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Investigation of drought-threatened areas through different drought indexes: A case study in Mersin, Türkiye

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Abstract

Global climate change is having a growing impact all around the world. Drought is one of the most destructive effects of global climate change in the Mediterranean basin. The study area is Mersin, which is located in southern Türkiye and is threatened by drought. Therefore, a drought analysis of the research area was conducted. Palmer Drought Severity Index (PDSI), Palmer Hydrological Drought Index (PHDI), Standardized Precipitation Index (SPI), and Standardized Precipitation-Evapotranspiration Index (SPEI) were chosen as drought indices that employ climatic data. The indices were calculated, and graphs were created. As a result, it was concluded that Mersin is at risk of drought.

1. Introduction

The harmful effects of global climate change are becoming more widespread and directly endanger the lives of all living beings. The world has currently warmed by 1.1°, while the agreed climate limit is 1.5° (Öztürk & Gürsoy, 2022). If the current trend continues, global warming will increase, and the adverse impacts of climate change on the world will gradually worsen. Natural disasters including floods, wildfires, and droughts will become increasingly common (Demir et al., 2021). At this point, these disasters will strike different regions based on their meteorological and geographical characteristics. Drought will be one of the most significant effects of climate change in Mediterranean basin regions (Hadri et al., 2021). This basin is currently becoming dry in some areas (İban, 2022).

Drought is a natural disaster that has a long-term detrimental impact with far-reaching implications. Drought is classified as meteorological, agricultural, and hydrological (Hobbins et al. 2008). A meteorological drought is defined as a drought that lasts months or years as a result of below-normal precipitation (Palmer, 1965). Agricultural drought is described as periods of below-average precipitation, substantial but infrequent precipitation, or higher-than-normal evaporation (Liu et al., 2016). In contrast, hydrological drought is defined as periods when stream flow and water storage fall below the long-term average level (Van Loon, 2015). Drought's harmful consequences must be identified, eliminated, or minimized (Alahacoon & Edirisinghe, 2022).

The study area, Mersin, is threatened by drought because of its location in the Mediterranean basin. At this point, it is critical to do a drought analysis. The Palmer Drought Severity Index (PDSI), Palmer Hydrological Drought Index (PHDI), Standardized Precipitation Index (SPI), and Standardized Precipitation-Evapotranspiration Index (SPEI) are standard drought indices that use climatic data (temperature and precipitation) during this time. These indices were utilized in this study to analyze Mersin's drought.

2. Study Area

Mersin province is the study area (Figure 1). Drought is a hazard in the region, which has a Mediterranean climate and is located in the Mediterranean basin. According to data from the General Directorate of Meteorology (MGM), Mersin has experienced severe drought in recent years (MGM, 2023). It was chosen as the study area for the investigation of the growing impact of drought.

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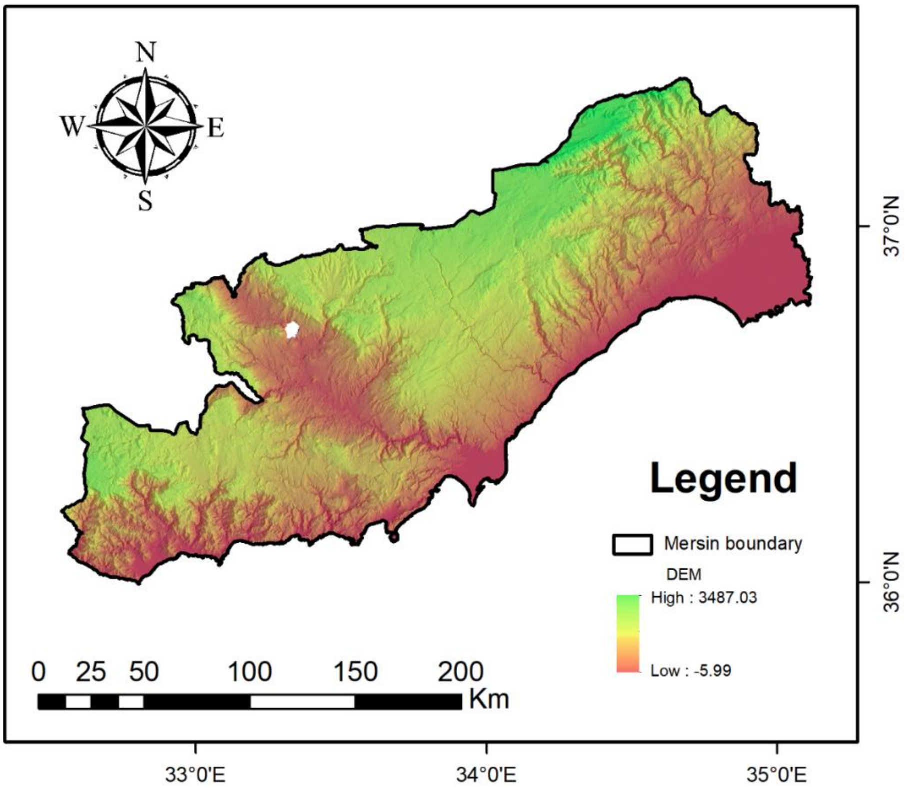

Figure 1. Study area

3. Material and Method

Drought analysis was performed using the PDSI, PHDI, SPI, and SPEI indices. A three-stage procedure was used for this. First, fundamental climate data, including maximum and minimum temperatures and precipitation, were gathered from the NASA Prediction Of Worldwide Energy Resources (POWER) website (NASA POWER, 2023). According to the World Meteorological Organization (WMO), at least 30 years of data should be available to generate drought indices and perform analysis (European Comission, 2013). Working with data over extended time periods improves accuracy. In this direction, 42 years of data from the research area's 1981-2023 time period were used for calculations. Second, after arranging the data, the PDSI, PHDI, SPI, and SPEI indices were calculated in R Studio. This application offers an environment for R, a computer language that permits statistical calculations and graphic creation. Finally, graphs for the calculated indices were constructed.

3.1. Palmer drought severity index (PDSI)

Temperature and precipitation data are used to calculate PDSI (Ramirez, 2023). Furthermore, drought analysis is carried out with the potential evapotranspiration (PET) parameter. PDSI was estimated in the study using PET data from Mersin province based on temperature, precipitation, and maximum and minimum temperature differences. PDSI values are classified into specified classes. As a result, scores range from -10 (dry) to +10 (wet), with values below -4 representing extreme drought and values over +4 representing extreme wet.

3.2. Palmer hydrological drought index (PHDI)

PHDI is a derivative of PDSI that was designed to study water storage, stream flow, and hydrological drought. Temperature and precipitation data are employed in its calculation, much like in PDSI.

3.3. Standardized precipitation index (SPI)

The standardized precipitation anomaly is generated using precipitation data from regions with varying climatic conditions, and SPI values are computed. Thus, drought analysis is carried out. SPI values are classified into standard classes. Extreme drought is represented by -2 and above, whereas extreme wetness is represented by +2 and above.

3.4. Standardized precipitation-evapotranspiration index (SPEI)

SPEI is a more advanced variant of SPI that employs PET data computed from precipitation and temperature changes (NCAR, 2023). The SPEI compares evaporation to available water capacity. Precipitation and PET data are used for this, and SPEI is calculated during the specified period.

4. Results

Drought indices were developed for the years 1981-2023, and the graphs are shown in Figure 2-6. When the PDSI graph is analyzed, it is clear that drought has been more prevalent, particularly in recent years (2018, 2019, and 2020) (Figure 2). In addition, when PDSI values were examined over 42 years, it was discovered that the maximum values did not approach the extreme wet value (+4 and above). Drought did, however, grow in five separate times, notably 1989-1991, 1996-1998, 2003-2006, and 2018-2020. These findings may be said to overlap with the region's geographical location and climate data.

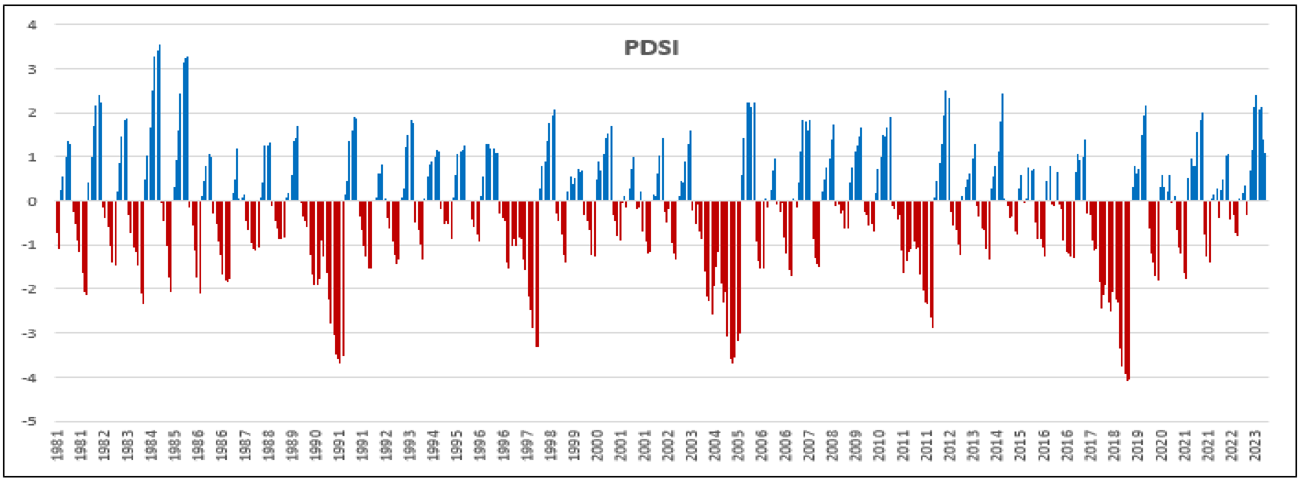

Figure 2. PDSI

Because PHDI is derived from PDSI, the values in the graph are similar (Figure 3). PHDI, on the other hand, gives reliable information regarding the research area's hydrological drought. This drought has been becoming worse in recent years (2018-2023). Indeed, the level of natural and artificial water resources decreased in the same period.

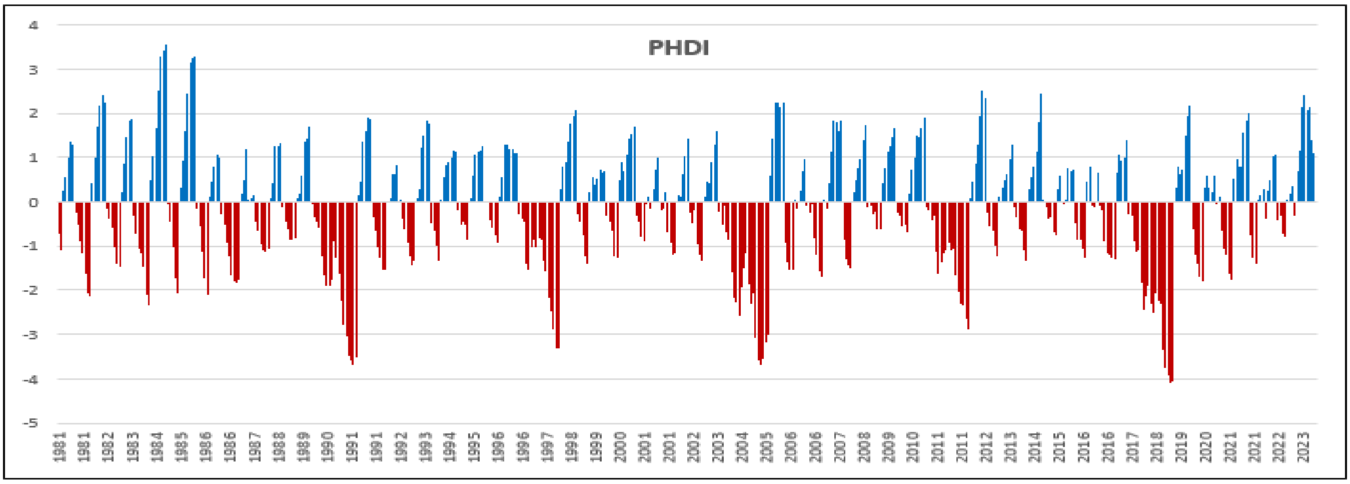

Figure 3. PHDI

The SPI graph (Figure 4) depicts value variations over 42 years. Similarly to the PDSI, the highest values did not exceed the excessive wet value (+2 and above), whereas the minimum values did (-2 and below).

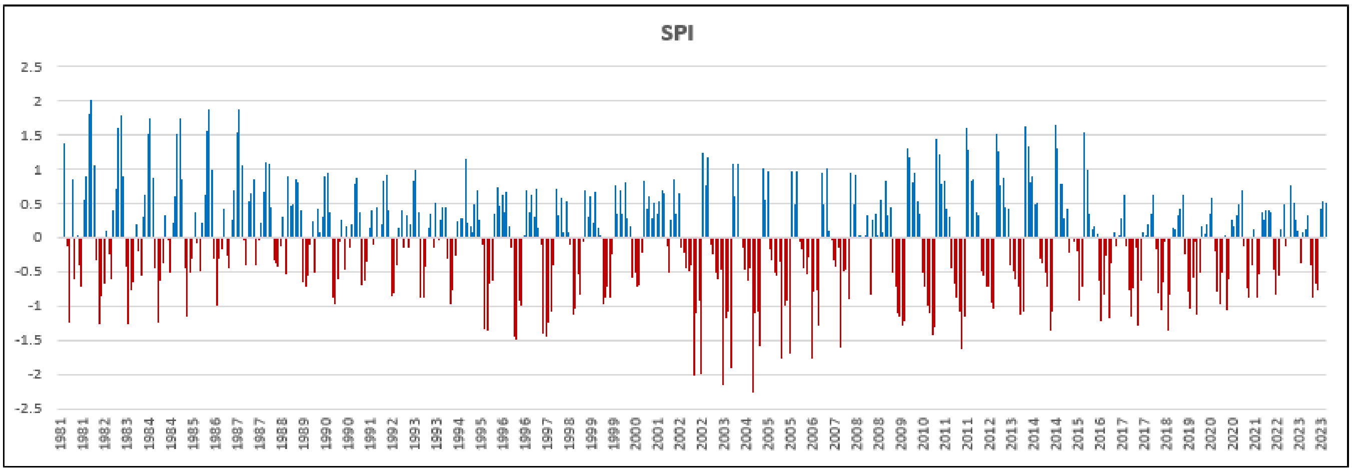

Figure 4. SPI

SPEI is a PET-based index that is a more advanced variant of SPI. As a result, looking at the SPEI values allows for more detailed analyses. In the last two years (2021, 2022) and today (2023), it is observed that drought has increased in the study area located in the Mediterranean basin with the effect of global warming (Figure 5).

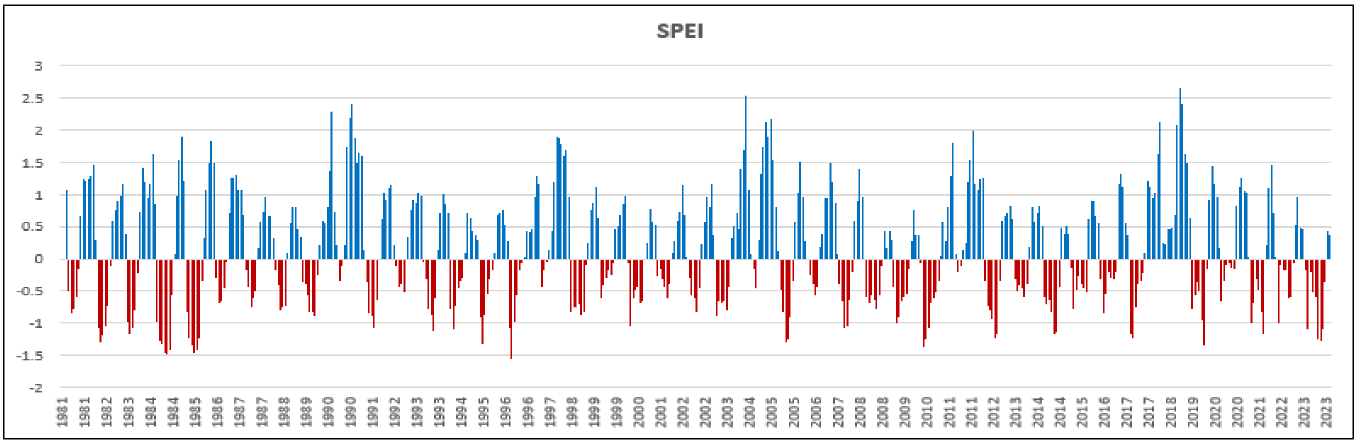

Figure 5. SPEI

5. Conclusion

Mersin, the study area, is vulnerable to the harmful consequences of global warming due to its location in the Mediterranean basin. Drought is one of these impacts. Furthermore, inappropriate land use and irresponsible land management practices contribute to global warming. All of these factors inspired the study that was completed. Four separate indices were calculated and graphs were made to analyze the drought. The obtained values were interpreted, and a drought analysis was carried out. The values obtained for sustainable land management and usage are expected to help decision-makers as a result of the implementation.

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