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Investigation of Transition Possibilities between Drought Classifications Using Standardized Precipitation Index for Wet and Dry Periods – Lower Seyhan Plain, Türkiye Case

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ABSTRACT

In this study, the Karaisalı region of Türkiye, which has a semi-arid climate and is known to contain the extensive plains and rich water resources of the Seyhan Basin, was preferred as a study area for investigating wet and drought periods for a long timescale. Forty-one years of total precipitation data, between 1980 and 2020, belonging to the closest precipitation observation station located in the Karaisalı region were used. By using the Standardized Precipitation Index (SPI), which is one of the frequently used meteorological drought indices, drought classification probabilities, expected first transition period and residence time in each drought severity class values were calculated for the 12-month time scale. As a result of the study, it was determined that the most drought period took place in 2012 according to the examined time duration. In addition, the most wet period was observed in 2001. When various time scales were considered, SPI-3 and SPI-6 have Near Normal Wet periods, while SPI-9 and SPI-12 have Near Normal Drought periods. Extremely Wet periods were more numerous, while Extremely Drought periods lasted longer. In addition, 3 months after the end of the drought categories, it can be seen that the Wet and Drought periods change into Near Normal Wet and Near Normal Drought periods.

Keywords: wet and drought periods, SPI, drought classifications, transition probabilities, Karaisalı (Türkiye).

INTRODUCTION

Due to the change in climatic conditions, the effect of drought has started to be felt above the expected level throughout the world [Mondal et al., 2021]. Drought is a natural disaster that can be evaluated internationally and can be defined as precipitation values less than the mean value [Çuhadar & Atış, 2019]. Because of the recent increase in global warming, noteworthy changes occur in hydrometeorological parameters such as precipitation and temperature. This crisis also affects other hydrological variables such as evaporation, and increased evaporation events may lead to drier periods [Hackenbruch et al., 2017; Baig et al., 2022]. In case of detecting drought in any region, early differences emerge in precipitation data and accordingly meteorological drought can be mentioned. After that, agricultural drought and finally hydrological drought take place. In semi-arid regions, the amount of precipitation is one of the most fundamental factors that sustain vitality. Significant changes in precipitation values must be considered for both settlement areas and the continuation of agricultural activities [Pham et al., 2021]. Henceforward, fluctuations in meteorological data should be carefully examined in order to meet agricultural, industrial, and domestic water requirements [Malik & Kumar, 2020].

In recent years, it is thought that the temperature increases in the world have provoked some changes in precipitation values [Siddig et al., 2020]. These deviations in the quantity of precipitation can bring along natural disasters such as floods and droughts. As a result of previous studies, it is predicted that such variations in the world may lead an upsurge in the number of droughts [Alawsi et al., 2022]. Accordingly, evaluations with various drought indices are frequently preferred by using the measured precipitation values [de Oliveira-Junior et al., 2021; Baig et al., 2022; Isia et al., 2023]. Standardized Precipitation Index (SPI) is one of the convenient drought indices and is often handled in most studies recently [Gasiorek & Musial, 2015; Radzka, 2015; Saada & Abu-Romman, 2017; Bahrami et al., 2019; Saini et al., 2020; Mega & Medjerab, 2021; Kamruzzaman et al., 2022; Chisadza et al., 2023]. The SPI method is computed by considering the mean and standard deviation values of the observed precipitation data, so that the drought and wet durations are classified [Baig et al., 2022]. Additionally, with the detection of potential shortcomings due to precipitation trends with SPI, there will be positive reflections on the planning procedures of water resources, especially on cost side.

In this study, Karaisalı region in the Seyhan River Basin, which is considered as one of the most essential basins of Türkiye in terms of agricultural activities, was selected as the study area for drought analysis. In this context, the total precipitation data from the precipitation measurement station of Karaisalı numbered 17936 (affiliated to the General Directorate of Meteorology, MGM) between the years of 1980 and 2020 was used. Considering the previous studies that deal with drought likewise, the data in question were obtained by fitting the SPI to the Gamma distribution. The probability of occurrence of drought and wet periods is emphasized by calculating SPI values in different time intervals such as 3, 6, 9 and 12 months. Also, in the scope of this study drought and wet class transition probabilities, expected first transition period and residence time some other arguments that was taken into account as well. It is foreseen that the outcomes of this study can provide critical contributions to the emergency action plans that will be created in the future and to the current literature.

MATERIALS AND METHODS

Standardized precipitation index (SPI)

The Standardized Precipitation Index (SPI) is a frequently selected index for examining drought and wet durations by fitting the observed precipitation data to the Gamma probability distribution function [McKee et al., 1993; Keskiner et al., 2016; Lyra et al., 2017]. The SPI method requires a minimum of 30 years of precipitation data, after providing enough observed data, it is calculated by dividing the difference between the precipitation values and the mean value by the standard deviation (Equation 1):

$$SPI_{i,j} = \frac{Y_{i,k} - \mu_{i,k}}{\sigma_k} \tag{1}$$

where: k = 1,2,3,…,12 (months), the measured precipitation value in k months (mm), – average value of k-month data series (mm), – standard deviation value of the data series.

The data used in the method are converted into indices that can be described as a numerical value suitable for evaluation, making it feasible to analyze drought and wet durations in 3, 6, 9, and 12 month periods. These durations are divided into various classifications as displayed in Table 1 [McKee et al., 1993]. According to this classification table, the periods when the SPI values are negative are considered as drought; on the contrary positive SPI values periods were categorized as wet periods. Cases where the SPI value sign changes from negative to positive or vice versa are of significant importance for the determination of the lengths of drought and wet periods.

Study area and precipitation data used

Within the scope of this study, the research data were collected from pluviometer measurement of the station no 17936 for the years of 1980-2020 which is in Seyhan Basin. Subsequently, the analysis of wet and drought periods for a long-time interval has been examined. In Figure 1, the location of Seyhan Basin and the observation station numbered 17936 in Türkiye is given. The Karaisalı district was selected as a study area, and it is located in the southwestern

Table 1. SPI classifications [McKee et al., 1993]

SPI values	Classifications
SPI≤-2	Extremely drought
-2<SPI≤-1.5	Severely drought
-1.5<SPI≤-1	Moderately drought
-1<SPI≤0	Near normal drought
0<SPI≤1	Near normal wet
1<SPI≤1.5	Moderately wet
1.5<SPI≤2	Severely wet
SPI>2	Extremely wet

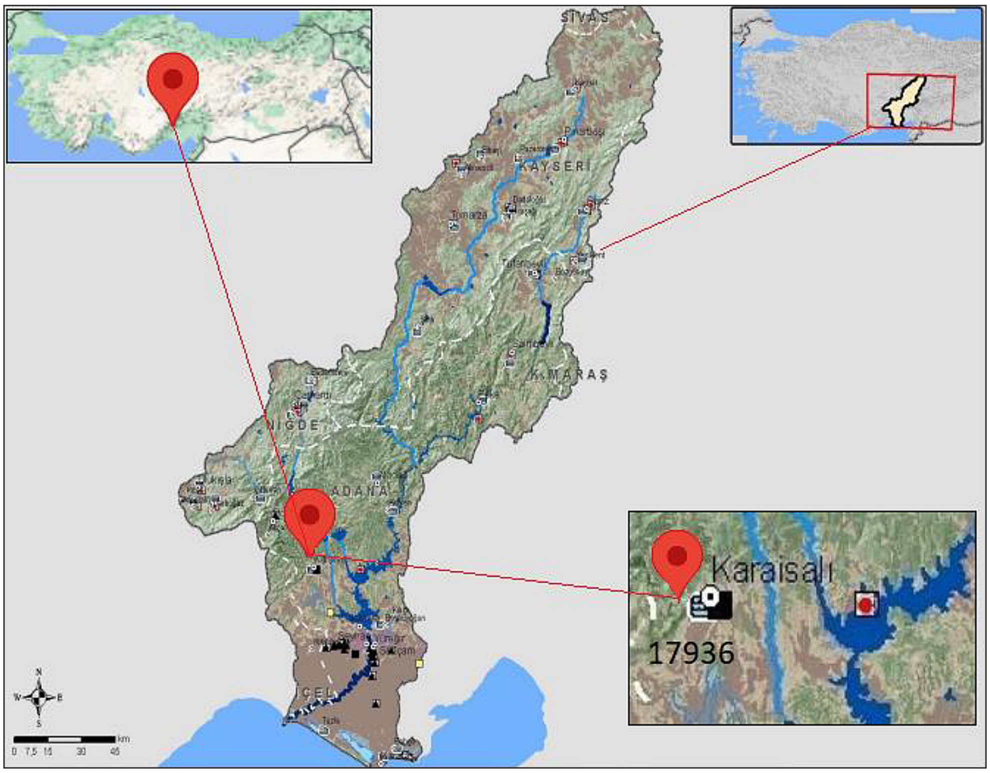

Figure 1. The location of the study area and the observation station

part of Adana province. Karaisalı stands out with its abundant resources in terms of streams. There are various water structures in the region such as Çatalan and Nergizlik Dams. Among these dams, Çatalan Dam is particularly known for supplying a large part of Adana's drinking water. It is seen that the characteristics of the Mediterranean climate are effective in Karaisalı and its surroundings. For this reason, summers are experienced as hot and dry, and winters as warm and rainy. Precipitation on the region is mostly formed because of the encounter of slope rains and air masses. Average precipitation amount of 40 years of data was measured as 917 mm. Temperature values were measured for the coldest month January as 8.82°C and 27.5°C for August, the hottest month. Average high temperature is 24°C, average low temperature is 13.9°C [The Republic of Türkiye Adana Metropolitan Municipality, 2019; Ministry of Forestry and Water Affairs of the Republic of Türkiye, 2019]. Observation station data of the General Directorate of Meteorology (MGM) in Karaisalı district center were used as precipitation data. The location of this station is coordinated as 37°15'02.2" North latitude (N) and 35°03'46.1" East longitude (E), and the precipitation area of the station is approximately 1440 km^2 [MGM, 2022; DSI, 2022].

RESULTS AND DISCUSSION

The 40-year precipitation measurement values of station 17936, for the years 1980–2020 are shown in Figure 2. According to this graph, the maximum precipitation values were measured as 676.6 mm in 2001, while the average precipitation value for the entire measured time span was 75 mm. In addition, it is observed that measurements smaller than the average precipitation value are frequently encountered in a total of 306 months.

3, 6, 9, and 12-month SPI values were calculated to perform a more detailed analysis of the precipitation data and the process of drought and wet periods, then the results are shown in Figure 3. When this figure is evaluated, the wettest period corresponds to 2001 and the driest period corresponds to 2012 in the 41-year data series.

The fact that the SPI-3 value calculated for December 2001 corresponds to the highest value in the data series supports the Extremely Wet period categorization. While the Extremely Drought period commonly seen in all periods in 2005 and 2012, it is noteworthy that the longest drought period took place between 2006–2009. The averages of 3, 6, 9 and 12 months SPI values were obtained. While in short scale mean values such as SPI-3 and SPI-6 indicate to the Near Normal

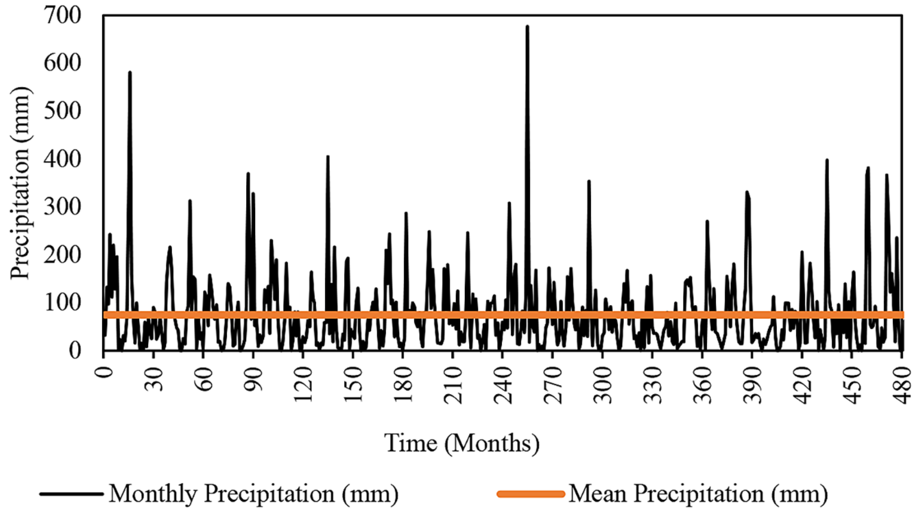

Figure 2. Precipitation values over time (1980–2020)

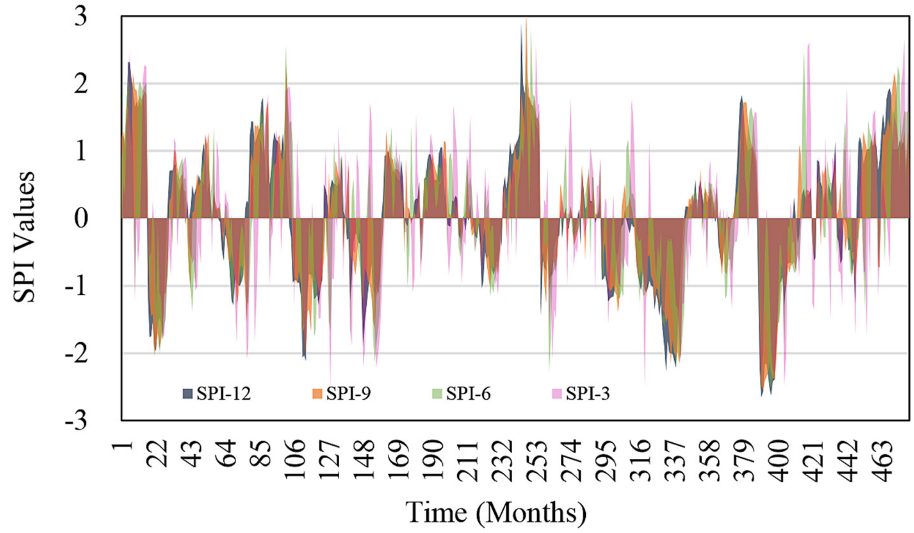

Figure 3. The changes of the SPI values over time (1980–2020)

Wet periods, in long-time spans mean SPI values changes towards Near Normal Drought periods (Figure 4). This result is compatible with the idea that SPI values are more likely to be affected by seasonal changes when short periods are considered [Alami et al., 2017].

Contour plots resulting from the comparison of SPI-3, SPI-6 and SPI-9 values with SPI-12 values are given in Figure 5. As seen in the Figure 5, the greatest concurrence in SPI results was seen in SPI-9 and SPI-12 values. In addition, SPI-3 and SPI-6 results were compared to determine the sensitivity of time scales. It is noteworthy that the October-March values are mostly parallel within the specified time scales. Along with the determination of drought and wet periods, it is aimed to determine the number of appearing of these periods in a year. In this way, it will be possible to analyse the effects of drought in more detail. As mentioned before, SPI-12 values were classified into eight different categories and the frequency of droughts in these categories was studied (Figure 6).

According to the Figure 6, 224 months of drought periods and 256 months of wet periods were observed. Even though it seems like the wet periods are more than the drought periods; it is noteworthy that the Extremely Dry and Extremely Humid periods have a 4% and 1% probability of occurrence, respectively. Although this situation shows the number of extremely wet periods to be higher in total, it is possible to say that drought periods are more dominant in the comparison between categories. Generally, Near Normal Wet

Figure 4. Mean SPI vales on different time scales

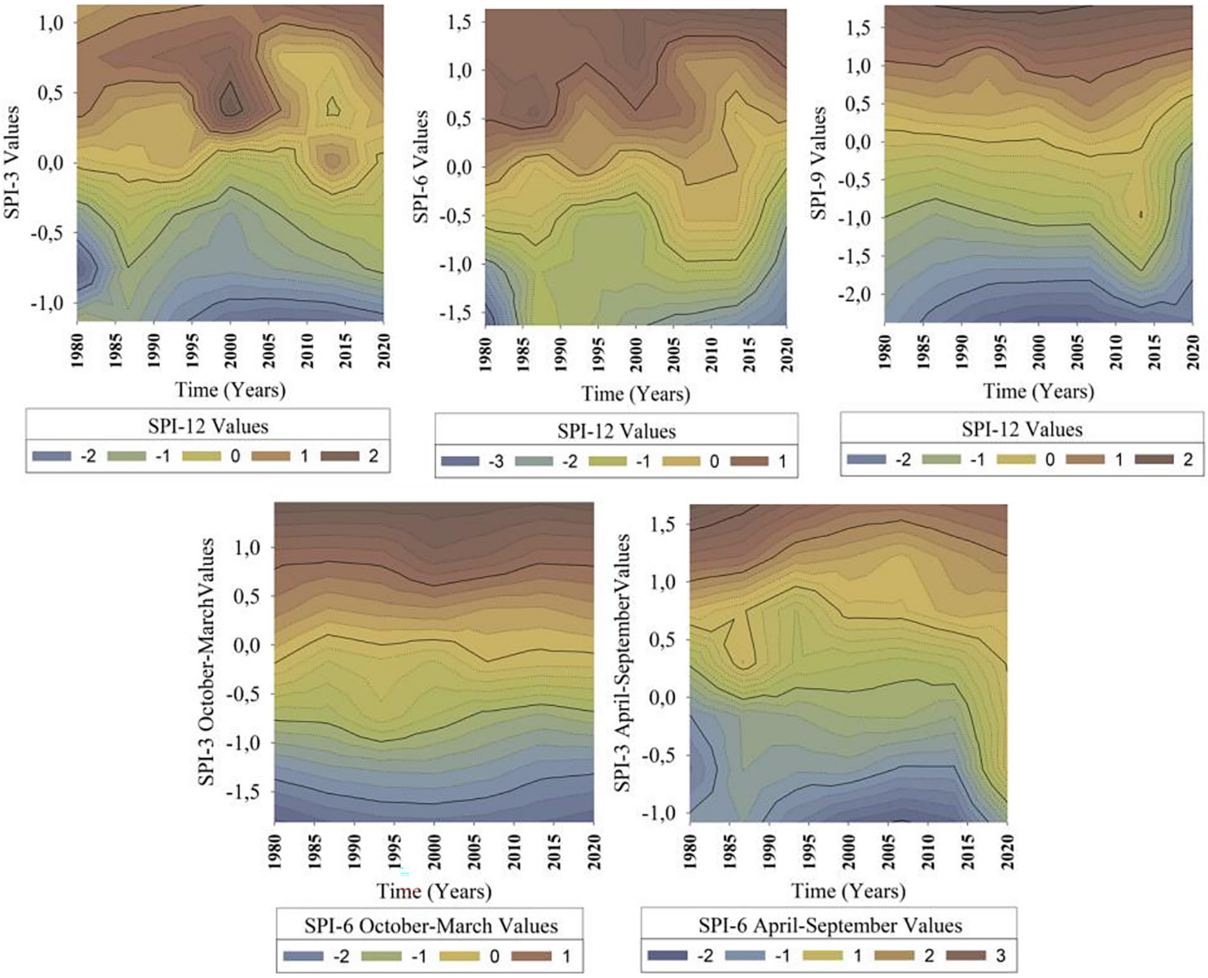

Figure 5. Contour plots of the SPI values for different time scales

and Near Normal Drought periods are accepted as the most likely drought categories to happen with a total incidence rate of 66%.

While the number of probabilities of a drought class in the data series can provide information about the general drought behaviour of the region, knowing how many months a drought class lasts on average will play an important role in determining long dry periods and deciding on contingency plans to be formed. Herein, it is thought that considering the SPI-12 values and the average expected residence time of each drought class will bring better understanding to the study. The expected residence time represents the average number of months it takes for one drought class to transition to another drought class [Yıldırım & Aksoy, 2019; Tatar & Eriş, 2022; Turhan et al., 2022]. According to the calculations, the most Extremely Drought period is monitored with a maximum expected residence time of 4.5 months (Figure 7). It is understood from this situation that the Extremely Drought

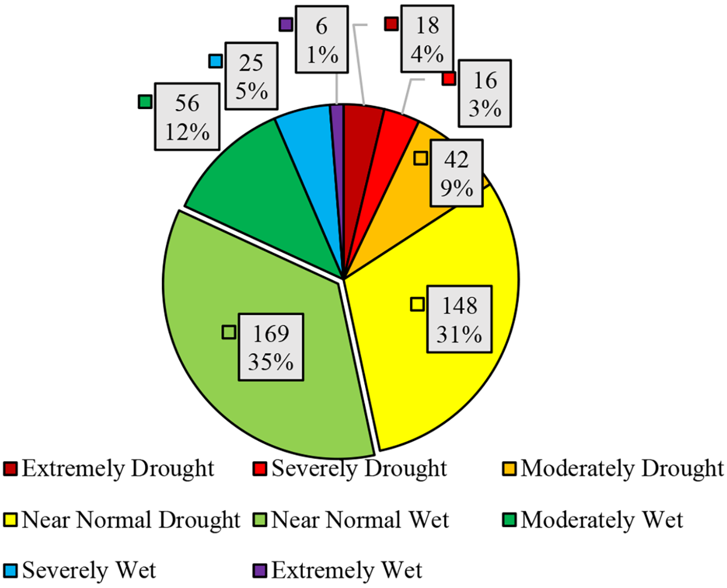

Figure 6. Drought classification probability results

period will continue for about 5 months following the observation of the Extreme Drought period for the Karaisalı region. Also, as seen in Figure 7, it can be concluded that dry periods are more effective than wet periods, other than Near Normal Drought and Near Normal Wet periods.

One of the most critical points in examining the drought periods is the estimation of the uninterrupted period from the drought duration to the first transition to the wet period [Yıldırım & Aksoy, 2019; Tatar & Eriş, 2022; Turhan et al., 2022]. Thus, it can be forecasted how long it takes to transition from a dry period to a wet period. According to the calculation of the average expected first transition times, it is understood that there is no significant difference between the beginning and the ending time of the categories (Figure 8). Another detail can be stated that the Extremely Drought period had the longest expected first transition period, this finding is compatible with the expected residence time results.

Which drought class could have seen in the past within a period of 1, 2 and 3 months following the end of any drought category provides a positive approach in terms of evaluating future periods. Therefore, by the SPI-12 values, the drought classes seen 1, 2, and 3 months after the end of the drought periods were determined and Table 2 was created with the results obtained. In the Table 2, it is noticed that one month after the

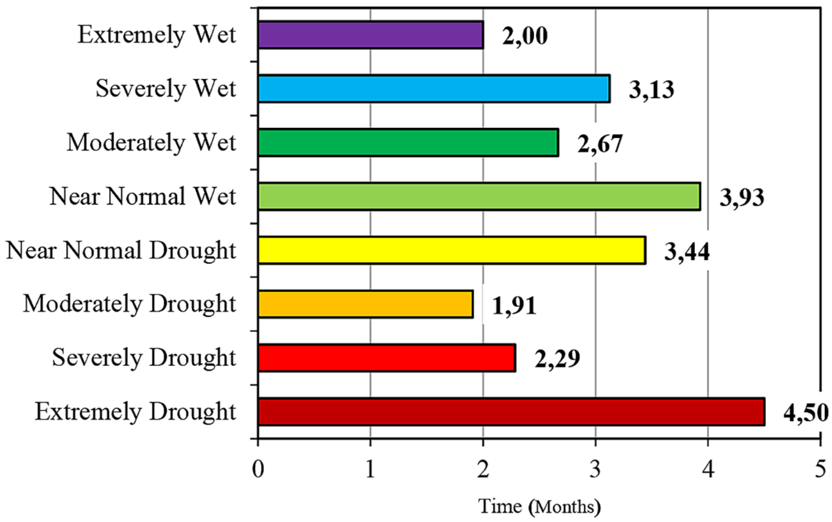

Figure 7. Expected residence time results

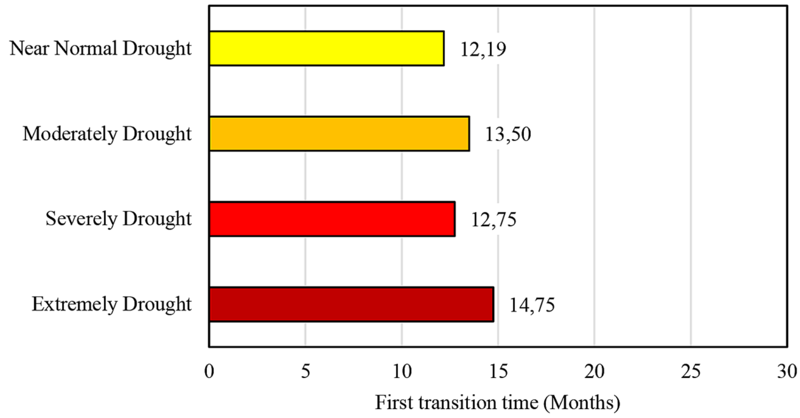

Figure 8. First transition time results for drought categories

Table 2. Comparison of future drought probabilities

Parameter	1 month later		2 months later		3 months later	
	Most possible category	Probability	Most possible category	Probability	Most possible category	Probability
Extremely drought	Severely drought	1.000	Severely drought	1.000	Near normal drought	0.750
Severely drought	Moderately drought	1.000	Near normal drought	0.750	Near normal drought	0.750
Moderately drought	Near normal drought	0.570	Near normal drought	0.670	Near normal drought	0.750
Near normal drought	Near normal wet	0.500	Near normal wet	0.670	Near normal wet	0.800
Near normal wet	Near normal drought	0.670	Near normal drought	0.700	Near normal drought	0.670
Moderately wet	Near normal wet	0.530	Near normal wet	0.600	Near normal wet	0.765
Severely wet	Moderately wet	0.630	Extremely wet	0.300	Near normal wet	0.670
Extremely wet	Severely wet	1.000	Severely wet	0.800	Near normal wet	1.000

Moderately, Severely, and Extremely Drought durations, they pass into a sub-category; after 3 months, it is seen that they have been stepped down to the Near Normal Drought category. It is possible to remark that a similar situation has been encountered in the Moderately, Severely, and Extremely Wet categories. This means that drought and wet periods with high SPI values often decrease within 3 months and turn into Near Normal periods.

CONCLUSIONS

In this study, the SPI values were calculated at 3, 6, 9, and 12 months time scales, and some drought assessments were carried out by using the precipitation data of the meteorological observation station no 17936 located in Seyhan Basin. The SPI values were computed by fitting the measurement data of 1980-2020 to the Gamma distribution. The number and probability of drought classes, the first expected transition times, and the expected residence times between classes can be listed as the parameters investigated. Considering the results of the study, it was determined that the most drought period occurred in 2012 with a minimum SPI value of (-2.6). While the maximum positive SPI value was obtained as 3, it is seen that the most wet period was experienced in 2001. It can be said that while the most common drought class for SPI-9 and SPI-12 values is the Near Normal Drought class, it is Near Normal Wet for SPI-3 and SPI-6 values. Although the number of Extremely Wet periods was the greater, it was noticed that Extremely Drought periods were more dominant and lasted longer. In accordance with the average SPI values, it can be stated that Slightly Dry and Slightly Wet periods are experienced 66% of the time. It is noteworthy that 3 months after the end of any drought classes, wet and drought periods lose their effects and pass into the Near Normal Wet and Near Normal Drought categories, which is the closest period to normal in their own classifications.

Evidently, due to its semi-arid climate characteristics, the rich water resources potential in the Karaisalı region will be exposed to the unfavourable effects of drought in the coming years. Therefore, it is thought that this study will make a considerable contribution to the literature and can act as a guide to the precautions that can be taken against drought and emergency action plans in the Karaisalı district. Future studies that can be carried out in similar regions with different drought indices will lead the way both for verifying current results and drought prediction.

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