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Determination of Meteorological and Hydrological Drought in Damlıca Creek Watershed in Çatalca-İstanbul, Turkey

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Abstract

Agricultural and Industrial water consumption increase with Industrial development, rapid population and urbanization in Thrace region of Turkey. Effect of drought increases with increasing of mean global temperature year by year in our region and the world. Drought is one of the most important results of climate change. The purpose of this study is to determine drought periods for Damlıca creek watershed in Çatalca. It was began in 1980 and finished in 2006. Its duration for precipitation observation is 27 and stream flow observation is 25 years. The seasonal precipitation distributions for autumn, winter, spring and summer are 28.0 %, 36.7 %, 23.1 % and 12.2 %, respectively. Drought analyses for meteorological and hydrological have been done using two methods (the Standardized Precipitation Index, the standardized Runoff Index). According to runoff values, 1990 year has been found to be extreme drought, for precipitation values, 1983, 1985 and 1990 years have been found to be severe drought.

Key words: Damlıca watershed, Drought, Standard Precipitation and Runoff Index

Introduction

Water is the most abundant substance on earth, the principal constituent of all living things, and a major force constantly shaping the surface of the earth. It is also a key factor in air-conditioning the earth for human existence and in influencing the progress of civilization.

Agricultural and Industrial water consumption increase with Industrial development, rapid population and urbanization in Thrace region of Turkey. Effect of drought increases with increasing of mean global temperature year by year in our region and the world.

Agricultural production affects four conditions these are Climate, Soil, Seed, and Agricultural methods respectively. As we know, 3 factors are controlled but climate conditions are not controlled. Climate is the most important factor timing of agricultural cropping like a seeding, irrigation, fertilization, harvesting etc.

As a natural disaster, drought develops slowly (Wilhite, 2000). There are many types of the drought like agricultural, meteorological, hydrological etc. Drought is a result of climate change. In recent years, many researchers focused on the effects of the climatic change and their effects on the earth's live. Thus, the importance of the description and determination or this phenomenon is increasing.

Drought is primarily caused when a geographic region receives little rain for an abnormally long time. A meteorological drought occurs when a drought is combined with increased temperatures and lower humidity. A drought can turn into an agricultural drought when irrigation water and soil moisture are insufficient for agriculture A hydrological drought develops when there is a reduction in river flow and underground water (Kurnaz L. 2014).

The purpose of this study is to determine drought periods (meteorological and hydrological) for long term precipitation data and stream flow data in Damlıca creek watershed in Çatalca. Observations were began in 1980 and finished in 2006. Its duration is 27 years.

Materials and Methods

Study area

Damlıca creek is a small watershed that is part of the Marmara Watershed in Thrace region in Turkey is far away 9 kilometers from Kumburgaz. The research watershed area (Figure.1) which locates at Northwest is 8.26 km2. The outlet of the basin is at the 41^0 06′ 04″ North longitude, the 28^0 25′ 00″ East latitude. Altitude of the watershed outlet is 110 meters. Damlıca is a dry creek it collects surface water and spring water that flows from Northwest to Southeast and joins to Tepecik River as a fourth degree tributary. And then, it flows Büyük Çekmece Lake which supplies drinking water for Istanbul.

Damlıca creek watershed rain and runoff observation network was found in 1980. Rainfall and runoff data for Damlıca creek are collected by means of three rain gauges and one water-level station. It is recorded the time distributions of runoff events, is located at the outlet of the watershed and near the 5:1 triangular weir (Bakanoğulları F. 2008).

Some characteristics of Damlıca watershed in Çatalca- İstanbul

-Watershed area(A) 8.26 square kilometres
-Watershed Length(LW): 4.10 kilometres
-Watershed Width(WW): 2.01 kilometres
-Watershed max. height(Hmax) : 258.0 meters
-Watershed min. height(Hmin): 110.0 meters
-Watershed median height(Hm): 148.0 meters
-Watershed average slope(SW) : % 5.9
-Total waterway length (Lu): 15.90 kilometres
-The Main waterway length(Ls):4.35 kilometres
-The Main waterway slope(Sa) :%2.15

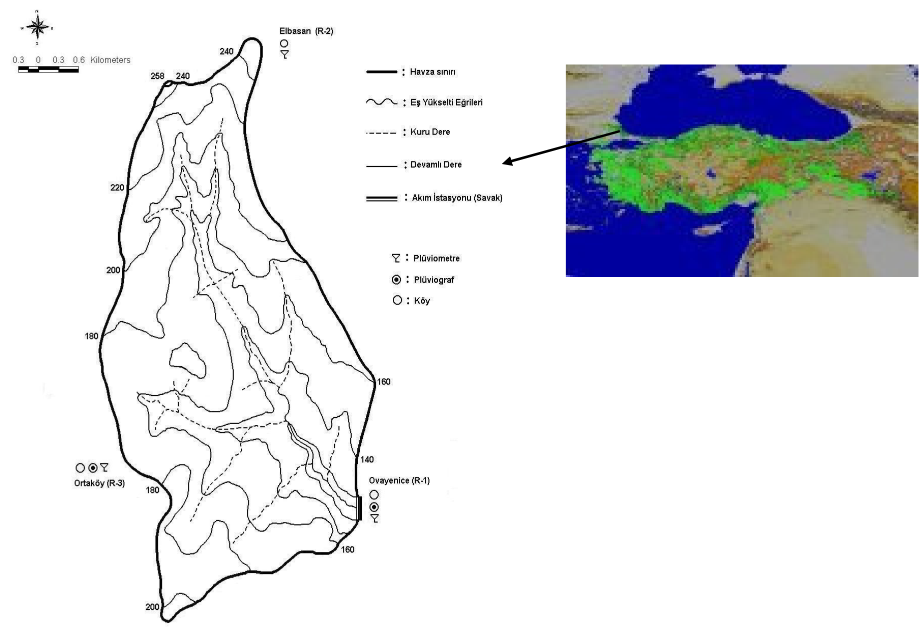

Figure 1. Location of Damlıca watershed precipitation and runoff stations

Methodology

The Standardized Precipitation Index (SPI) was developed to give a better representation of abnormal wetness and dryness than Palmer Index for drought monitoring.

McKee et al. (1993) suggested that the Palmer index is designed for agriculture, but does not accurately the hydrological impacts resulting from droughts of longer time scales. The palmer index was also applied within the United States and has little acceptance elsewhere (Kogan, 1995). Smith et al. (1993) suggested that it does not do well in regions where there are extremes in the variability of rainfall or runoff. (Yoo, W. et al. 2000)

The understanding that a deficit of precipitation has different impacts on the ground water, reservoir storage, soil moisture, snow pack, and stream flow led McKee et al. (1993) to developed the standardized Precipitation Index (SPI) for the purpose of defining and monitoring drought. The nature of the SPI allows determining the rarity drought or an anomalously wet event at a particular time scale for any location in the world that has a precipitation record for a continuous period of at least 30 years.

This method is illustrated in figure distribution to the standard normal distribution

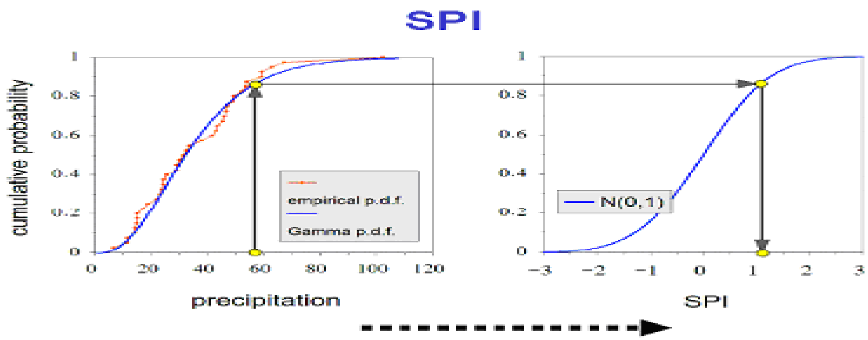

Figure.2 Example of equiprobability transformation from fitted gamma distribution to the standard normal distribution

The SPI is an index based on the probability for precipitation any time period. McKee et al. (1993) used the classification system that is normalized so that wetter and drier climates can be represented in the same way by the use of the SPI. In addition, wet periods can also be monitored using the SPI (McKee et al., 1993). They also defined the criteria for a "drought event" for any of the time scales. A deficit occurs any time that the SPI is negative. The SPI is probability based and was designed to be a spatially invariant indicator of drought that recognizes the importance of time scales in the analysis of water availability and water use. It is essentially a standardizing transform of the probability of the observed precipitation (Çaldağ, B et al. 2004).

The calculation for SPI is given with under equations;

$$\bar{X} = \sum_{i=1}^{M} Xi, \quad \sigma^2 = \frac{\sum_{i=1}^{M}(\bar{X}-X_i)^2}{M-1},$$

$$\sigma = \sqrt{\sigma^2}, \quad \text{SPI} = \frac{X_i}{\sigma}$$

There are $\bar{X}$, mean precipitation, σ^2, variance σ, standard deviation and SPI, Standardized Precipitation Index

The SPI is probability based and was designed to be a spatially invariant indicator of drought that recognizes the importance of time scales in the analysis of water availability and water use. It is essentially a standardizing transform of the probability of the observed precipitation (Sırdaş and Şen, 2003). Both indices have some advantages and disadvantages.

McKee et al. used the classification system shown in table 1 to define intensities resulting from the SPI and also defined the criteria for a "drought event" for any of the time scales. A drought event occurs any time when the SPI is continuously negative and reaches intensity where the SPI is -1.0 or less. The event ends when the SPI becomes positive. Theoretically, the SPI is unbounded. Practically, however, because of limit the number of observations of the precipitation data, bounds is suggested based on sample sizes.

Table 1 The SPI Values and Classifications

SPI Values	Classifications
2.0 and more	Extreme Wet
1.5 to 1.99	Very Wet
1.0 to 1.49	Moderate Wet
-0.99 to 0.99	Near Normal
-1.00 to -1.49	Moderate Drought
-1.50 to -1.99	Severe Drought
-2.0 and less	Extreme Drought

Modern hydrology models can provide a valuable counterpart to existing climate-based drought indices by simulating hydrologic variables such as land surface runoff. We contrast the behavior of a standardized runoff index (SRI) with that of the well-known standardized precipitation index (SPI) during drought events in a snowmelt region. Although the SRI and SPI are similar when based on long accumulation periods, the SRI incorporates hydrologic processes that determine seasonal lags in the influence of climate on stream flow. As a result, on monthly to seasonal time scales, the SRI is a useful complement to the SPI for depicting hydrologic aspects of drought (Shukla, S., and A. W. Wood -2008). We can use same values to classification for runoff data that is shown table 1.

Results and Discussion

According to precipitation and runoff data obtained between 1980 and 2006 years; The average annual precipitation and runoff depth at the watershed have been found as 709.2 mm and 52.6 mm, respectively. The average annual coefficient of surface flow was found as 3.1 %.

The seasonal precipitation distributions for autumn, winter, spring and summer are 28.0 %, 36.7 %, 23.1 % and 12.2 %, respectively.

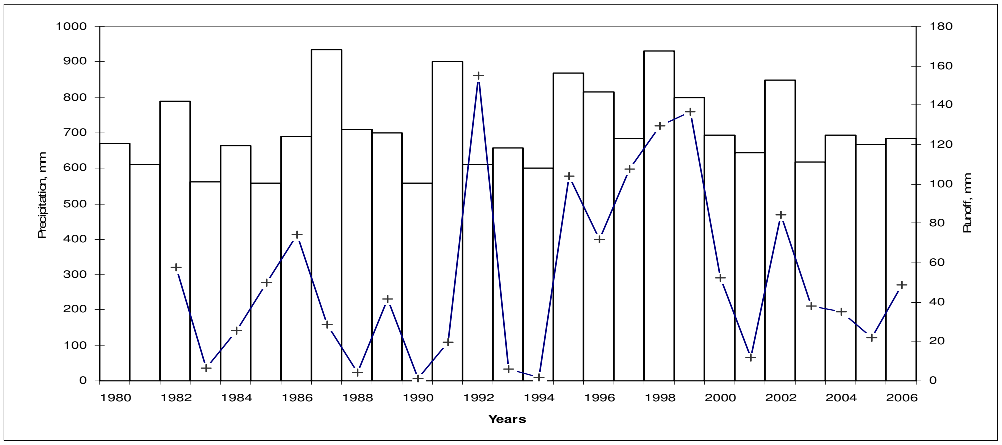

Figure 3. Distribution of Yearly Precipitation and Runoff values in Damlıca Watershed

Drought analyses have been done using the SPI and SRI methods for the watershed precipitations and runoff values that are shown fig.4, fig.5, and fig. 6 respectively. According to the SRI, for stream flow values, it has been found Extreme drought in 1990 and severe drought in 1994. 1983, 1988 and 1993 years have been found to be Moderate drought.. According to the SPI, for precipitation values, it has been found severe drought in 1983, 1985, and 1990 respectively. During observing periods in 1994 year, it has been found to be moderate drought at the damlıca watershed. Table 2 shows the SPI and the SRI for meteorological and hydrological drought values years by years.

Finally, Drought by itself is not a disaster. Whether it becomes a disaster depends on its impact on local people, economies and the environment and their ability to cope with recover from it. Therefore, the key to understanding drought is to grasp its natural and social dimensions. Drought monitoring and early warning are major components of drought risk management. Therefore to determine the SPI and the SRI from precipitation and stream flows is an important for drought risk management Because, Agriculture is the first sector to be affected from drought. Thus this study results can be useful drought monitoring and management of water resources for this region and like a similar region.

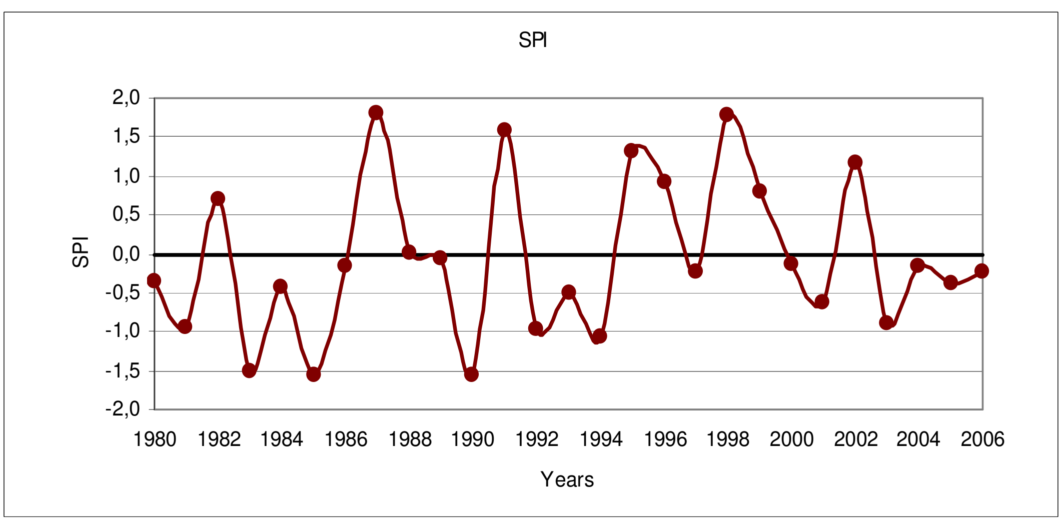

Figure 4. The SPI in distribution for observed Precipitation in Damlıca Watershed

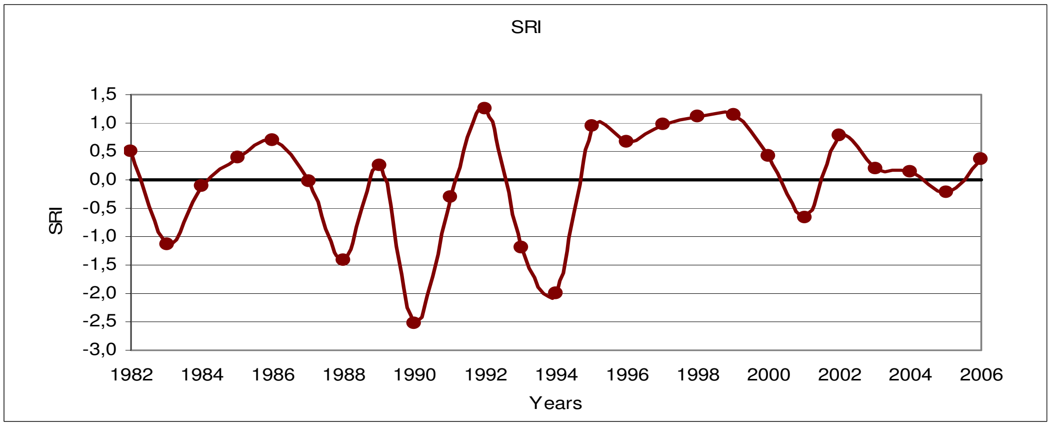

Figure 5. The SRI in distribution for observed stream flow in Damlıca Watershed

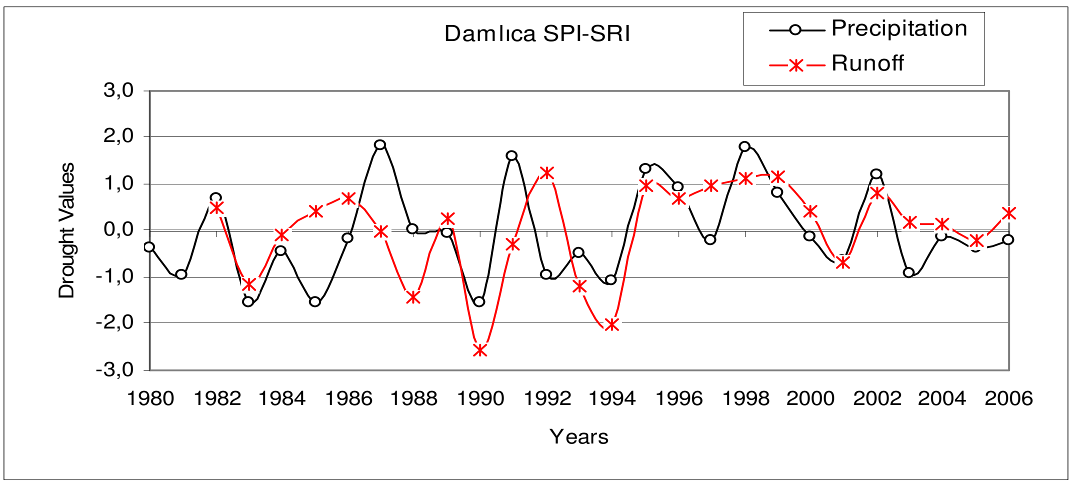

Figure 6. Comparison of the SPI and the SRI in distribution for observed values in Damlıca Watershed

Table 2. Intensity of Drought and the SPI, the SRI values in Damlıca Watershed

YEARS	SPI Values	SRI Values
1980	-0,35 NN	No data
1981	-0,96 NN	No data
1982	0,70 NN	0,49 NN
1983	-1,52 SD	-1,13 MD
1984	-0,44 NN	-0,10 NN
1985	-1,55 SD	0,40 NN
1986	-0,17 NN	0,69 NN
1987	1,81 VW	-0,02 NN
1988	0,00 NN	-1,43 MD
1989	-0,07 NN	0,26 NN
1990	-1,55 SD	-2,54 ED
1991	1,57 VW	-0,31 NN
1992	-0,96 NN	1,24 MW
1993	-0,50 NN	-1,20 MD
1994	-1,06 MD	-1,99 SD
1995	1,32 VW	0,94 NN
1996	0,91 NN	0,66 NN
1997	-0,23 NN	0,97 NN
1998	1,78 VW	1,11 MW
1999	0,79 NN	1,14 MW
2000	-0,15 NN	0,43 NN
2001	-0,62 NN	-0,66 NN
2002	1,17 MW	0,79 NN
2003	-0,90 NN	0,19 NN
2004	-0,15 NN	0,13 NN
2005	-0,38 NN	-0,22 NN
2006	-0,22 NN	0,37 NN

Conclusion

It is clear that research will be at a risk of experiencing meteorological droughts as well as these droughts turning into agricultural and hydrological droughts in the near future.

As we have showed above table 2 , a variety of meteorological data and drought indices indicate that after going through a drought in 1983-85, 1990-94 years. Between 2003 and 2006 years the amount of yearly precipitation has been observed under mean values. The increased frequency and severity of meteorological droughts in Region are caused by changes in global climate patterns. We can expect global climate changes will bring about drought as a normal part of daily life.

Finally, Drought by itself is not a disaster. Whether it becomes a disaster depends on its impact on local people, economies and the environment and their ability to cope with recover from it. Therefore, the key to understanding drought is to grasp its natural and social dimensions. Drought monitoring and early warning are major components of drought risk management. Therefore to determine the SPI and the SRI from precipitation and streamflows is an important for drought risk management Because, Agriculture is the first sector to be affected from drought. Thus this study results can be useful drought monitoring and management of water resources for this region and like a similar region

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