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Research Article

Long-Term Meteorological Drought Analysis of Bursa Province

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Abstract
Drought disaster is at the center of fundamental problems of civilizations. Meteorological drought is observed primarily due to lack of precipitation, high temperatures, and increased evaporation. Meteorological drought is followed by agricultural and hydrological drought. Hydrometeorological time series include trends particularly over the last 30 years as a result of the impact of climate change according to the Intergovernmental Panel on Climate Change. In this study, drought analyses were conducted for Bursa province, which intersects with the Nilüfer sub-basin, which is in the Susurluk Basin, one of the 25 river basins of Turkey. In the analysis, precipitation data of 17116-Bursa and 17676-Uludağ stations between 1967-2022 were used. Drought analyzes were made using Standardized Precipitation Index (SPI) and Percent of Normal Index (PNI) methods. With the drought analyses, drought phases were found by calculating the amount of drought recurrence, drought duration, drought severity, and drought amplitude values. The seasons with the most drought were determined. As a result of the drought analyses, it was observed that the Standardized Precipitation Index (SPI) and Percent of Normal Index (PNI) methods gave compatible results with each other.

Keywords
“Meteorological drought, Standardized precipitation index, Percentage of normal index, Drought, Bursa province”

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1.Introduction

All living beings require basic nutritional and shelter needs to sustain their lives (Şen, 2009). One of the essential nutrients is water. All living beings need water according to their specific requirements. Due to the increasing population and current living conditions, the demand for water is rising day by day. Furthermore, the loss of water resources, exacerbated by the effects of climate change, has made water even more critical. Drought is one of the climatic disasters that begin with the reduction in precipitation. Although drought is a natural event, it can have devastating effects due to societies' vital dependence on water resources (Gümüş, 2017). Turkey is located in a semi-arid climate zone. Due to geographical and topographical characteristics, temperature, precipitation, and wind vary depending on the region and time. Turkey's long-term average annual precipitation is 574 mm. The Eastern Black Sea Region is the region with the highest precipitation (1200–2500 mm/year), while the Central Anatolia Region (around Lake Tuz) receives the least precipitation (250-300 mm/year) (DSİ, 2020). Drought primarily manifests itself as meteorological drought, which results from the lack of precipitation. After meteorological drought, agricultural drought and hydrological drought follow in sequence (Wilhite & Glantz, 1985). Various methods are used to calculate meteorological drought.

Various drought index studies for different purposes have been conducted and are available in the literature. Drought indices commonly used in drought studies mainly focus on precipitation parameters and meteorological drought. Frequently used meteorological drought indices include the Palmer Drought Severity Index (PDSI) (Palmer, 1965; Booth & Voeller, 1967; Karl, 1986), Standardized Precipitation Index (SPI) (Mckee et al., 1993; Wu et al., 2001; Li et al., 2008), the China Z Index, and the Z-score Index (Wu et al., 2001). In Turkey, drought studies for various regions have been calculated using different indices. These indices include the De Martonne Index (İnandık, 1951; Tümertekin, 1955; Çelenk, 1974), the Thronthwaite Index (Tümertekin, 1955; Altuğlu, 1972), the Erinç Precipitation Effectiveness Index (EPEI) (Erinç, 1965; Türkeş, 1990; Çelik & Gülersoy, 2018), the Standardized Precipitation Index (SPI) (Kömüşçü, 1999; Türkeş, 1990; Sırdaş, 2002; Sırdaş & Şen, 2003; Yeğnidemir, 2005; Yıldız, 2007; Tonkaz, 2008; Keskin & Şorman, 2010; Ilgar, 2010; Fidan, 2011; Dinç et al., 2016; Keskiner et al., 2016; Çetin et al., 2016; Çelik & Gülersoy, 2018; Kumanlıoğlu & Fıstıkoğlu, 2019; Çavuş & Aksoy, 2019; Sarış & Gedik, 2021; Aktürk et al., 2022; Keskiner & Şimsek, 2023), the Standardized Precipitation Evapotranspiration Index (SPEI) (Çamalan et al., 2017; Aktürk et al., 2022), the Topçuoğlu Index (Topçuoğlu et al., 2004), and the Percentage of Normal Index (Çelik & Gülersoy, 2018).

Global warming affects climates and leads to differences in natural events. Precipitation patterns resulting from climate change show regional variations. The lack of precipitation primarily manifests itself through meteorological drought. In this study, drought analyses were conducted for Bursa province, which intersects with the Nilüfer sub-basin of the Susurluk Basin, one of Turkey's 25 river basins. The aim was to determine the meteorological drought caused by precipitation deficiency in Bursa using the Standardized Precipitation Index (SPI) method, which is recognized by the World Meteorological Organization (WMO) as the initial index for monitoring meteorological drought. Using the SPI method, the recurrence the rate, duration, severity and the amplitude values of drought were calculated, and the percentages of the drought periods were determined. The SPI values for scales of 1-3-6-9-12-24 months were considered important: the 1-month SPI values for meteorological drought, 1-6 month SPI values for agricultural drought, and 6-24 month SPI values for hydrological drought analysis and applications. Therefore, the results obtained in the study should also be examined and compared for agricultural and hydrological aspects. Additionally, the seasonal meteorological droughts were detected using two different drought methods, SPI and PNI, and a comparison of these two methods was conducted.

2. Material And Method

2.1.Study area and data

The Susurluk Basin is located in the western part of Turkey, between the latitudes of 39º-40º North and the longitudes of 27º-30º East. Covering approximately 2.98% of Turkey's total area, the basin has a total area of about 24,319.09 km². The basin, which mainly extends in an east-west direction, is home to Uludağ, the highest mountain in the Marmara Region. To the west, the basin is bordered by the Madra and Deliçal mountains; to the north, it is bordered by the Karadağ and Mudanya Hills, and by the Sea of Marmara. The main rivers of the Susurluk Basin are the Nilüfer Stream, Mustafakemalpaşa Stream, Simav (Susurluk) Stream, and Kocaçay. The Susurluk Basin includes the provinces of Balıkesir, Bursa, and Kütahya. Studies have been conducted at two precipitation stations located within the borders of Bursa province. The general overview of the Susurluk Basin, the Nilüfer Sub-basin, and Bursa province boundaries is shown in Figure 1. Detailed information about the precipitation stations is provided in Table 1.

Table 1. Precipitation Station Information

Station Number	Station Name	Province	Town	Years of Data	Latitude	Longitude	Altitude
17116	Bursa	Bursa	Osmangazi	1967-2022	40.2308	29.0133	100
17676	Uludağ	Bursa	Osmangazi	1967-2022	40.1075	29.1290	1877

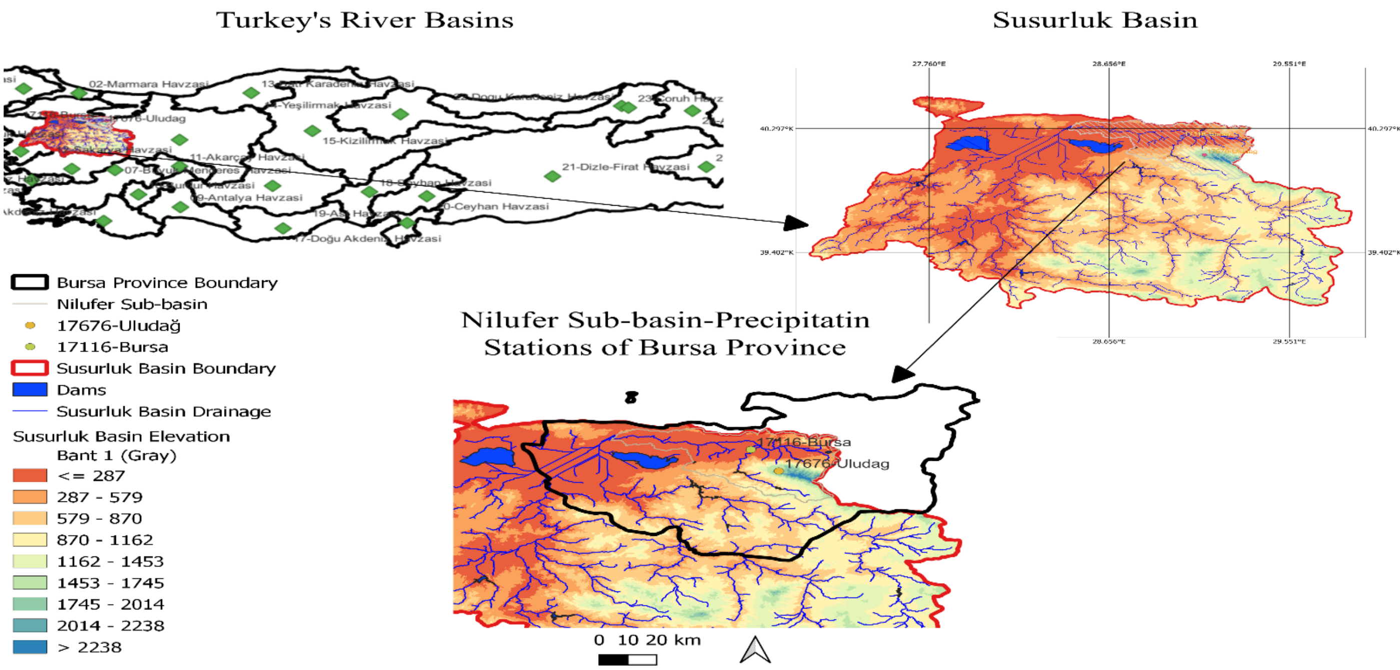


Figure 1. Susurluk Basin, Nilüfer Sub-basin, and General Overview of Bursa Province

2.2.Method

2.2.1. Drought analyses

Different indices are used in meteorological drought studies worldwide. The most important factor upon which almost every index is based is precipitation. The SPI has been designated by the WMO as the initial index for drought calculations. Additionally, it has been determined that the PNI provides good results both regionally and seasonally.

2.2.1.1. Standardized precipitation index (SPI)

This index was developed by McKee et al. (1993) to understand the reduction in precipitation and to determine its effects on groundwater, water storage reservoirs, soil moisture, snowpack, and rivers. In the SPI, $\bar{X}$ represents the arithmetic mean of the precipitation series, S_x is the standard deviation of the precipitation series, and X_i refers to the value of the i-th precipitation variable. The SPI calculation is shown in Equation 1.

$$SPI = \frac{X_i - \bar{X}}{S_x} \quad (1)$$

SPI allows drought analysis over multiple time scales of 1, 3, 6, 9, 12, and 24 months. For meteorological drought, the 1-month SPI values are used; for agricultural drought, the SPI values range from 1 to 6 months; and for hydrological drought analysis and applications, the SPI values range from 6 to 24 months. The strength of the SPI lies in its ability to conduct drought analysis over different time scales and in different regions using only precipitation input data. As a result of drought analysis, the severity of drought can be calculated. The drought classifications corresponding to the SPI values are shown in Table 2.

Table 2. SPI Values Drought Classification (McKee et al., 1993; WMO, 2012)

SPI Values	Drought Classification
> 2	Excessively humid
1.5 ile 1.99	Very humid
1.0 ile 1.49	Partially humid
0.99 ile -0.99	Near normal
-1.00 ile -1.49	Mild drought
-1.50 ile -1.99	Severe drought
≤ -2.00	Extreme drought

2.2.1.2. Percent of normal index (PNI)

It is the ratio of the amount of precipitation in a given area to the "normal" 30-year arithmetic average of precipitation for that region. It can be applied over different time periods (day, week, month, year). It gives good results for small areas and short periods. In the PNI, X_i represents the value of the i-th precipitation variable, and $\bar{X}$ represents the long-term average. Seasonal drought analyses have been conducted. The PNI calculation is shown in Equation 2. The drought classifications corresponding to the PNI values, along with the drought periods, are shown in Table 3.

$$PNI = 100\,\frac{X_i}{\bar{X}} \quad (2)$$

Table 3. PNI Values Drought Classification (Willeke et al.,1994)

Time Period	Normal and Above	Mild Drought	Moderate Drought	Severe Drought
1	>75	65-75	55-65	<55
3	>75	65-75	55-65	<55
6	>80	70-80	60-70	<60
9	>83.5	73.5-83.5	63.5-73.5	<63.5
12	>85	75-85	65-75	<65

2.2.1.3. Run analysis

A period of precipitation below the expected value is referred to as a drought phase. In the analysis of drought phases, the duration and amplitude of the drought are of significant importance. The severity of drought indicates how much below the expected value the precipitation has fallen. Drought severity is calculated as the ratio of the drought amplitude to the drought duration. The duration of the drought shows how long the drought phase lasted. The amplitude of the drought is the sum of the standardized SPI values obtained during the dry period (Figure 2). The dry and wet periods corresponding to the SPI values are shown in Figure 2.

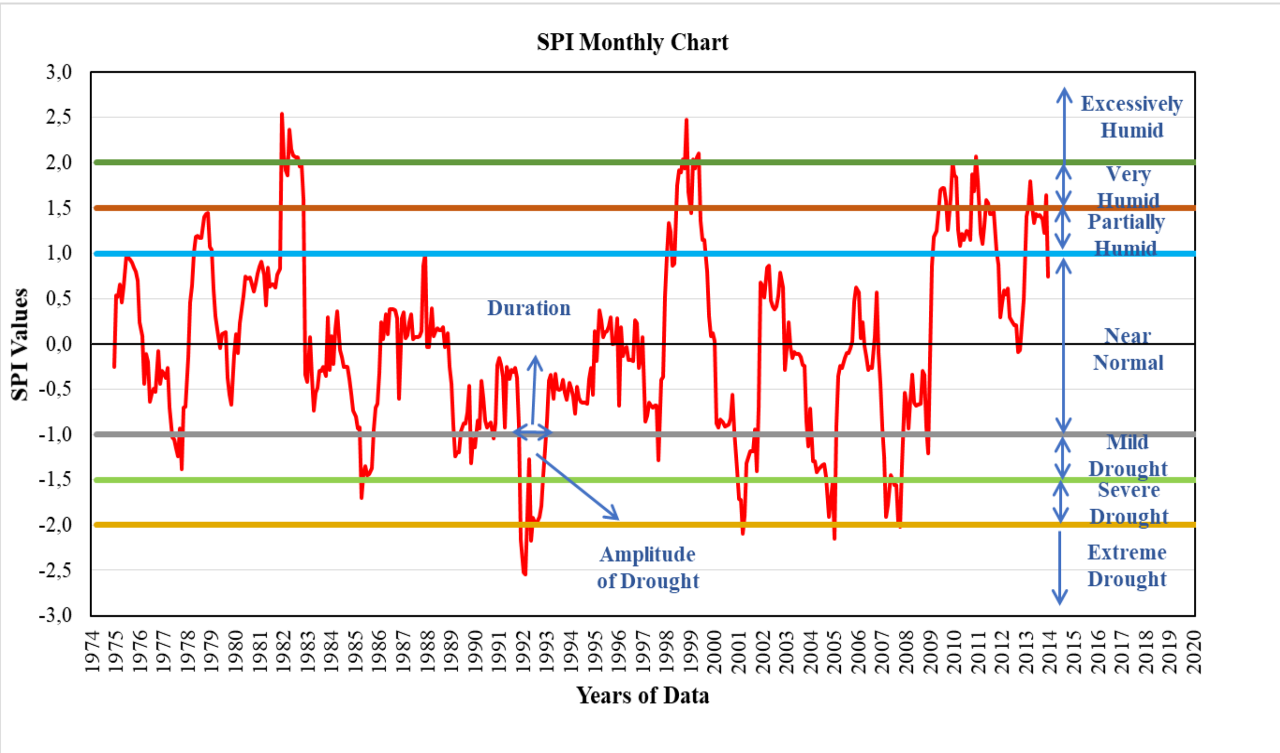


Figure 2. Run Analysis Chart

3. Findings and Discussion

3.1. Drought Analysis

3.1.1. 17116-Bursa station SPI drought analysis

At the 17116-Bursa station, the annual average precipitation between 1967 and 2022 is 685.90 mm. It can be observed that the precipitation for 32 years has fallen below the long-term annual average. All drought phases were observed in the SPI-1 results. The Mild Drought, Severe Drought, and Extreme Drought phases occurred 50 times, lasting for 86 months, covering 12.79% of the time period. In November 2015 and January 2016, during a 2-month period, the Extreme Drought phase reached its maximum amplitude of 4.66. During the same months, the maximum drought severity value was 3.48. In different months, the drought severity also reached a maximum value of 3.44 (Figure 3).

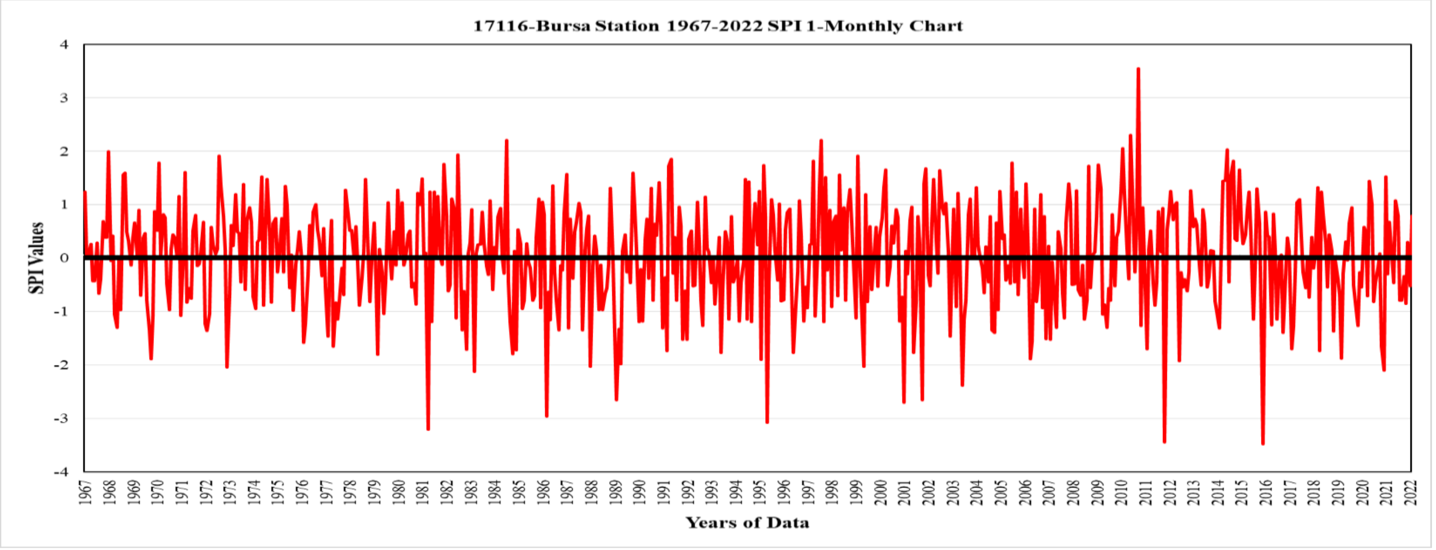


Figure 3. 17116-Bursa Station SPI 1-Monthly Chart

In the SPI-3 results, the most severe drought class, Extreme Drought, was not detected. Mild Drought and Severe Drought phases were identified. The Mild Drought and Severe Drought phases occurred 34 times, lasting for 99 months, covering 14.73% of the time period. In February 1989 and July 1989, during a 5-month period, the Extreme Drought phase reached its maximum amplitude of 11.21. The maximum drought severity and drought severity values reached their highest levels in different periods, with values of 3.47 and 2.39, respectively (Figure 4).

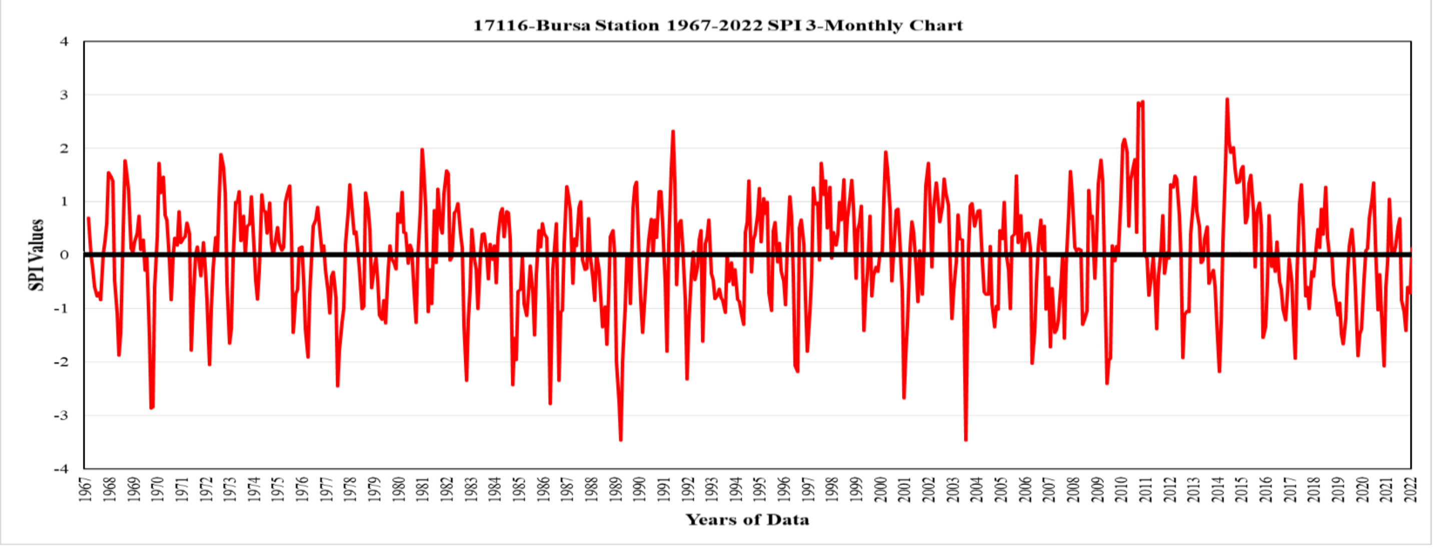


Figure 4. 17116-Bursa Station SPI 3-Monthly Chart

According to the SPI-6 results, only the Mild Drought phase was identified among the drought phases. The Mild Drought phase occurred 15 times, lasting for 107 months, covering 15.92% of the time period. In June 1988 and October 1988, during a 4-month period, the Mild Drought phase reached its maximum amplitude of 22.93. During the same months, the maximum drought severity value was 3.05, which was the highest observed. In different months, the drought severity also reached its maximum value of 1.65 (Figure 5).

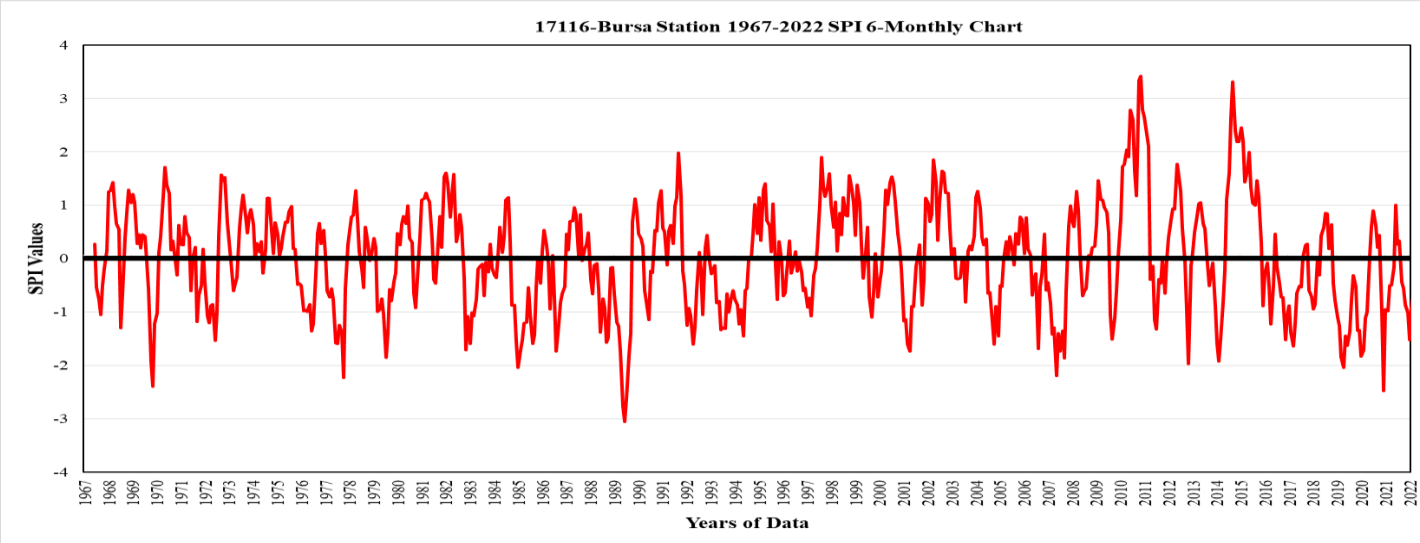


Figure 5. 17116-Bursa Station SPI 6-Monthly Chart

According to the SPI-9 results, the most severe drought class, Extreme Drought, was not observed. The Mild Drought and Severe Drought phases were dominant. The Mild Drought and Severe Drought phases occurred 12 times, lasting for 114 months, covering 16.96% of the time period. From September 1988 to November 1989, during a 14-month period, the Severe Drought phase reached its maximum amplitude of 22.39. During the same months, the maximum drought severity and drought severity values reached their highest levels, with values of 3.09 and 1.60, respectively (Figure 6).

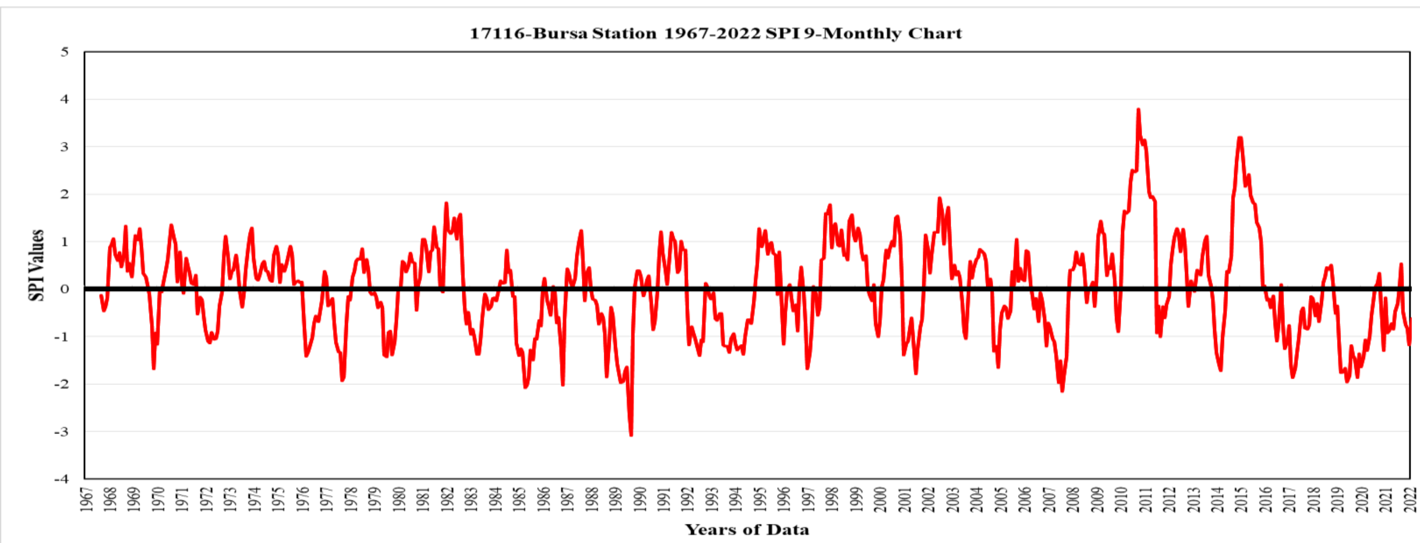


Figure 6. 17116-Bursa Station SPI 9-Monthly Chart

According to the SPI-12 results, the Mild Drought phase was observed immediately after the Near Normal. Severe Drought and Extreme Drought phases were not encountered. The Mild Drought phase occurred 7 times, lasting for 102 months, covering 15.18% of the time period. From March 2019 to December 2021, during a 33-month period, the Mild Drought phase reached its maximum amplitude of 25.74. The maximum drought severity and drought severity values reached their highest levels in a different period, with values of 2.48 and 1.21, respectively (Figure 7).

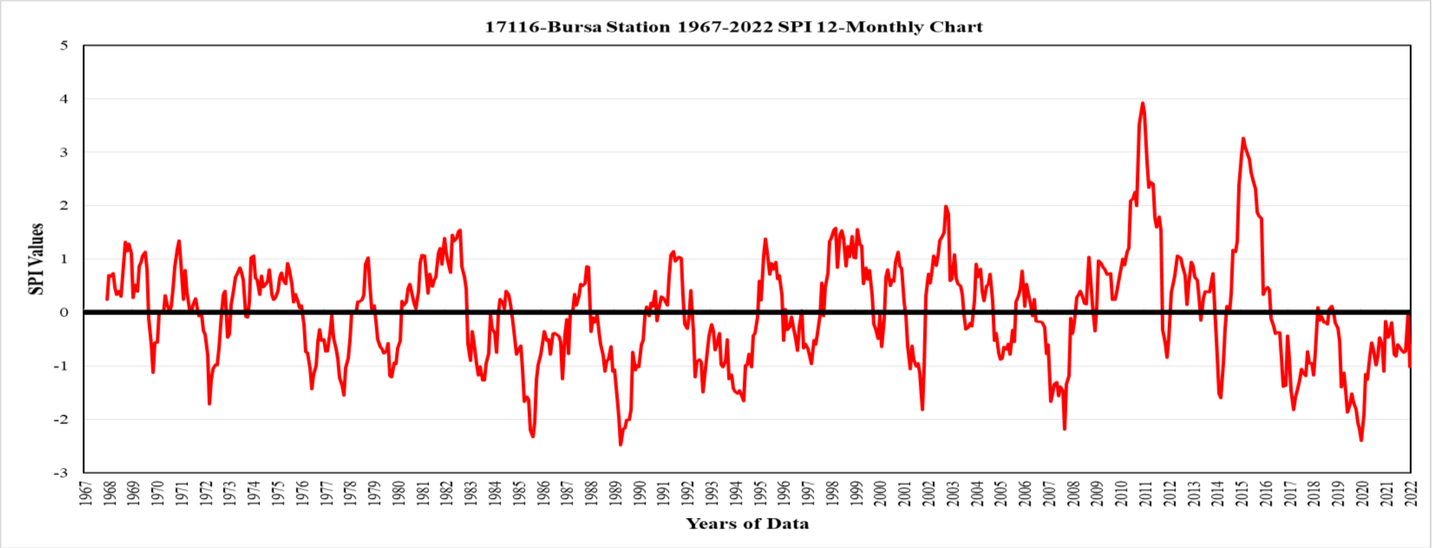


Figure 7. 17116-Bursa Station SPI 12-Monthly Chart

According to the SPI-24 results, the Mild Drought phase was observed immediately after the Near Normal. Severe Drought and Extreme Drought phases were not encountered. The Mild Drought phase occurred 3 times, lasting for 74 months, covering 11.01% of the time period. From February 1989 to April 1991, during a 26-month period, the Mild Drought phase reached its highest amplitude of 32.56. The maximum drought severity and drought severity values also reached their highest levels during the same months, with values of 2.03 and 1.25, respectively (Figure 8).

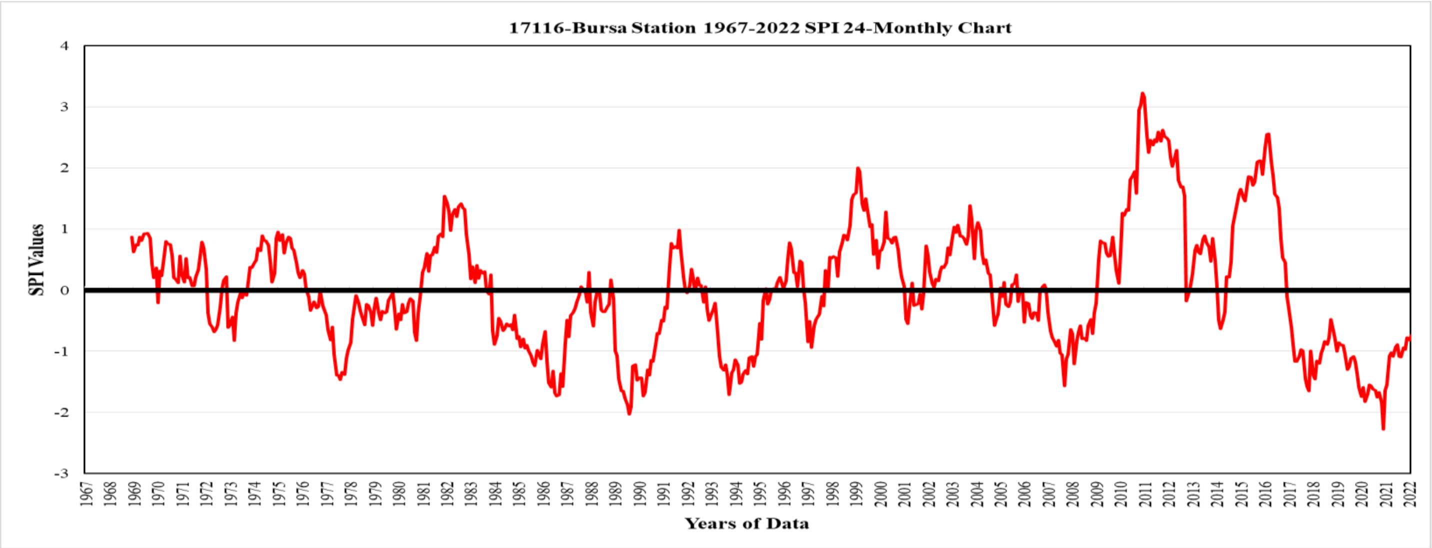


Figure 8. 17116-Bursa Station SPI 24-Monthly Chart

3.1.2. 17676-Uludağ station SPI drought analysis

At the 17676 Uludağ station, precipitation data is available for the period between 1967 and 2022. The annual average precipitation between 1967 and 2022 is 1467.40 mm. It can be observed that the precipitation for 27 years has fallen below the long-term annual average. According to the SPI-1 results, similar to the Bursa station, all drought phases were observed at the Uludağ station. The Mild Drought, Severe Drought, and Extreme Drought phases occurred 60 times, lasting for 100 months, covering 14.88% of the time period. In November 2015 and January 2016, during a 2-month period, the Extreme Drought phase reached its maximum amplitude of 4.76. The maximum drought severity also reached its highest value during the same months, with a value of 3.48. In different months, the drought severity reached a maximum value of 2.41 (Figure 9).

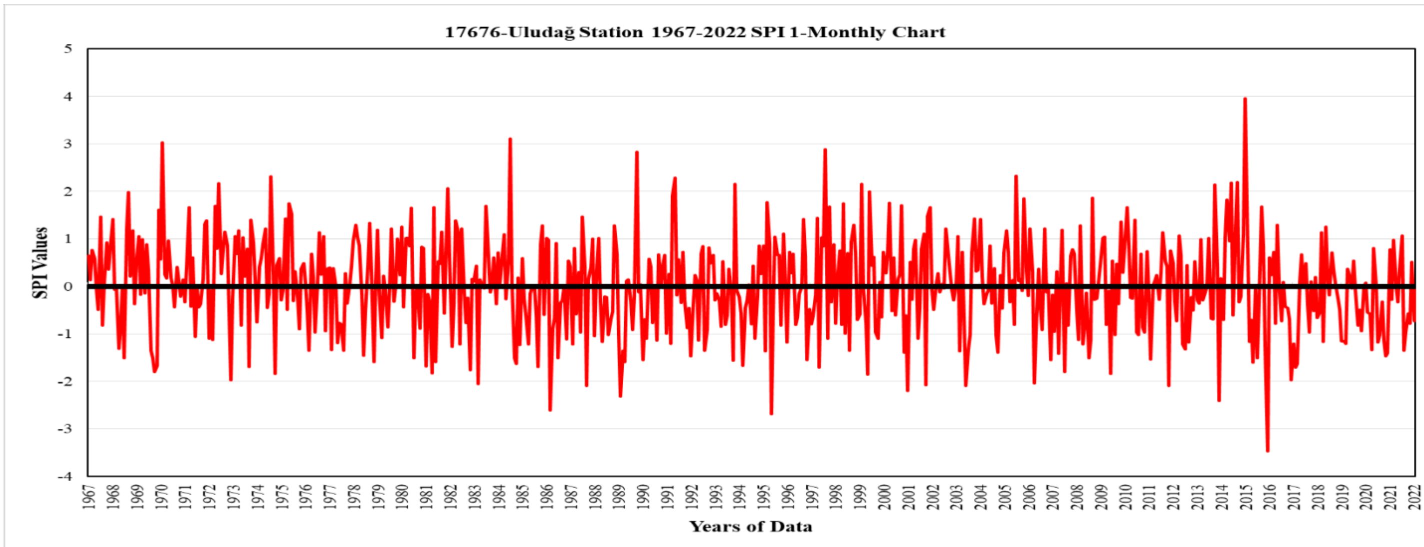


Figure 9. 17676-Uludağ Station SPI 1-Monthly Chart

In the SPI-3 results, all the drought phases observed in the SPI-1 results were also detected. The Mild Drought, Severe Drought, and Extreme Drought phases occurred 26 times, lasting for 86 months, covering 12.80% of the time period. From September 1969 to December 1969, during a 4-month period, the Extreme Drought phase reached its maximum amplitude of 7.12. The maximum drought severity and drought severity values reached their highest levels in a different period, with values of 3.69 and 2.17, respectively (Figure 10).

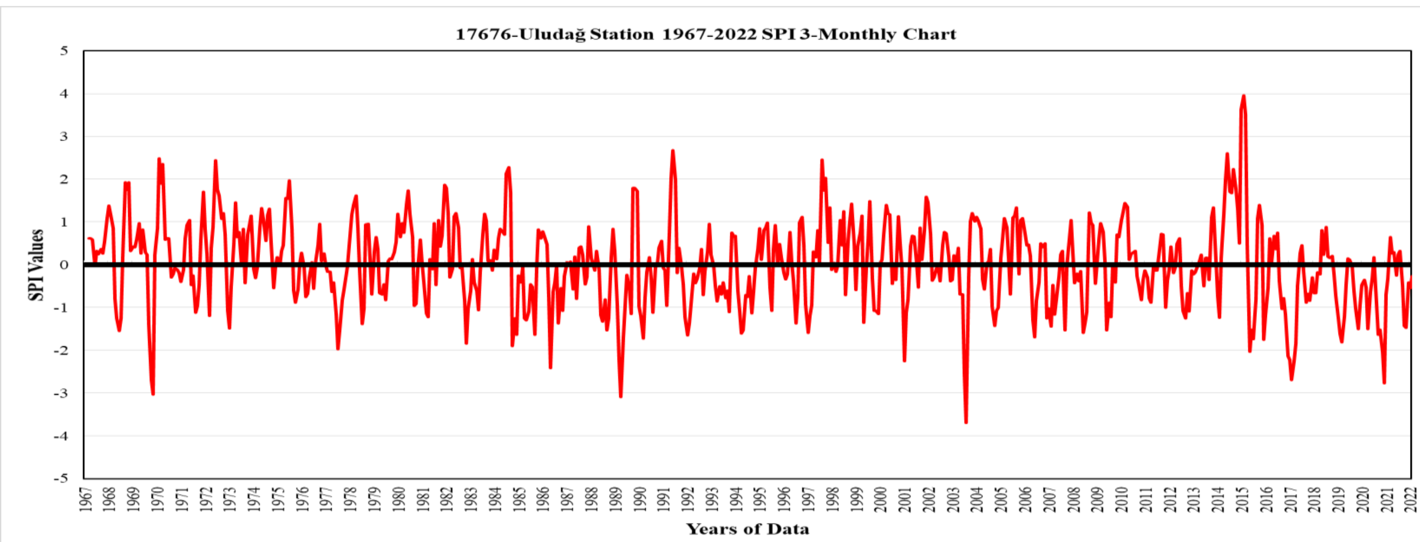


Figure 10. 17676-Uludağ Station SPI 3-Monthly Chart

When the SPI-6 results were examined, no values for the most severe drought class, Extreme Drought, were encountered. The Mild Drought and Severe Drought phases were observed in the analysis results. The Mild Drought and Severe Drought phases occurred 12 times, lasting for 93 months, covering 13.84% of the time period. From April 1989 to October 1989, during a 6-month period, the Severe Drought phase reached its maximum amplitude of 10.88. The maximum drought severity value, however, reached its highest level during a different period, with a value of 3.27. The drought severity value also reached its highest level during a different period, with a value of 1.81 (Figure 11).

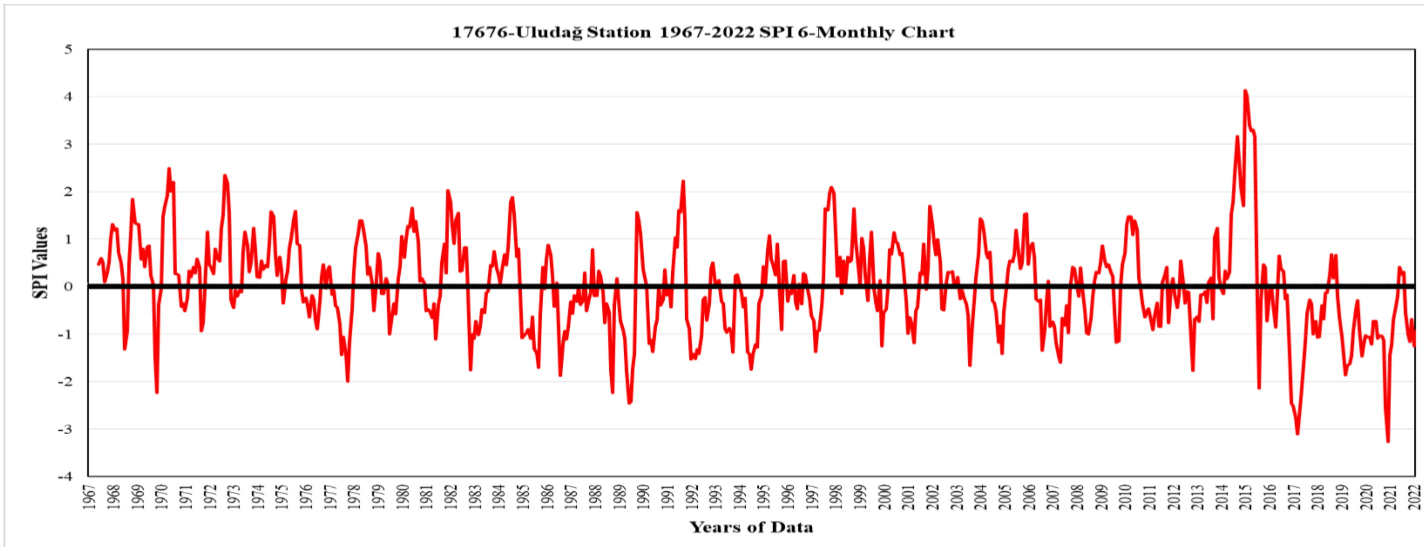


Figure 11. 17676-Uludağ Station SPI 6-Monthly Chart

According to the SPI-9 results, it was determined that the Severe Drought and Extreme Drought phases did not occur. The Mild Drought phase was dominant. The Mild Drought phase occurred 9 times, lasting for 108 months, covering 16.07% of the time period. From February 2019 to September 2021, during a 31-month period, the Mild Drought phase reached its maximum amplitude of 40.35. Unlike the drought amplitude, the maximum drought severity and drought severity values reached their highest levels during a different period, with values of 3.15 and 1.44, respectively (Figure 12).

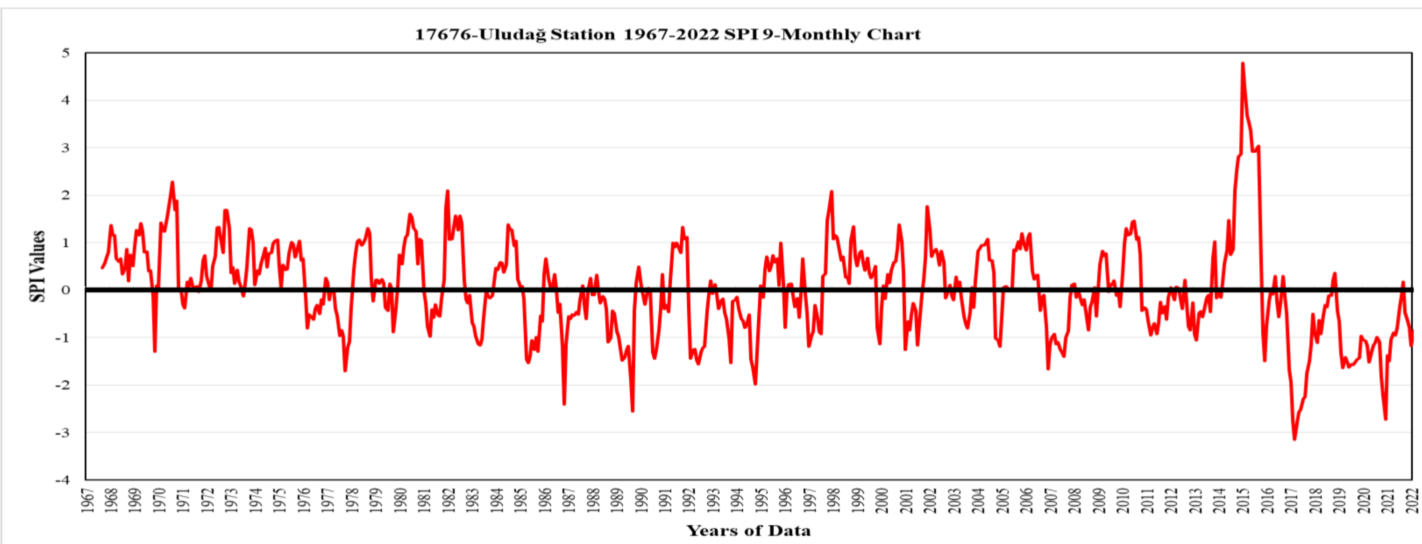


Figure 12. 17676-Uludağ Station SPI 9-Monthly Chart

In the SPI-12 results, similar to the SPI-9 results, it was determined that the Severe Drought and Extreme Drought phases did not occur. However, the Mild Drought phase was observed only once. The Mild Drought phase occurred 1 time, lasting for 7 months, covering 1.04% of the time period. From July 1985 to February 1986, during a 7-month period, the Mild Drought phase reached its maximum amplitude of 7.61. During the same months, the maximum drought severity and drought severity values reached their highest levels, with values of 1.67 and 1.09, respectively (Figure 13).

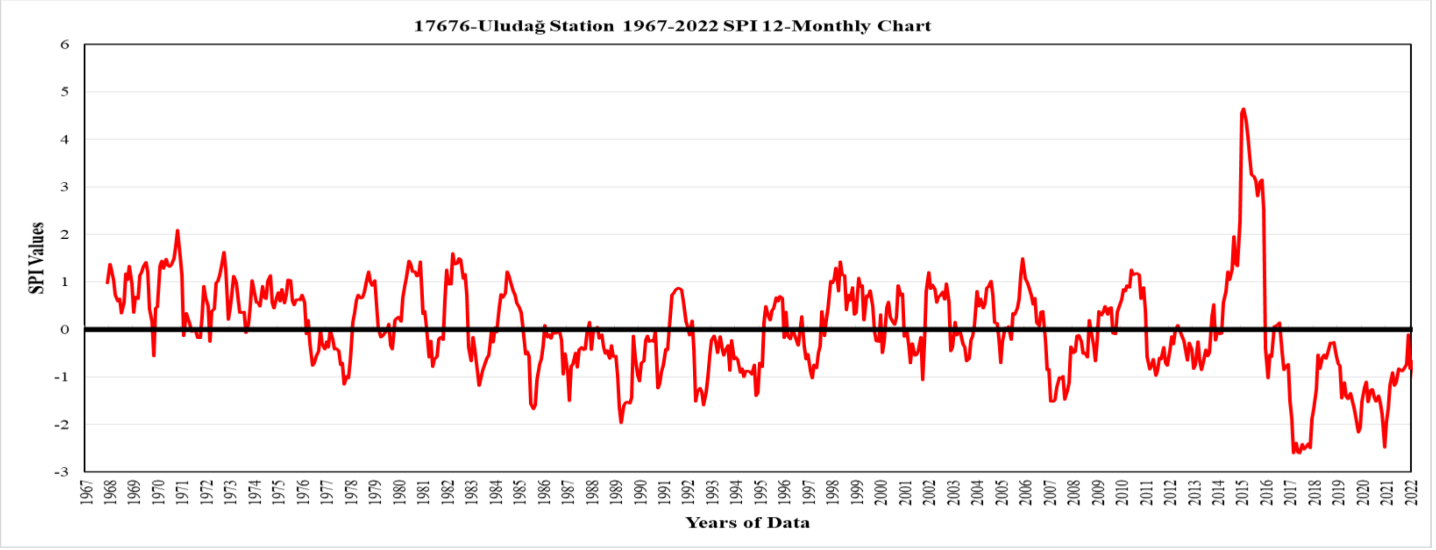


Figure 13. 17676-Uludağ Station SPI 12-Monthly Chart

The SPI-24 results showed values close to Normal. The drought phases, including Mild Drought, Severe Drought, and Extreme Drought, were not detected (Figure 14).

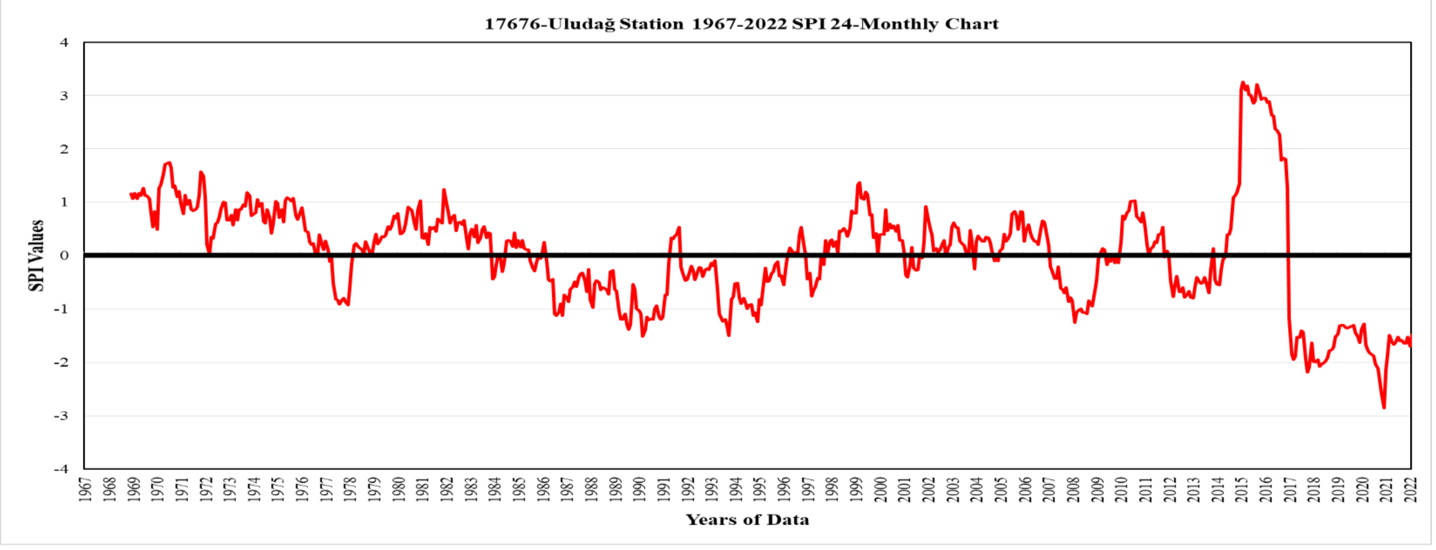


Figure 14. 17676-Uludağ Station SPI 24-Monthly Chart

3.1.3. 17116-Bursa station and 17676-Uludağ station SPI seasonal drought analysis

When the SPI results of the 17116-Bursa station were examined seasonally, the following observations were made: In the spring seasons, drought phases occurred 12 times, representing 21.43%, the highest proportion. In the summer seasons, drought phases were observed 7 times, accounting for 12.50%, which is lower than in the spring. In the autumn seasons, drought phases occurred 11 times, making up 19.64%, the second highest proportion. Finally, in the winter seasons, drought phases occurred 4 times, representing 7.27%, making it the season with the least drought occurrence (Figure 15).

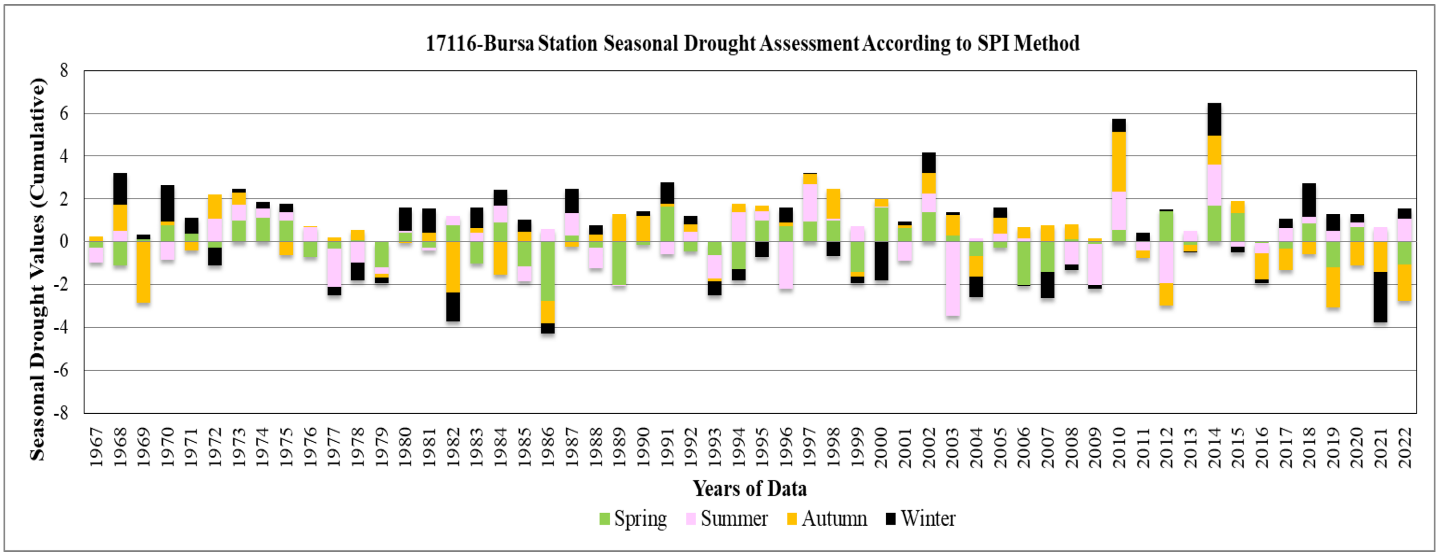


Figure 15. 17116-Bursa Station Seasonal Drought Assessment According to SPI Method

When the SPI results of the 17676-Uludağ station were examined seasonally, the following observations were made: In the spring seasons, drought phases occurred 10 times, accounting for 17.86%. In the summer seasons, drought phases were observed 8 times, representing 14.29%, which is lower than in the spring. For the autumn seasons, the highest drought occurrence was observed, with drought phases occurring 12 times, reaching the maximum value of 21.43%. In the winter seasons, the least drought was recorded, with drought phases occurring 4 times, representing 7.27% (Figure 16).

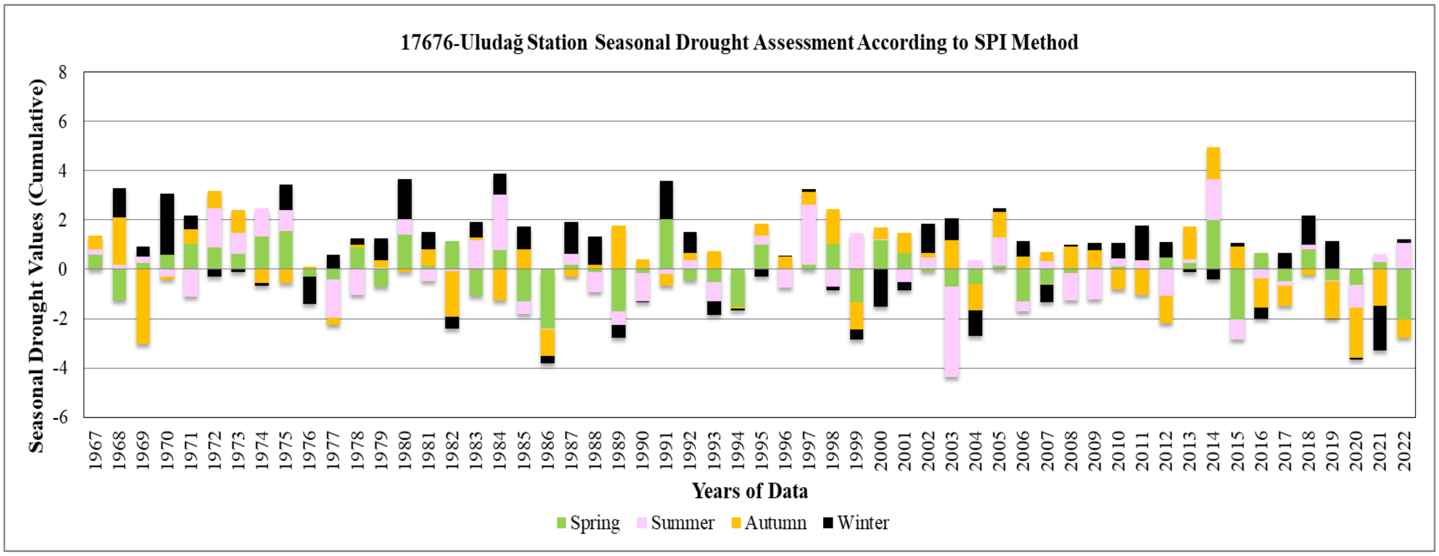
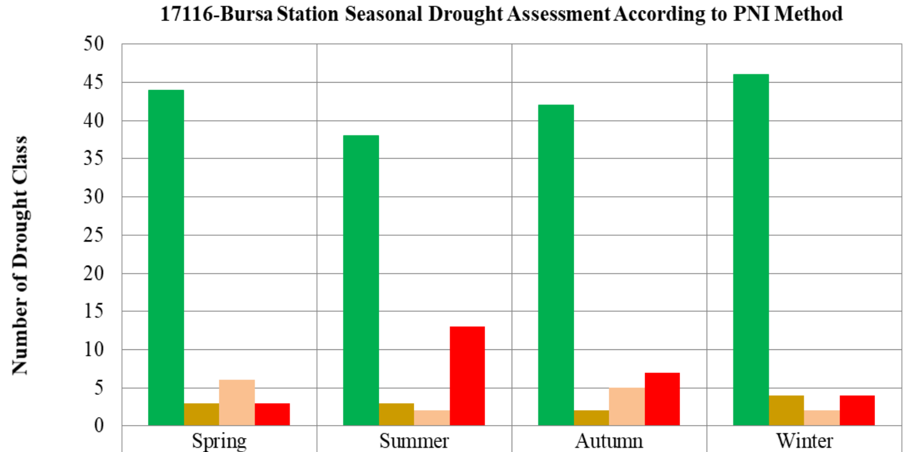


Figure 16. 17676-Uludağ Station Seasonal Drought Assessment According to SPI Method

3.1.4.17116-Bursa station and 17676-Uludağ station PNI seasonal drought analysis

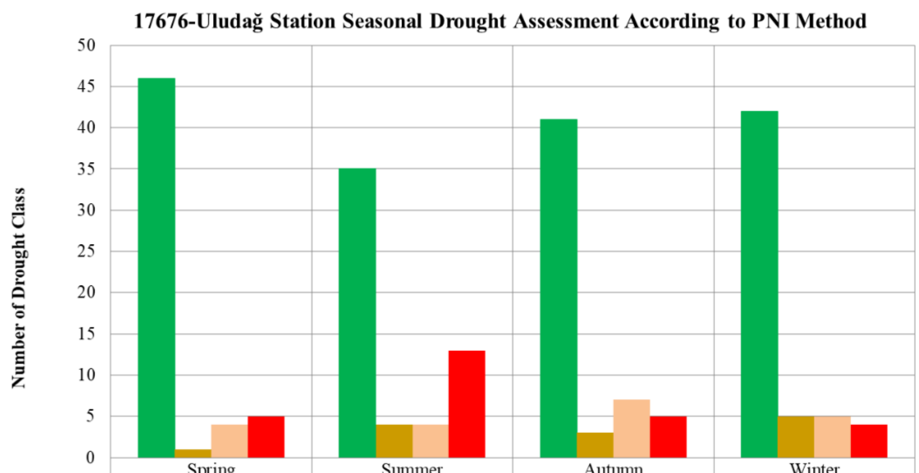
When the PNI results of the 17116-Bursa station were examined seasonally, the following observations were made: In the spring seasons, drought phases occurred in 12 seasons, accounting for 21.43%, ranking third. In the summer seasons, the maximum number of drought phases was observed in 18 seasons, representing 32.14%, making it the highest proportion. In the autumn seasons, the second most drought phases were observed after summer, with 14 occurrences, representing 25.00%, making it the second most drought-prone season. In the winter seasons, the least drought phases were observed, with 10 occurrences, accounting for 17.86% (Figure 17).



	Spring	Summer	Autumn	Winter
Normal and Above	44	38	42	46
Mild Drought	3	3	2	4
Moderate Drought	6	2	5	2
Severe Drought	3	13	7	4

Figure 17. 17116-Bursa Station Seasonal Drought Assessment According to PNI Method

When the PNI results of the 17676-Uludağ station were examined seasonally, the following observations were made: In the spring seasons, drought phases occurred in 10 seasons, accounting for 17.86%. In the summer seasons, the highest number of drought phases was observed, with 21 occurrences, representing 37.50%, making it the most prevalent season. In the autumn seasons, after summer, the second most drought phases were observed, with 15 occurrences, representing 26.79%. In the winter seasons, following the summer season, drought phases were observed in 14 occurrences, accounting for 25.00% (Figure 18).



	Spring	Summer	Autumn	Winter
Normal And Above	46	35	41	42
Mild Drought	1	4	3	5
Moderate Drought	4	4	7	5
Severe Drought	5	13	5	4

Figure 18. 17676-Uludağ Station Seasonal Drought Assessment According to PNI Method

3.1.5. Comparison of SPI and PNI seasonal drought

When comparing the seasonal SPI method results of the 17116-Bursa station with those of the 17676-Uludağ station, it was observed that 158 seasons were in harmony with each other, showing a similarity rate of 70.54%. The seasonal SPI method results for the 17116-Bursa station indicate 34 seasons of drought. Similarly, the seasonal SPI method results for the 17676-Uludağ station also indicate 34 seasons of drought. The drought phases of 25 seasons were observed in both stations during the same periods. It was found that the year 2014 was a wet year for both stations. A comparison of the SPI seasonal analysis results for the Bursa and Uludağ stations is shown in Table 4.

Table 4. Comparison of SPI Results for 17116-Bursa and 17676-Uludağ Stations

Stations	Similarity	
	SPI (All Phases-Seasonal) Number of Seasons	SPI (Drought Phases-Seasonal) Number of Seasons
17116-Bursa ve 17676-Uludağ	158	25

When comparing the seasonal PNI method results of the 17116-Bursa station with those of the 17676-Uludağ station, it was observed that 175 seasons were in harmony with each other, showing a similarity rate of 78.13%. The seasonal PNI method results for the 17116-Bursa station indicate 54 seasons of drought. Similarly, the seasonal PNI method results for the 17676-Uludağ station indicate 60 seasons of drought. The drought phases of 41 seasons were observed in both stations during the same periods. A comparison of the PNI seasonal analysis results for the Bursa and Uludağ stations is shown in Table 5.

Table 5. Comparison of PNI Results for 17116-Bursa and 17676-Uludağ Stations

Stations	Similarity	
	PNI (All Phases-Seasonal) Number of Seasons	PNI (Drought Phases-Seasonal) Number of Seasons
17116-Bursa ve 17676-Uludağ	175	41

A total of 34 drought seasons were calculated for the 17116-Bursa station based on the seasonal SPI method. A total of 54 drought seasons were calculated for the 17116-Bursa station based on the seasonal PNI method. For the 17116-Bursa station, 30 drought phases from the SPI and PNI methods coincided in the same periods. A comparison of the seasonal SPI-PNI drought phase analysis results for the Bursa station is shown in Table 6.

Table 6. Seasonal Comparison of Drought Phases for 17116-Bursa Station SPI-PNI Results

Station	SPI (Drought Phases-Seasonal) (Number of Seasons)	PNI (Drought Phases-Seasonal) (Number of Seasons)	SPI-PNI (Drought Phases-Seasonal Similarity) (Number of Seasons)
17116-Bursa	34	54	30

A total of 34 drought seasons were calculated for the 17676-Uludağ station based on the seasonal SPI method. A total of 60 drought seasons were calculated for the 17676-Uludağ station based on the seasonal PNI method. For the 17676-Uludağ station, 30 drought phases from the SPI and PNI methods coincided in the same periods. A comparison of the seasonal SPI-PNI drought phase analysis results for the Uludağ station is shown in Table 7.

Table 7. Seasonal Comparison of Drought Phases for 17676-Uludağ Station SPI-PNI Results

Station	SPI (Drought Phases-Seasonal) (Number of Seasons)	PNI (Drought Phases-Seasonal) (Number of Seasons)	SPI-PNI (Drought Phases-Seasonal Similarity) (Number of Seasons)
17676-Uludağ	34	60	30

4.Conclusions

In this study, meteorological drought assessments were made for the 17116-Bursa station and the 17676-Uludağ precipitation observation station located within the borders of Bursa province, using the SPI and PNI methods for the period 1967-2022. The average precipitation at the Bursa station between 1967 and 2022 is 685.90 mm. Data for 32 years of precipitation were found to be below the long-term average precipitation. Drought phases were observed in all calculations. When the maximum SPI values were examined, the SPI-1 result showed 50 occurrences and a maximum drought value of 3.48. The longest drought duration, 114 months and a 16.96% drought percentage, was found in the SPI-9 result. The maximum drought magnitude was 32.56, recorded in the SPI-24 result. When examining the seasonal SPI drought results, the highest number of drought phases (12 times) was observed in the spring season. When the seasonal drought results were analyzed using the PNI method, the highest number of drought phases (18 times) was observed in the summer season. In the seasonal comparison of SPI-PNI, 30 drought phases occurred in the same periods. The average precipitation at the Uludağ station between 1967 and 2022 is 1467.40 mm. Data for 27 years of precipitation were below the long-term average precipitation. Drought phases were observed in all calculations except for SPI-24. When examining the maximum SPI values, the SPI-1 result showed 60 occurrences. The longest drought duration, 108 months and a 16.07% drought percentage, was found in the SPI-9 result. The maximum drought magnitude of 40.35 was recorded in the SPI-9 result. The maximum drought value of 3.69 was found in the SPI-3 result. When examining the seasonal SPI drought results, the highest number of drought phases (12 times) occurred in the autumn season. When analyzing the seasonal drought results using the PNI method, the highest number of drought phases (21 times) occurred in the summer season. In the seasonal comparison of SPI-PNI at the 17676-Uludağ station, 30 drought phases occurred in the same periods.

When the SPI results of the examined stations were compared seasonally, it was found that 158 seasons showed consistency, with a similarity rate of 70.54%. When comparing seasonal drought phases, 25 seasons had drought phases in the same seasonal years. When comparing the PNI results for seasonal wet and dry phases, consistency was observed in 175 seasons, with a similarity rate of 78.13%. Additionally, when comparing the seasonal drought phases of the PNI results, 41 seasons had drought phases in the same seasonal years. In both the SPI and PNI methods, drought phases were observed. To determine when a continuous and ongoing drought disaster begins and ends, it is essential to continuously track drought values. For both stations, as seen in the results of both drought assessment methods, the values were found to be seasonally consistent with each other.

Due to the fluctuations in precipitation amounts on a regional scale, each region should be evaluated individually. Bursa province ranks fourth in terms of population, and therefore, a significant number of people will be affected by any droughts that occur in the region. The drought disaster, which begins with meteorological drought, must be well planned. Measures should be taken to prevent water scarcity in the future for areas with lower precipitation, by comparing them to regions with higher precipitation. The number of stations should be increased, and more regions should be compared with each other. Drought analyses should also be conducted spatially for the precipitation stations in Bursa province. Physical phenomena resulting from reduced precipitation, increased temperatures, and higher evaporation rates should also be observed.

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