE - ID**	**Selected Method**
1	Esentepe	Alevkaya, Girne, Lapta	1.01	1.62	NR
2	Güzelyurt	Çamlıbel, Lapta	2.13	2.33	NR
3	Ercan	Lefkoşa	1.63	1.63	NR
4	Yeni Erenköy	Mağusa, Ercan	1.15	1.18	ID
5	Gazimagusa	Yeni Erenköy, Geçitkale, Ercan	1.49	1.52	NR

5.2 The AWC of the stations

In PDSI method, AWC is a required input. There are a lot of methods to evaluate AWC (see Chapter 2). Since, soil textures (%sand, %silt and %clay) of the 108 soil serials are provided in the soil map of North Cyprus which is available in Agriculture Office of TRNC (Dinç et al., 2000) and the other soil parameters required to calculate the AWC by using different methods have not been studied by the Agriculture Office yet, the method which considers soil texture is used to calculate AWC.

In the development of soil map of North Cyprus, 108 different types of soil series have been identified (Dinç et al., 2000). In the soil map, the soil texture of each series that belongs to different soil layers are provided (Appendix B). First of all, considering the depth of layers the average soil texture of each soil series have been calculated. Then using Equation 9, the AWC values of 108 soil serials are calculated.

The AWC of fifteen soil serials are given in Table and the whole calculated AWC values for 108 serials are given in Table B.2 (Appendix B). After that the polygone map (Figure 4.3) and soil map that show the area of each soil serial across North Cyprus, have been overtop each other. Using the percent ration of each soil serials the average AWC values for each polygone that represents the area of a meteorological station, have been calculated.

Table 5.3 Name of the serials, abbreviation, soil texture and calculated AWC values.

	Name of the soil serial	**Abbreviation**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**AWC (mm)**
1	Balıkesir	Ba	19.16	41.00	39.84	73.08
2	Cengiz Topel	Ct	55.39	29.33	15.28	44.79
3	Cengizköy	Ck	32.71	43.14	24.15	57.00
4	Çakıldere	Cd	59.29	27.99	12.78	41.88
5	Derindere	Dd	39.20	34.60	26.13	57.32
6	Erdemli	Ed	26.84	54.26	18.93	53.82
7	Güvercinlik	Gr	12.55	22.90	64.53	95.31
8	Güzelyurt	Gy	24.56	47.63	27.81	61.79
9	Kanlıdere	Kd	20.68	36.67	42.66	75.15
10	Lefke	Le	24.97	34.61	40.40	72.33
11	Margo	Mg	26.25	32.97	40.82	72.44
12	Piyale Paşa	Pp	26.44	31.91	41.67	73.12
13	Yeşilırmak	Ye	32.95	45.86	21.21	54.48
14	Yukarı Yeşilırmak	Yy	59.98	27.29	12.73	41.68
15	Acıkuyu	Ac	44.99	30.52	24.49	54.73

Table 5.4 The name of the station and AWC values

	Name of the station	AWC (mm)		Name of the station	AWC (mm)
1	Çamlıbel	58.74	18	Lefkoşa	60.21
2	Akdeniz	46.49	19	Ercan	55.41
3	Lapta	60.35	20	Serdarlı	63.8
4	Boğaz	62.3	21	Gönendere	67
5	Girne	53.89	22	Geçitkale	58.48
6	Beylerbeyi	68.3	23	Vadili	59.64
7	Değirmenlik	68.01	24	Dörtyol	73.64
8	Alevkaya	63.92	25	Beyarmudu	54.7
9	Esentepe	55.99	26	Salamis	68.98
10	Tatlısu	59.63	27	İskele	63.44
11	Kantara	61.82	28	Çayırova	59.94
12	Zümrütköy	57.75	29	Mehmetçik	55.44
13	Lefke	54.15	30	Ziyamet	54.28
14	Gaziveren	59.28	31	YeniErenköy	57.14
15	Güzelyurt	57.46	32	DipKarpaz	58.67
16	Yeşilırmak	51.28	33	Gazimağusa	59.59
17	Alayköy	62.82			

5.3 The Results of PDSI Analysis

Monthly PDSI values were calculated for 33 stations between the years of 1978 and 2015 by developing a MATLAB code according to flowchart given in Chapter 4. The time series of calculated monthly PDSI values are given in Appendix C. The frequency of calculated PDSI values that are given from Figure 5.1 to 5.33 are investigated. In these figures, x-axis shows the PDSI class intervals which were classified according to the Palmer Classifications as illustrated in

Table and y-axis illustrates the number of total months that are in the given class intervals.

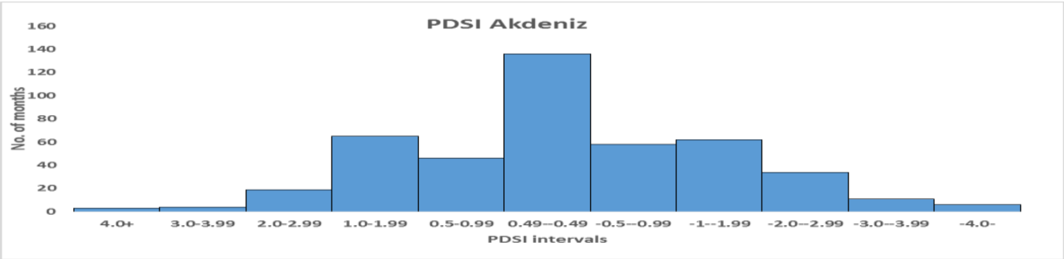


Figure 5.1 The number of months at each PDSI interval for Akdeniz

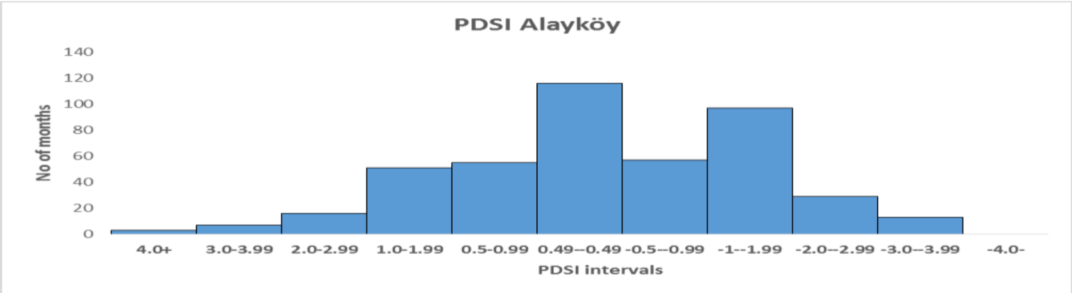


Figure 5.2 The number of months at each PDSI interval for Alayköy

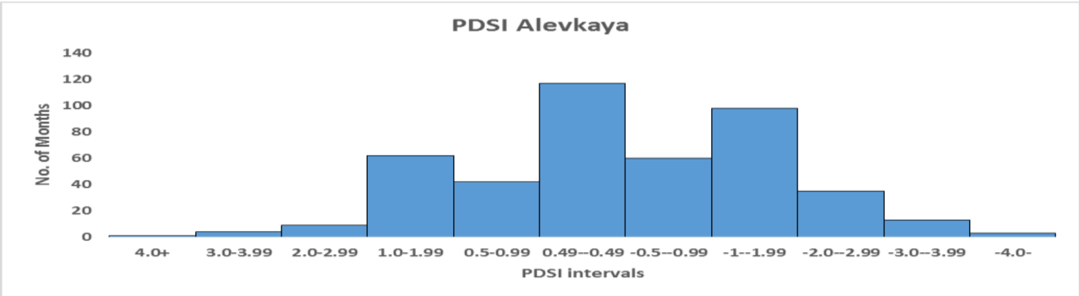


Figure 5.3 The number of months at each PDSI interval for Alevkaya

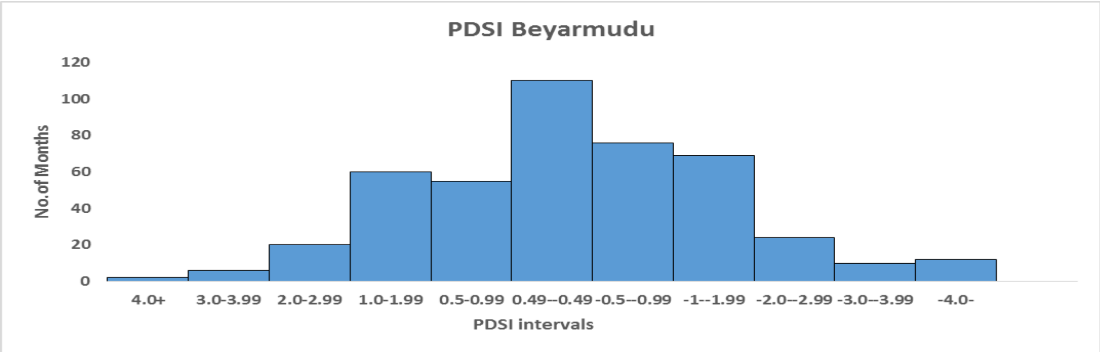


Figure 5.4 The number of months at each PDSI interval for Beyarmudu

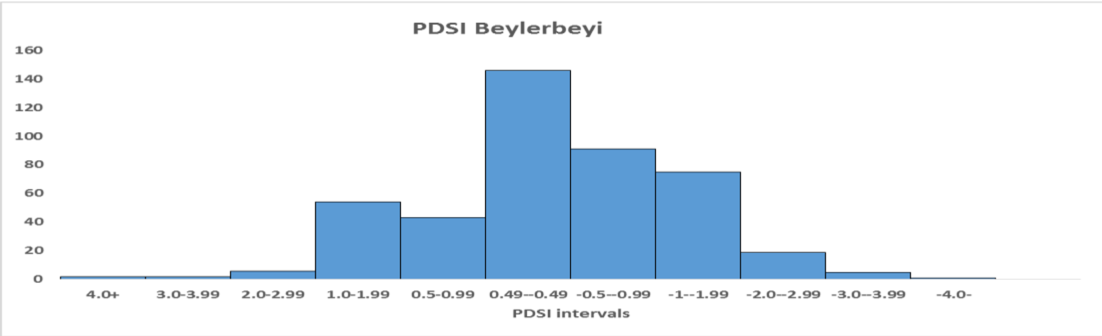


Figure 4.5 The number of months at each PDSI interval for Beylerbeyi

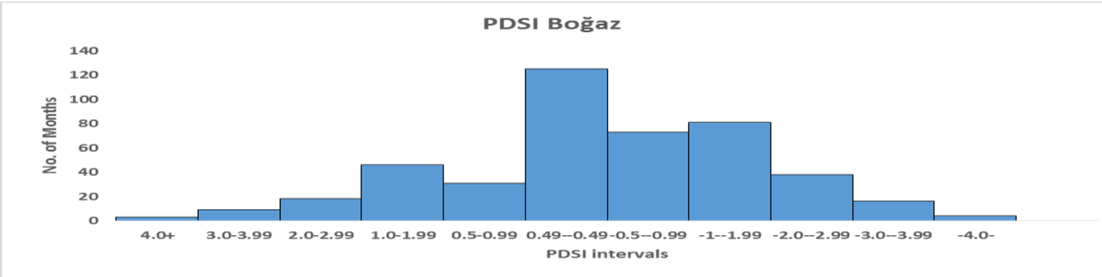


Figure 5.6 The number of months at each PDSI interval for Boğaz

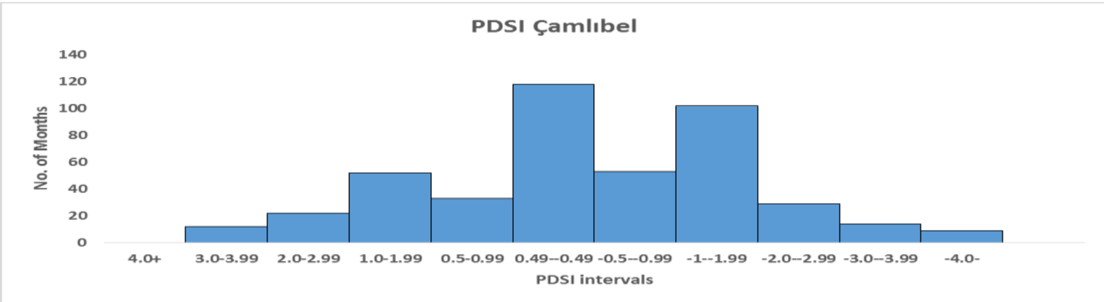


Figure 5.7 The number of months at each PDSI interval for Çamlıbel

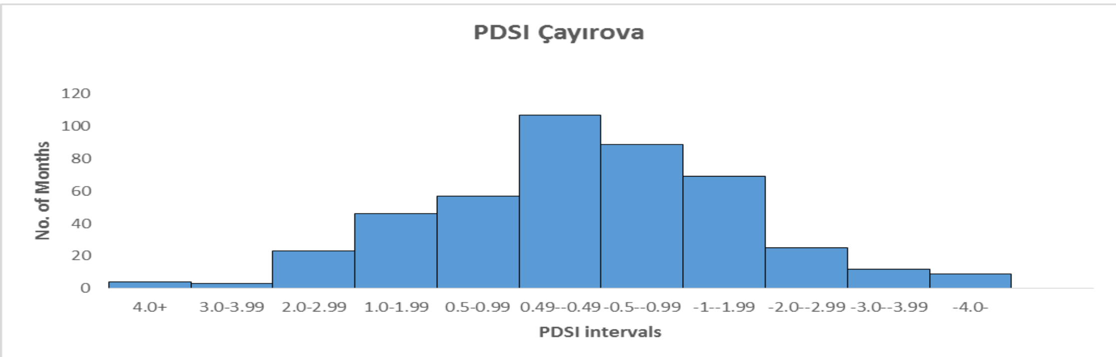


Figure 5.8 The number of months at each PDSI interval for Çayırova

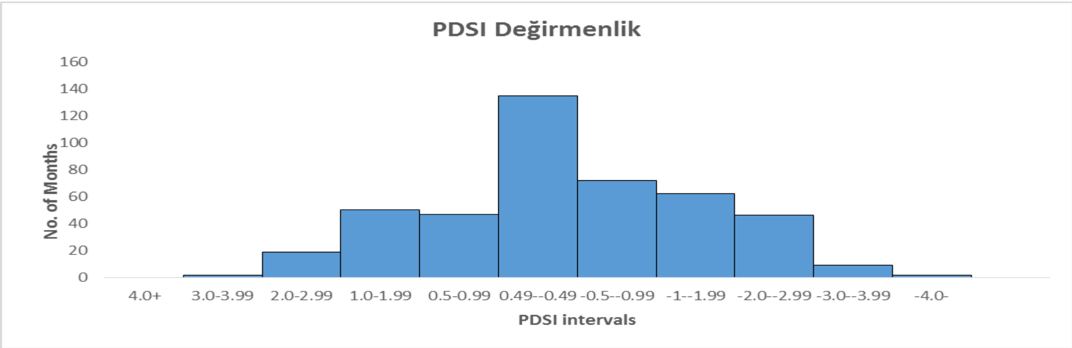


Figure 5.9 The number of months at each PDSI interval for Değirmenlik

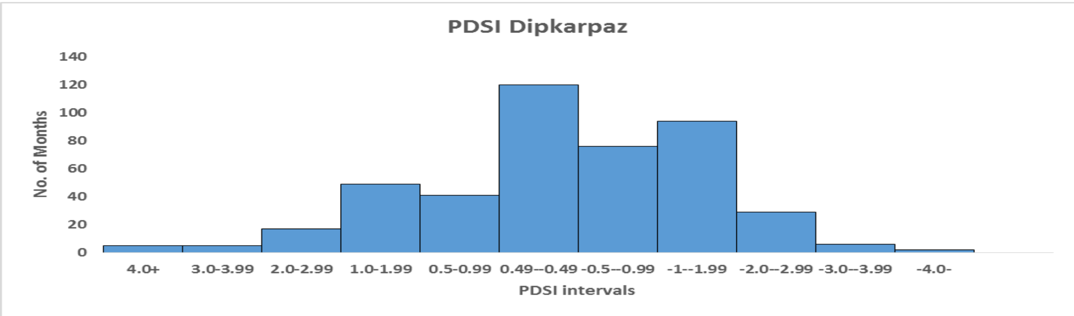


Figure 5.10 The number of months at each PDSI interval for Dipkarpaz

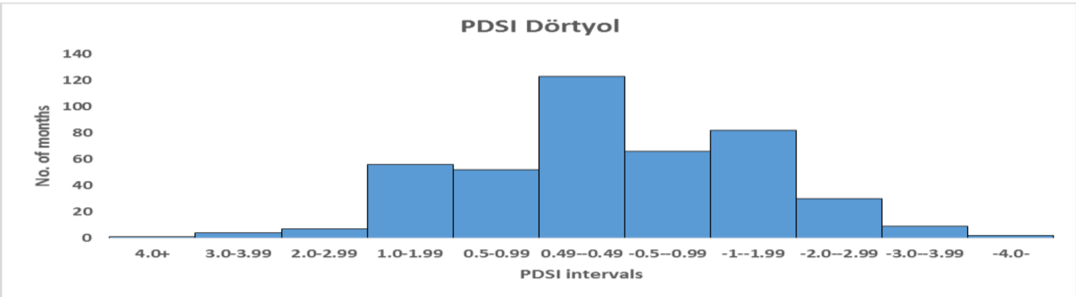


Figure 5.11 The number of months at each PDSI interval for Dörtyol

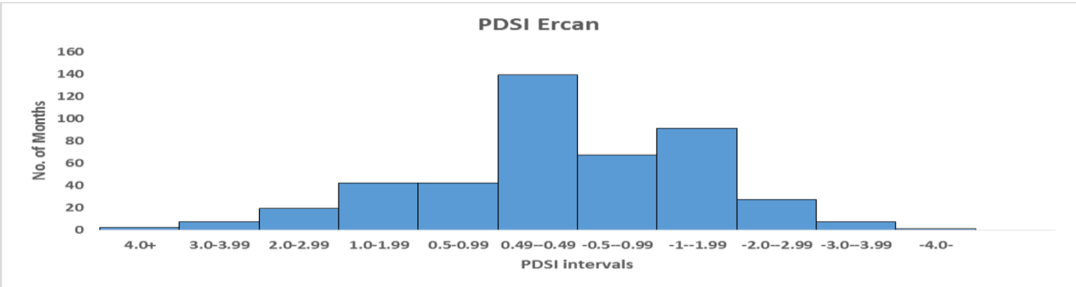


Figure 5.12 The number of months at each PDSI interval for Ercan

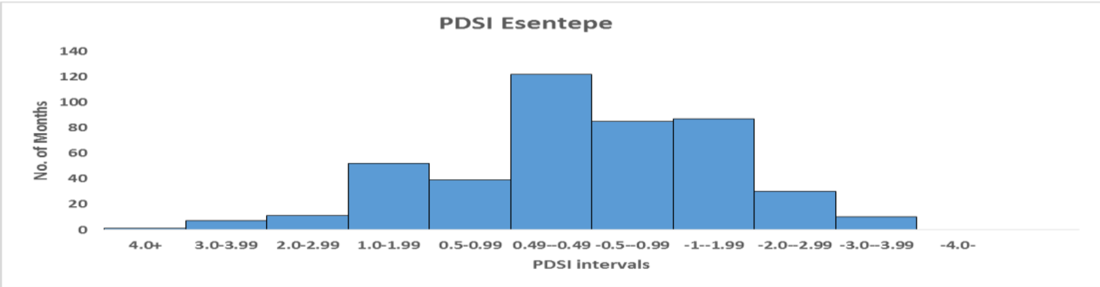


Figure 5.13 The number of months at each PDSI interval for Esentepe

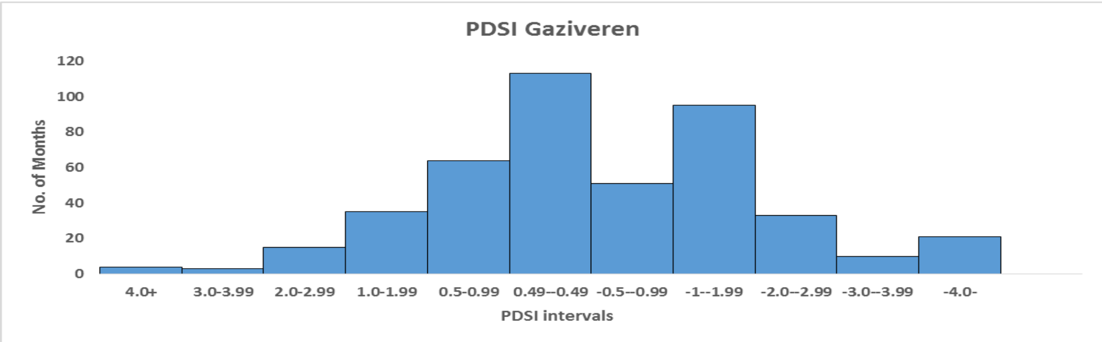


Figure 5.14 The number of months at each PDSI interval for Gaziveren

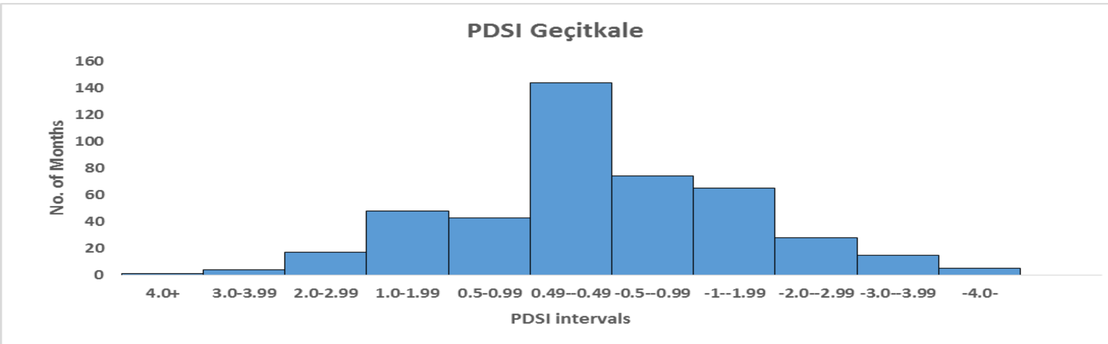


Figure 5.15 The number of months at each PDSI interval for Geçitkale

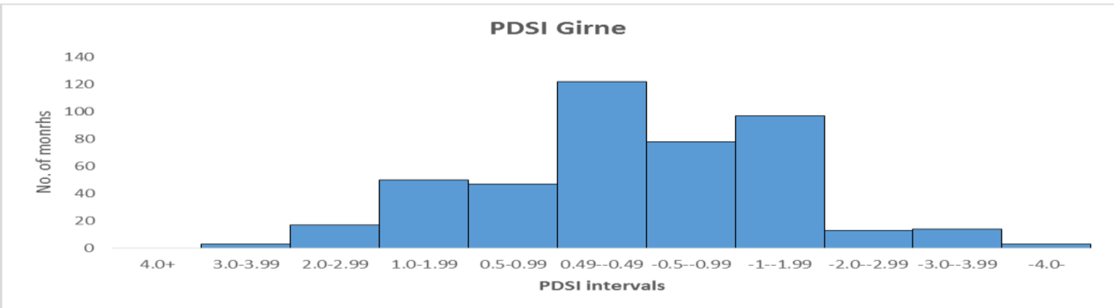


Figure 5.16 The number of months at each PDSI interval for Girne

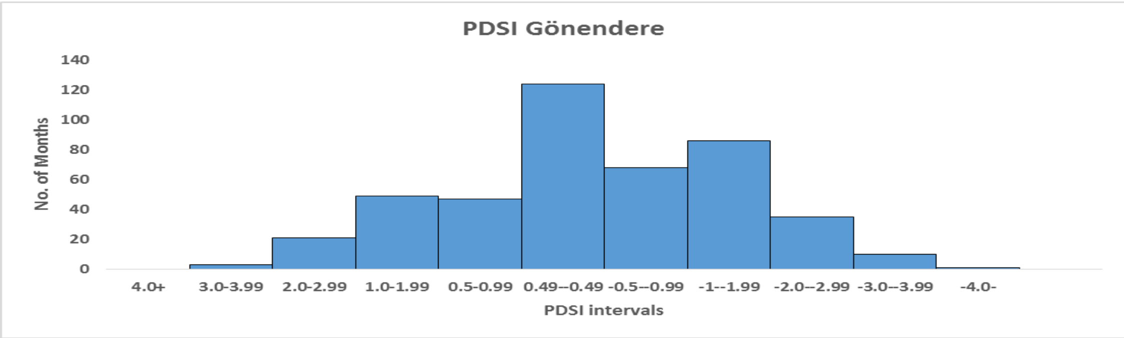


Figure 5.17 The number of months at each PDSI interval for Gönendere

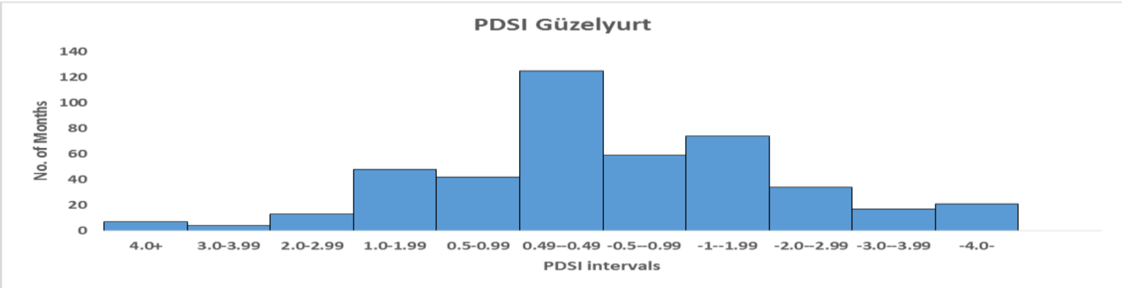


Figure 5.18 The number of months at each PDSI interval for Güzelyurt

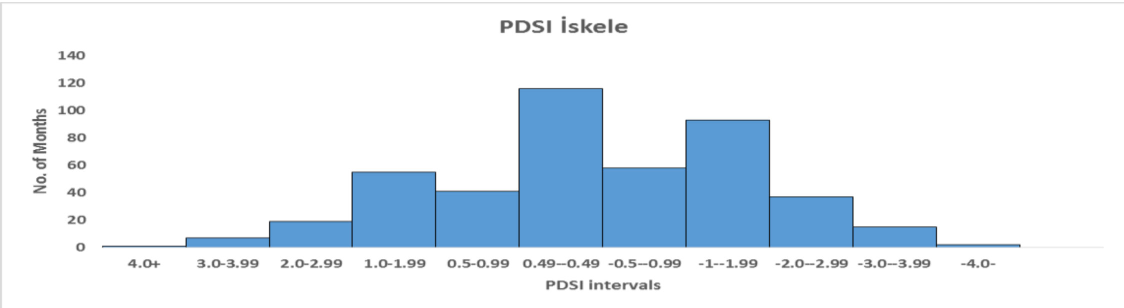


Figure 5.19 The number of months at each PDSI interval for İskele

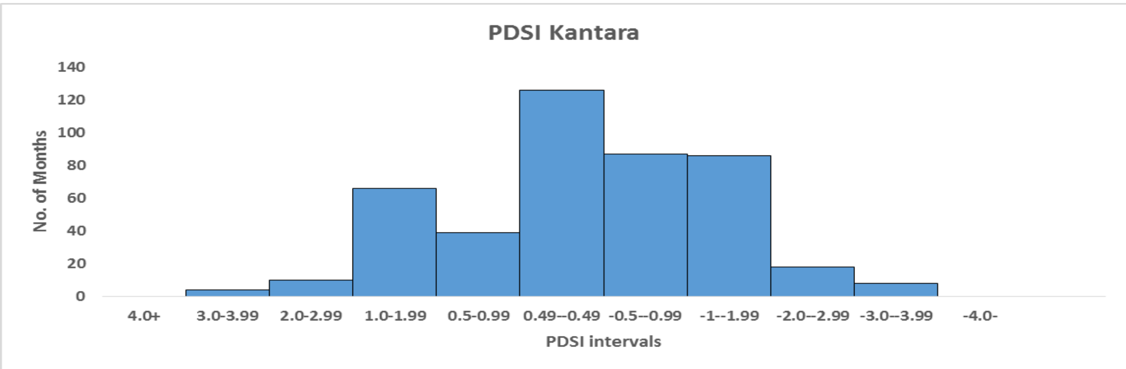


Figure 5.20 The number of months at each PDSI interval for Kantara

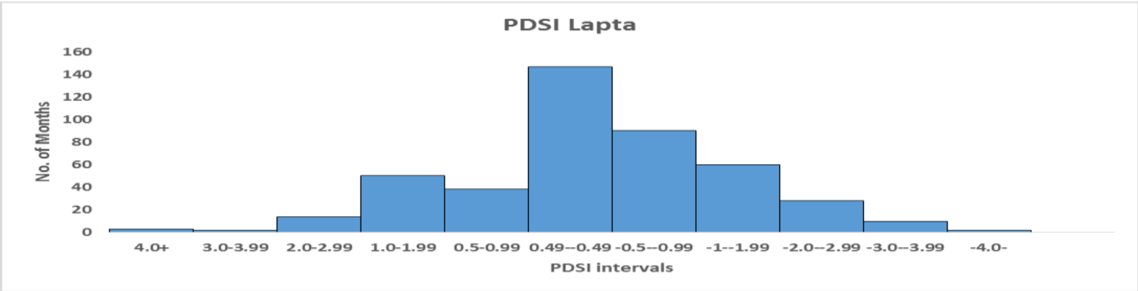


Figure 5.21 The number of months at each PDSI interval for Lapta

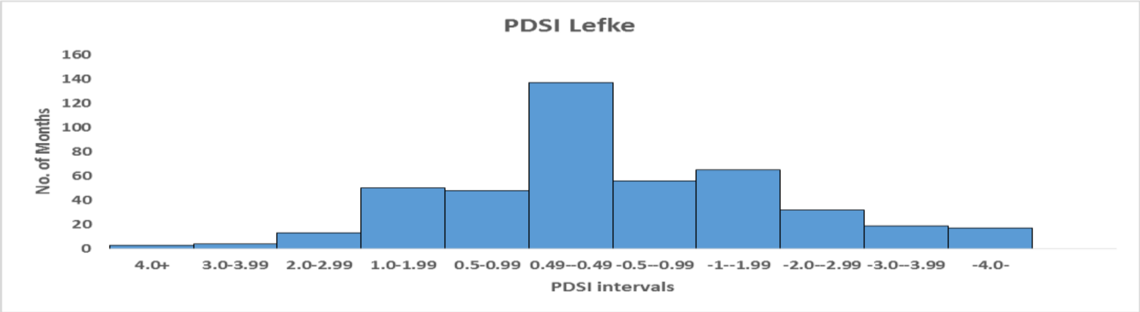


Figure 5.22 The number of months at each PDSI interval for Lefke

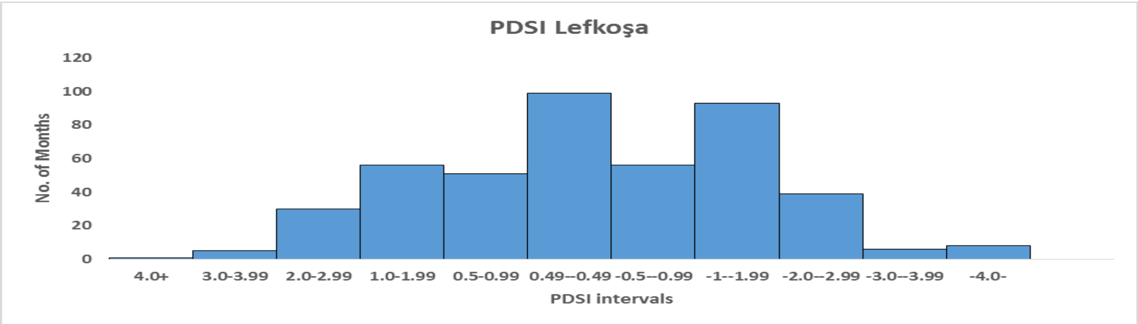


Figure 5.23 The number of months at each PDSI interval for Lefkoşa

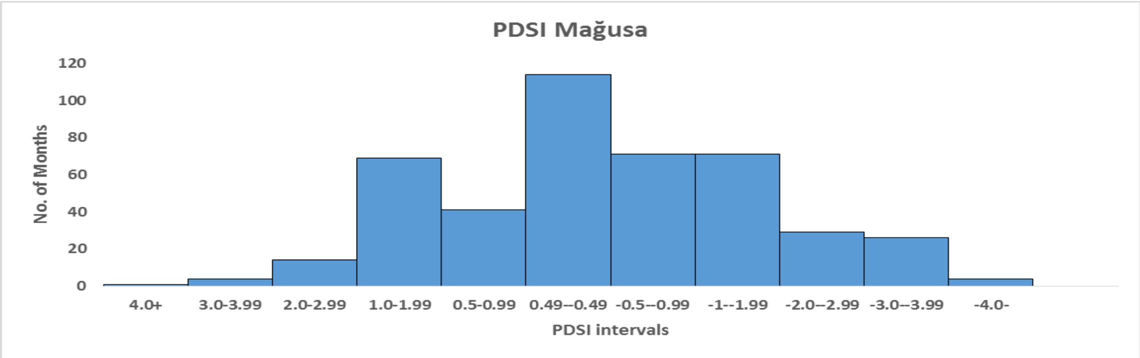


Figure 5.24 The number of months at each PDSI interval for Mağusa

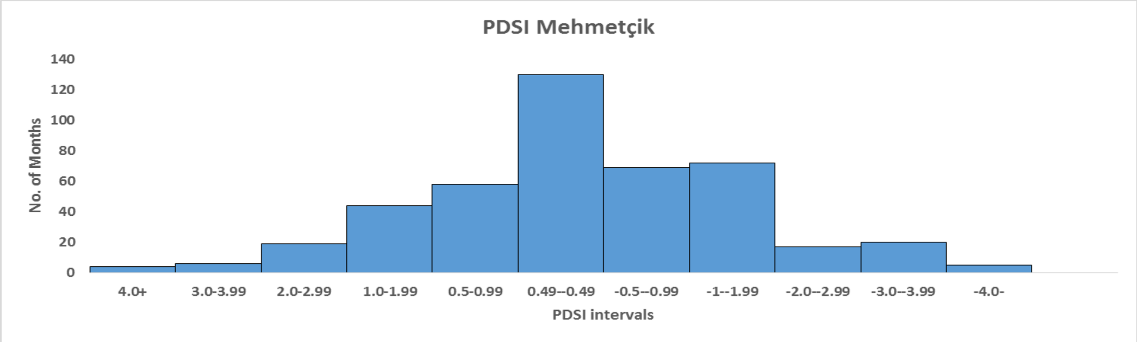


Figure 5.25 The number of months at each PDSI interval for Mehmetçik

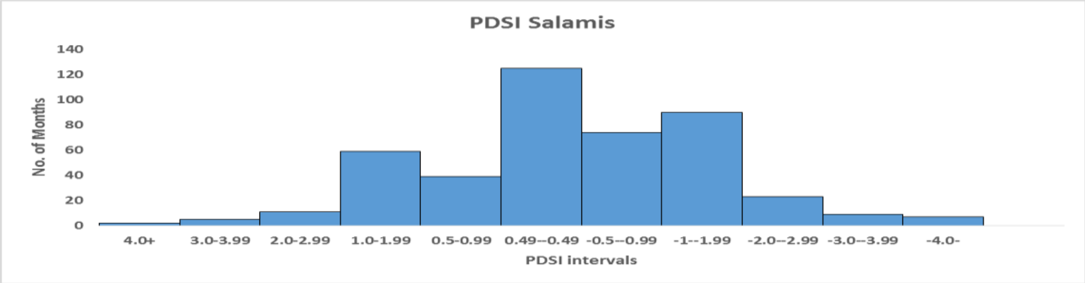


Figure 5.26 The number of months at each PDSI interval for Salamis

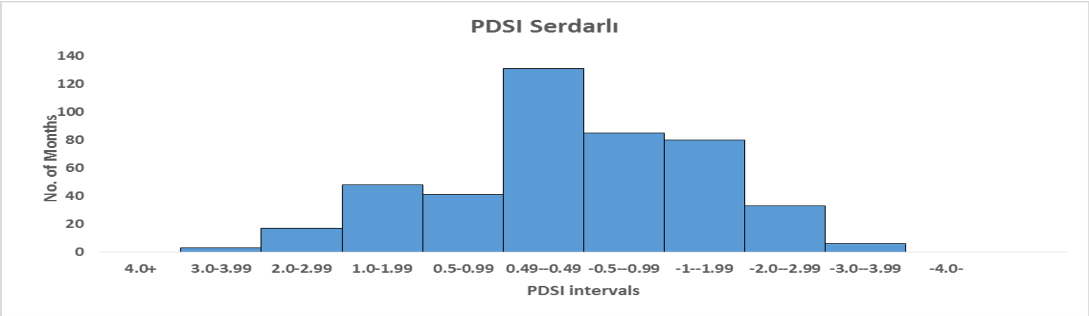


Figure 5.27 The number of months at each PDSI interval for Serdarlı

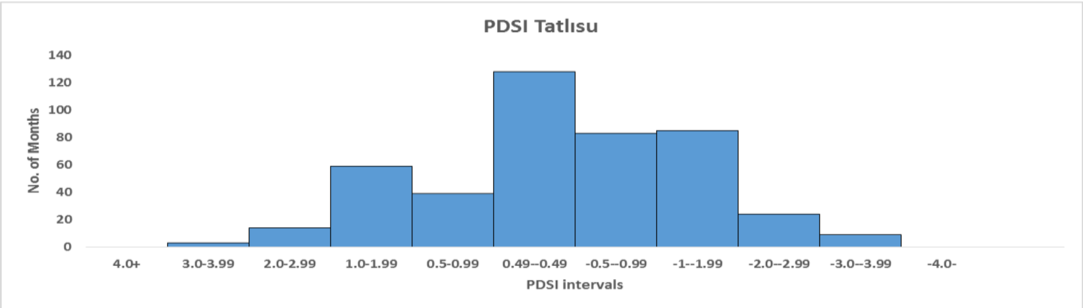


Figure 5.28 The number of months at each PDSI interval for Tatlısu

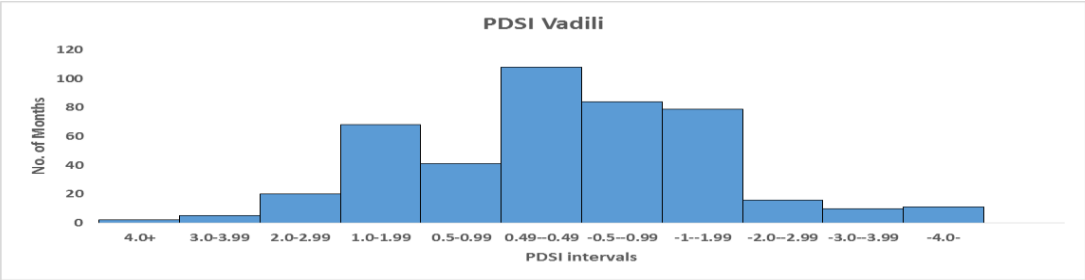


Figure 5.29 The number of months at each PDSI interval for Vadili

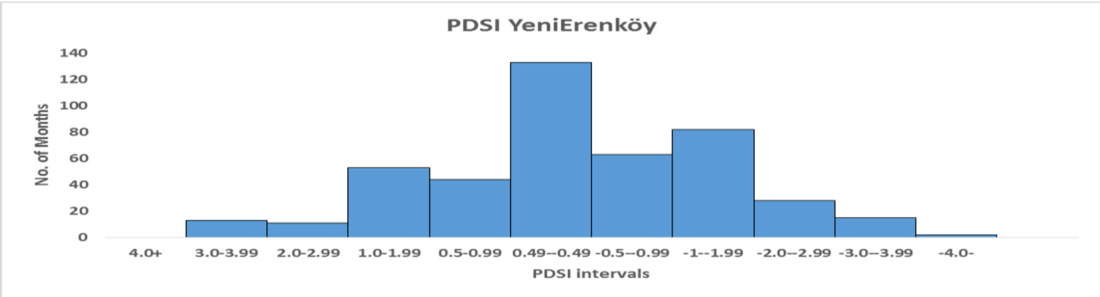


Figure 5.30 The number of months at each PDSI interval for Yeni Erenköy

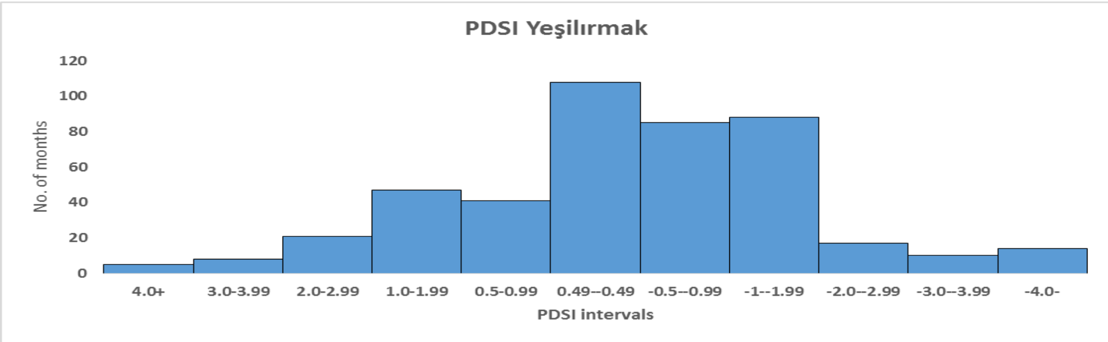


Figure 5.31 The number of months at each PDSI interval for Yeşilırmak

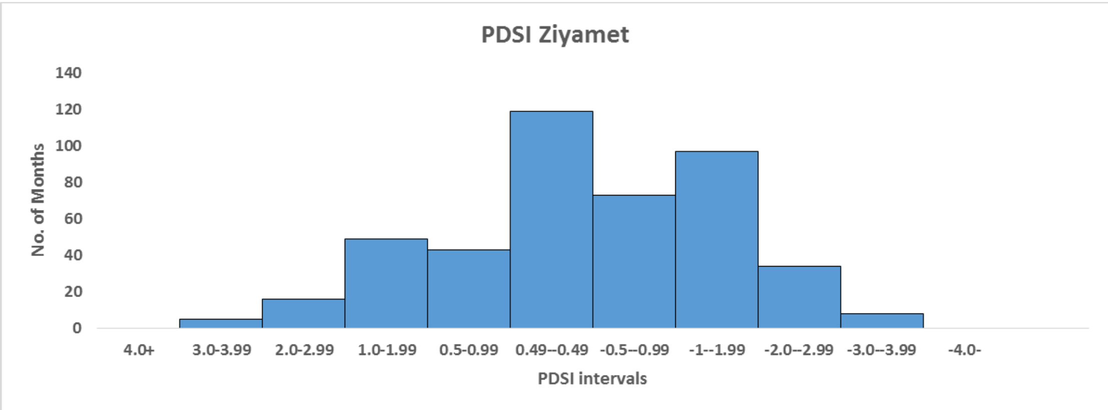


Figure 5.32 The number of months at each PDSI interval for Ziyamet

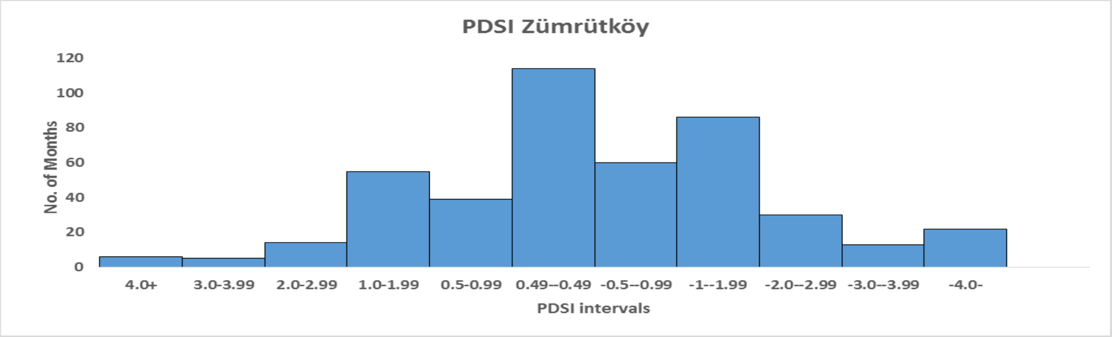


Figure 5.33 The number of months at each PDSI interval for Zümrütköy

As it can be seen from Figure 5.1 to 5.33, in general, in all locations, the number of dry periods are more than the number of normal and wet periods. Considering PDSI values of all 33 stations, wet periods are ranging from 24% to 32%, normal periods are ranging from 22% to 33%, and dry periods are ranging form 39% to 48%. When percent frequencies are averaged to get over all results, it has been observed that from September 1978 to August 2015, the wet, normal, and dry periods in North Cyprus climate are 27%, 28%, and 45%. In other words, almost half of the time North Cyprus is in drought situation.

The PDSI characteristics of the some of the stations which are close to each other, give similar results. For instance; west part of the North Coast and Kyrenia Mountain Regions as shown in Figure 5.34 such as Akdeniz, Çamlıbel, Lapta, Boğaz, Beylerbeyi and Girne have similar drought periods as shown in Figure 5.35. The driest period started at the end of the 2004 and continued until the middle of 2005 and the severity of drought increased to -5 values in this period. The longest dry period was 8 years from 1999 to 2007 as given in Table and also the driest month was alse seen in this period.

Figure 5.34 The areas of Akdeniz, Çamlıbel, Lapta, Boğaz, Beylerbeyi and Girne that show similar PDSI characteristics

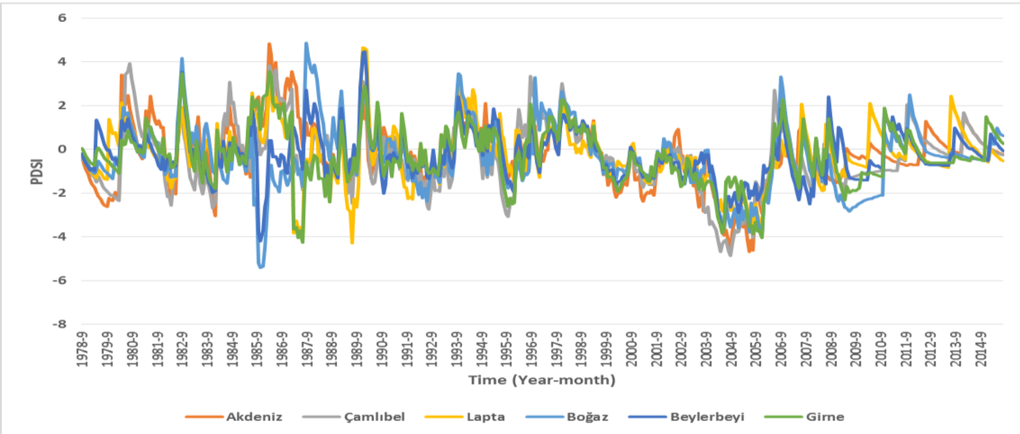


Figure 5.35 The PDSI of Akdeniz, Çamlıbel, Lapta, Boğaz, Beylerbeyi and Girne

Table 5.5 The duration period of dry spells for Akdeniz, Çamlıbel, Lapta, Boğaz, Beylerbeyi and Girne

Start Month	**End Month**	**Duration (in Month)**
1978-Oct	1980-March	18
1982-Feb	1984-Jan	23
1988-May	1989-July	10
1991-Dec	1993-Jan	14
1999-August	2007-May	93
2009-April	2012-Feb	34

Figure 5.36 The areas of Esentepe, Alevkaya, Tatlısu and Kantara that show similar PDSI characteristics

As shown in Table , Esentepe, Alevkaya, Tatlısu and Kantara have 5 dry periods. Different than other stations the driest month was seen in 2008 instead of 2005. The longest dry period was between 1999 and 2008. In this period, the PDSI values reached down to -4.00 which was classified as extreme drought in Palmer Classification, but in general the severity of drought is not too effective in these stations. It may affect the drought conditions. Then two year of dry spells was seen between 2013 and 2015.

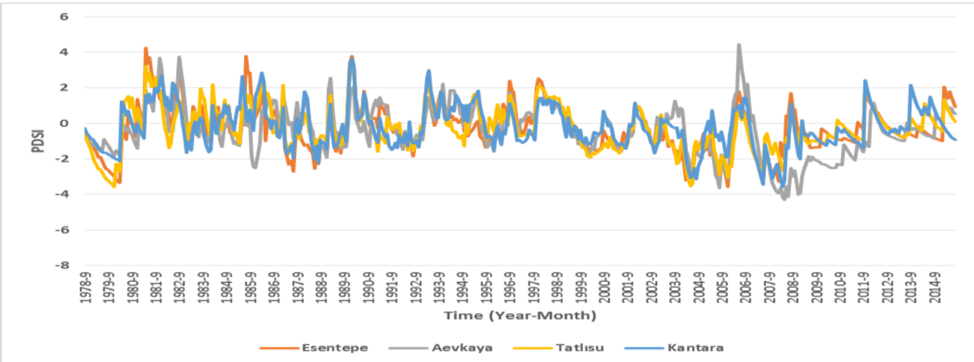


Figure 5.37 The PDSI of Esentepe, Alevkaya, Tatlısu and Kantara

Table 5.6 The duration period of dry spells for Esentepe, Alevkaya, Tatlısu and Kantara

Start Month	**End Month**	**Duration (in Month)**
1978-Oct	1980-July	20
1987-March	1989-Sep	24
1992-March	1996-Jan	24
1999-August	2008-May	105
2013-Jan	2015-Jan	24

Figure 5.38 The areas of Yeşilırmak, Güzelyurt, Gaziveren, Lefke and Zümrütköy that show similar PDSI characteristics

The west Mesaria Plain Region shown in Figure including Yeşilırmak, Güzelyurt, Gaziveren, Lefke and Zümrütköy are drier than other stations as given in Figure 6. Due to the low amount of rainfall, their PDSI values are lower and the drought is more severe then other regions. In 2005, when the most severe drought was seen in almost all regions, the PDSI values of these stations were less than -6 and 2003-05 is the driest period among the dry spells.

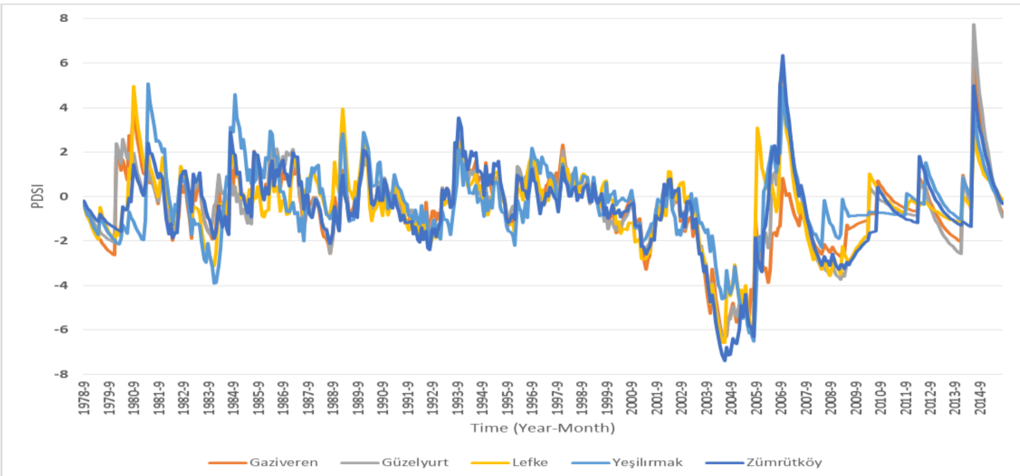


Figure 6 The PDSI of Yeşilırmak, Güzelyurt, Gaziveren, Lefke and Zümrütköy

Table 5.7 The duration period of dry spells for Yeşilırmak, Güzelyurt, Gaziveren, Lefke and Zümrütköy

Start Month	**End Month**	**Duration (in Month)**
1978-Oct	1979-Dec	10
1982-Feb	1984-July	19
1987-Juny	1988-Dec	17
1991-June	1993-Jan	18
1999-August	2001-Nov	21
2002-Sep	2010-July	94
2012-Nov	2013-Dec	13

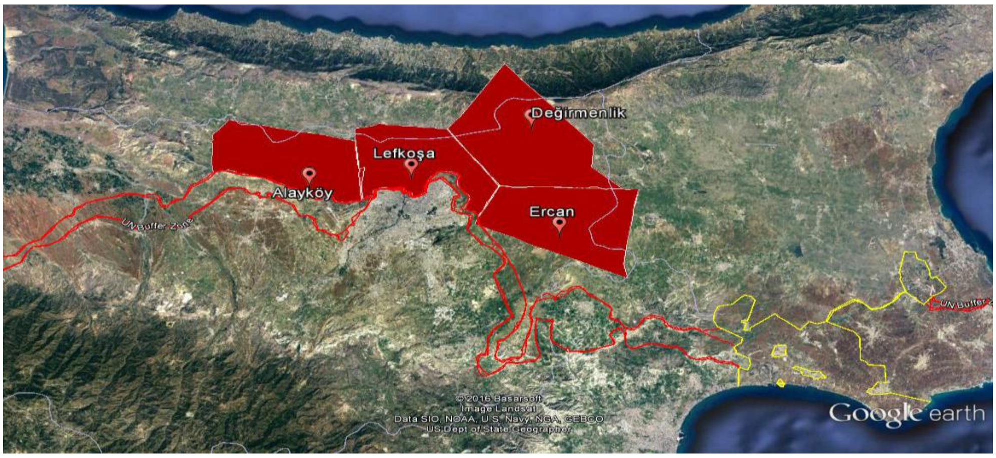


Figure 5.40 The areas of Alayköy, Lefkoşa, Ercan and Değirmenlik that show similar PDSI characteristics

In the analysis of PSDI values, Alayköy, Lefkoşa, Ercan and Değirmenlik as inland stations, are also show similarity in their results. They have more and shorter dry periods than other stations. The driest month was seen in 2004. These stations mostly had severe drought months, since the PDSI values did not reach -4 as illustrated in Figure.

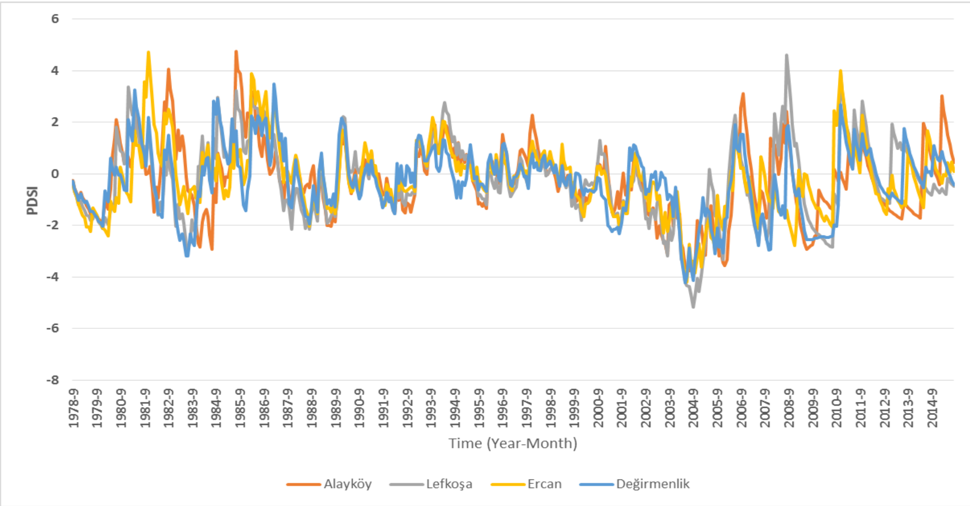


Figure 5.41 The PDSI of Alayköy, Lefkoşa, Ercan and Değirmenlik

Table 5.8 The duration period of dry spells for Alayköy, Lefkoşa, Ercan and Değirmenlik

Start Month	**End Month**	**Duration (in Month)**
1978-Oct	1980-April	19
1983-July	1984-Sep	10
1988-August	1990-Sep	23
1991-Sep	1993-Jan	22
1999-August	2006-May	81
2012-May	2014-March	22

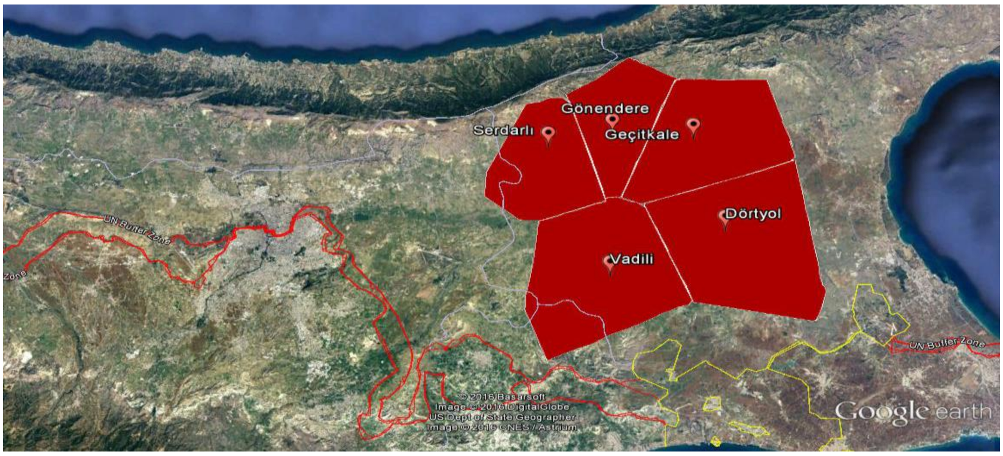


Figure 5.42 The areas of Vadili, Serdarlı, Gönendere, Geçitkale and Dörtyol that show similar PDSI characteristics

Vadili, Serdarlı, Gönendere, Geçitkale and Dörtyol are the neighbor stations. According to the Palmer classification, the PDSI values of Vadili, Serdarlı, Gönendere, Geçitkale and Dörtyol are classified as moderate drought. Since, in general most of the values are just around zero. Although, the duration of dry period is so long between 1999 and 2007 that it lasted in 94 months; short time wet and dry periods are seen at certain time intervals as shown in Figure3.

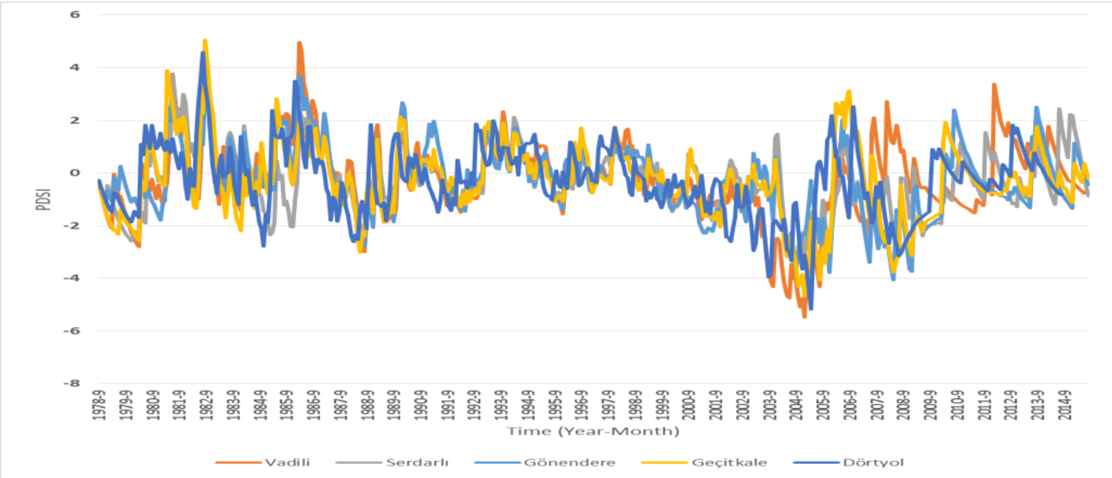


Figure 5.43 The PDSI of Vadili, Serdarlı, Gönendere, Geçitkale and Dörtyol

Table 5.9 The duration period of dry spells for Vadili, Serdarlı, Gönendere, Geçitkale and Dörtyol

Start Month	**End Month**	**Duration (in Month)**
1978-Oct	1981-March	30
1987-Oct	1989-Oct	24
1991-August	1993-Jan	17
1999-August	2007-June	94
2009-August	2012-Jan	29

Figure 5.44 The areas of Beyarmudu, Gazimağusa, Salamis, İskele, and Çayırova that show similar PDSI characteristics

Beyarmudu, Gazimağusa, Salamis, İskele and Çayırova have very similar fluctuations in PDSI values between 1979 and 2015. Furthermore, a very dry year is observed in 2005 and prolong dry spells were seen from 1999 to 2006. The worst extreme drought was seen in 2004-05 in these stations and the severity of drought was around -6 as demonstrated in Figure 5.45. A lot of short dry years was seen that can be classified as mild drought.

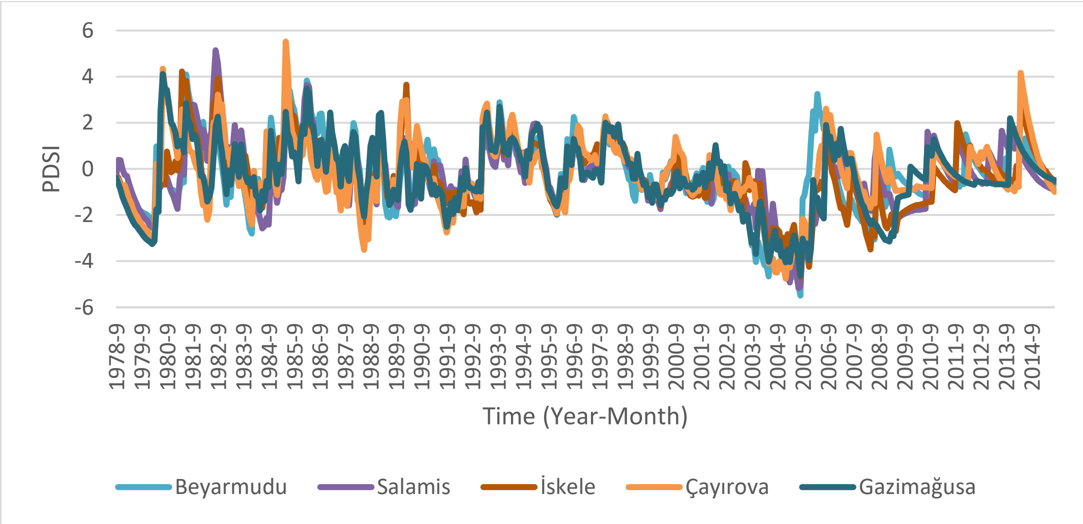


Figure 5.45 The PDSI of Beyarmudu, Gazimağusa, Salamis, İskele, and Çayırova

Table 5.10 The duration period of dry spells for Beyarmudu, Salamis, İskele and Çayırova

Start Month	End Month	Duration (in Month)
1978-Sep	1981-March	29
1983-Jan	1984-July	19
1989-April	1993-Jan	45
1999-Jan	2002-July	42
2003-March	2009-Jan	69
2013-Feb	2013-August	6

Figure 5.46 The areas of Mehmetçik, Ziyamet, Yeni Erenköy and Dipkarpaz that show similar PDSI characteristics

As shown in Figure , Mehmetçik, Ziyamet, Yeni Erenköy, and Dipkarpaz are located at the tip of the North Cyprus called the Karpass Peninsula. These stations have similar PDSI patterns as shown in Figure 5.47. When the duration of drought events are analyzed, as shown in Table , these stations have five dry periods. The longest dry spells occurred between 1999 and 2008. These stations have more wet periods than other stations, because the amount of yearly average rainfall is more than 400 mm in these regions. Thus, the drought was not as severe as other regions. Only one time, the PDSI value decreased to below -4 as it can be seen in Figure.

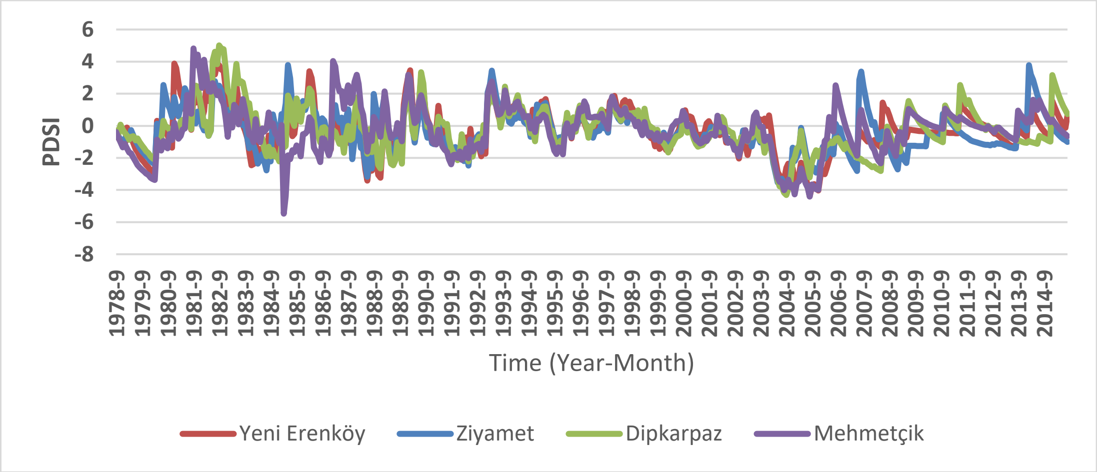


Figure 5.47 The PDSI of Mehmetçik, Yeni Erenköy, Ziyamet, and Dipkarpaz

Table 5.11 The duration period of dry spells for Mehmetçik, Yeni Erenköy, Ziyamet, and Dipkarpaz

Start Month	**End Month**	**Duration (in Month)**
1978-Oct	1980-March	18
1983-Oct	1985-April	19
1991-June	1993-Jan	19
1999-June	2008-May	97
2012-Dec	2014-Jan	14

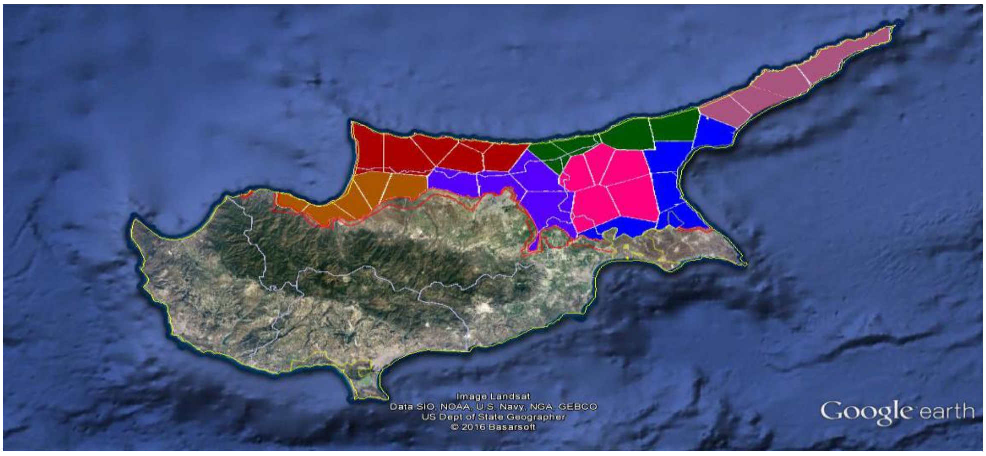


Figure 5.48 The drought regions across North Cyprus according to PDSI values

As it can be seen from the Figures 5.34-5.47, North Cyprus can be divided into seven drought regions according to the results of PDSI. Since, the close stations show similarity depending on the drought periods and severity. The drought regions are shown in Figure and in this figure each colour represents a drought region across North Cyprus. The stations which experienced the most severe drought in North Cyprus are Gaziveren, Zümrütköy, Güzelyurt and Lefke respectively. The driest period started in August 2003 and continued until September 2005. During this period, almost all PDSI values are smaller than -3 indicating extreme drought and also it decreased to -6.

In addition to evaluation PDSI results region by region across North Cyprus, all monthly PDSI values obtained for 33 stations are averaged to get one representative PDSI time series for whole North Cyprus (Figure 5.49).

From starting September 1978 and ending March 1980 mostly, mild drought months were happened. A drought was seen between 1982 and 1984, but it is not an extreme dry spell, because the values are just around -0,5 and the main reason of this is the decrease in the rainfall. Between 1988 and 1993 in addition to mild drought also moderate drought period was seen. However,wet periods were also seen from the results during the long period. It was the second driest period among the other dry periods. Between 1995 and 1996, a short period drought was occurred, but it was not as serious as other dry spells. A mild drought period was seen between 1999 and 2001. The PDSI values increased to -2 in this period. The longest duration of drought was experienced from 2000 to 2010. In 2004 and 2005, the driest seasons were seen. Mostly, the months were 'Extremely dry' in these two years. After two years from 2010, an incipient dry spell was happened until August 2013.

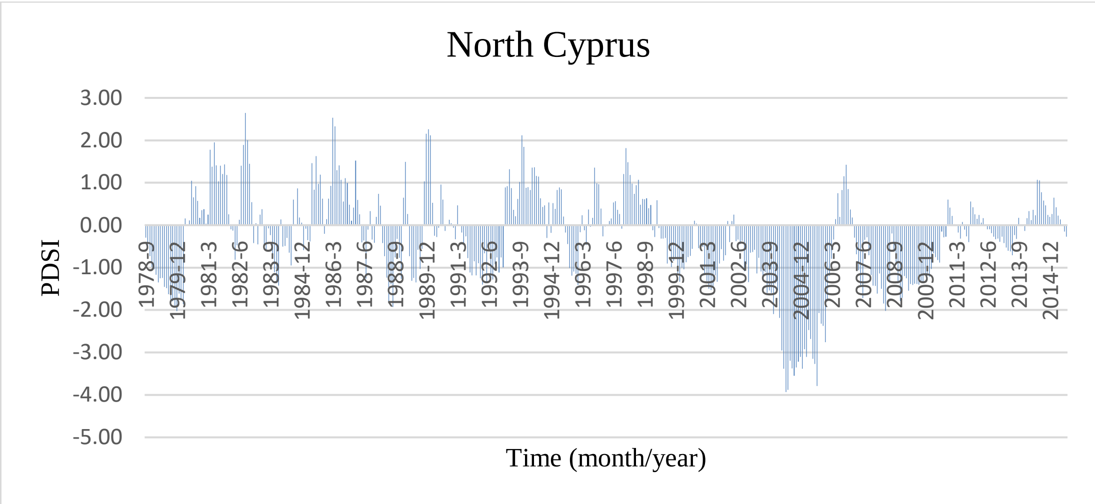


Figure 79 Monthly averaged PDSI values for North Cyprus

In addition to determine the dry periods, wet periods can also be obtained by using the PDSI. It is found that 1981, 1984 and the last two months of 2010 are the wet periods that have been occurred during 37- year period in North Cyprus. Although dry periods were seen in 2006, the peak values of wet spells were obtained in the September, October and November. This observation shows that the global warming changes the trends of both temperature and rainfall and it will illustrate it's impact in years to come.

Table 5.12 The duration period of dry spells for North Cyprus

Starting Month	Ending Month	Duration (Month)
1978-Sep	**1980-Jan**	**16**
1988-Sep	1989-Dec	19
1991-March	**1993-Jan**	**21**
1999-June	**2006-March**	**87**
2007-March	**2010-Jan**	**34**
2012-Dec	2014-Jan	14

In general, when one analyzes averaged PDSI values across North Cyprus (Figure 5.49, Table 5.12), 4 prolonged drought events are observed (1978-1980, 1991-1993, 1999-2006, 2007-2010). However, there is only one year between last two long drought periods. If it is ignored, one can say that the most severe drought event has been observed between 1999-2010 which is 11 years.

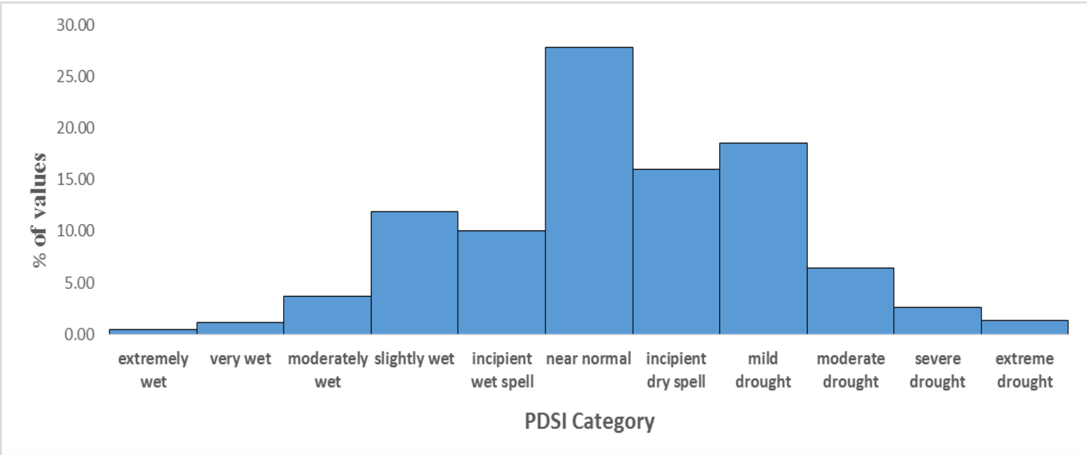


Figure 80 The percentage of the PDSI interval for all the stations

In Figure 80 the percentage of each PDSI intervals which were calculated for 33 stations across the North Cyprus is given. According to the whole stations, the percentage of ‘Near normal’, ‘Incipient dry spell’, ‘Mild drought’, ‘Incipient wet spell’, ‘Slightly wet’ conditions in the North Cyprus are 27.85%, 16.03%, 18.53%, 10.03%, and 11.93% respectively. As a result, it is certain that the dry years have been experienced in the regions more frequently than wet years.

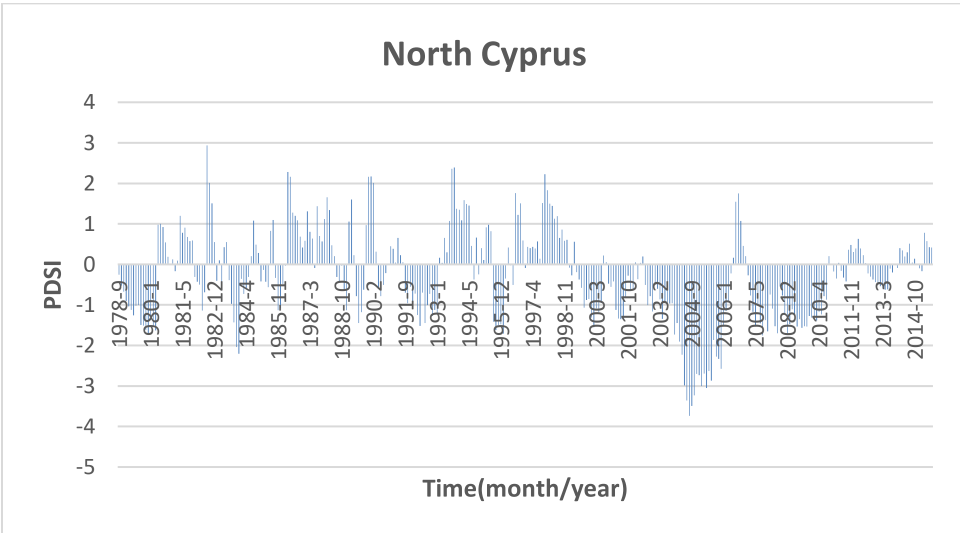


Figure 5.51 Monthly averaged PDSI values for North Cyprus

In Figure1, the monthly averaged PDSI values without including the summer months are shown. In North Cyprus, by May the rains have mostly stopped and the summer season is usually dry. However, this index depends on long-term average values and even one or two day in a summer month is rainy, then this month might be wet according to this index. This is the reason of examining the monthly PDSI time series without summer months. Since, it is certain that most of the time, the result of the index for summer gives dry periods. Therefore, in order to obtain more reliable PDSI results, the summer months from June to August are removed. When Figure 7 and Figure1 are compared, it is concluded that the number of dry spells increase and the number of wet spells decrease, because the summer months including rainy days are the reason of short wet periods. It may cause incorrect interpretation of the results. Morever, the severity of wet periods also reduces as shown in Figure1.

5.4 Trend Analysis of PDSI values

After the calculation of PDSI, Mann Kendall Trend Test was applied in R-program to analyze whether there is an upward or downward trend in the long-term PDSI values. In this test the confidence interval was 95% and the critical value is absolute value of 1.96 (|1.96|). If the Z value is greater than |1.96| and the S value is positive, this shows an upward trend whereas if S is negative, a downward trend is indicated. However, if the Z value is smaller than |1.96|, this means that there is not any trend in the time series. The results of the trend test in R-program are shown in the Table (Appendix E) and according to the these results, it is found that except Çamlıbel,Yeşilırmak, Çayırova and Mehmetçik, in the all stations downward trend has been observed in the PDSI values from 1978 to 2015. However, there has not been any trends in the four stations as illustrated in the Table 5.13.

Table 5.13 Trend analysis result for 33 PDSI stations

Name of the station	Mann-Kendall Trend Analysis	Name of the station	Mann-Kendall Trend Analysis
Çamlıbel	-	Alayköy	↓
Akdeniz	↓	Lefkoşa	↓
Lapta	↓	Ercan	↓
Boğaz	↓	Serdarlı	↓
Girne	↓	Gönendere	↓
Beylerbeyi	↓	Geçitkale	↓
Değirmenlik	↓	Vadili	↓
Alevkaya	↓	Dörtyol	↓
Esentepe	↓	Beyarmudu	↓
Tatlısu	↓	Salamis	↓
Kantara	↓	İskele	↓
Zümrütköy	↓	Çayırova	-
Lefke	↓	Mehmetçik	-
Gaziveren	↓	Ziyamet	↓
Güzelyurt	↓	YeniErenköy	↓
Yeşilırmak	-	DipKarpaz	↓
GaziMağusa	↓		

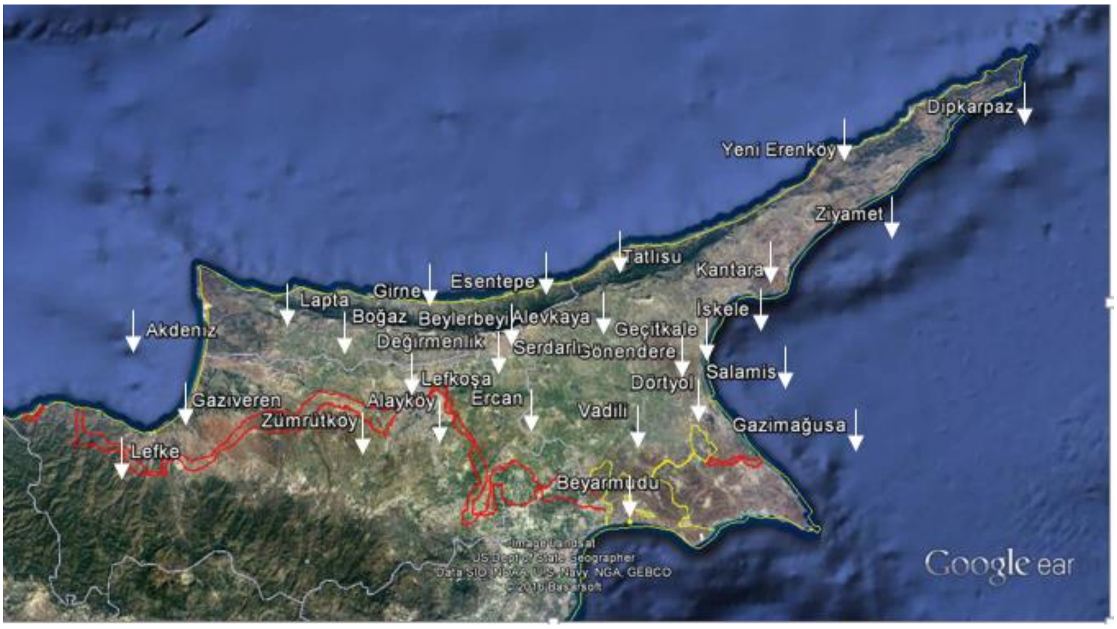


Figure 5.52 The stations which decreasing trends have been seen

The selected stations to evaluate PDSI are spread out along the North Cyprus uniformly demonstrating the whole properties of the regions. Therefore, the results show that the drought spells are more predominant than wet spells in the island and according to the trendline of the stations, it is seen that it will continue to decrease in the future. The main reason of this downward trend is the fluctuation of the rainfall owing to the climate change. The stations which do not have any trends may also be affected from the climate change. Since, natural hazards such as floods and droughts have tendency to occur more frequently. Therefore, some years such as 2010 flood events have been experienced whereas other years droughts have happened. This may be caused uncertainity in the trends.

5.5 Comparison of Results with Other Studies

Pashiardis & Michaelides (2009) analyzed drought in southern Cyprus between 1971 and 2008 using the SPI and the RDI. As a result, it was found that the dry spells were experienced in the country in 1971-1974, 1981-1984, 1989-1991, 1993-1994, 1995-2000 and 2004-2008. When their results are compared with this study, some shifts are shown, but in both study 2007-2008 was found one of the most dry periods which extreme drought occured.

Papakonstantinou et al. (2011) examined the impact of climate change on especially drought and other natural disasters such as forest fires from 1979 to 2009 for some regions that are found in the southern part of Cyprus by using two drought indices. Similar to this study, it was concluded that the drought has been rising significantly in all studied regions.

Griggs et al. (2014), analyzed the yearly precipitation and a 250-year drought period from four Pinus brutia tree-ring chronologies across the four regions with different heights in west-central Cyprus. According to the results, generally, the annual droughts repeat every 5 years and the duration of dry periods changes from 2 to 6 years. However, in this study it is found that, the dry spells occured for every two years, but for the duration it is found that it was changing between 2 and 6 years same as their result.

The study of Akıntuğ (1997) examined the level of drought in northern part of Cyprus from 1976 to 1995 with Palmer Drought Severity Index for seven meteorological stations. As a conclusion, the results showed that the most drought station is

Güzelyurt located along the West Mesarya Plain. In this study, it is also concluded that the driest regions: Gaziveren, Zümrütköy, Güzelyurt and Lefke which are located at the West Mesarya Plain.

CHAPTER 6

CONCLUSION

Drought has become to be the most common problem in North Cyprus. Due to the climate change, there is an increase in average temperature and decrease in total precipitation which causes a significant reduction in the water level of aquifers, reservoirs, and streams. Accordingly, it is required to analyze the drought and its trends in North Cyprus. In this study, the drought periods of 33 areas in North Cyprus have been identified by using Palmer Drought Severity Index (PDSI), in order to prevent adverse impacts of drought on agriculture, water resources, and many significant environmental and economic effects. Furthermore, determination of PDSI values may be helpful for water resources management in North Cyprus.

The PDSI was chosen as a drought index, in addition to the dry periods, wet spells can also be determined within this index. As a result, it has been found that there are mainly 6 dry periods and 4 prolonged drought events (1978-1980, 1991-1993, 1999-2006, 2007-2010) occurred from the September 1978 to August 2015. The longest drought period took place in almost all regions from 1999 to 2010 and the most severe period was experienced in this region during two years between 2005 and 2006. When the monthly PDSI were studied, it has been concluded that generally these stations are mild drought and usually severe drought has been seen in summer times. However, in addition to summer seasons, the drought has been also occured in winter seaons and commonly between October and March, the values in PDSI have started to decrease in recent years. In the years between 1978 and 1998, the dry spells were occurred in a short time period. However, in recent years the duration of drought spells has increased and the drought has started to be occurred more frequently. For instance, a drought was experienced between 2002 and 2010 in North Cyprus, and after two years a one-year drought repeated. However, from starting 2011, a certain fluctuation has been seen in the PDSI values. After a decreasing period, a sharp increase can be seen and then it continues to go down.

The main reason of this result is global warming. Since, due to the global warming, natural events have been changed and the droughts and wet spells have started to happen more frequently than in the past years.

When we compare the stations used in this study to obtain drought conditions, the Karpass Peninsula Region including Ziyamet, YeniErenköy, Dipkarpaz, Salamis and İskele are found wetter than other regions whereas the west Mesaria Plain Region including Yeşilırmak, Güzelyurt, Gaziveren, Zümrütköy and Lefke are found drier than other stations. The PDSI values of the Karpass Peninsula Region are between -1 and -2 whereas, they are less than -3 in the west Mesaria Plain Region during the driest seasons. The stations which experienced the most severe drought in North Cyprus are Gaziveren, Zümrütköy, Güzelyurt and Lefke respectively. The driest period started in August 2003 and continued until September 2005. During this period, almost all PDSI values are smaller than -3 indicating extreme drought and also it decreased to -6.

To sum up, between 1978 and 2015, 28% of the time climate of North Cyprus demonstrated normal condition, 27% of the time wet condition, and 45 % of the time drought condition. In other word, almost half of the time the climate of North Cyprus is in drought condition. During last 37 years, number of prolonged drought events have been observed with the long one between 1999 and 2010 which is 11 years. According to Mann-Kendal trend test, across North Cyprus, there is a decreasing trend in PDSI values which means there is an increasing trend in drought events.

It is obvious that the dry years will also occur in the coming years. Therefore, more meteorological studies should be performed for North Cyprus. As a further study, analyzing the relationship between PDSI and other hydrologic variables such as rainfall, temperature, soil moisture etc. and ocean atmosphere circulations such as Pacific Decadal Oscillation (PDO), North Atlantic Oscillation (NAO), El Nino Southern Oscillation (ENSO) etc., calculation of weekly PDSI and comparison of weekly and monthly PDSI is recommended. Calculation of weekly PDSI is significant. Since, the PDSI index depends on water balance model and for the monthly calculation, the Runoff, Stored Soil Moisture and Recharge are considered on monthly basis. However, the weekly PDSI studies these parameters on weekly basis. When the duration of studied period decreases, it is certain that the sensitivity of the index will be increased and it will give more alert and clear estimation of drought events (Rhee and Carbone, 2007).

The Self-calibrated PDSI, which is the calibrated model of PDSI including empirical constants changing from region to region, should be also tested for the region. Moreover, the methods; SPI, De Martonne, Aydeniz and the Percent of Normal Index (PNI) which have been used by the TRNC Department of Meteorology to analyze drought should be compared with the PDSI results in order to find the most suitable index for North Cpyrus. If there is an opportunity to obtain the drought analysis of South Cyprus which has been done by the Water Development Department and Cyprus Department of Meteorology , it will be more preferable to compare the results and analyze the drought for the whole island.

The main contribution of this study is the identification of the major drought events and their duration and severity by using Palmer Drought Severity Index (PDSI) for 33 stations in North Cyprus between 1978 and 2015. In this study, North Cyprus is divided into 33 meteorological stations uniformly and the AWC values of these stations have been calculated which has not been studied before. After this study, Meteorological Office of TRNC will use this index as a drought index of the country to monitor the monthly drought conditions according to the academic protocol that was signed between METU NCC and Meteorological Office of TRNC. Moreover, the completed rainfall and temperature data, the PDSI and AWC values can be used in further studies to analyze different issues and apply tests. Identifying the drought periods and finding the trends of PDSI might be beneficial for the country to realize the condition of drought and take precations to decrease the level of water shortage.

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APPENDICES

APPENDIX A

Table A.1 The candidate temperature station and the selected method

	Station Name	The neighbouring stations	Selected Method
1	Çamlıbel	Girne, Lapta	NR
2	Akdeniz	Çamlıbel, Güzelyurt	NR
3	Lapta	Alevkaya, Çamlıbel, Esentepe, Girne	NR
4	Boğaz	Alevkaya, Girne, Lapta, Lefkoşa	NR
5	Girne	Çamlıbel, Lapta	NR
6	Beylerbeyi	Girne,Alevkaya, Lefkoşa	ID
7	Değirmenlik	Ercan, Alevkaya, Lefkoşa	ID
8	Alevkaya	Esentepe, Girne, Lapta	NR
9	Esentepe	Alevkaya, Girne, Lapta	NR
10	Tatlısu	Esentepe, Alevkaya	ID
11	Kantara	Alevkaya, Esentepe, Erenköy	ID
12	Zümrütköy	Güzelyurt, Çamlıbel	ID
13	Lefke	Güzelyurt	NR
14	Gaziveren	Güzelyurt	ID
15	Güzelyurt	Çamlıbel, Lapta	NR
16	Yeşilırmak	Güzelyurt	NR
17	Alayköy	Lefkoşa, Çamlıbel	ID
18	Lefkoşa	Ercan	NR
19	Ercan	Lefkoşa	NR
20	Serdarlı	Ercan, Alevkaya, Esentepe	ID
21	Gönendere	Ercan, Esentepe	ID
22	Geçitkale	Beyarmudu, Ercan	NR
23	Vadili	Ercan, Beyarmudu	NR
24	Dörtyol	Ercan, Beyarmudu	ID
25	Beyarmudu	Mağusa, Ercan, Lefkoşa	NR
26	Salamis	Magusa, Beyarmudu	ID
27	İskele	Magusa	NR
28	Çayırova	Yeni Erenköy	ID
29	Mehmetçik	Yeni Erenköy	NR
30	Ziyamet	Yeni Erenköy	ID
31	Yeni Erenköy	Mağusa, Ercan	NR
32	Karpaz	Yeni Erenköy	NR
33	Gazimağusa	Yeni Erenköy, Geçitkale, Ercan	NR

APPENDIX B

Table B.1 The texture and organic matter characteristic of TRNC's soil series (Dinç et al., 2000).

Horizon	Depth	Organic Matter	Sand	Silt	Clay	Horizon	Depth	Organic Matter	Sand	Silt	Clay
	cm	%	%				cm	%	%		
BALIKESİR SERIAL						**GÜNEBAKAN SERIAL**					
Ap	0-14	2,61	26,6	39,3	34,1	A1	0-12	2,69	29,8	41,3	29,0
A2	14-31	0,95	28,9	41,3	29,8	A2	Ara.38	1,02	30,1	47,2	22,7
C	31-66	0,82	15,8	43,6	40,6	Ac	38-70	0,58	36,1	44,6	19,3
Ab	66-114	0,81	12,8	31,2	56,1	Cr	70-150	0,38	42,1	43,6	14,3
Cb	114-170	0,58	21,9	48,1	30,0						
CENGİZ TOPEL SERIAL						**KARADAĞ SERIAL**					
Ap	0-14	1,60	50,6	32,8	16,6	A	0-11	6,13	63,1	20,9	16,0
Ac	14-31	1,44	46,2	33,0	20,8	Bt1	Kas.25	2,24	65,5	12,4	22,1
C	31-54	0,92	65,1	24,5	10,4	Bt2	25-55	1,00	67,8	10,3	21,9
CENGİZKÖY SERIAL						**KORUYAKA SERIAL**					
Ap	0-14	1,12	39,8	35,2	25,0	A1	0-13	1,79	30,0	51,6	18,5
A2	14-27	0,84	41,9	33,1	25,0	A2	13-36	0,51	32,9	45,3	21,8
C1	27-43	0,24	30,6	46,3	23,1	Bw	36-60	0,42	62,7	24,9	12,5
C2	43-64	0,28	22,0	48,4	29,6	Cr	60-125	0,15	72,6	15,4	12,0
C3	64-80	0,18	35,2	48,2	16,6						
ÇAKILDERE SERIAL						**ÜMİTTEPE SERIAL**					
Ap	0-15	1,01	53,9	31,0	15,1	A	0-12	1,06	48,7	31,9	19,4
AC	15-63	0,32	58,2	28,7	13,2	Bw	Ara.27	0,87	54,0	28,2	17,8
C1	63-120	0,24	65,4	24,7	9,9	BC	27-45	0,33	58,0	26,3	15,7
C2	120-150	0,19	52,1	31,6	16,4	Cr	45-198	0,16	72,8	18,2	9,0
DERİNDERE SERIAL						**AKDENİZ SERIAL**					
Ap	0-25	1,97	37,6	34,5	27,9	Ap	0-19	2,27	76,3	11,7	12,1
A2	25-50	0,94	33,4	33,8	32,8	C1	19-70	0,34	86,7	7,5	5,8
C1	50-82	0,71	12,3	48,2	39,4	C2	70-92	0,31	78,4	9,6	12,0
C2	82-130	0,62	61,0	26,0	12,9	2ck	92-110	0,40	65,9	17,9	16,2
ERDEMLİ SERIAL						**GAZİVEREN SERIAL**					
Ap	0-13	1,53	27,3	49,2	23,5	Ap	0-15	1,44	82,2	10,7	7,1
A2	13-27	1,01	29,3	47,2	23,5	CA	15-35	0,44	90,3	1,6	8,0
C1	27-77	0,54	27,8	55,1	17,1	C	35-135	0,04	95,3	0,6	4,0
C2	77-115	0,54	24,5	57,5	18,1						

Table B.1 The texture and organic matter characteristic of TRNC's soil series (Dinç et al., 2000) (con't)

Horizon	Depth	Organic Matter	Sand	Silt	Clay	Horizon	Depth	Organic Matter	Sand	Silt	Clay
	cm	%	%				cm	%	%		
GÜVERCİNLİK SERIAL						**PİRHAN SERIAL**					
Ap	0-17	1,58	20,7	25,0	54,3	Ap	0-18	1,16	53,9	36,2	9,9
Ad	17-36	1,16	16,5	22,9	60,6	A2	18-32	0,29	61,9	28,1	9,9
Css1	36-93	0,87	13,9	20,9	65,2	C1	32-45	0,35	53,7	31,2	15,1
Css2	93-120	0,65	1,8	25,8	72,3	C2	45-75	0,23	58,0	30,0	11,9
						C3	75-120	0,17	43,1	38,6	18,3
GÜZELYURT SERIAL						**ÇINARLI SERIAL**					
Ap	0-24	1,41	27,0	40,7	32,3	Ap	0-12	1,15	17,0	42,4	40,5
A2	24-48	0,94	27,7	37,3	35,0	A2	12--25	0,67	17,0	36,0	46,9
C1	48-75	0,44	7,0	60,6	32,4	Cr	25-73	0,55	12,0	40,6	47,3
C2	75-99	0,29	17,5	49,6	32,9						
C3	99-135	0,23	38,7	48,1	13,2						
KANLIDERE SERIAL						**ÇOBANYERİ SERIAL**					
Ap	0-13	1,67	10,8	47,2	42,1	A1	0-25	1,15	19,5	31,5	48,9
Az2	13-42	0,69	30,3	54,6	15,1	A2	25-50	0,58	18,3	33,3	48,4
Cz1	42-109	0,68	19,4	31,1	49,5	C1	50-77	0,44	15,7	34,5	49,7
C2	109-160	0,50	19,4	31,1	49,5	Cr	77-150	0,29	13,6	36,7	49,7
LEFKE SERIAL						**GÜZELYALI SERIAL**					
Ap	0-21	1,50	27,5	32,9	39,6	Ap	0-14	2,69	47,0	27,9	25,1
Ac	21-40	1,15	25,0	35,2	39,8	Bw	14-29	1,73	50,1	20,6	29,3
C1	40-63	0,81	22,4	35,4	42,2	BC	29-58	0,70	42,0	23,6	34,4
C2	63-80	0,65	25,3	35,0	39,6	Ckm	58-75	0,29	53,2	32,4	14,4
MARGO SERIAL						**MEHMETCİK SERIAL**					
Ap	0-21	2,41	28,0	39,8	32,2	Ap	0-17	3,11	47,8	28,3	23,9
A2	21-39	1,63	28,4	32,0	39,6	AB	17-31	0,97	45,7	24,2	30,0
Ass3	39-81	1,15	25,7	29,2	45,2	Bw	31-77	0,49	41,3	26,4	32,2
A4	81-120	0,87	24,9	33,8	41,3	C	77-105	0,29	30,3	24,6	45,1
PİYALE PAŞA SERIAL						**PINARLI SERIAL**					
Ap	0-17	2,14	26,1	35,0	38,8	Ap	0-21	1,86	53,1	26,2	20,7
A2	17-45	0,58	21,6	37,3	41,1	Ac	21-39	0,67	48,9	21,0	30,1
C1	45-92	0,55	13,5	33,5	53,1	C	39-68	0,50	25,6	32,7	41,8
C2	92-129	0,38	46,7	24,4	28,9	Cr	68-150	0,38	36,5	28,2	35,2

Table B.1 The texture and organic matter characteristic of TRNC's soil series (Dinç et al., 2000) (con't)

Horizon	Depth	Organic Matter	Sand	Silt	Clay	Horizon	Depth	Organic Matter	Sand	Silt	Clay
	cm	%	%				cm	%	%		
YEŞİLIRMAK SERIAL						**ÇAKMAKTEPE SERIAL**					
Ap	0-20	2,43	28,1	38,7	33,3	A	0-10	3,25	51,4	30,0	18,6
Ac	20-34	1,32	45,9	36,4	17,7						
C	34-82	0,94	31,2	51,6	17,2						
YUKARI YEŞİLIRMAK SERIAL						**BEŞPARMAK SERIAL**					
Ap	0-13	2,16	40,3	31,9	27,8	A1	0-17	4,15	52,9	26,4	20,6
A2	13-26	0,94				Ac	17-31	1,66	50,9	24,4	24,7
C	26-80	0,73	63,8	26,4	9,8						
ACIKUYU SERIAL						**GİRNE SERIAL**					
Ap	0-14	1,99	48,0	31,5	20,5	A1	Eki.15	3,31	9,1	32,5	58,4
Ac	14-34	0,89	36,2	34,2	29,6						
C1	34-87	0,79	36,2	34,2	29,6						
C2	87-140	0,70	56,3	25,2	18,5						
AKINCILAR SERIAL						**YENİCEKÖY SERIAL**					
Ap	0-10	1,44	22,0	33,6	44,4	Ap	0-8	1,78	53,5	24,4	22,1
A2	Eki.25	1,03	24,0	30,5	45,5	AB	Ağu.22	1,56	53,2	20,3	26,5
Css1	25-55	0,58	32,7	29,3	38,0	Bw	22-31	1,12	39,0	16,5	44,5
Css2	55-120	0,55	19,9	28,4	51,7	Ckm	31+				
AKOVA SERIAL						**ZİNCİRLİ SERIAL**					
Ap	0-14	1,28	40,5	35,3	24,2	Ap	0-9	0,94	55,1	23,8	21,2
A2	14-44	0,86	40,5	35,3	24,2	A2	9--40	1,54	55,1	27,6	17,4
C1	44-92	0,55	33,8	35,5	30,7	C	40-80	0,86	55,0	20,3	24,7
C2	92-140	0,29	64,0	18,3	17,7						
AKINCILAR SERIAL						**GELİNCİK SERIAL**					
Ap	0-10	1,44	22,0	33,6	44,4	Ap	0-13	0,86	51,7	28,8	19,5
A2	Eki.25	1,03	24,0	30,5	45,5	Ckm1	13-27	0,57	49,6	30,9	19,5
Css1	25-55	0,58	32,7	29,3	38,0	Ckm2	27-70	0,70	38,9	43,6	17,5
Css2	55-120	0,55	19,9	28,4	51,7						
AKOVA SERIAL						**İNÖNÜ SERIAL**					
Ap	0-14	1,28	40,5	35,3	24,2	Ap	0-7	1,74	44,2	33,0	22,8
A2	14-44	0,86	40,5	35,3	24,2	A2	7--19	1,05	43,7	31,2	25,1
C1	44-92	0,55	33,8	35,5	30,7	ABk	19-36	0,44	25,1	25,5	49,4
C2	92-140	0,29	64,0	18,3	17,7	Bk	36-67	0,28	5,5	29,7	64,8
						Ck	67-95	0,20	25,3	31,9	42,8

Table B.1 The texture and organic matter characteristic of TRNC's soil series (Dinç et al., 2000) (con't)

Horizon	Depth	Organic Matter	Sand	Silt	Clay	Horizon	Depth	Organic Matter	Sand	Silt	Clay
	cm	%	%				cm	%	%		
ALSANCAK SERIAL						**TÜRKELİ SERIAL**					
Ap	0-10	2,02	52,9	26,8	20,2	Ap	0-20	1,26	21,5	35,0	43,5
A2	Eki.30	1,45	54,8	24,9	20,4	A2	20-37	0,68	19,4	30,8	49,8
2Ab	30-51	0,83	46,5	31,1	22,4	Acss	37-87	0,51	14,8	31,0	54,3
2C1	51-77	0,29	61,4	24,6	14,0	Cr	87+	0,35	19,4	38,2	42,4
2C2	77-115	0,12	73,8	18,4	7,8						
KARAOĞLANOĞLU SERIAL						**ALTINOVA SERIAL**					
A1	0-17	1,44	34,4	44,3	21,3	Ap	0-17	1,67	26,6	35,7	37,7
A2	17-35	0,29	29,0	42,8	28,3	A2	17-27	1,06	22,2	33,7	44,1
Css1	35-65	0,17	41,1	31,5	27,4	ACy	27-44	0,58	60,9	25,6	13,5
Css2	65-104	0,12	23,6	37,1	39,2	C1	44-58	0,42	61,2	23,2	15,6
						C2	58-77	0,44	63,2	21,6	15,2
						C3	77-110	0,33	68,1	20,7	11,2
KARPAZ SERIAL						**NALBANTOĞLU SERIAL**					
Ap	0-12	1,32	13,3	35,8	50,9	Ap	0-11	1,71	38,0	42,3	19,6
A2	Ara.33	1,16	14,5	34,0	51,4	A2	Kas.25	1,32	44,0	39,1	16,9
C	33-60	0,29	13,8	48,2	38,1	Cy	25-39	0,58	jips		
						Cr	39-68	0,23			
LEFKOŞA SERIAL						**ÇAMLIBEL SERIAL**					
Ap	0-22	0,70	38,3	34,5	27,2	Ap	0-17	2,21	38,0	22,5	39,4
Ad	22-51	0,41	53,2	23,9	22,9	A2	17-34	1,71	42,3	22,5	35,2
Ac	52-69	0,41	32,0	34,5	33,5	Bt1	34-61	0,35	35,2	12,1	52,7
Ck	69-93	0,29	27,8	40,8	31,4	Bt2	61-88	0,29	23,3	7,9	68,8
Css	93-50	0,17	1,5	1,5	1,5	Bt3	88-120	0,22	23,7	7,9	68,4
MALLIDAĞ SERIAL						**ÖRENLER SERIAL**					
Ap	0-28	1,95	65,2	26,4	8,4	A1	0-9	2,50	43,6	40,7	15,7
C1	28-52	0,51	75,7	18,0	6,3	Cr	9--50	0,83	47,3	36,3	16,4
C2	52-103	0,33	65,1	25,4	9,5						
MEYDANCIK SERIAL						**TEPEBAŞI SERIAL**					
Ap	0-15	1,13	55,2	22,6	22,2	A1	0-11	4,94	68,4	17,2	14,4
Ac	15-27	2,02	52,9	25,8	21,3	A2	Kas.30	2,82	69,4	16,1	14,4
C1	27-50	0,55	56,0	22,7	21,3	C	30-50	1,03	82,1	7,8	10,2
C2	50-90	0,55	61,2	17,5	21,3						

Table B.1 The texture and organic matter characteristic of TRNC’s soil series (Dinç et al., 2000) (con’t)

Horizon	Depth	Organic Matter	Sand	Silt	Clay	Horizon	Depth	Organic Matter	Sand	Silt	Clay
	cm	%	%				cm	%	%		
ALTIOK SERIAL						**BOLTAŞLI SERIAL**					
Ap	0-10	1,66	45,5	30,7	23,7	Ap	0-26	2,56	52,0	22,8	25,2
Bw	Eki.25	0,68	37,3	24,5	38,2						
Ck	25-47	0,56	34,8	22,4	42,8						
AMBARLIK SERIAL						**DEĞİRMENLİK SERIAL**					
Ap	0-16	1,99	61,3	26,2	12,5	A1	0-9	1,35	42,8	32,8	24,4
BA	16-30	0,84	44,3	16,5	39,2	Ac	Eyl.38	1,07	38,4	30,8	30,8
Bw	30-53	0,58	42,6	14,2	43,2	C1	38-64	0,74	21,5	39,2	39,2
Ck	53-75	0,54	69,9	13,6	16,5	C2	64-85	0,77	19,1	39,4	41,5
AYDINKÖY SERIAL						**AYTEPE SERIAL**					
Ap	0-14	1,16	24,4	39,8	35,8	A	0-15	2,67	27,5	33,6	39,0
A2	14-37	1,18	24,3	42,1	33,6						
C	37-64	0,78	18,7	41,2	40,2						
2Ass1	64-96	0,55	19,4	33,6	47,0						
2Ass2	96-125	0,41	18,0	31,6	50,5						
AYGÜN SERIAL						**BOĞAZİÇİ SERIAL**					
Ap	0-17	2,76	39,4	28,5	32,2	Ap	0-14	1,74	44,5	21,2	34,3
A2	17-47	1,12	34,5	25,6	40,0	BA	14-27	1,45	44,2	21,3	34,5
AB	47-57	0,84	34,3	23,5	42,2	Bw1	27-41	0,97	46,3	21,3	32,4
Bw	57-97	0,60	21,9	28,3	49,8	Bw2	41-67	0,58	46,5	16,9	36,6
C	97-115	0,55	22,0	35,4	42,6						
BOSTANCI SERIAL						**ÇATALKÖY SERIAL**					
Ap	0-26	2,03	43,6	27,7	28,7	A1	0-12	2,80	52,5	20,5	27,1
Bw1	26-47	0,55	37,4	14,2	48,4	Bw	Ara.22	2,32	52,5	16,3	31,3
Bwss2	47-64	0,44	36,3	14,2	49,5	Cb	22-42	0,84	43,8	14,3	41,9
BCkss	64-90	0,29	43,8	13,1	43,1						
SERHATKÖY SERIAL						**DOĞANCI SERIAL**					
Ap	0-12	1,50	44,4	29,0	26,6	Ap	0-15	1,15	46,4	20,2	33,4
A2	Ara.29	0,29	40,3	31,1	28,6	A2	15-33	0,84	41,5	19,4	39,1
Ck1	29-58	0,23	28,9	41,5	29,7	Bt1	33-48	0,46	34,0	15,3	50,7
Ck2	58-73	0,15	43,9	41,1	15,0	Bt2	48-76	0,46	29,3	13,2	57,5
Cz	73-110	0,04	32,3	48,6	19,2	Bc	76-96	0,16	49,1	16,8	34,1
						Ckm	96-110	0,10	60,7	22,6	16,8

Table B.1 The texture and organic matter characteristic of TRNC's soil series (Dinç et al., 2000) (con't)

Horizon	**Depth**	**Organic Matter**	**Sand**	**Silt**	**Clay**	**Horizon**	**Depth**	**Organic Matter**	**Sand**	**Silt**	**Clay**
	cm	%	%				cm	%	%		
ŞAHİNKUYU SERIAL						**ERCAN SERIAL**					
Ap	0-14	2,50	19,0	33,2	47,8	A1	0-11	1,73	52,8	13,5	33,7
A2	14-32	1,77	19,8	33,4	46,9	Bt1	Kas.24	1,44	42,5	19,7	37,8
Bw1	32-53	0,87	20,6	36,3	43,1	Bt2	24-33	1,19	47,0	13,1	39,9
Bw2	53-66	0,48	52,8	19,7	27,5	Ck	33-54	0,73	59,8	13,9	26,4
CBk	66-89	0,35	50,6	19,3	30,1						
Ck	89-115	0,29	48,6	25,5	25,9						
ÜÇTAŞ SERIAL						**ESENTEPE SERIAL**					
Ap	0-13	1,96	33,6	37,5	28,9	A1	0-12	3,14	52,0	23,5	24,6
Ad	13-30	1,04	28,8	29,3	41,9	A2	Ara.22	0,87	64,8	16,0	19,2
Ac	30-50	0,76	27,1	29,2	43,8						
Ck	50-125	0,54	25,1	32,3	42,6						
YAYLA SERIAL						**GAZİLER SERIAL**					
Ap	0-21	4,07	20,3	39,7	40,0	Ap	0-16	1,18	67,4	15,8	16,7
A2	21-37	1,15	15,0	45,5	39,5	Ac	16-35	0,80	44,7	19,9	35,4
AB	37-60	0,84	34,2	31,6	34,2	Ck	35-58	0,58	19,8	23,0	57,2
Bw1	60-82	0,32	63,5	16,9	19,6						
Bw2	82-101	0,48	34,9	40,8	24,3						
B C	101-125	0,49	16,9	41,3	41,8						
ZÜMRÜTKÖY SERIAL						**KIRKLAR SERIAL**					
Ap	0-16	2,43	44,7	26,6	28,7	Ap	0-12	1,96	63,2	27,0	9,8
A2	16-35	1,00	39,3	27,4	33,3	A2	Ara.23	1,32	63,5	26,8	9,7
BA	35-57	0,29	54,5	16,7	28,8	Ckm	23-44	0,89	74,5	18,0	7,5
Bw	57-73	0,23	54,5	14,6	30,9						
ÇAMUROVA SERIAL						**MORMENEKŞE SERIAL**					
A1	0-17	1,93	13,4	25,7	60,9	Ap	0-16	2,06	35,9	22,4	41,7
A2	17-32	1,15	14,7	23,8	61,5	Ad	16-27	2,03	22,5	30,5	47,0
Ac	32-47	0,58	15,6	30,0	54,4	Bw	27-39	1,16	33,4	22,1	44,5
2Css1	47-66	0,45	15,6	21,3	63,0	BC	39-49	0,88	44,7	16,9	38,4
2Css2	66-96	0,29	13,4	24,6	62,0	Ckm	49+				
2Css3	96-120	0,29	16,1	23,4	60,5						
ÇAYÖNÜ SERIAL						**NERGİZLİ SERIAL**					
A1	0-21	1,89	19,0	24,9	56,1	Ap	0-11	1,26	56,3	26,1	17,6
A2	21-41	1,26	12,9	17,9	69,1	A2	Kas.25	0,95	56,3	26,1	17,6
Cz1	41-91	0,72	3,3	26,1	70,6	C1	25-69	0,24	55,8	18,0	26,2
Cz2	91-131	0,57	12,9	28,6	58,5	2Cr	69-90	0,19	30,8	43,0	26,2

Table B.1 The texture and organic matter characteristic of TRNC's soil series (Dinç et al., 2000) (con't)

Horizon	Depth	Organic Matter	Sand	Silt	Clay	Horizon	Depth	Organic Matter	Sand	Silt	Clay
	cm	%	%				cm	%	%		
GÖLLER SERIAL						**PAŞAKÖY SERIAL**					
A1	0-10	5,40	15,5	33,5	51,1	Ap	0-10	2,18	34,0	26,1	40,0
Ac	Eki.25	1,15	11,2	26,4	62,4	A2	Eki.20	1,16	50,9	25,2	23,9
C1	25-40	0,84	14,4	23,1	62,4	ACk	20-38	0,39	31,3	31,8	36,9
Ck	40-73	0,55	9,2	20,2	70,7	Ck1	38-68	0,29	40,0	40,2	19,8
2C	73-108	0,12	88,1	3,7	8,2	Ck2	68-89	0,20	41,3	38,9	19,7
						2A	89-120	0,13	34,9	26,8	38,3
SALAMİS SERIAL						**YARKÖY SERIAL**					
A1	0-25	1,53	40,8	16,1	43,1	A1	0-17	0,51	49,8	26,3	23,9
2C1	25-48	0,55	51,6	15,0	33,4	Ac	17-28	1,03	56,4	24,0	19,6
2C2	48-130	0,37	34,2	18,3	47,5	C	28-100	0,44	24,2	39,6	36,2
TÜRKMENKÖY SERIAL						**TATLISU SERIAL**					
Ap	0-11	2,05	33,6	30,0	36,4	A1	0-16	1,55	43,4	37,2	19,5
A2	Kas.25	1,29	26,7	25,8	47,5	Ac	16-35	1,09	19,5	52,9	27,7
Bw	25-47	0,48	31,7	23,4	44,9	C	35+	0,87	33,7	44,6	21,8
Bk1	47-65	0,45	27,1	27,7	45,2						
Bk2	65-140	0,23	24,5	30,0	45,5						
BADEMLİKÖY SERIAL						**YILDIRIM SERIAL**					
A	0-28	3,53	29,0	42,8	28,3	Ap	0-26	1,22	68,1	17,6	14,4
AC	28-88	1,84	10,2	32,5	27,4	Ck	26-45	0,77	55,2	26,1	18,7
C	88-115	1,73	48,2	37,9	13,2	Ckm	45-75	0,38	62,7	26,7	10,6
DEMİRHAN SERIAL						**ZAFERBURNU SERIAL**					
A1	0-12	1,51	46,4	34,4	19,2	A	0-30	2,03	75,0	9,9	15,1
A2	12--37	0,97	39,4	36,9	23,7						
C1	37-63	0,95	24,3	47,7	28,0						
C2	63-120	0,68	31,2	36,8	32,0						
EĞLENCE SERIAL						**ASLANKÖY SERIAL**					
A1	0-16	1,94	47,3	20,1	32,7	Ap	0-21	1,96	26,9	38,9	34,2
Bw	16-36	0,74	44,6	16,8	38,7	Ad	21-38	0,97	38,0	35,3	26,7
BC	36-53	0,62	49,3	21,0	29,7	Bw	38-54	0,91	39,7	33,4	26,9
C	53-86	0,61	54,3	18,5	27,1	Ck	54-61	0,48	53,5	18,2	28,3
GEMİKONAĞI SERIAL						**SAMANYOLU SERIAL**					
Ap	0-18	2,45	46,1	35,2	18,7	Ap	0-20	1,41	61,9	18,8	19,2
A2	18-35	1,83	43,4	31,3	25,3	Ac	20-33	0,35	76,8	12,4	10,7
Bw	35-71	1,44	36,6	35,8	27,6	C	33-53	0,29	76,9	12,4	10,7
2Ck	71-113	0,35	39,6	42,9	17,6	Ckm	53-63	0,12	55,9	28,1	16,0
2C	113-135	0,17	32,3	30,8	36,9	2A	63-101	0,12	31,8	31,6	36,6
						2Ck	101-130	0,06	27,7	41,3	31,1

Table B.1 The texture and organic matter characteristic of TRNC's soil series (Dinç et al., 2000) (con't)

Horizon	Depth	Organic Matter	Sand	Silt	Clay	Horizon	Depth	Organic Matter	Sand	Silt	Clay
	cm	%	%				cm	%	%		
KALKANLI SERIAL						**SEDEFDÜZÜ SERIAL**					
Ap	0-14	1,07	59,3	17,4	23,2	Ap	0-14	0,83	95,0	1,3	3,7
A2	14-30	0,65	59,3	16,4	24,2	A2	14-37	0,38	87,8	4,4	7,8
C1	30-53	0,35	45,4	24,0	30,6	A1b	37-53	0,35	67,8	15,9	16,3
C2	53-81	0,23	45,4	26,1	28,5	A2b	53-78	0,24	59,2	13,9	26,8
C3	81-99	0,17	51,6	21,9	26,4	Acb	78-99	0,45	36,5	20,1	43,4
						Ckb	99-120	0,39	35,1	24,0	40,9
KÜÇÜKERENKÖY SERIAL						**GEÇİTKÖY SERIAL**					
Ap	0-15	1,53	48,1	22,7	29,2	Ap	0-16	2,02	44,7	22,7	32,6
A2	15-32	1,42	46,8	23,8	29,4	Bw	16-36	0,77	35,5	18,8	45,7
C	32-60	0,73	43,7	22,8	33,5						
KARAAĞAÇ SERIAL						**GÜLEK SERIAL**					
Ap	0-21	1,44	39,5	30,7	29,8	Ap	0-10	1,79	57,1	29,0	14,0
Ac	21-41	1,26	34,3	31,8	33,9	A2	Eki.19	1,04	54,7	29,2	16,2
Ck	41-100	0,51	33,7	34,7	31,7	Ck1	19-62	0,71	27,3	41,8	30,9
						Ck2	62-100	0,48	39,7	42,0	18,3
						C	100-140	0,28	60,5	30,6	9,0
MAGUSA SERIAL						**GÜNEŞKÖY SERIAL**					
Ap	0-7	2,25	53,0	19,5	27,5	Ap	0-15	4,97	55,6	25,7	18,8
A2	Tem.37	0,74	53,5	13,1	33,4	Ac	15-30	0,96	59,1	24,4	16,5
AB	37-53	0,64	48,8	15,3	35,9	Ck	30-50	0,74	65,7	20,0	14,3
Bw1	53-70	0,58	48,5	12,3	39,2						
Bw2	70-130	0,17	40,4	18,5	41,1						
MERSİNLİK SERIAL						**GÜRPINAR SERIAL**					
A1	0-12	3,18	42,8	24,9	32,3	A1	0-8	2,91	67,5	22,4	10,1
A2	Ara.38	0,84	38,9	22,7	38,4	AC	Ağu.13	1,74	64,2	21,5	14,3
A3	38-55	0,83	40,4	20,8	38,9						
Ab	55-76	0,93	35,4	18,9	45,7						
Cb	76-150	0,23	49,4	18,5	32,2						
POLAT PAŞA SERIAL						**DENİZLİ SERIAL**					
Ap	0-16	0,73	41,6	22,4	36,0	A	0-21	1,44	56,8	27,2	16,0
A2	16-45	0,70	54,5	22,2	23,3	C1	21-51	0,29	73,8	16,6	9,6
						C2	51-80	0,12	48,7	33,3	18,0

Table B.1 The texture and organic matter characteristic of TRNC’s soil series (Dinç et al., 2000) (con’t)

Horizon	Depth	Organic Matter	Sand	Silt	Clay	Horizon	Depth	Organic Matter	Sand	Silt	Clay
	cm	%	%				cm	%	%		
TEKNELİK SERIAL						**DİPKARPAZ SERIAL**					
Ap	0-13	2,43	45,1	30,6	24,3	A	0-15	2,91	43,0	33,7	23,4
Ac	13-28	1,96	48,8	26,7	24,5	C	15-100	1,32	30,2	37,0	32,8
C	28-80	1,65	46,4	37,4	16,2						
TINAZTEPE SERIAL						**DÜZOVA SERIAL**					
Ap	0-18	2,19	51,8	23,1	25,2	Ap	0-10	1,76	23,6	37,2	39,2
Ac	18-38	1,38	58,2	19,9	21,9	Ad	Eki.45	1,19	20,9	33,3	45,9
C	38-78		42,6	25,5	31,9	Ass3	45-80	1,16	23,0	29,0	48,0
						C	g	0,53	32,6	34,8	32,6
TOPÇUKÖY SERIAL						**GEÇİTKALE SERIAL**					
Ap	0-14	1,97	37,3	32,8	30,0	Ap	0-10	1,66	27,2	43,0	29,8
Ad	14-31	0,90	45,8	26,4	27,8	A2	10--25	0,95	16,5	51,5	32,0
Ac	31-48	0,51	33,1	26,6	40,3	C1	25-56	0,86	22,8	49,4	27,8
C	48-92	0,51	26,9	32,8	40,3	Css2	56-100	0,76	19,9	39,3	40,8
						C3	100-150	0,50	35,6	36,7	27,7
PAMUKLU SERIAL						**YEDİDALGA SERIAL**					
Ap	0-18	1,74	41,2	24,0	34,8	Ap	0-17	1,57	66,2	21,8	12,0
A2	18-30	1,53	37,3	25,3	37,4	A2	17-38	0,64	66,7	19,4	14,0
AB	30-42	0,87	32,8	25,4	41,8	C	38-100	0,42	64,7	23,8	11,6
Bt1	42-61	0,83	39,1	20,2	40,8						
Bt2	61-92	0,62	33,8	18,4	47,8						
YENİ ERENKÖY SERIAL											
Ap	0-20	1,16	47,8	33,8	18,4						
A2	20-35	0,86	48,1	34,7	17,2						
Ac	35-54	0,51	48,1	32,6	19,3						
C	54-84	0,17	62,7	24,2	13,0						

Table B.2 Name of the serials, abbreviation, soil texture and calculated AWC values.

	Name of the soil serial	**Abbreviation**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**AWC (mm)**
1	Balıkesir	Ba	19.16	41.00	39.84	73.08
2	Cengiz Topel	Ct	55.39	29.33	15.28	44.79
3	Cengizköy	Ck	32.71	43.14	24.15	57.00
4	Çakıldere	Cd	59.29	27.99	12.78	41.88
5	Derindere	Dd	39.20	34.60	26.13	57.32
6	Erdemli	Ed	26.84	54.26	18.93	53.82
7	Güvercinlik	Gr	12.55	22.90	64.53	95.31
8	Güzelyurt	Gy	24.56	47.63	27.81	61.79
9	Kanlıdere	Kd	20.68	36.67	42.66	75.15
10	Lefke	Le	24.97	34.61	40.40	72.33
11	Margo	Mg	26.25	32.97	40.82	72.44
12	Piyale Paşa	Pp	26.44	31.91	41.67	73.12
13	Yeşilırmak	Ye	32.95	45.86	21.21	54.48
14	Yukarı Yeşilırmak	Yy	59.98	27.29	12.73	41.68
15	Acıkuyu	Ac	44.99	30.52	24.49	54.73
16	Akıncılar	Ar	23.79	29.32	46.89	78.08
17	Akova	Ak	46.26	29.54	24.20	54.23
18	Alsancak	Al	60.89	23.98	15.14	43.53
19	Karaoğlanoğlu	Ko	31.35	37.65	30.98	63.06
20	Karpaz	Kp	13.95	40.75	45.32	78.79
21	Lefkoşa	Lf	38.99	32.86	28.15	59.08
22	Mallıdağ	Md	67.60	23.95	8.46	36.48
23	Meydancık	My	57.76	20.79	21.45	49.51
24	Altıok	Ao	37.87	24.84	37.27	67.01
25	Ambarlık	Ab	54.91	17.01	28.07	55.70
26	Aydınköy	An	20.39	37.04	42.62	75.19
27	Aygün	Ag	28.87	28.32	42.85	73.62
28	Bostancı	Bs	40.83	17.78	41.39	69.88
29	Serhatköy	Sk	35.54	40.86	23.66	56.01
30	Şahinkuyu	Sh	36.25	27.75	36.01	66.30
31	Üçtaş	Uc	26.81	31.94	41.27	72.70
32	Yayla	Yl	31.35	35.41	33.24	64.97
33	Zümrütköy	Zk	48.40	21.19	30.41	59.03
34	Çamurova	Co	14.73	24.57	60.69	91.62
35	Çayönü	Cy	10.21	25.42	64.35	95.65
36	Göller	Gr	36.35	17.35	46.33	74.99
37	Salamis	Ss	38.55	17.29	44.16	72.70
38	Türkmenköy	Tm	26.90	28.25	44.85	75.70
39	Bademliköy	Bd	23.70	36.28	24.29	55.41
40	Demirhan	Dm	32.93	38.94	28.12	60.31

Table B.2 Name of the serials, abbreviation, soil texture and calculated AWC values.

	Name of the soil serial	**Abbreviation**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**AWC (mm)**
41	Eğlence	Ec	32.93	38.94	28.12	59.55
42	Gemikonağı	Gm	38.96	36.55	24.53	56.03
43	Kalkanlı	Kn	50.78	22.05	27.17	55.79
44	Küçükerenköy	Ke	45.68	23.06	31.26	60.32
45	Karaağaç	Kr	35.02	33.26	31.72	62.92
46	Mağusa	Ma	46.19	16.1	37.7	65.65
47	Mersinlik	Mn	44.05	20.03	35.92	64.59
48	Polatpaşa	Pt	49.91	22.27	27.82	56.52
49	Teknelik	Tk	46.64	34.29	19.07	49.82
50	Tınaztepe	Tt	48.69	23.52	27.79	56.75
51	Topçuköy	Tp	33.12	30.46	36.42	67.29
52	Yedidalga	Yd	65.34	22.52	12.13	40.06
53	Yeni Erenköy	Yr	53.24	30.28	16.47	46.25
54	Düzova	Dv	22.13	31.91	45.96	77.63
55	Geçitkale	Gk	25.88	41.99	32.13	65.17
56	Pamuklu	Pm	36.66	21.67	41.67	70.99
57	Denizli	Dz	60.24	25.44	14.33	42.97
58	Dipkarpaz	Dp	32.11	36.48	31.41	63.26
59	Geçitköy	Gt	39.59	20.53	39.88	68.86
60	Gülek	Gl	44	36.92	19.07	50.37
61	Güneşköy	Gn	60.68	23.03	16.29	44.54
62	Gürpınar	Gp	66.23	22.05	11.72	39.52
63	Meriç	Mr	51.19	30.44	18.37	48.27
64	Samanyolu	Sy	48.82	26.66	24.52	53.97
65	Sedefdüzü	Sd	61.83	13.73	24.44	51.19
66	Tatlısu	Ts	30.39	45.7	23.91	57.28
67	Yıldırım	Yd	62.67	23.39	13.97	42.18
68	Zaferburnu	Zb	75	9.9	15.1	40.56
69	Aslanköy	As	36.4	34.08	29.52	60.77
70	Aytepe	Ay	27.49	33.57	38.95	70.6
71	Boğaziçi	Bo	45.59	19.57	34.83	67.29
72	Çatalköy	Cl	48.36	16.55	35.15	63.05
73	Doğancı	Dc	41.87	17.31	40.84	69.21
74	Ercan	Er	52.08	15.08	32.88	60.36
75	Esentepe	Es	57.82	20.09	22.15	50.1
76	Gaziler	Gz	41.09	20	38.89	67.71
77	Kırklar	Kk	68.67	22.65	8.68	36.45
78	Mormenekşe	Mm	34.08	23.02	42.9	72.56
79	Nergisli	Nr	50.11	26.08	23.81	53.1
80	Paşaköy	Pk	38.01	32.83	29.15	60.12

Table B.2 Name of the serials, abbreviation, soil texture and calculated AWC values.

	Name of the soil serial	**Abbreviation**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**AWC (mm)**
81	Yarköy	Yk	32.09	35.62	32.28	64
82	Yeniceköy	Yn	49.15	20.25	30.59	59.02
83	Zincirli	Zc	55.05	23.52	21.48	50.11
84	Gelincik	Gc	43.42	38.31	18.27	49.81
85	İnönü	İn	22.52	30.03	47.45	78.81
86	Türkeli	Tr	17.24	31.88	50.94	82.87
87	Altınova	At	54.68	25.43	19.89	48.84
88	Nalbantoğlu	Nb	41.36	40.51	18.09	50.07
89	Çamlıbel	Cb	30.86	12.98	56.15	84.42
90	Örenler	Or	46.63	37.09	16.27	47.45
91	Tepebaşı	Tb	74.26	13.02	12.72	38.7
92	Boltaşlı	Bt	52	22.8	25.2	53.88
93	Değirmenlik	Dg	28.93	35.71	35.34	67.23
94	Çınarlı	Cn	13.71	40.08	46.11	79.49
95	Çobanyeri	Cp	15.74	34.87	49.35	81.82
96	Güzelyalı	Ga	47.09	25.8	27.11	56.51
97	Mehmetçik	Mh	40.01	25.93	34	63.8
98	Pınarlı	Pr	38.2	27.93	33.83	64.04
99	Çakmaktepe	Cm	51.4	30	18.6	48.43
100	Beşparmak	Bp	52	25.5	22.45	51.54
101	Girne	Gi	9.1	32.5	58.4	90.86
102	Günebakan	Gb	37.76	44.25	18	50.76
103	Karadağ	Kr	66.27	12.95	20.77	47.17
104	Koruyaka	Ky	58.96	26.49	14.58	43.46
105	Ümittepe	Üm	68.57	20.52	10.91	38.35
106	Akdeniz	Ad	79.84	10.35	9.83	35.1
107	Gaziveren	Gv	93.1	1.87	4.94	28.19
108	Pirhan	Pr	51.79	34.06	14.11	44.55

APPENDIX C

MATLAB PROGRAM FOR PALMER DROUGHT SEVERITY INDEX

```
function PDSI_Monthly

% Calculation of Monthly Palmer Drought Severity Index(PDSI)

%INPUT:
% 1. Montly Rainfall of the station (Sept-Aug)
% 2. Montly Temperature of the station (Sept-Aug)
% 3. AWC of the station

%
================================================================
% READING RAINFALL, TEMP. AND AWC DATA
%
================================================================
AWC=53.89; % (mm)

% Reading monthly rainfall of the station
P=xlsread('MonthlyRainfall.xlsx');

% Reading monthly temp of the station
T=xlsread('MonthlyTemp.xlsx');
 [r,c]=size(T)


%
================================================================
% CALCULATION OF POTENTIAL EVAPORATION (PE) USING
THORNTHWAITE METHOD
%
================================================================

% Monthly Heat index
j=(T/5).^(1.514) %(Nx12)
j

% Annual Heat index
J=sum(j')%(Nx1)
J

% a
a=((675*10^-9)*(J.^3))-((771*10^-7)*(J.^2))+((179*10^-4)*J)+0.492;
a

% Potential Evapotranspiration (PEx)in mm:
```

```
for k=1:r;
    for i=1:c;
        PEx(k,i)=16*(((10*T(k,i))/J(k)).^a(k));
    end
end
PEx

% cx value for 35 N latitude
cx=0.97;

% Adjusted Potential Evapotranspiration(PEad)
PEad=(PEx).*cx

%=========================================================


%=========================================================
% CALCULATION OF STORAGE,RUNOFF, EVAPOTRANPIRATION, EVAP.
LOSS,& RECHARGE
%=========================================================

% Storage (S) at the beginning of the month:
% Runoff (RO) at the end of the month:
% Evapotranspiration (ET) at the end of the month:

for k=1:r;
    S(k,1)=0; %Storage at the begining of September is equal to zero.
    for i=1:c-1
        if (S(k,i)+P(k,i)-PEad(k,i)<=0);
            S(k,i+1)=0;
            RO(k,i)=0;
            ET(k,i)=S(k,i)+P(k,i);
        else
            if (S(k,i)+P(k,i)-PEad(k,i)>=AWC);
                S(k,i+1)=AWC;
                RO(k,i)=(S(k,i)+P(k,i)-PEad(k,i)-AWC);
                ET(k,i)=PEad(k,i);
            else
                S(k,i+1)=S(k,i)+P(k,i)-PEad(k,i);
                RO(k,i)=0;
                ET(k,i)=PEad(k,i);
            end
        end
    end
    % For the last month.
    i=12;
    if (S(k,i)+P(k,i)-PEad(k,i)<=0);
        RO(k,i)=0;
```

```
        ET(k,i)=S(k,i)+P(k,i);
    else
        if (S(k,i)+P(k,i)-PEad(k,i)>=AWC);
            RO(k,i)=(S(k,i)+P(k,i)-PEad(k,i)-AWC);
            ET(k,i)=PEad(k,i);
        else
            RO(k,i)=0;
            ET(k,i)=PEad(k,i);
        end
    end
end

S
PEad
ET
RO


% Storage at the Surface(SS) and Storage at the underlying(SU)layers
% at the beginnig of the month.
for k=1:r
    for i=1:c
        if S(k,i)<=25
            SS(k,i)=S(k,i);
            SU(k,i)=0;
        else
            SS(k,i)=25;
            SU(k,i)=S(k,i)-25;
        end
    end
end

SS
SU

% Evaporation Losses(LS,LU,L)
for k=1:r;
    for i=1:c
        if PEad(k,i)>P(k,i);
            LS(k,i)=min(SS(k,i),(PEad(k,i)-P(k,i)));
            LU(k,i)=((PEad(k,i)-P(k,i))-LS(k,i))*SU(k,i)/AWC;
        else
            LS(k,i)=0;
            LU(k,i)=0;
        end

    end
end
```

```
LS
LU
L=LS+LU

% Recharge(R)
for k=1:r
    for i=1:c-1
        if S(k,i+1)>=S(k,i);
            R(k,i)=S(k,i+1)-S(k,i);
        else
            R(k,i)=0;
        end
    end
    % for the last month (August)
    R(k,12)=0;
end
SS
SU
R

%=================================================================
% HYDROLOGIC CALCULATIONS: OTHER POTENTIAL TERMS
%=================================================================
% a)Potential Recharge(PR)
PR=AWC-(SS+SU)
% b)Potential Loss(PL)
PLS=min(PEad,SU)
PLU=(PEad-PLS).*SU./AWC
PL=PLS+PLU
% c)Potential Runoff(PRO)
PRO=AWC-PR
%PRO2=SS+SU

%=================================================================
% CLIMATIC COEFFICIENTS
%=================================================================
% Average Values
Px=mean(P)
ETx=mean(ET)
PEadx=mean(PEad)
Rx=mean(R)
PRx=mean(PR)
ROx=mean(RO)
PROx=mean(PRO)
Lx=mean(L)
PLx=mean(PL)

% Climatic coefficients(aj,bj,cj,dj)
```

```
% Note that if any of the average potential terms is equalt to zero,
% the coefficient should be taken as zero as well.
for i=1:c
    % aj:
    if PEadx(i)==0;
        aj(i)=0;
    else
        aj(i)=ETx(i)/PEadx(i);
    end
    % bj:
    if PRx(i)==0;
        bj(i)=0;
    else
        bj(i)=Rx(i)/PRx(i);
    end
    % cj:
    if PROx(i)==0;
        cj(i)=0;
    else
        cj(i)=ROx(i)/PROx(i);
    end
    % dj:
    if PLx(i)==0;
        dj(i)=0;
    else
        dj(i)=Lx(i)/PLx(i);
    end
end
aj
bj
cj
dj

%=============================================================
% CLIMATICALLY APPROPRIATE FOR EXISTING CONDITION (CAFEC)
VALUES
%=============================================================

% CAFEC Values
for k=1:r
    ETj(k,:)=aj.*PEad(k,:);
    Rj(k,:)=bj.*PR(k,:);
    ROj(k,:)=cj.*PRO(k,:)
    Lj(k,:)=dj.*PL(k,:)
end
ETj;
Rj;
ROj;
```

```
Lj;


% CAFEC Values of Precipitation (P)
for k=1:r
   for i=1:c
      CAFECP(k,i)=ETj(k,i)+ROj(k,i)+(Rj(k,i)-Lj(k,i));
      if CAFECP(k,i)<0;
         CAFECP(k,i)=0;
      else
         CAFECP(k,i)=CAFECP(k,i);
      end
   end
end
CAFECP
size(CAFECP)
size(P)

%===========================================================
% MOISTURE ANOMALY INDEX (Z-INDEX)
%===========================================================

% Departures
d=P-CAFECP;
D=abs(d);
Dx=mean(D);

%Weighting factor
for i=1:c
   E(i)=((PEadx(i))+Rx(i)+ROx(i))/(Px(i)+Lx(i));
   KH(i)=(1.5*(log10(E(i))))+(2.8*(1/Dx(i)))+0.5;
end
Dx
KH
SUM_DxKH=sum(Dx.*KH)
Kj=(17.67/SUM_DxKH)*KH


% Z-index
for k=1:r
   Z(k,:)=Kj.*d(k,:);
end

Z

r
c
%===========================================================
```

```
% PALMER DROUGHT SEVERITY INDEX (PDSI-INDEX)
%==========================================================
% First: Convert Z-Matrix into a Z-Vector
ZZ(1:c)=Z(1,:);
for k=1:r-1
    start=(k*12)+1;
    finish=(k+1)*c;
    ZZ(start:finish)=Z(k+1,:);
end
size(ZZ)
Zvector=ZZ';
size(Zvector)

% Calculation of PDSI:
X(1)=Zvector(1)/3;
for m=2:(r*c)
    X(m)=(0.897*(X(m-1)))+((Z(m))/3);
end

PDSI=X'
size(PDSI)

%Saving PDSI valuse in an excel file.
xlswrite('PDSI.xlsx',PDSI) %

 Plotting PDSI as Histogram
 figure(1)
 [Y]=hist(PDSI)

Plotting PDSI Time Series
figure(2)
plot(PDSI)
```

APPENDIX D

The results of Palmer Drought Severity Index for 33 stations

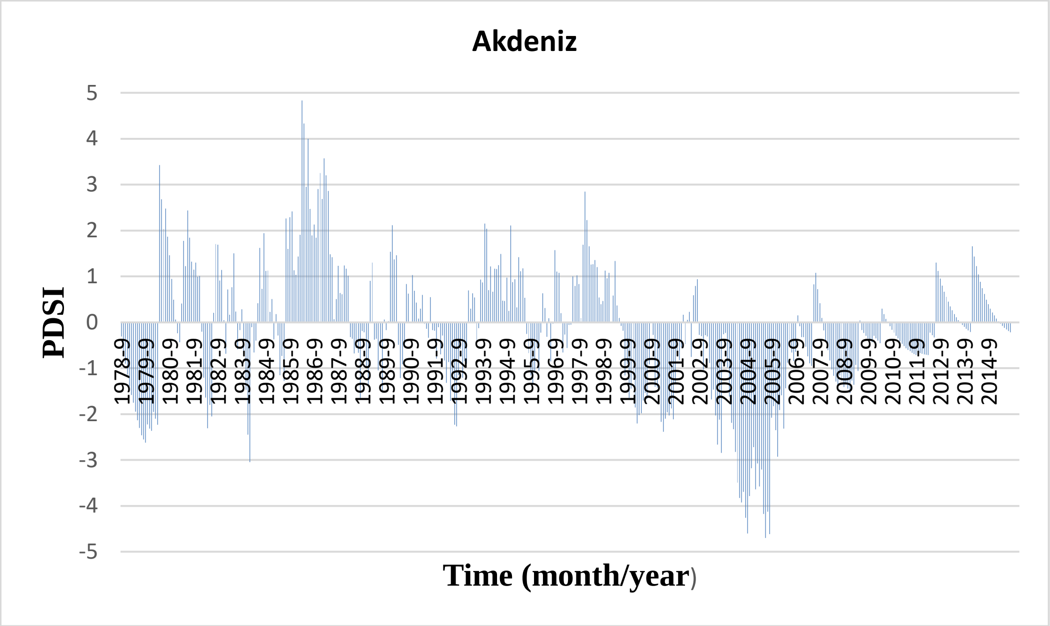

Figure D.1 Palmer Drought Severity Index of Akdeniz

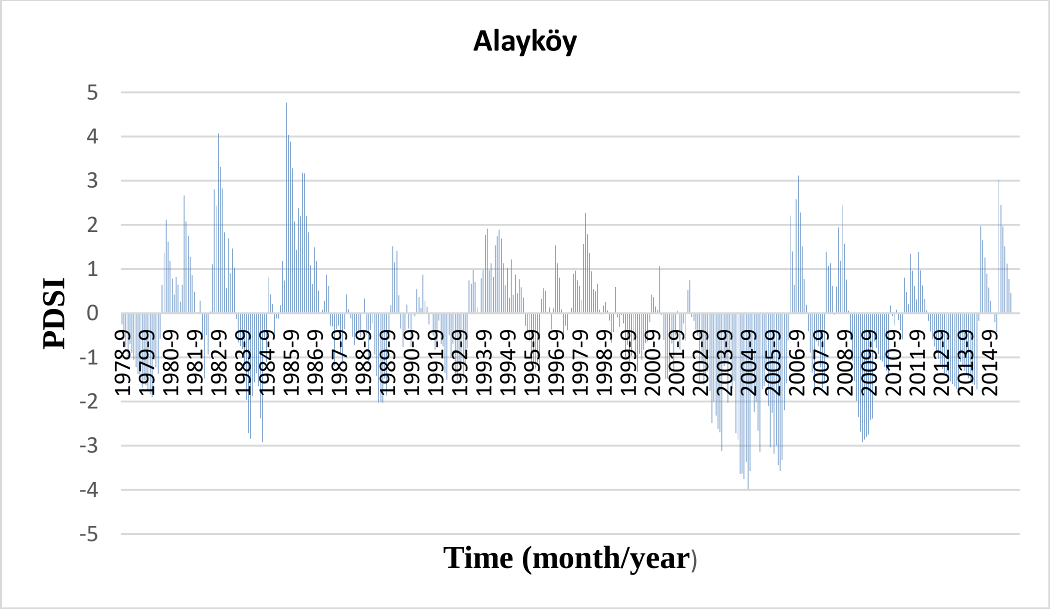

Figure D.2 Palmer Drought Severity Index of Alayköy

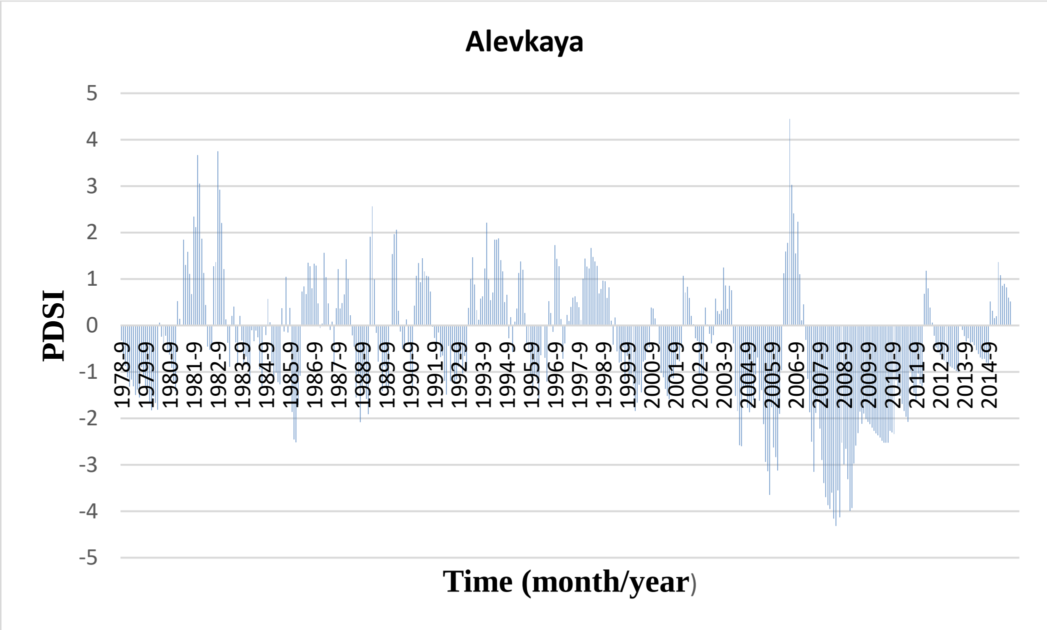

Figure D.3 Palmer Drought Severity Index of Alevkaya

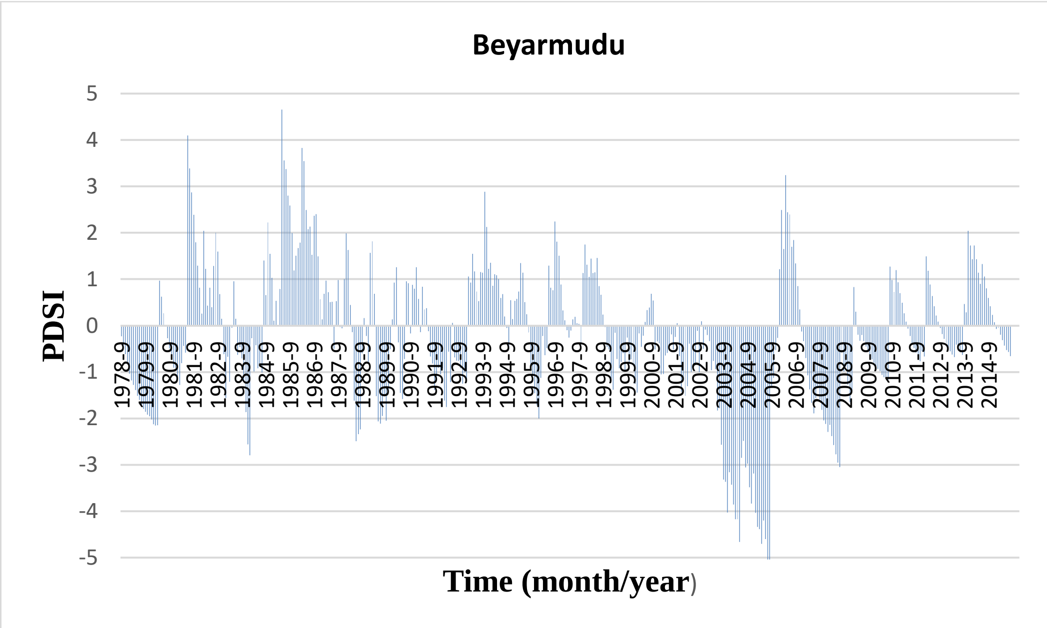

Figure D.4 Palmer Drought Severity Index of Beyarmudu

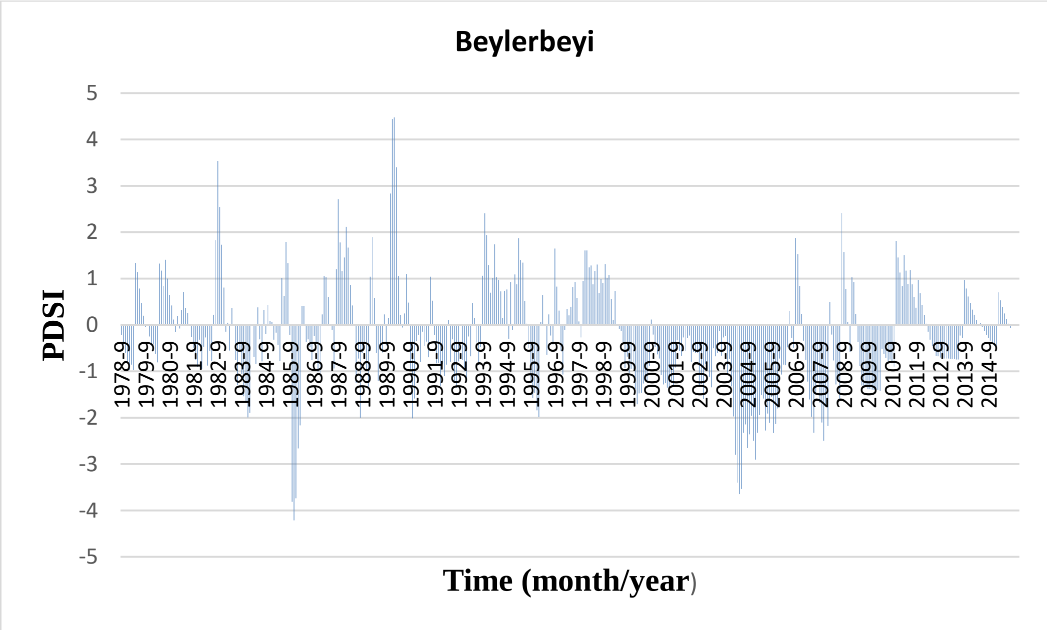

Figure D.5 Palmer Drought Severity Index of Beylerbeyi

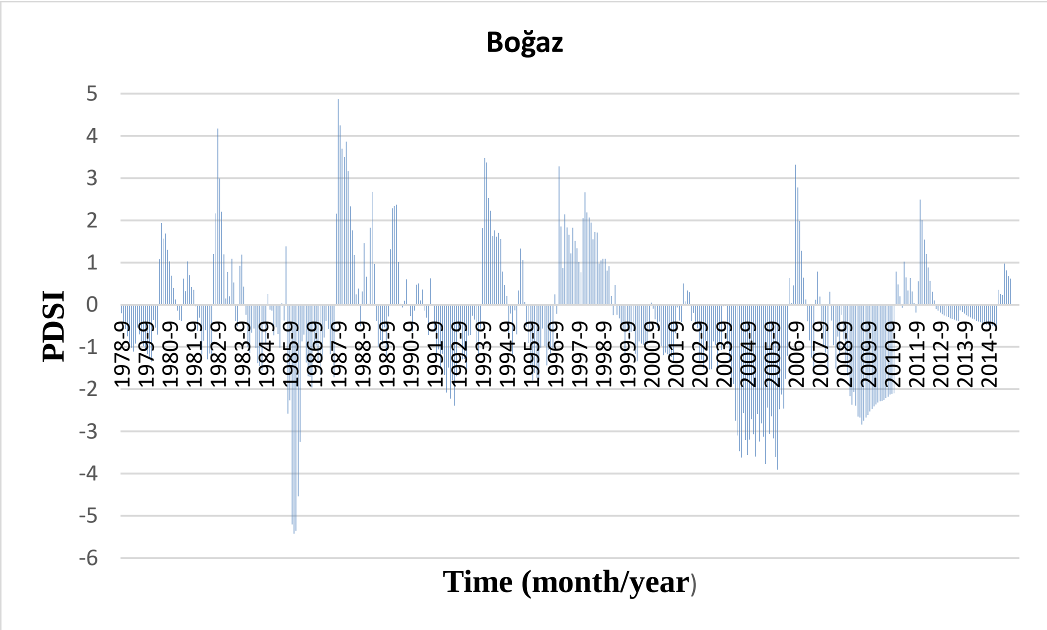

Figure D.6 Palmer Drought Severity Index of Boğaz

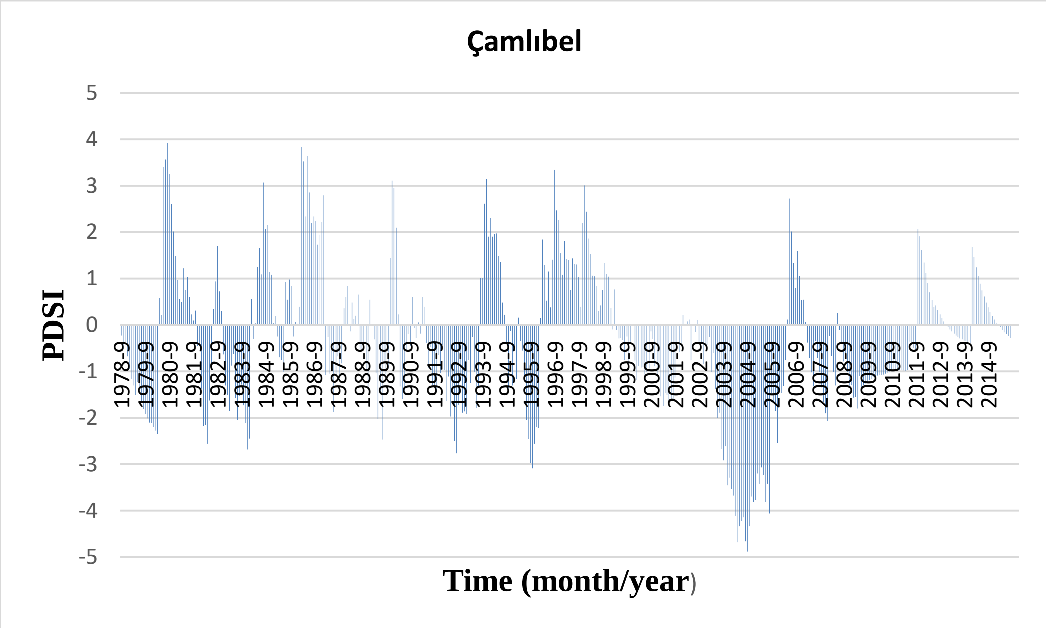

Figure D.7 Palmer Drought Severity Index of Çamlıbel

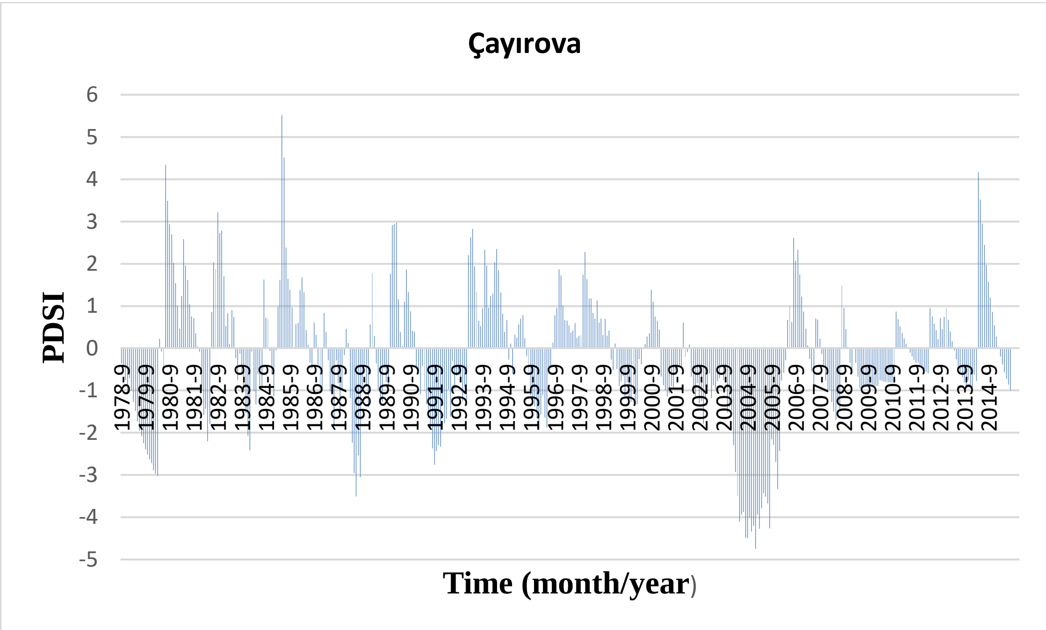

Figure D.8 Palmer Drought Severity Index of Çayırova

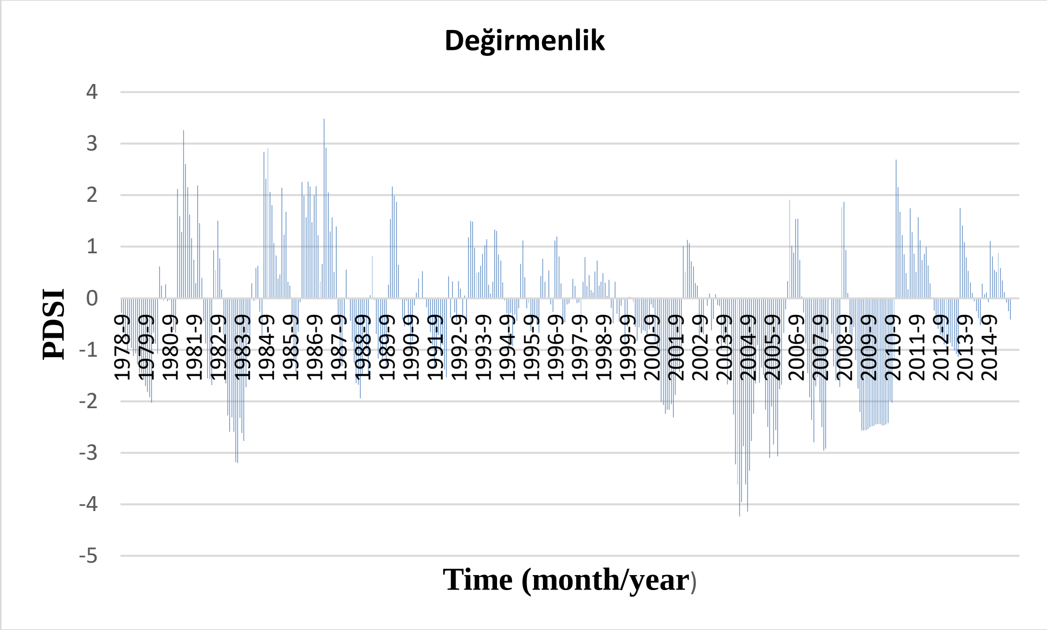

Figure D.9 Palmer Drought Severity Index of Değirmenlik

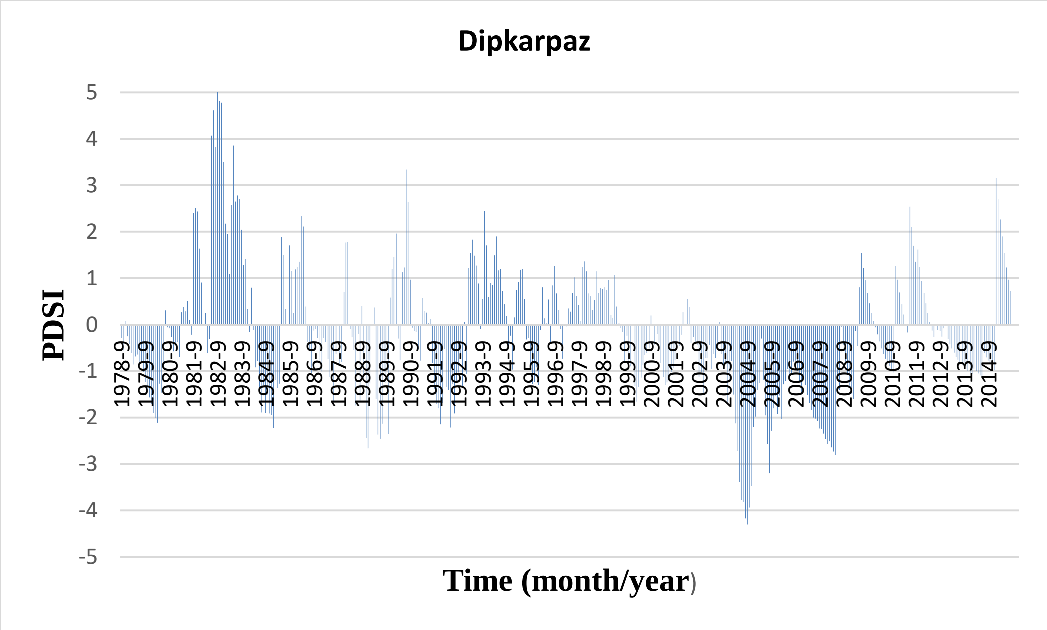

Figure D.10 Palmer Drought Severity Index of Dipkarpaz

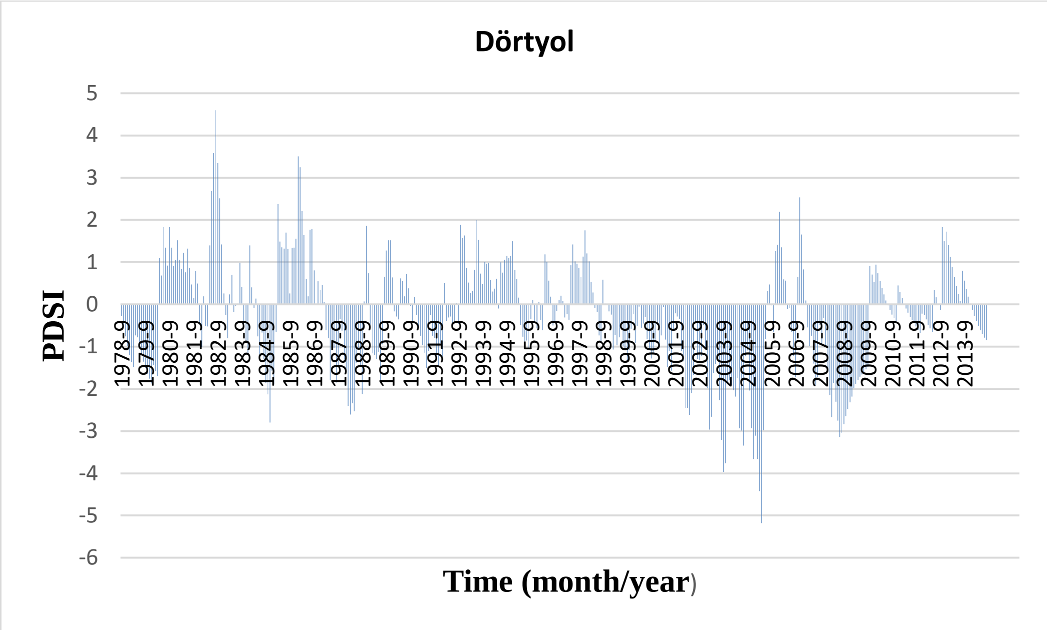

Figure D.11 Palmer Drought Severity Index of Dörtyol

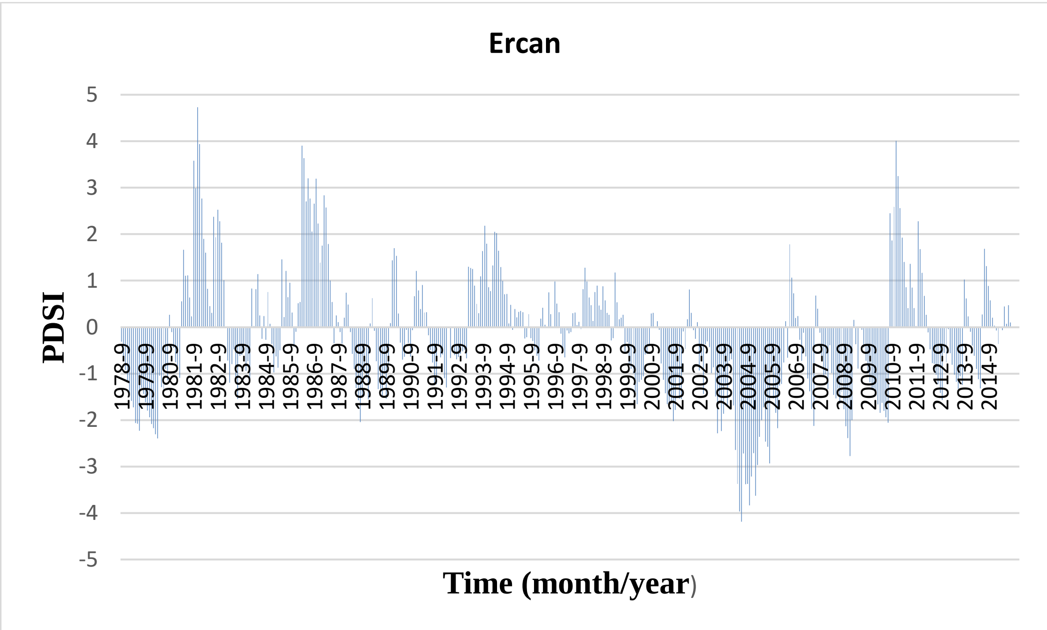

Figure D.12 Palmer Drought Severity Index of Ercan

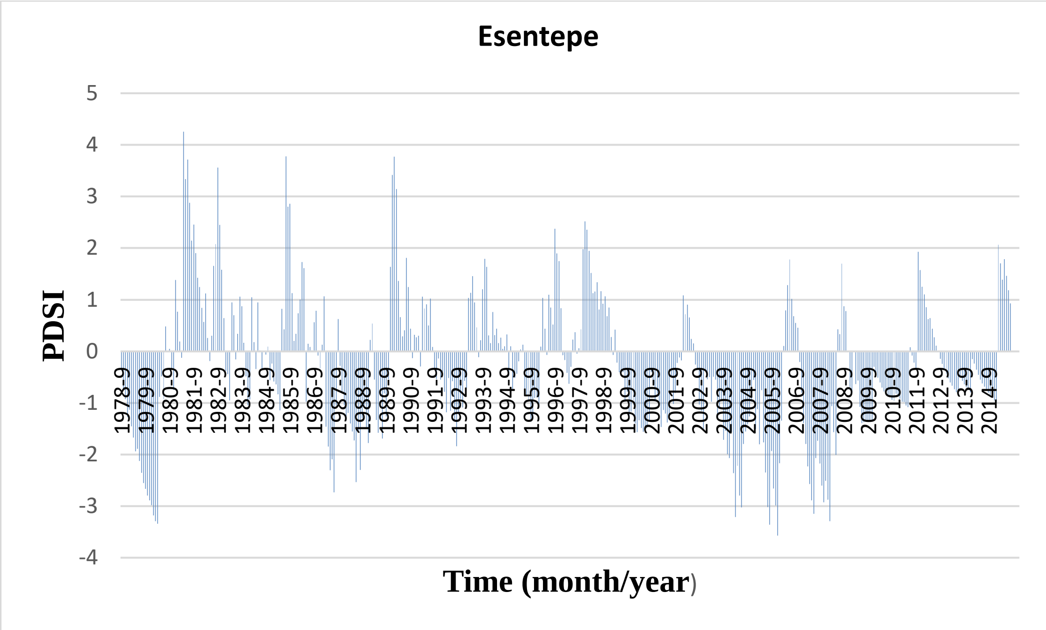

Figure D.13 Palmer Drought Severity Index of Esentepe

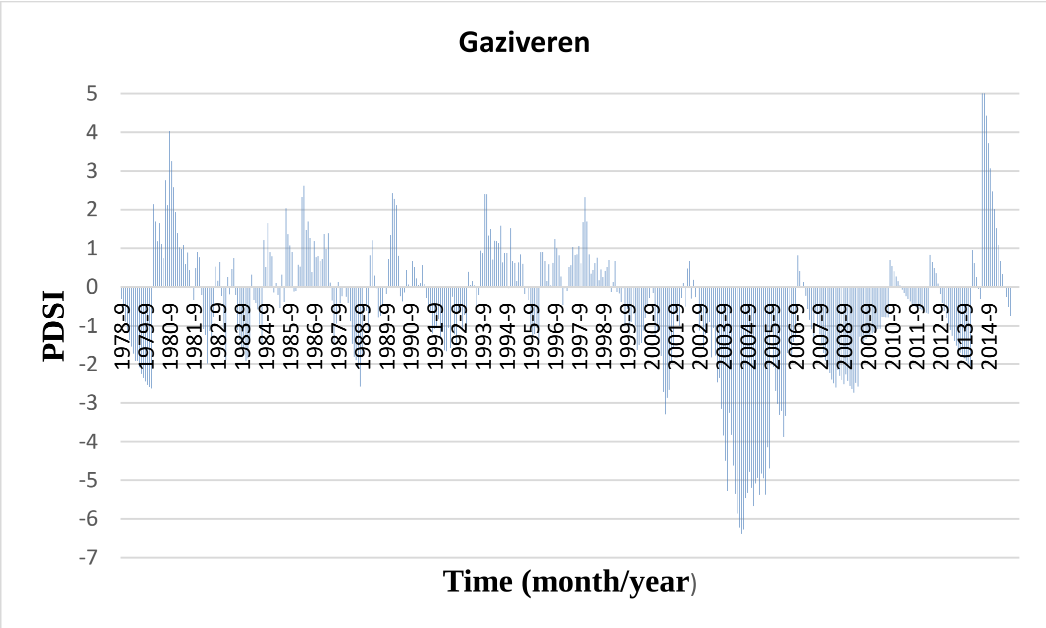

Figure D.14 Palmer Drought Severity Index of Gaziveren

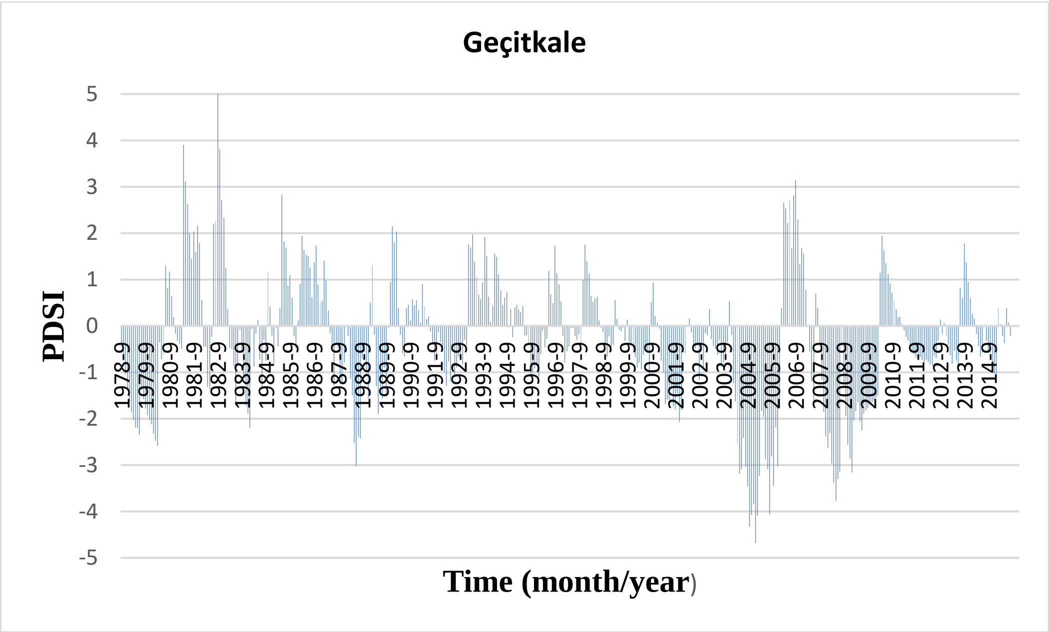

Figure D.15 Palmer Drought Severity Index of Geçitkale

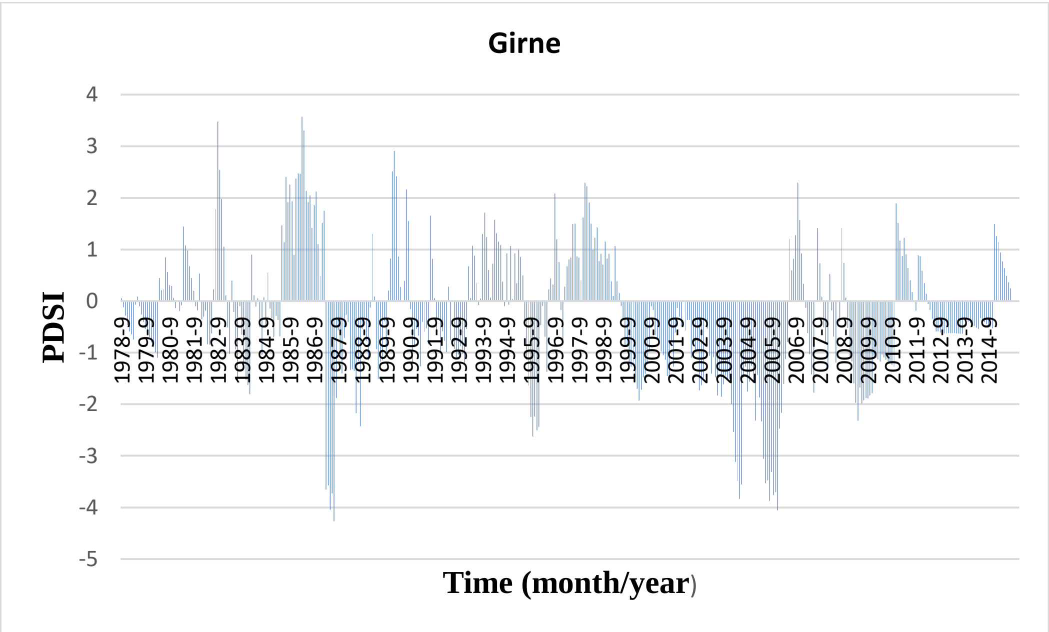

Figure D.16 Palmer Drought Severity Index of Girne

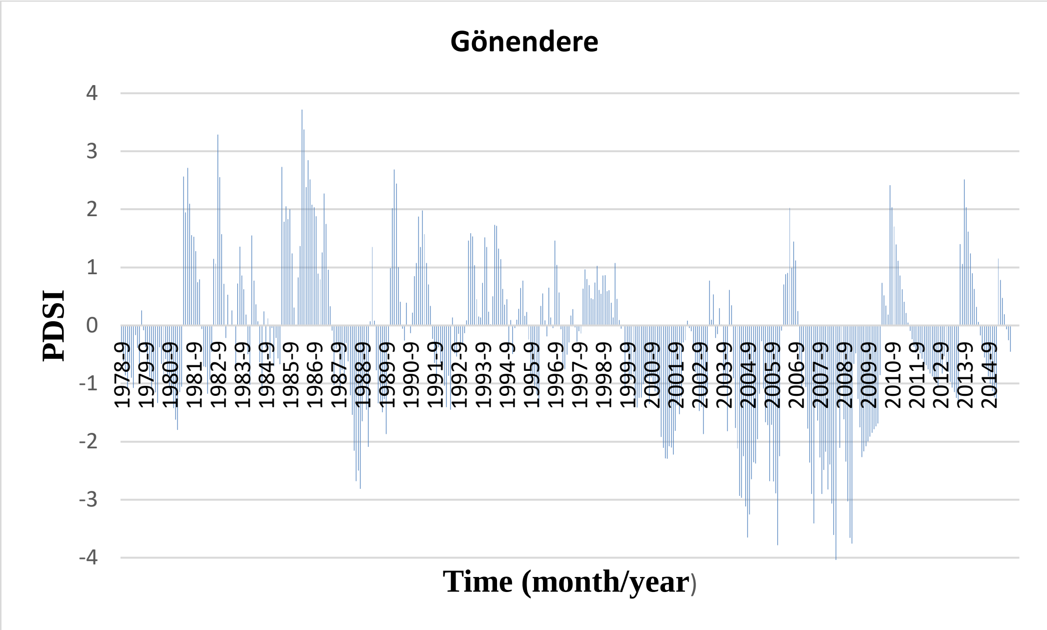

Figure D.17 Palmer Drought Severity Index of Gönendere

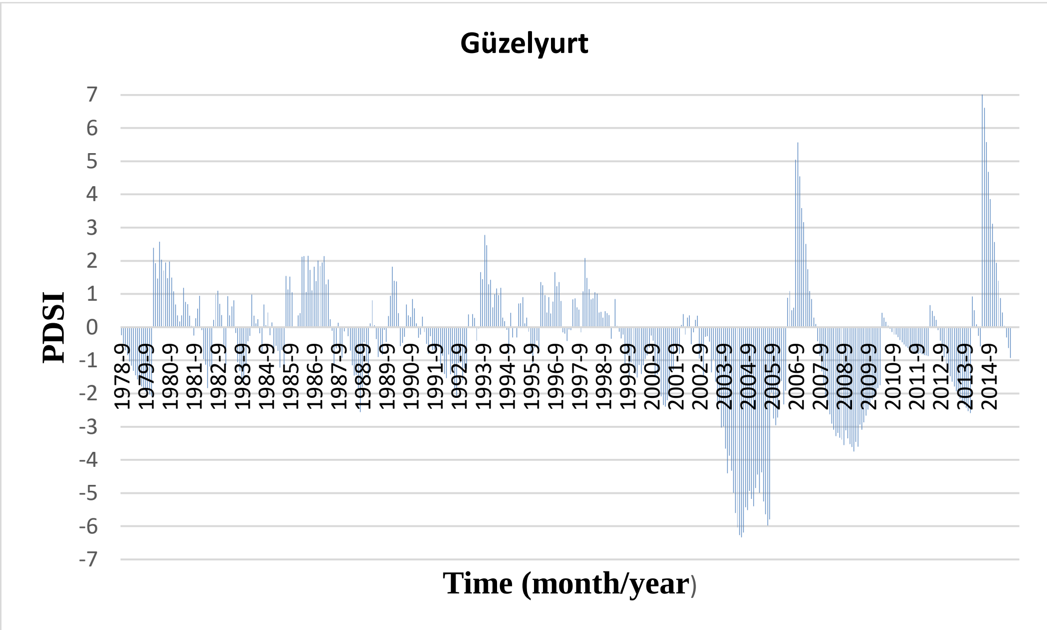

Figure D.18 Palmer Drought Severity Index of Güzelyurt

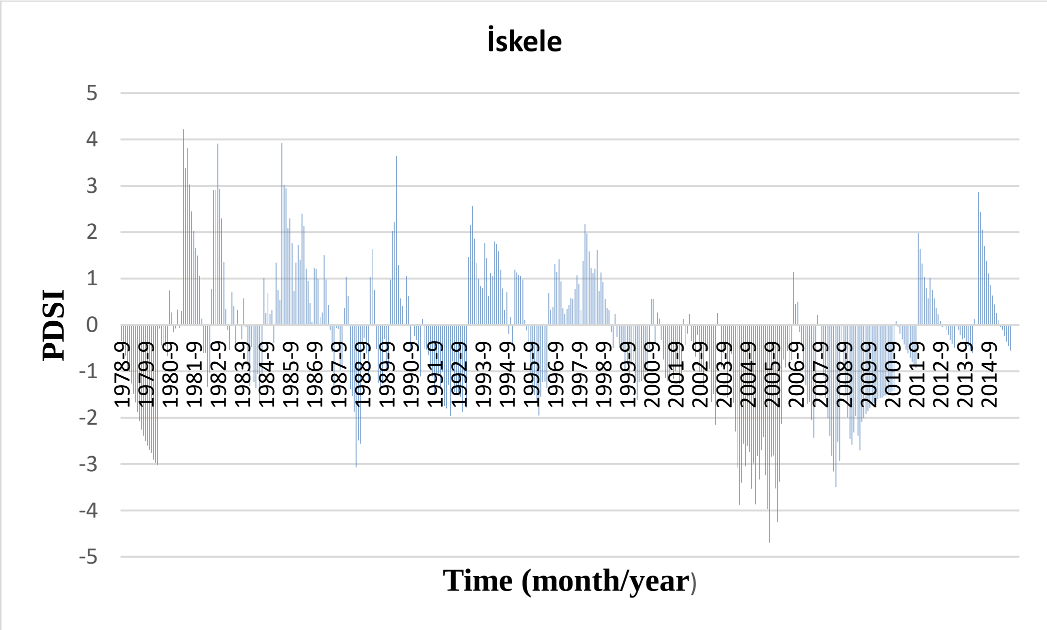

Figure D.19 Palmer Drought Severity Index of İskele

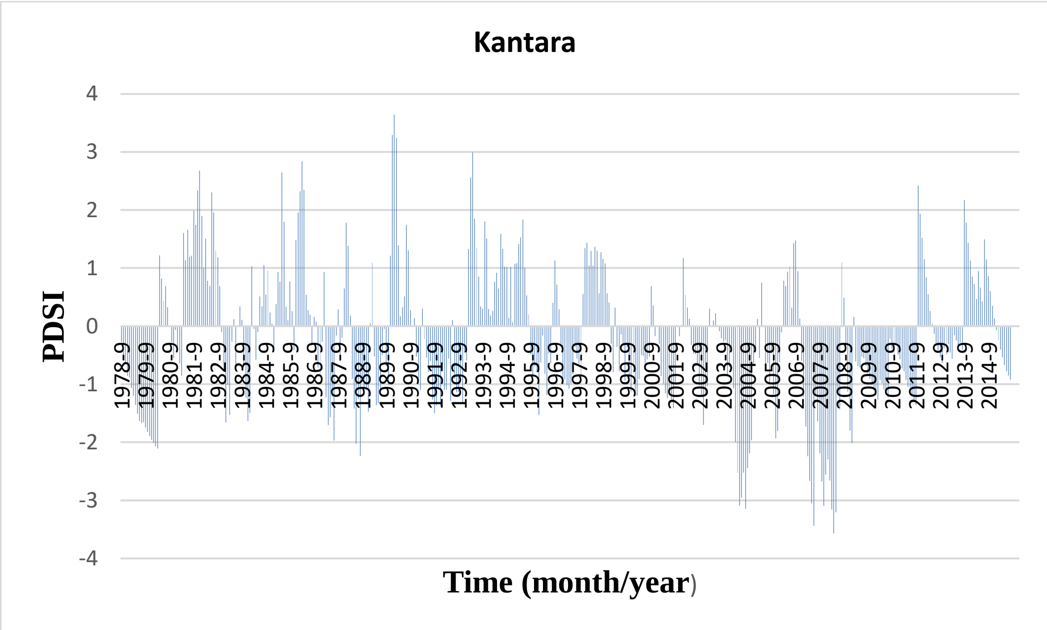

Figure D.20 Palmer Drought Severity Index of Kantara

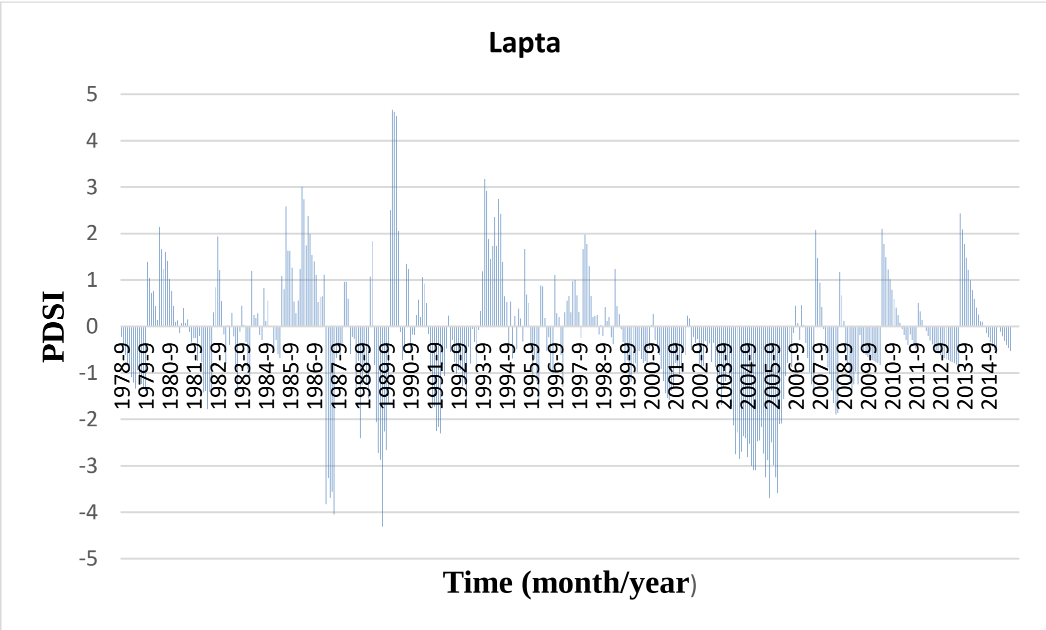

Figure D.21 Palmer Drought Severity Index of Lapta

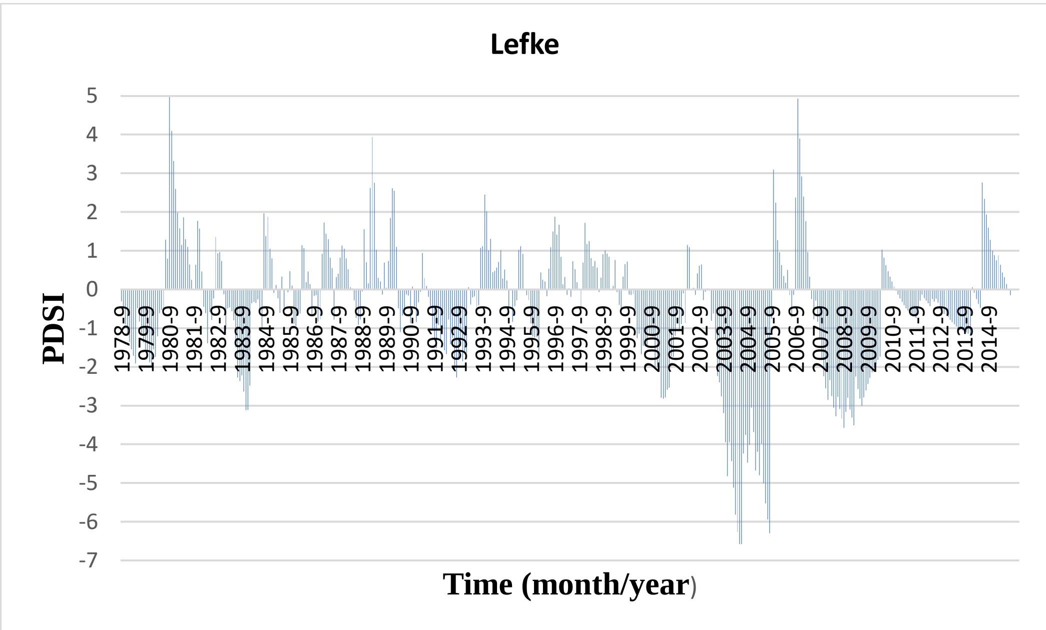

Figure D.22 Palmer Drought Severity Index of Lefke

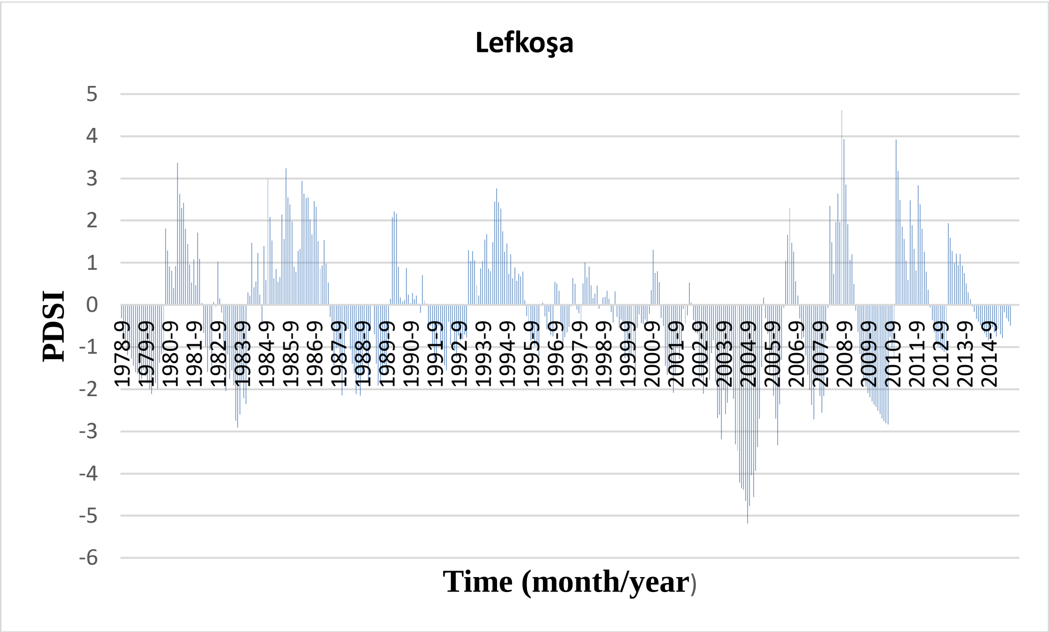

Figure D.23 Palmer Drought Severity Index of Lefkoşa

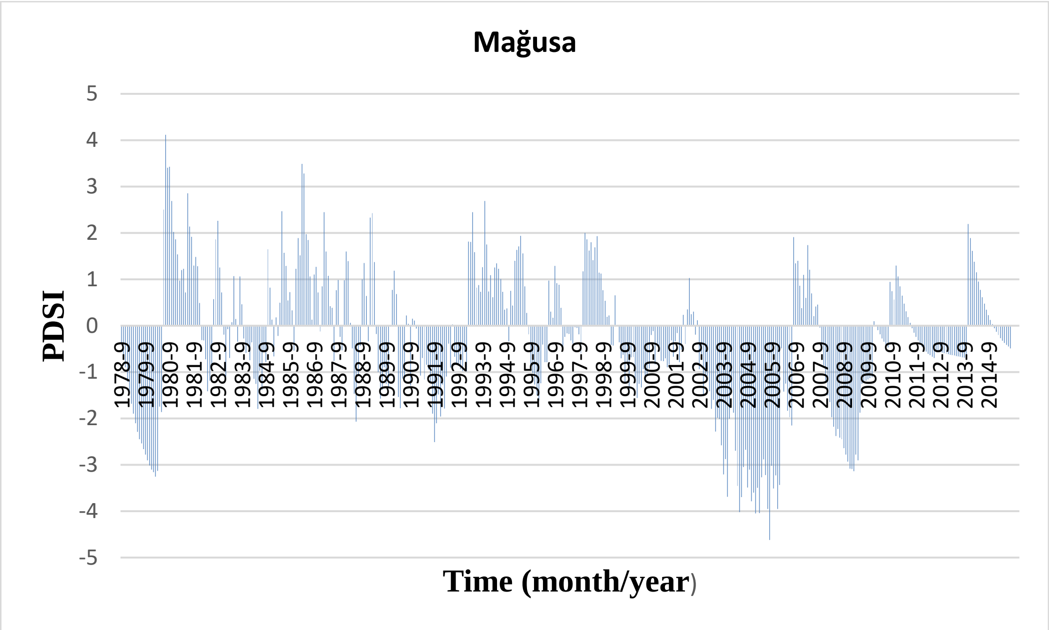

Figure D.24 Palmer Drought Severity Index of Mağusa

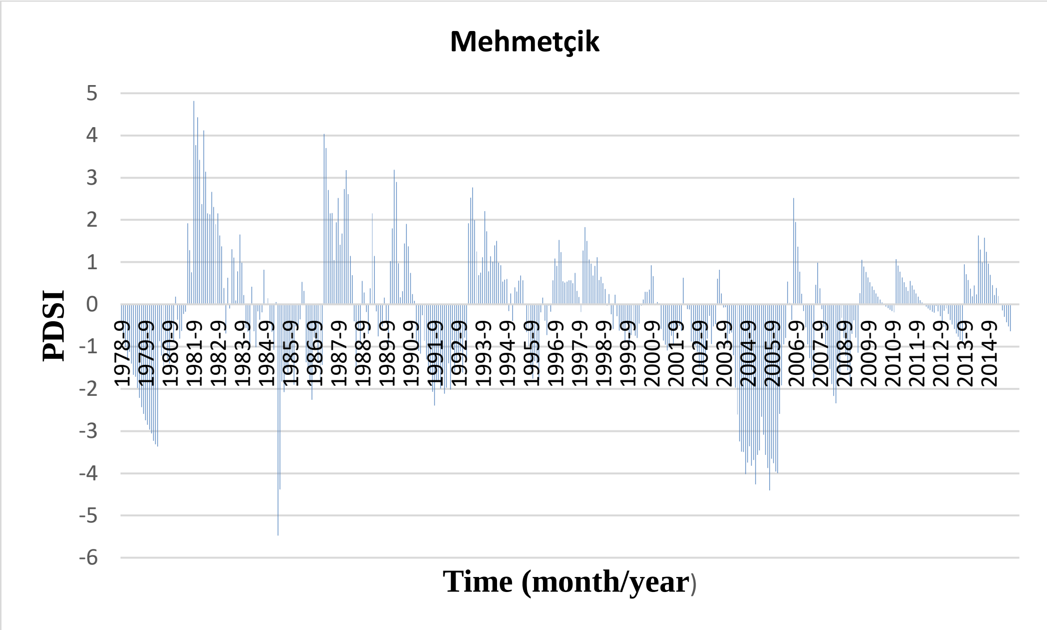

Figure D.25 Palmer Drought Severity Index of Mehmetçik

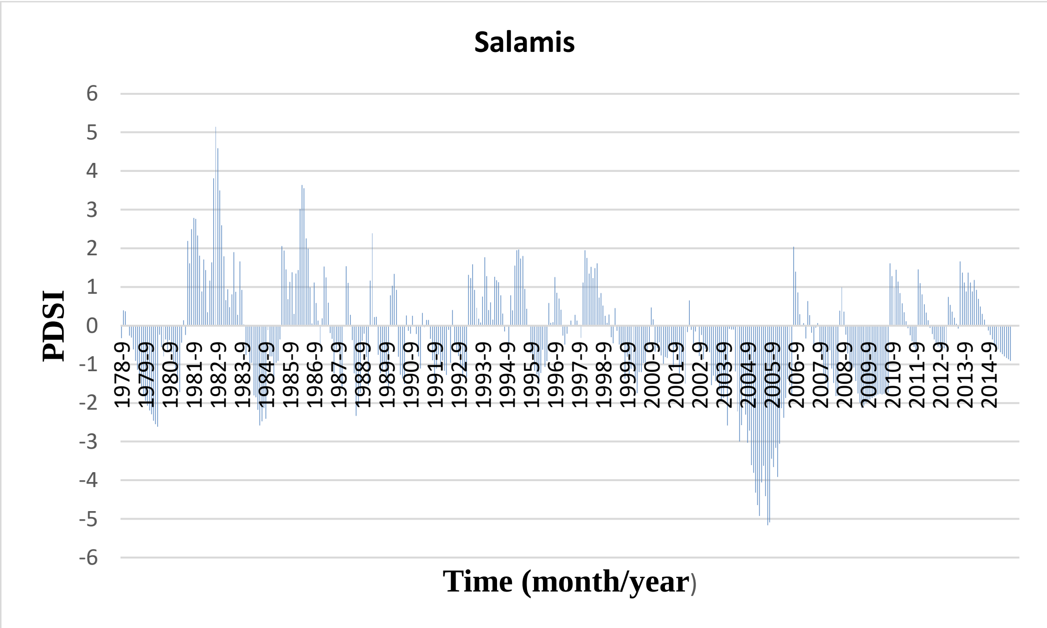

Figure D.26 Palmer Drought Severity Index of Salamis

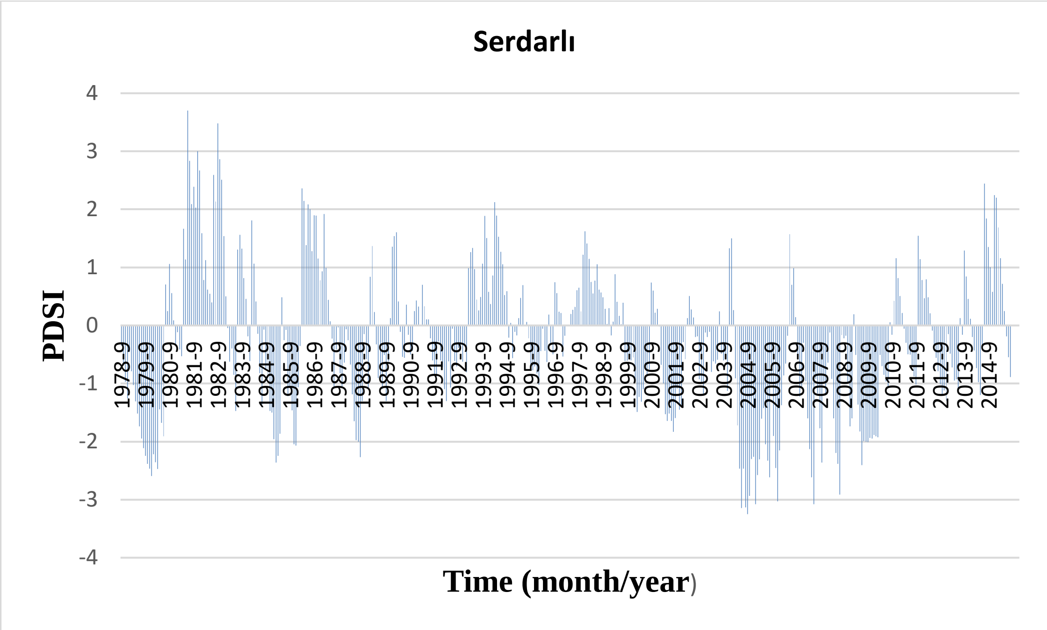

Figure D.27 Palmer Drought Severity Index of Serdarlı

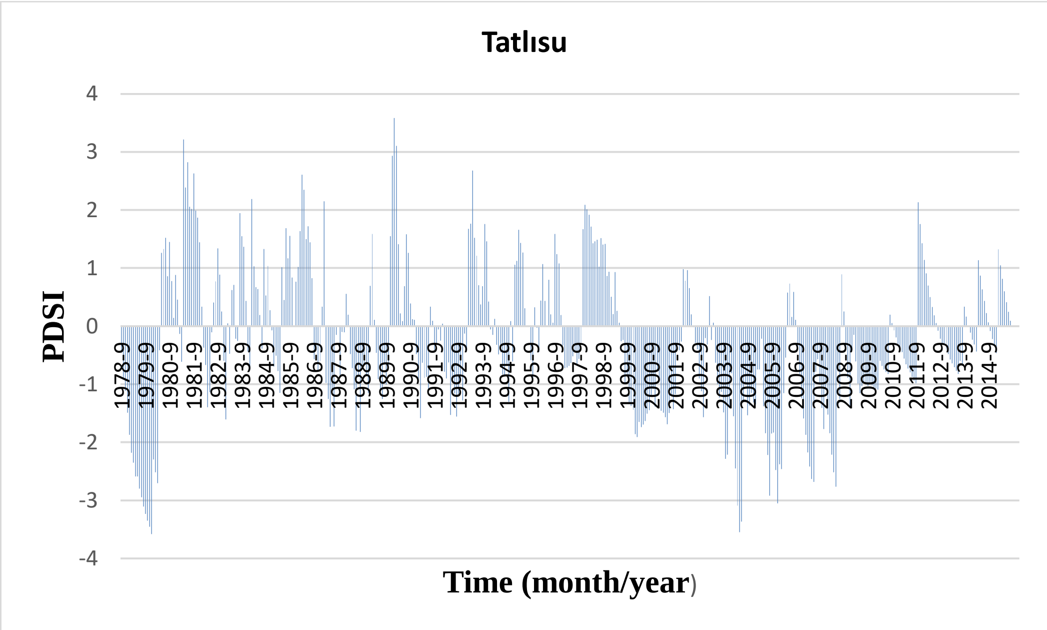

Figure D.28 Palmer Drought Severity Index of Tatlısu

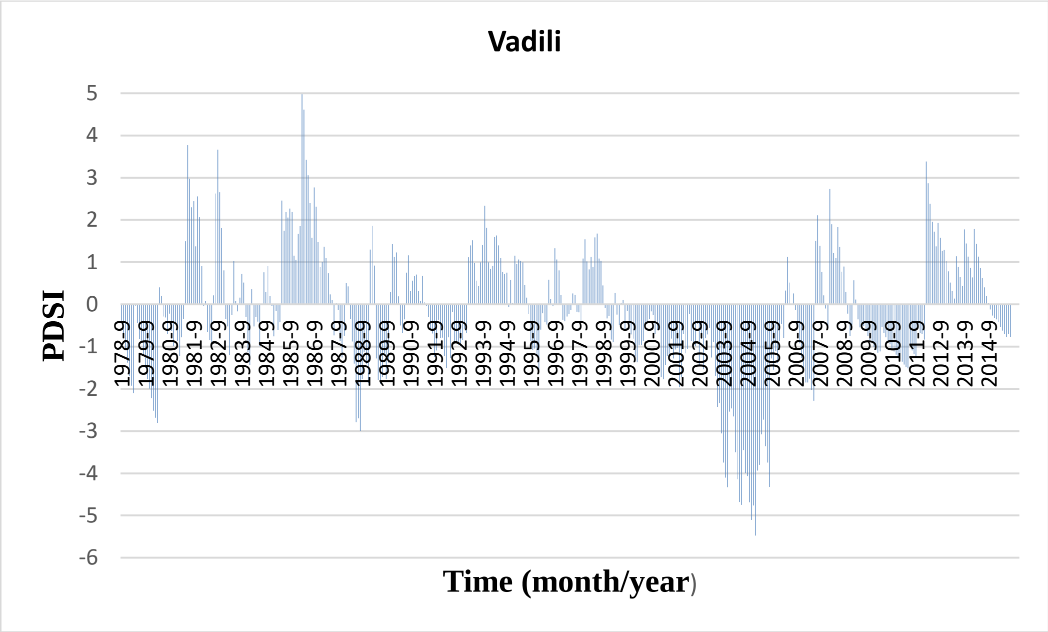

Figure D.29 Palmer Drought Severity Index of Vadili

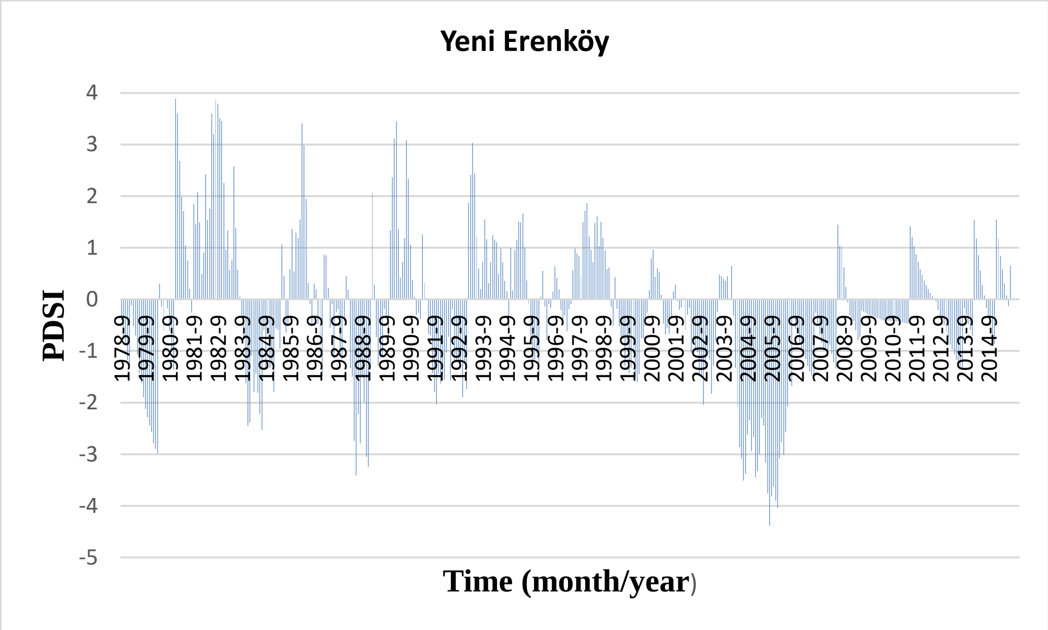

Figure D.30 Palmer Drought Severity Index of YeniErenköy

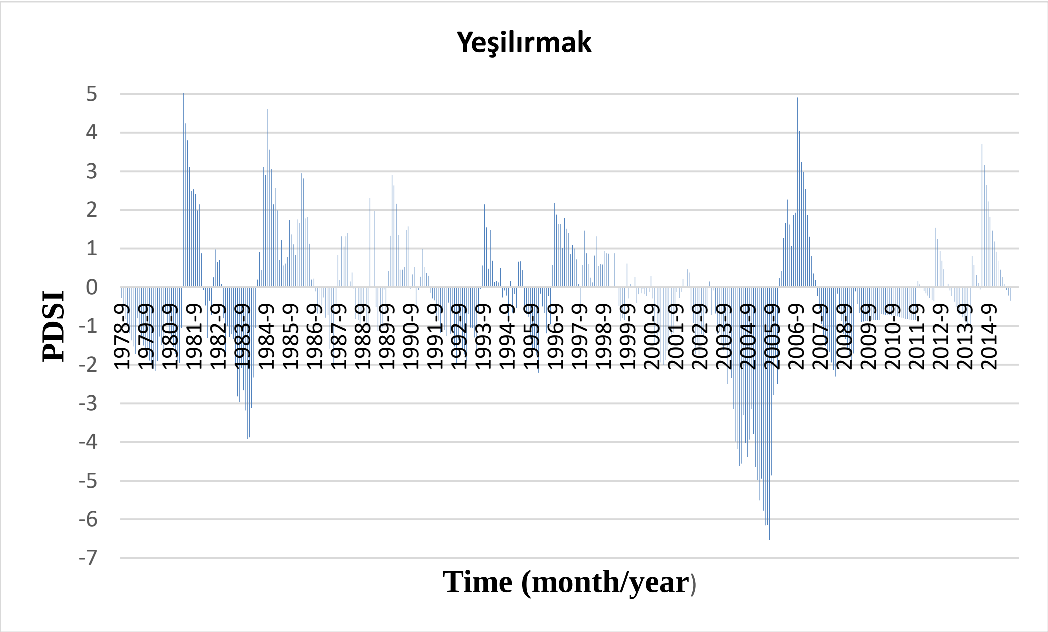

Figure D.31 Palmer Drought Severity Index of Yeşilırmak

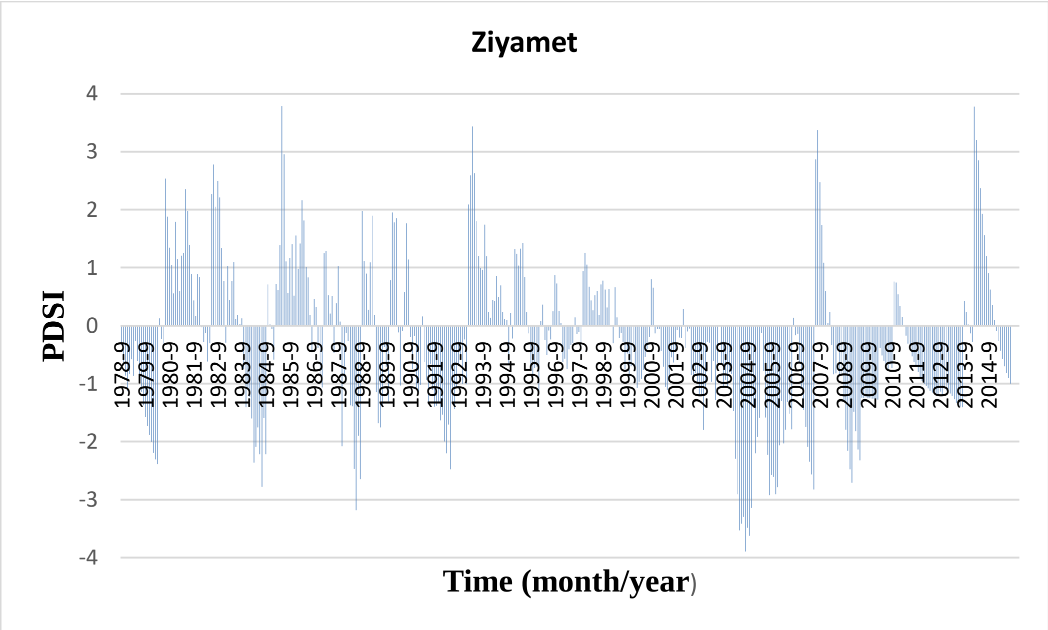

Figure D.32 Palmer Drought Severity Index of Ziyamet

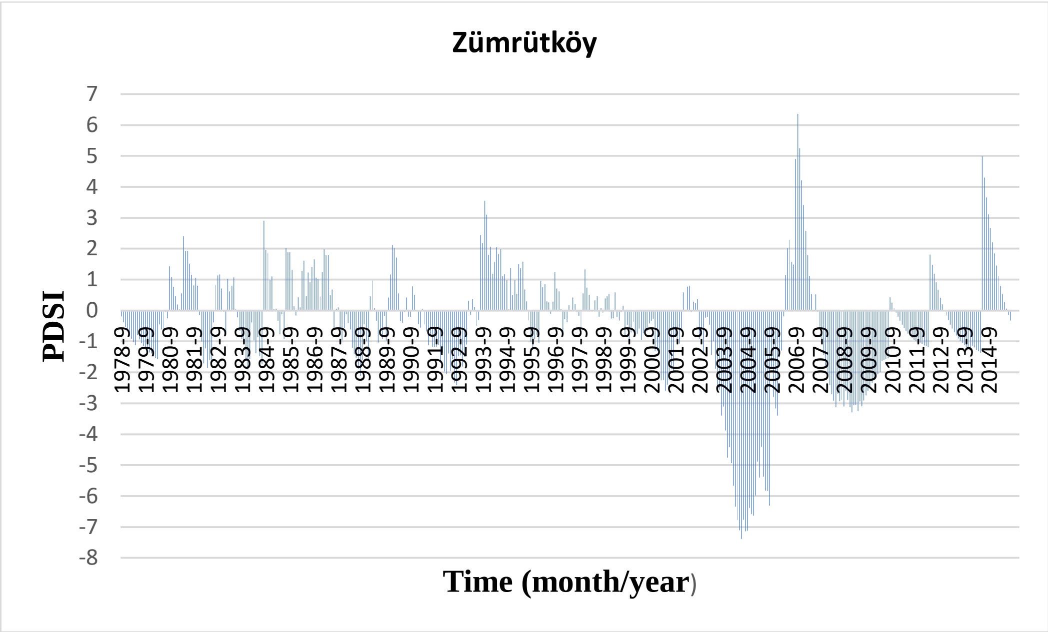

Figure D.33 Palmer Drought Severity Index of Zümrütköy

APPENDIX E

Table E.1 The result of Mann Kendall Trend Analysis in R-program

Name of the station	S	varS	Z	Name of the station	S	varS	Z
Çamlıbel	-5734	9758109	-1.8	Yeşilırmak	-3188	9758109	-1
Akdeniz	-13196	9758109	-4.2	Alayköy	-13562	9758109	-4.3
Lapta	-9818	9758109	-3.1	Lefkoşa	-6834	9758109	-2.2
Boğaz	-9620	9758109	-3.1	Ercan	-11678	9758109	-3.7
Girne	-12494	9758109	-4	Serdarlı	-10448	9758109	-3.3
Beylerbeyi	-10896	9758109	-3.5	Gönendere	-16844	9758109	-5.4
Değirmenlik	-9620	9758109	-3.1	Geçitkale	-10342	9758109	-3.3
Alevkaya	-16332	9758109	-5.2	Vadili	-8538	9758109	-2.7
Esentepe	-11426	9758109	-3.7	Dörtyol	-12550	8988936	-4.2
Tatlısu	-10808	9758109	-3.5	Beyarmudu	-8880	9758109	-2.8
Kantara	-9004	9758109	-2.9	Salamis	-10856	9758109	-3.5
Zümrütköy	-13832	9758109	-4.4	İskele	-14522	9758109	-4.6
Lefke	-11674	9758109	-3.7	Çayırova	-4490	9758109	-1.4
Gaziveren	-17800	9758109	-5.7	Mehmetçik	-1816	9758109	-0.6
Güzelyurt	-18004	9758109	-5.8	Ziyamet	-17852	9758109	-5.7
DipKarpaz	-11674	9758109	-3.7	YeniErenköy	-7558	9758109	-2.4
GaziMagusa	-12862	9758109	-4.1				

In this test the confidence interval was 95% and the critical value is absolute value of 1.96 (|1.96|). If the Z value is greater than |1.96| and the S value is positive, this shows an upward trend whereas if S is negative, a downward trend is indicated. However, if the Z value is smaller than |1.96|, this means that there is not any trend in the time series.

APPENDIX F

Table F.1 Mean possible duration of sunlight, in units of 30 days of 12 hours each (Botkin, 1993; Thornthwaite, 1948).

	Latitude(Degrees)							
Month	**00.0**	**10.0**	**20.0**	**30.0**	**35.0**	**40.0**	**45.0**	**50.0**
January	1.04	1.00	0.95	0.90	0.87	0.84	0.80	0.74
February	0.94	0.91	0.90	0.87	0.85	0.83	0.81	0.78
March	1.04	1.03	1.03	1.03	1.03	1.03	1.02	1.02
April	1.01	1.03	1.05	1.08	1.09	1.11	1.13	1.15
May	1.04	1.08	1.13	1.18	1.21	1.24	1.28	1.33
June	1.01	1.06	1.11	1.17	1.21	1.25	1.29	1.36
July	1.04	1.08	1.14	1.20	1.23	1.27	1.31	1.37
August	1.04	1.07	1.11	1.14	1.16	1.18	1.21	1.25
September	1.01	1.02	1.02	1.03	1.03	1.04	1.04	1.06
October	1.04	1.02	1.00	0.98	0.97	0.96	0.94	0.92
November	1.01	0.98	0.93	0.89	0.86	0.83	0.79	0.76
December	1.04	0.99	0.94	0.88	0.85	0.81	0.75	0.70