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Assessment of Drought in Izmir District Using Standardized Precipitation Index

Denizhan Mersin[1], Ayse Gulmez[2], Mir Jafar Sadegh Safari[3] , Babak Vaheddoost[2] and Gokmen Tayfur[1]

[1] Department of Civil Engineering, Izmir Institute of Technology, Izmir, Turkey
denizhanmersin@iyte.edu.tr
[2] Department of Civil Engineering, Bursa Technical University, Bursa, Turkey
[3] Department of Civil Engineering, Yaşar University, Izmir, Turkey
jafar.safari@yasar.edu.tr

Abstract: Droughts are one of the major concerns associated with agro-food and socio-economical security in the World. The continuously changing climate regardless of its cause and effect pushes the limit of the water deficit to the limits. Izmir is a raising city of Turkey that owns various water resources including but not limited to seashores, lakes, river streams, and groundwater reserves. Therefore, the assessment of the historical and future drought events and their potential effect on these water resources is important in the planning and development of the region. In this respect, this study aims to evaluate the historical droughts across İzmir District. For this, monthly precipitation time series in three meteorological stations recorded between 1973-2020 related to the Küçük Menderes basin is used. First, the consistency, randomness, and trend in the time series are investigated using the double mass curve, run test, and linear trend analysis respectively to ensure the credibility of the posterior drought analysis. Next, the standardized precipitation index (SPI) together with the moving average (MA) operator is used to evaluate the historical deficit associated with meteorological (SPI-1), agricultural (SPI-3), and hydrological (SPI-6 and SPI-12) droughts within a year. It is concluded that there is no permeant drought occurred during the study period, while there are some extreme events in the past that should be evaluated separately. Results also showed that the severity of drought increases from the seashore toward the land.

Keywords: Drought assessment, historical drought, Izmir, spatiotemporal analysis, Standardized Precipitation Index

1 Introduction

Linked to the complexity of the drought phenomenon, it is a quite difficult task to present a common definition for expressing the drought consequences. However, it is known that all types of droughts including meteorological, agricultural, hydrological, and socio-economical; start with a significant decrease in precipitation in space and time which causes to occurring a complex hydro-meteorological condition. The aforementioned drought types respectively illustrate the decrease in precipitation, moisture deficient in soil, streamflow reduction, potable water scarcity and water shortage in biota. In order to define, predict and measure the drought, variety of indices were developed. In this respect, the standardized precipitation index (SPI) is the most famous

drought index, which is usually implemented in the evaluation of droughts. This study aims to evaluate the historical droughts across the Izmir district [1-7].

2 Materials and Methods

This study uses daily total precipitation data which is obtained from the Turkish State Meteorology Service at average daily scale between 1973-2020 years in Çeşme, İzmir, and Seferihisar station of Küçük Menderes basin (Figure 1). Initially, the missing daily data were reconstructed using historical properties of the time series including seasonal averages and the spatiotemporal properties of the precipitation time series in other stations. Then, the time series were converted respectively into average monthly data and total monthly data. Afterward, the consistency, randomness, and trend in the data run were examined using the double mass curve, run test, and linear trend test, respectively. Finally, the reconstructed monthly time series were used in SPI drought analysis together with 1, 3, 6, and 12-month moving averages. For this, a data series is transformed to a standard normal distribution after which are fitted to a Gamma distribution. Then the obtained results are evaluated based on the predefined selection criteria of a range between extreme droughts to extreme wet conditions.

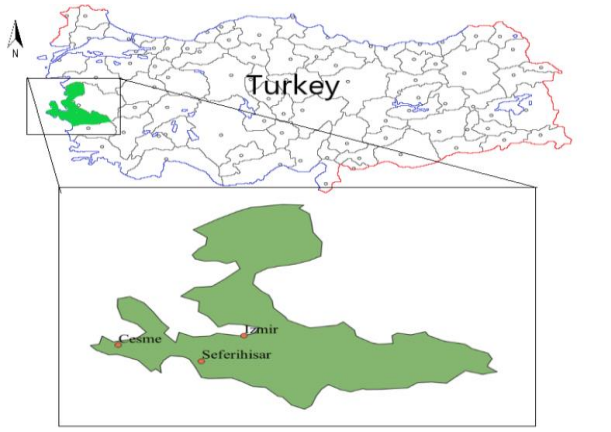

Fig. 1. Location of the selected stations

3 Results and Discussion

Initially, the double mass curve, run test, and linear trend analysis have been performed to investigate the credibility of the analysis. All of the selected stations showed a consistent behavior. In addition, Table 1 shows that the time series at the selected stations are not random and experienced a decreasing trend, where Z is the score of the run test and a is constant coefficient denoting the decreasing or increasing trend of the data.

Table 1. Summary of Results of the Run test and Linear Trend Analysis

	Linear Trend	Run test
	a	*Z*
Çeşme	-6.94	-61.32
Izmir	-8.74	-60.01
Seferihisar	-8.38	-4.22

Once the selected time series were found to be eligible, they were used in SPI analysis. For this, SPI-1, SPI-3, SPI-6, and SPI-12 (moving average, MA) values were calculated for each of three stations (Çeşme, İzmir, and Seferihisar). In this respect, Figure 2-5 depicts the results of the SPI for the selected stations. Once SPI-1 is considered, the behavior of the time series in Seferhisar and Çeşme stations are very similar. There are several droughts in the early 1990s, 2011, and 2016. However, when the SPI-3, SPI-6, or SPI-12 are considered, the behavior of the stations showed similarities. It is concluded that the worst drought occurred in 2007 while the subsequent events revealed a drawback as a wet period in the mid-1990s'.

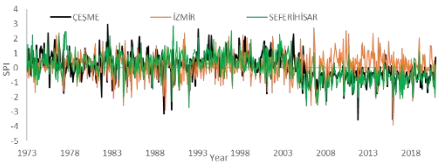

Fig. 2. SPI values for 1 month (SPI-1)

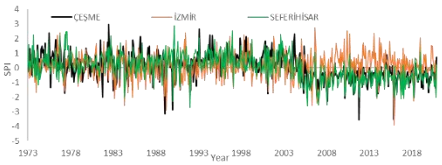

Fig. 3. SPI values for 3 month period (SPI-3)

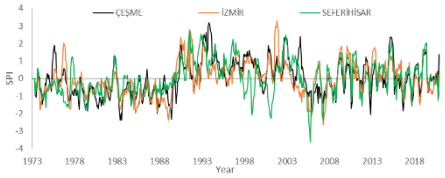

Fig. 4. SPI values for 6 month period (SPI-6)

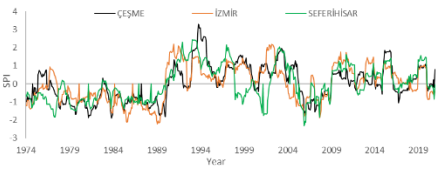

Fig. 5. SPI values for 12 month period (SPI-12)

After the year 2005, moderate and extreme droughts emerged at the monthly time scale (SPI-1) in Seferihisar and Çeşme stations that are relatively close to the sea. But, in the Izmir station, a moderately wet period emerged in the same years. Similarly, several dry spells emerged between 1988 and 1993, which are shown in Figure 2. When considering SPI-3 events, it can be proved (Figure 3) that the years between 1973-1988, was generally a dry period. Yet, several droughts occurred in Seferihisar station between 1998-2001. In the following years between 2004-2006, an extreme drought emerged which was thought to be the worst agricultural drought in the half a century

(i.e. 47 years). As represented in Figure 4, 1973-1990 years were moderately dry in all of the stations when SPI-6 is considered (hydrological drought). After 1990, all of the stations showed moderately wet spells. In Seferihisar station extreme droughts emerged in 1998, 2001, 2006, and 2008; while the extreme drought in Izmir emerged in 2006 and 2008. According to Figure 5, in the periods of 1973-1990 and 2005-2010, there were moderately dry seasons in all stations when SPI-12 is considered (streamflow and reservoir storage). The moderately dry season in 1998 and extremely dry season in 2000 year were also observed in Seferihisar station.

4 Conclusions

This study presents the application of SPI together with the moving average operator to evaluate the meteorological, agricultural, and hydrological droughts in Izmir, Turkey. For this data reconstruction, trend analysis, consistency check, and randomness tests are used to evaluate the credibility of the analysis. The SPI-1, SPI-3, SPI-6, and SPI-12 with Gamma distribution are used. It was concluded that several droughts occurred in the past while the behavior of Seferihisar and Çeşme stations were quite similar and under the effect of air fronts coming from the Aegean Sea.

Acknowledgement

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