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ORIGINAL ARTICLE

Determination of drought distribution using palmer drought severity ındex: Case study of Susurluk basin*

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ABSTRACT

The results such as decrease in agricultural production, product quality and change in diversity because of drought create important socio-economic problems. Due to these reasons, it is becoming an increasingly strategic study topic in academic circles. The fact is that it is not observed instantly like natural disasters makes it possible to take necessary measures on a basin basis in case of drought. Accordingly, obtained data, from meteorological stations in the Susurluk Basin, were used in this study. Within the scope of the study, the starting and ending dates, and intensities of dominant dry periods were determined by using the PDSI (Palmer Drought Severity Index). Using data such as precipitation, evaporation, transpiration, and the water holding capacity of soil as inputs, a tool was developed in the R environment for PDSI, and annual values were calculated for each meteorology station by running all inputs in this tool. For calculated PDSI values, spatial and temporal analyze were made using the digital elevation model of the Susurluk Basin using the ordinary cokriging interpolation method in ArcGIS 10.8 program.

Keywords: drought, geographic information system, PDSI, statistical computing, Susurluk Basin

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1. INTRODUCTION

It is estimated that the world population, which is 7.6 billion today, expected to reach 9.8 billion in 2050 and 11.2 billion in 2100. (United Nations Anon 2017). If this population estimation is realized, developing countries should increase their food production by 100%. Despite the increasing population, the perceived climate change and drought change the efficiency of agricultural land use and reduce the rate of food production. It can be possible with appropriate irrigation, fertilization, and precision agriculture practices for efficient production of agricultural lands (FAO Anon 2009). Water demand is expected to increase by 55% due to increasing urbanization, thermal electrical energy production and domestic waste in developing countries (WWAP Anon 2015). This situation will directly affect agriculture, which is the sector that uses water the most. To optimize agricultural production and to provide irrigation water in the agricultural field in line with the needs of the plant, the amount of water in the growing medium must be constantly monitored and given as needed, because drought is a meteorological disaster that occurs very slowly, does not show itself and causes significant social-economic damage. Therefore, drought climate directly affects water resources and agricultural activities negatively (Anon 1999). For this reason, the analysis of the relationship between precipitation and runoff, and the analysis of dry and rainy seasons is very important. Monitoring drought is an important process in tackling some climate problems because if it is predicted and warned early, its damage can be reduced (Hao et al. 2017). Since drought indices are related to climate and environment, it is stated as an effective way of determining drought.

According to Vanders et al. 2017, 10 out of 20 drought monitoring indices are frequently used for drought detection in all parts of the hydrological cycle. In addition, if we want to specify the two most used indices in drought determination so far, one of them is Palmer (1965) and the other is MCkee et al. (1993) The SPI (standardized precipitation index) developed (Tirivarambo et al., 2018). SPI is a drought index calculated from precipitation data only, while PDSI is calculated based on precipitation and evapotranspiration. It is stated that PDSI is more appropriate than that of the SPI in assessing the potential impact of climate change on the future perspective of drought, since drought is dependent on temperature and precipitation. In addition, in the calculation of PDSI, how two parameters such as precipitation and evapotranspiration change over time, flow moisture determination and water holding capacity of the soil at the desired location are used as input variables (Wells et al. 2004). However, PDSI does not consider the spatial variation of the soil structure, vegetation, topography, and hydrological processes of the basin in drought calculations. Although Palmer has some disadvantages as stated above, considering its advantages over SPI, palmer drought index was chosen for drought estimation in this study.

2. MATERIALS AND METHODS

The Susurluk basin is situated in the Northwest of Anatolia, between 39^{o}-40^{o} North latitudes and 27o-30o East longitudes. As can be seen in Figure 1, the total area surrounded the Susurluk Basin is 24,299 km2, and the most important river it has is the Simav Stream. Within the scope of the Ramsar contract, there are two main freshwater lakes namely, Kuş lake with an area of 24,400 ha and the Uluabat lake with an area of 19,900 ha (Anon 2022). When the agricultural activities in the Susurluk Basin are examined, the plant production pattern can be said to be 65% cereals and other plant products, 28% vegetables and 7% fruits.

Figure 1. Streams and lakes in the Susurluk basin (Anon 2018)

When the climate of the Susurluk Basin is examined, it is generally semi-humid in winters and hot in summers. The annual average precipitation map of the basin is given in Figure 2. The average annual precipitation of the basin is recorded as 662 mm/year (Anon 2018). As seen in Figure 2, the average annual precipitation in the regions of Bursa, Bandırma, Keles and Simav meteorological stations is observed as 750-800 mm and 570-630 mm in Balıkesir and Dursunbey, and 510-570 mm in Tavşanlı meteorological stations.

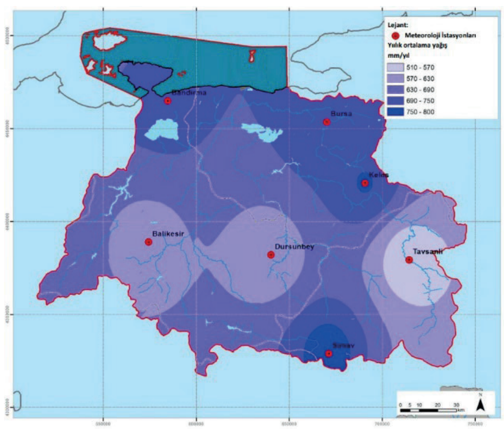

Figure 2. Average annual precipitation compared to 1995-2011 (Anon 2018)

The drought in the basin was examined by using the palmer drought index method by using the average monthly precipitation and monthly average temperature values of the meteorological stations in the Susurluk Basin and the latitude of that station for many years. Data regarding precipitation and temperature of 11 meteorological stations located the Susurluk Basin between 1970 and 2020 were obtained from the General Directorate of State Meteorology Affairs. By calculating the palmer drought severity with the data obtained, it was tried to provide a complete drought analysis of the basin with the Ordinary Co-Kriging interpolation method within the basin.

The palmer drought index was developed by Wayne Palmer in 1960s for hydrological drought determination using monthly average precipitation and temperature data. These class ranges are given in Table 1.

Table1. Palmer drought index classes

CLASSICIFATION	
4 or more	Extremely wet
3.00 - 3.99	Very wet
2.00 - 2.99	Moderately wet
1.00 - 1.99	Lightly wet
0.50 - 0.99	Incipient Wet Spell
0.49 - -0.49	Near Normal
-0.50 - -0.99	Incipient Dry Spell
-1. 00 - -1.99	Mild Drought
-2.00 - -2.99	Moderate Drought
-3.00 - -3.99	Severe Drought
4 or less	Extreme Drought

Palmer divides the soil layer into two parts while calculating the drought index. Palmer (1965) uses monthly total precipitation and monthly total temperature data when calculating the water balance. It empirically assumes that the usable water in the field capacity in the upper layer of the soil is approximately 25 mm. This layer is also the layer where the rain falls, and evaporation movements occur. It assumes that the evaporation loss in the top layer of the soil occurs at a potential level. Since the moisture on the surface of the soil is constantly saturated or completely evaporates, the amount of usable water in the lower layer of the soil depends on the effective root depth of the plant roots and the soil properties.

This study use of palmer drought index using potential evapotranspiration and Thornthwaite method. Thornthwaite (1948) With this method, we derive the coefficients of the ratio of the monthly average of the evaporation and evapotranspiration losses in the soil to the potential value, find the CAFEC: (Climatologically Appropriate for Existing Conditions.) precipitation from these coefficients, use a series of empirical equations according to the difference of this precipitation value from the actual precipitation value, and calculate the drought value and determines the intensity.

The results obtained from these empirical formulas were calculated by the software created in the R program.

3. RESULTS AND DISCUSSION

Long-term precipitation and temperature data of 11 selected meteorological stations used in drought analysis in the Susurluk Basin were used. The importance of the relationship between the data of meteorological stations in the basin and the palmer drought index has been observed. The more precipitation and temperature deviate from the average value in the basin, the drier or rainy it is. This feature of the palmer drought index shows that it is statistically significant.

Drought classes of all months were determined by palmer drought index. However, the drought classes of February and July 2020 were considered. Because it was thought that the drought or rainy situation in February felt in July. Considering the forecast maps created by interpolation on the basin in Figure 3, the similarity between February and July is clearly seen. In Figure 3, it is clearly seen that the onset of drought and mild dryness in the southern regions, which started in February, increased intensity, and became mild and moderately dry in July. The drought that started in Keles and Dursunbey meteorological stations in February increased its severity in July. In addition, it is seen that it is rainier in the Balıkesir meteorological station region in July than that in February.

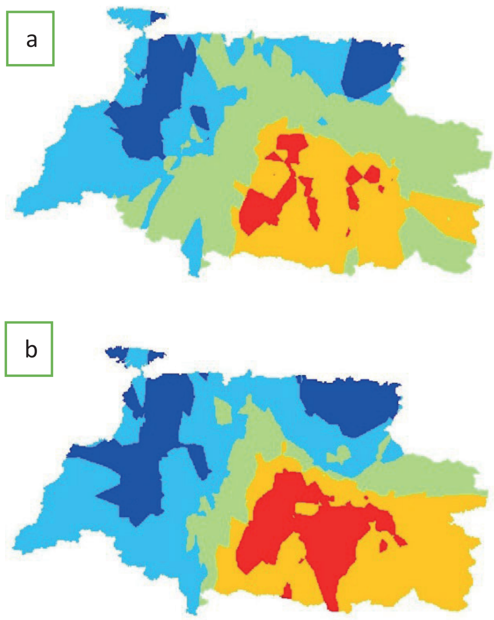

Figure 3. Palmer drought index average drought map between 1990-2020 a: drought averages for February b: averages for July

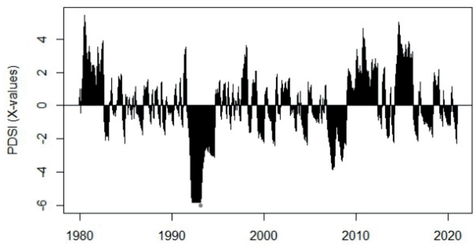

Figure 4. Palmer drought index to Balıkesir meteorological station between 1980-2020

As can be seen from Figure 4, Balıkesir meteorology station was extremely dry between 1993-1995 and humid in 2015.

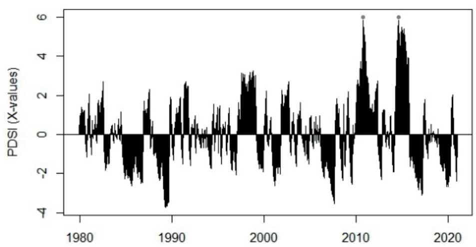

Figure 5. Palmer drought index to Bursa meteorological station between 1980-2020

When Figure 5 is examined, it has been determined that Bursa meteorological station has excessive wet in 2009 and 2014 and light drought in 2020.

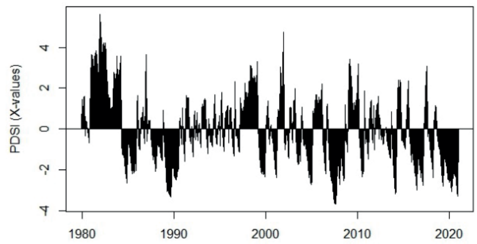

Figure 6. Palmer drought index to Simav meteorological station between 1980-2020

As seen in Figure 6. it has been determined that mild drought is more intense towards 2020 at Simav meteorological station.

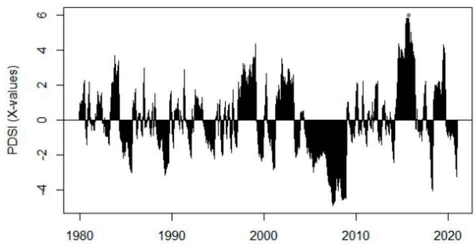

Figure 7. Palmer drought index to Dursunbey meteorological station between 1980-2020

The palmer drought index values of the Dursunbey meteorological station in Figure 7. show that an extremely dry period was detected starting from 2007 and continuing increasingly towards the middle of 2009. Considering the year 2017, an excessive humidity is observed.

4. CONCLUSION

This study was carried out for drought determination by using Palmer Drought Index Severity on the Susurluk Basin, which has an important socio-economic value for Turkiye. When some meteorological stations namely Bursa, Balıkesir, Simav and Dursunbey in the Susurluk Basin were examined, it was determined that 2020 was a dry year. Drought was estimated by using the ordinary kriging method on a basin basis by interpolation.

The possible drought situation in February was determined and interpreted with the climate data of the region, where it was more severe in July. However, the prediction that the drought analysis to be made in February for each region will be drought or wet felt in July may not be valid.

The Palmer drought index uses a set of complex empirical formulas for drought determination. Since these formulas are complex and difficult and there are too many meteorological stations in the drought analyzes to be made on the basin basis, it has been concluded that the evaluation of the palmer drought index on the basin basis is very laborious and difficult. A calculation approach with some artificial intelligence models is suggested for the determination of the palmer drought index on a basin basis.

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