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A Study on Drought Analysis Using Time Series, Standardized Precipitation Index (SPI) and Standardized Precipitation Evapotranspiration Index (SPEI) in Bursa Region

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ABSTRACT

All agricultural activities are directly related to the climate. In recent years, temperature increases and changes in precipitation regimes adversely affect the Mediterranean Basin, including Türkiye. While increasing temperatures and irregular precipitation rise the need for irrigation in crop production in some regions, excessive and irregular rainfall in some areas seriously damages production. Nowadays, climate change has been accepted by many climate scientists as a problem that cannot be ignored. In our country, drought is one of the natural disasters that will affect agricultural production the most. In this study, a drought analysis was made for Bursa, one of Türkiye's important cities in agricultural production. In addition, non-parametric Mann-Kendall and Sen's Trend Analyzes were conducted between 1990 - 2019 for precipitation and temperature values. According to the trend analysis results, statistically significant trends could not be reached in the precipitation data; increasing trends were observed in the temperature data. SPI (Standardized Precipitation Index) and SPEI (Standardized Precipitation and Evapotanspiration Index) methods were used for drought analysis; although extreme values were reached for the years 1960 – 2019 due to both ways, it was determined that normal drought levels were dominant in general.

Keywords: Drought, Precipitation, Temperature, Standardized Precipitation Index (SPI), Standardized Precipitation Evapotranspiration Index (SPEI), Trend Analyzes

INTRODUCTION

Climate is a phenomenon that will directly affect all agricultural activities. In recent years, temperature increases and changes in precipitation regimes negatively affect the whole world, especially the Mediterranean Basin, where Türkiye is located. Temperature increases and rainfall irregularities increase the need for irrigation in crop production.

According to the Intergovernmental Panel on Climate Change, a global temperature increase of 1 to 3.5°C will occur on average by 2100 (IPCC 2001). These predicted increases will bring along extreme natural events and natural disasters. It is stated that events that will reach disaster dimensions such as floods, storms, drought, and desertification will go global and increase their incidence (Öztürk 2002).

Türkiye has a complex climate structure and therefore it is fragile in terms of climate change (Öztürk 2002). Due to its topography and complex climate, different country regions will be affected by climate change at different rates and ways (Öztürk 2002). Decreases in water resources will be clearly felt in agriculture and livestock. Türkiye may be exposed to drought, forest fires, and heatwaves (Şen 2013).

Drought is a natural disaster that is the most difficult to predict but has wide-ranging effects (Anonymous, 2019). Even if its effect is not seen suddenly, it is one of the most harmful natural disasters (Gümüş et al. 2016). In order to minimize its effects, it needs to be monitored. If the drought can be determined and monitored beforehand, measures can be taken before its severity increases (Ilgar 2010).

The order of importance and types of natural disasters may differ between regions. For example, in Türkiye, especially in the Mediterranean Region, the threat of drought takes the first place (AFAD 2016). Drought analysis is of great importance in minimizing the effects of drought. Many drought indices define drought and determine its severity (Dinç et al. 2016). The results obtained with drought indices help us get information about the climate of a country or region and the increase or decrease in drought (Ilgar 2010).

In this study, with the trend analysis applied to the average temperature and precipitation data for many years, temperature and precipitation trends were determined; thus, it was observed whether there were precipitation and temperature anomalies. In addition, using the SPI and SPEI indices, drought analysis was carried out

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considering the 12 months. The annual drought characteristics of the obtained data were evaluated, and the two methods were compared.

MATERIALS AND METHODS

Bursa is located in the Southern Marmara Section of the Marmara Region, between 39°35´ - 40°37´ northern parallels and 28°5´ - 29°57´ east meridians. Bursa generally feature temperate climate characteristics. However, the climate varies according to the regions, with the mild and warm Mediterranean climate of the Sea of Marmara in the north and the harsh climate of Uludağ in the south. As of the 52-year observation period, the monthly average precipitation is 70.6 mm, and the annual total precipitation is 708.7 mm. The average relative humidity in the province is around 69%. The annual average temperature is 14.5 °C as given Table 1 (Anonymous 2019 a).

Table 1. Climate in Bursa (Anonymous 2019 a, b).

Extreme Max., Min. and Average Temperatures Measured in Long Period in Bursa													
Months	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Max. Temp. (°C)	23.8	26.9	32.0	36.2	36.5	41.3	43.8	42.2	39.6	37.3	31.0	27.3	43.8
Ave. Max. Temp. (°C)	9.6	10.9	13.7	18.8	23.7	28.4	30.8	31.0	27.2	21.7	16.4	11.7	20.3
Ave Temp. (°C)	5.4	6.3	8.4	12.8	17.6	22.1	24.6	24.3	20.1	15.2	10.7	7.4	14.5
Ave. Min. Temp. (°C)	1.7	2.2	3.6	7.1	11.2	14.9	17.2	17.1	13.6	9.9	6.0	3.5	9.0
Min. Temp. (°C)	-19.2	-16.8	-10.5	-3.1	0.9	4.0	9.0	8.6	4.4	-1	-5.4	-16.3	-19.2
Ave. Pre. (mm)	87.6	74.6	69.7	63.4	44.3	34.3	15.3	15.7	39.5	68.8	78.5	103.4	695.1

From 1960 to 2019, daily average temperature and precipitation data were used in this study. Trend analysis was performed with Mann – Kendall and Sen's Trend Analysis methods, and the MAKESENS program was used for these analyzes.

SPI and SPEI programs were used for drought analysis, and the results obtained from both programs were compared. Standardized Precipitation Index (SPI), developed by McKee et al. (1993), is a time-flexible method that can be easily calculated, depends only on precipitation values and is related to probability, allows monitoring of water resources for all times (Sırdaş 2002). Precipitation is the main factor affecting the presence of water. Therefore, it makes it possible to follow the increase or decrease in the drought situation in any region and at a particular time scale by using precipitation data (Dinç et al. 2016). The normal distribution of SPI allows for monitoring humid periods and dry periods (McKee et al. 1993).

$$SPI = \frac{\text{Xi} - \text{Xort}}{\sigma}$$

Xi:total precipitation over a given period (mm)
Xort:Average total precipitation for the same period
σ:standart deviation

SPI is the most widely used method in drought analysis (Dinç et al. 2016). The dry period starts with the negative value of SPI and ends with its conversion to a positive value (Arslan et al. 2016). The World Meteorological Organization adopted the Standardized Precipitation Index (SPI) for measuring meteorological droughts. However, SPI is based only on precipitation data and does not consider other drought factors such as temperature, relative humidity, evaporation and wind speed (Çamalan et al. 2017, Sırdaş 2002).

SPEI; it is a method based on precipitation and temperature data developed by Serrano, Beguveria and Moreno. It can evaluate drought with temperature variability. SPEI calculation is based on the SPI calculation method. In the method, monthly precipitation and potential evapotranspiration values are used. Regular and complete temperature and precipitation data are needed. SPEI can explain the possible effects of variations and extremes in temperature (Çamalan et al. 2017).

$$SPEI = w - \frac{C_0 + C_1 w + C_2 w^2}{1 + d_1 w + d_2 w^2 + d_3 w^3}$$

$P \leq 0.5 \rightarrow w = \sqrt{(-2 \ln(P)}$
$P > 0.5 \rightarrow$ Sign of the SPEI is reversed.

C0 = 2,515517 d1 = 1,432788
C1 = 0,802853 d2 = 0,189269
C2 = 0,010328 d3 =0,01308
Values are the constant values of the formulation.

Standard Precipitation and Evapotranspiration Index is a method based on precipitation and temperature data and calculates based on water balance, calculates with regular and complete rainfall and temperature data for at least 30 years on different time scales.

RESULTS AND DISCUSSION

By applying trend analysis to the precipitation and temperature values used in this study, it was determined whether the change in temperature values was statistically significant. According to the trend analysis applied to the temperature data; for the period studied, the difference in temperature values in the Bursa region in march, april, may, june, july, august, september, spring, summer, autumn, winter seasons and at the level of years was found to be significant at the 5% level. It was concluded that the temperature has an increasing trend (Table 2).

Table 2. Temperature trend analysis results.

Time	Max.	Min.	Avg.	Changing (°C/year)	MK-Z (+/-1.96) %5 Significance Value	MK-Z (+/-2.57) %1 Significance Value
January	25.2	-19.2	5.35	0.0152	0.87	0.87
February	26.9	-16.8	6.41	0.0218	1.42	1.42
March	30.6	-10.5	8.65	0.0331	**2.22**	2.22
April	35.5	-3.1	13.01	0.0249	**1.98**	1.98
May	36.1	1.4	17.79	0.0350	**3.74**	**3.74**
June	41.3	4	22.34	0.0358	**4.47**	**4.47**
July	43.8	9	24.67	0.0423	**5.14**	**5.14**
August	41.9	8.6	24.36	0.0522	**5.01**	**5.01**
September	40.3	5	20.26	0.0362	**4.16**	**4.16**
October	37.3	-1	15.45	0.0180	1.84	1.84
November	31	-4.6	10.81	-0.0024	-0.01	-0.01
December	27.3	-16.3	7.32	-0.0215	-1.45	-1.45
Spring	36.1	-10.5	14.7	0.0310	**3.25**	**3.25**
Summer	43.8	4	13.15	0.0435	**6.12**	**6.12**
Autumn	40.3	-4.6	23.79	0.0173	**2.42**	2.42

Winter	27.3	-19.2	15.51	0.0019	**2.42**	2.42
Annual	43.8	-19.2	6.42	0.0243	**4.14**	**4.14**
1990 - 1999	40	-14.8	14.36	0.1377	1.25	1.25
2000 - 2009	43.8	-14	14.98	0.0532	0.45	0.45
2010 - 2019	40.3	-13.1	15.65	0.0990	1.07	1.07

Changes in may, june, july, august, september, spring, summer seasons and annual values were also significant at the 1% level.

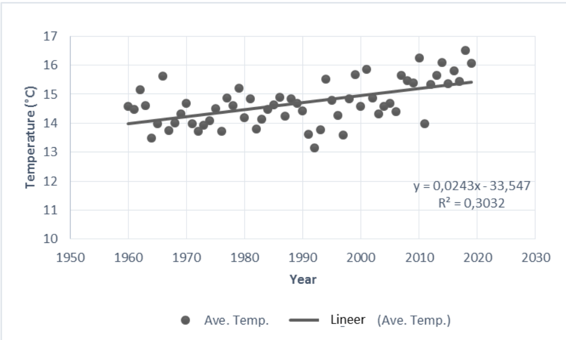

Figure 1. Average annual temperature trend.

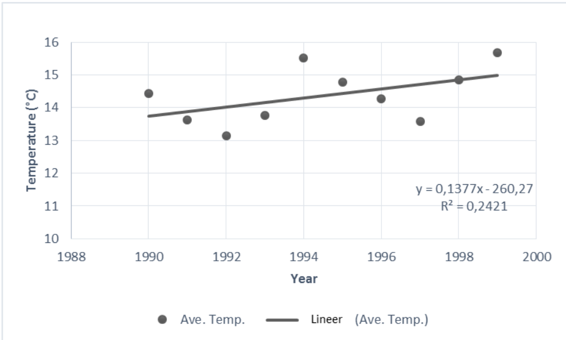

Figure 2. 1990 – 1999 average temperature.

According to the Mann-Kendall and trend analysis applied to the annual average temperature data, it was observed that there was a significant increase of 5% and 1%. This increase is statistically significant. The value of the increase in the annual average temperature was calculated as 0.0243 ˚C/year.

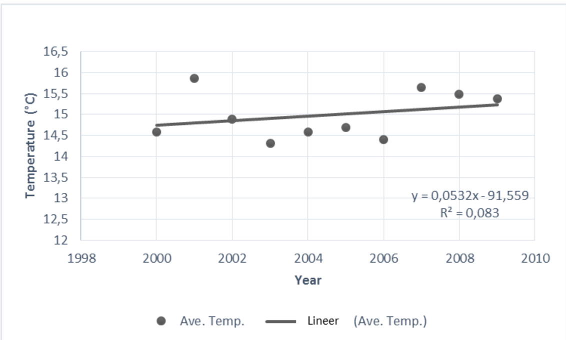

Figure 3. 2000 – 2009 average temperature.

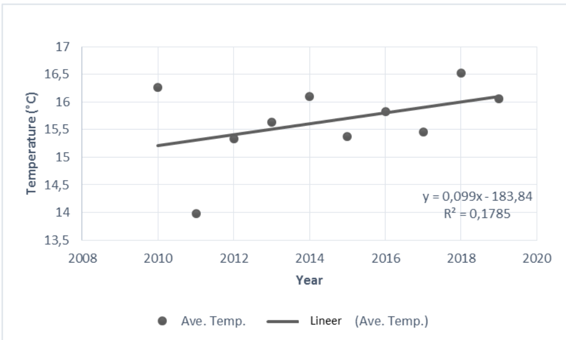

Figure 4. 2010 – 2019 average temperature.

The Mann – Kendall test and trend analysis applied to the annual average temperature data were applied separately for 1990 – 1999, 2000 – 2009, and 2010 – 2019 in the form of 10-years averages. Although not statistically significant at the 5% and 1% significance levels, there is an increase of 0.1377 ˚C/year for 1990 – 1999, 0.0532 ˚C/year for 2000 – 2009, 0.0990 ˚C/year for 2010 – 2019. (Figure 1-4).

Figure 5. Average temperature for four seasons.

Trend analysis was applied to the average temperature data of spring, summer, autumn, and winter. There is an increase for all seasons. Statistically, while the change was significant for all seasons at the 5% significance level, the change in the spring and summer seasons was important at the 1% significance level. At the 5% significance level, the highest increase was observed in summer with 0.0435 ˚C/year, and the lowest increase was observed in winter with 0.0019 ˚C/year. At the 1% significance level, while the increase was 0.0435 ˚C/year for the summer season, it was 0.0310 ˚C/year in the spring (Figure 5).

As a result of the trend analysis applied to the monthly average temperature data, there is a decrease of -0.0024 ˚C/year and -0.0215 ˚C/year in November and December, respectively. But in these months, the temperature change was not statistically significant. The temperature increase is observed in the ten months other than these months. Among the statistically significant values, at a 5% significance level, the highest temperature increase was observed in august with 0.0522 ˚C/year, and the lowest temperature increase was observed in april with 0.0249 ˚C/year. At the 1% significance level, the highest increase was seen in august with 0.0522 ˚C/year, and the lowest increase was observed in May with 0.0350˚C/year.

According to the Mann–Kendall test and trend analysis applied to the annual average precipitation data, the change in precipitation is statistically insignificant. Although it is not statistically significant, it can be said that the average yearly precipitation increased by 0.0577 mm/year (Table 3).

Table 3. Precipitation trend analysis .

Time	Max. (mm)	Min. (mm)	Average (mm)	Changing (mm/year)	MK-Z (+/-1,96) %5 Significance Value	MK-Z (+/-2,57) %1 Significance Value
January	56.7	0	84.84	-0.1361	0.24	0.24
February	72.3	0	71.31	0.1348	0.62	0.62
March	41.4	0	68.99	0.0940	0.39	0.39
April	55	0	65.19	-0.0623	-0.57	-0.57
May	49.2	0	45.95	0.1186	0.35	0.35
June	47.2	0	36.61	0.3646	1.14	1.14
July	55	0	15.79	0.0190	0.18	0.18

August	68.9	0	16.39	-0.1464	-0.46	-0.46
September	79.4	0	40.4	0.4077	1.44	1.44
October	114.4	0	69.89	0.7666	1.49	1.49
November	79.7	0	74.89	-0.2355	-0.78	-0.78
December	89.2	0	108.58	-0.6432	-1.55	-1.55
Spring	55	0	60.04	0.0501	0.04	0.04
Summer	68.9	0	23.05	0.0874	0.76	0.76
Autumn	114.4	0	63.8	0.3717	1.61	1.61
Winter	89.2	0	87.52	-0.1757	1.61	1.61
Annual	114.4	0	58.21	0.0577	-0.16	-0.16
1990 -1999	79.7	0	56.96	0.9361	0.36	0.36
2000 - 2009	79.4	0	58.46	-0.8016	-1.25	-1.25
2010 - 2019	114.4	0	63.34	-4.1937	-1.61	-1.61

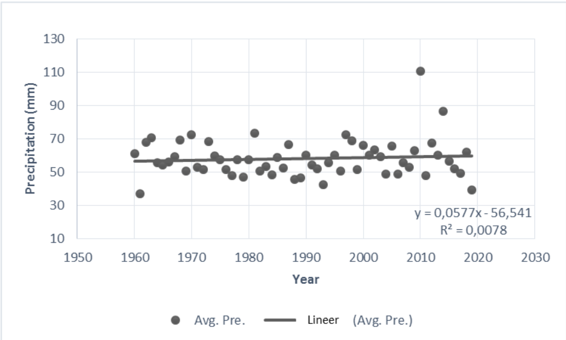

Figure 6. Average annual precipitation.

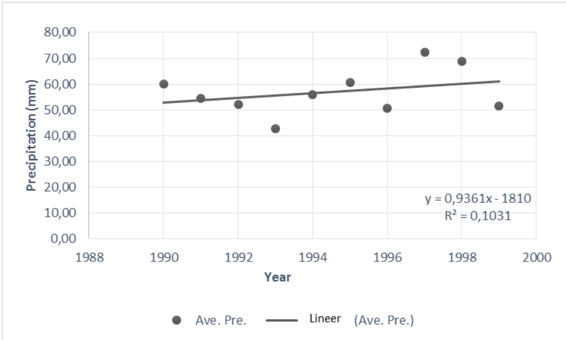

Figure 7. 1990 – 1999 average precipitation

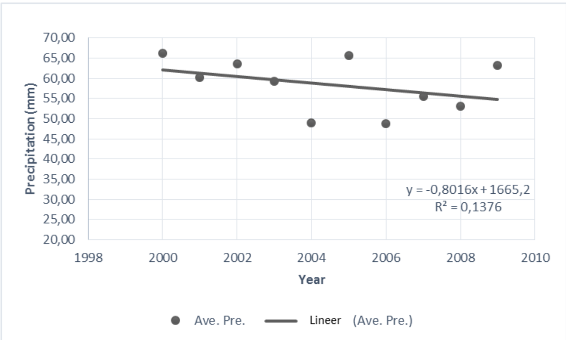

Figure 8. 2000 – 2009 average precipitation

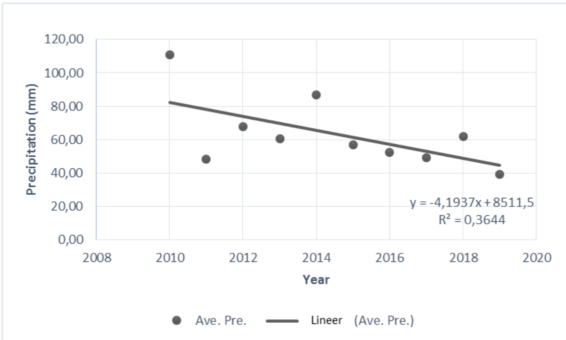

Figure 9. 2010 – 2019 average precipitation.

The Mann – Kendall test and trend analysis applied to the annual average precipitation data were applied separately for 1990 – 1999, 2000 – 2009, and 2010 – 2019 as 10-year averages. No statistically significant value was found at the 5% and 1% significance levels (Figure 6-9).

Considering these insignificant results, while an increase of 0.9361 mm/year was observed between 1990 and 1999, there was a decrease of -0.8016 mm/year in precipitation between 2000 and 2009, and a decrease of -4.1937 mm/year between 2010 and 2019 decrease has occurred.

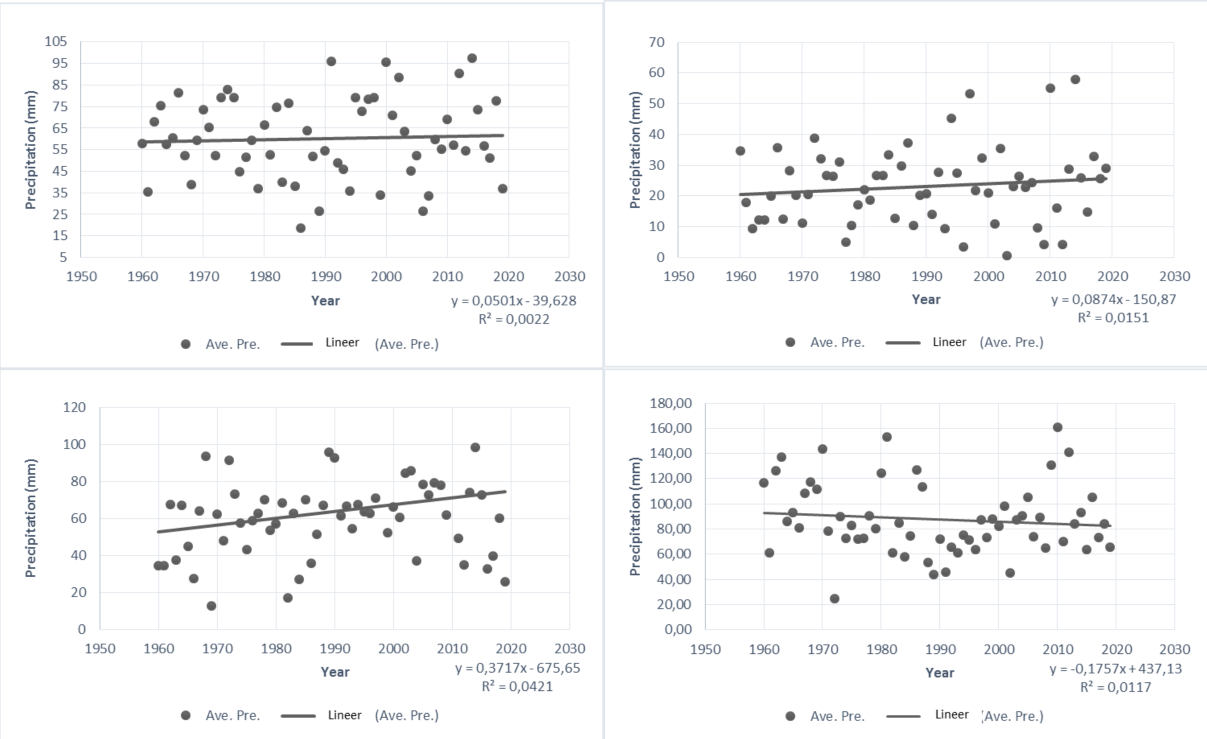

Figure 10. Average seasonal precipitation.

Mann–Kendall test and trend analysis were applied to the average precipitation data of the spring, summer, autumn, and winter seasons, and no statistically significant result could be obtained (Figure 10). Although not statistically significant, for the spring, summer, and autumn seasons, respectively, while there was an increase in precipitation at values of 0.0501 mm/year, 0.0874 mm/year, and 0.3717 mm/year, a decrease of -0.1757 mm/year occurred for the winter season.

A statistically significant value could not be reached due to the Mann–Kendall test and trend analysis applied to the monthly average precipitation data. Among the results that were not found to be significant, the most considerable decrease in precipitation was in december, with a value of -0.6432 mm/year. The precipitation values decreased to -0.2355 mm/year in november, -0.1464 mm/year in august, -0.1361 mm/year in January and -0.0623 mm/year in april.

Although not significant, the tremendous increase in precipitation values occurred in october with 0.7666 mm/year, 0.4077 mm/year in september, 0.3646 mm/year in june, 0.1348 mm/year, 0.1186 mm/year in february, 0.0940 mm/year in may, 0.0190 mm/year march and july, respectively.

Table 4. SPI – SPEI drought severity classification.

2.00 > value	Extremely wet
1.50 - 1.99	Very Wet
1.00 - 1.49	Moderately Wet
(-0.99) - 0.99	Normal
(-1.00) - (-1.49)	Moderately Dry
(-1.50) - (-1.99)	Severely Dry
(-2.00) < value	Extremely Dry

According to the SPI drought analysis results, drought classification was made using the intervals in Table 3. According to the effects of drought classification, monthly and annual drought values are given in Table 4. The year 1961 was extremely dry with -2.20 SPI, 1993 and 2019 were severely dry, 1979, 1988, 1989 were moderately dry, 2010, 2014 were extremely humid with 3.95 and 2.37 SPI values, and 1963, 1968, 1970, 1981, 1997 years were found to be moderately humid. A very humid year was not encountered and the remaining 47 years were observed to be at normal drought levels.

SPEI drought analysis was performed for the same period, and the results are given in Table 5. While 2019 was extremely dry with a value of -2.66751, 1961 was severely dry, 1979, 1988, 1989, 1993, 1999, 2008, 2016 and 2017 were moderately dry, 2010 was extremely humid with 2.56467, 1997, 2017 were very humid. The years 1963, 1968, 1970, 1973, 1980, 1981, and 1987 were moderately humid. It was observed that the remaining 40 years were at normal drought levels.

Table 5. SPI analysis over the 12-month time period 1960 – 2019.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Year
1960												0.32	1960
1961	-0.09	-0.22	-0.30	-0.53	-0.74	-1.11	-1.15	-1.22	-1.07	-0.87	-1.21	-2.20	1961
1962	-2.84	-2.15	-1.41	-0.86	-1.07	-1.46	-1.28	-1.34	-1.18	-0.52	-0.42	0.91	1962
1963	1.87	1.52	1.25	1.11	1.58	1.82	1.64	1.68	1.61	1.11	1.04	1.14	1963
1964	0.02	0.18	0.30	-0.03	-0.23	-0.50	-0.49	-0.25	0.25	-0.04	0.44	-0.19	1964
1965	-0.13	0.59	0.23	0.67	0.62	0.79	0.97	0.81	0.10	0.24	0.33	-0.29	1965
1966	0.45	-0.84	-0.12	-0.01	-0.23	-0.12	-0.36	0.14	0.17	0.21	-0.28	-0.11	1966
1967	0.04	0.45	-0.08	-0.34	-0.23	-0.37	-0.23	-0.83	-0.66	-0.12	0.10	0.17	1967
1968	0.62	0.62	0.70	0.40	0.28	0.36	0.25	0.64	1.29	1.14	1.27	1.05	1968
1969	0.20	0.46	0.33	0.84	0.90	1.02	1.10	0.75	-0.17	-0.70	-1.25	-0.65	1969
1970	-0.64	-0.08	-0.06	-0.10	0.27	0.10	-0.03	0.06	0.40	0.82	1.16	1.31	1970
1971	0.87	0.17	0.76	0.32	-0.01	-0.05	0.10	0.21	0.03	-0.13	-0.12	-0.42	1971
1972	-0.50	-0.90	-1.89	-1.42	-1.18	-1.05	-1.06	-0.72	-0.04	0.30	0.35	-0.56	1972
1973	-0.47	0.08	0.39	0.62	0.68	0.80	0.71	0.55	-0.14	-0.15	0.13	0.98	1973
1974	0.99	0.58	0.58	0.27	0.64	0.43	0.49	0.53	0.76	0.28	0.17	0.21	1974
1975	0.33	0.59	0.72	0.56	0.48	0.88	0.77	0.49	0.14	0.30	0.15	0.02	1975
1976	0.06	-0.32	-0.85	-0.87	-1.17	-1.51	-1.24	-1.07	-0.60	-0.39	-0.63	-0.58	1976
1977	-0.81	-0.82	-0.47	-0.14	-0.57	-0.75	-0.95	-1.29	-1.43	-1.69	-1.15	-0.95	1977
1978	-0.58	-0.05	-0.05	-0.09	0.14	0.14	0.19	0.27	0.87	1.01	0.45	0.00	1978
1979	0.05	-0.26	-0.60	-0.76	-0.79	-0.83	-0.80	-0.63	-1.24	-1.33	-1.05	-1.06	1979
1980	-0.76	-0.63	0.16	0.07	0.14	0.40	0.49	0.26	0.12	0.02	0.33	0.88	1980
1981	1.01	1.02	0.67	0.31	0.68	0.44	0.56	0.62	1.07	1.20	0.87	1.35	1981
1982	1.04	0.90	0.72	1.45	1.31	1.37	1.48	1.51	0.83	0.63	0.39	-0.67	1982
1983	-0.99	-0.44	-0.68	-1.09	-1.30	-1.08	-1.35	-1.34	-1.02	-0.85	-0.12	-0.38	1983
1984	-0.46	-0.85	-0.11	0.18	0.12	0.01	0.36	0.28	0.11	-0.14	-0.59	-0.88	1984
1985	-0.79	-0.72	-1.22	-1.84	-1.72	-1.72	-2.30	-2.41	-2.14	-1.37	-1.09	-0.87	1985
1986	-0.65	-0.44	-0.64	-0.60	-0.89	-0.46	-0.45	-0.47	-0.50	-0.65	-1.36	-0.47	1986
1987	-0.20	-0.87	-0.10	-0.04	0.30	0.08	0.26	0.48	0.45	0.51	0.83	0.80	1987
1988	-0.44	-0.17	-0.27	-0.12	-0.44	-0.66	-0.89	-1.17	-0.96	-0.98	-0.73	-1.19	1988
1989	-1.16	-1.70	-2.15	-2.70	-2.35	-2.26	-2.10	-2.09	-1.90	-0.84	-1.20	-1.09	1989
1990	-1.12	-0.70	-0.63	-0.14	0.04	-0.13	0.13	0.05	0.36	-0.23	-0.01	0.23	1990
1991	0.19	0.15	0.08	0.64	1.06	1.12	0.92	0.94	1.00	1.01	0.24	-0.30	1991
1992	-0.39	-0.16	0.37	-0.46	-1.34	-0.98	-0.96	-0.99	-1.56	-1.13	-0.84	-0.52	1992
1993	-0.30	-0.44	-0.81	-0.71	-0.47	-1.05	-1.10	-0.97	-0.56	-1.36	-1.28	-1.53	1993
1994	-1.58	-1.63	-1.61	-1.70	-1.81	-1.07	-1.06	-0.83	-1.09	-0.51	-0.47	-0.16	1994
1995	0.52	0.15	1.05	1.38	1.11	0.67	0.88	0.75	0.91	0.59	0.65	0.27	1995
1996	-0.62	-0.02	-0.42	-0.37	-0.16	-0.31	-0.56	-0.78	-0.32	-0.02	-0.78	-0.67	1996
1997	-0.77	-0.91	-1.09	-0.62	-0.69	-0.44	-0.10	0.51	-0.11	0.43	0.68	1.29	1997
1998	1.33	1.51	1.60	0.81	1.45	1.50	1.37	0.81	1.20	1.02	1.43	0.98	1998
1999	0.96	1.53	1.26	1.25	0.50	0.80	0.58	0.75	0.30	-0.29	-0.39	-0.57	1999
2000	-0.11	-0.74	-0.19	0.62	0.77	0.45	0.57	0.53	0.91	1.13	0.83	0.77	2000
2001	0.10	-0.14	-0.73	-1.20	-0.72	-0.95	-1.08	-1.01	-1.21	-1.97	-1.14	0.25	2001
2002	0.65	0.48	0.75	1.05	0.85	1.03	1.32	1.39	1.47	2.02	1.84	0.54	2002
2003	0.55	1.04	0.60	0.49	0.45	0.29	-0.11	-0.37	-0.34	-0.26	-0.34	0.16	2003
2004	0.83	0.60	0.80	0.34	0.16	0.45	0.47	0.67	0.16	-0.62	-0.47	-0.86	2004
2005	-0.97	-0.95	-0.75	-0.81	-0.68	-0.85	-0.40	-0.61	0.16	0.27	0.40	0.72	2005
2006	0.03	0.48	0.30	0.07	-0.14	0.20	-0.22	-0.23	-0.23	-0.25	-0.37	-0.86	2006
2007	-0.69	-1.80	-1.69	-1.51	-1.45	-1.66	-1.49	-1.56	-2.28	-1.49	-1.34	-0.19	2007
2008	-0.50	-0.29	0.22	0.27	0.35	0.22	0.12	0.11	1.00	0.58	0.08	-0.43	2008
2009	0.04	0.92	0.90	0.82	0.78	0.66	0.67	0.68	0.18	0.18	0.32	0.51	2009
2010	0.75	0.94	0.86	1.12	1.18	2.07	2.12	2.21	1.97	3.61	3.81	3.95	2010
2011	3.67	2.82	2.40	2.50	2.44	1.76	1.56	1.76	1.52	-0.41	-0.67	-0.94	2011
2012	-0.57	0.32	0.49	0.66	1.03	1.00	0.98	0.81	0.65	0.10	0.48	0.90	2012
2013	0.80	0.61	0.56	0.20	-0.23	0.23	0.34	0.34	0.33	0.96	1.19	0.26	2013
2014	-0.31	-0.96	-1.10	-0.46	0.17	0.61	0.46	0.84	1.57	1.13	1.33	2.37	2014
2015	2.90	3.28	3.21	3.04	2.68	2.34	2.31	2.09	1.69	1.67	1.56	0.05	2015
2016	0.12	0.18	0.16	-0.42	-0.23	-0.32	-0.43	-0.42	-0.92	-1.49	-1.48	-0.51	2016
2017	-0.94	-1.59	-2.00	-1.75	-1.63	-1.29	-1.07	-1.14	-1.17	-0.69	-0.92	-0.81	2017
2018	-1.00	-0.54	0.30	0.04	0.15	0.02	0.00	-0.02	0.21	0.30	0.45	0.40	2018
2019	0.35	0.16	-0.73	-0.46	-0.83	-1.08	-0.98	-0.76	-0.97	-1.30	-1.69	-1.92	2019

Table 6. SPEI analysis over the 12-month time period 1960.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Year
1960												0.74	1960
1961	0.46	0.31	0.13	-0.26	-0.51	-0.96	-1.04	-1.14	-1.05	-0.77	-1.03	-1.92	1961
1962	-2.85	-1.83	-1.33	-0.74	-0.92	-1.18	-1.05	-1.11	-1.13	-0.60	-0.57	0.85	1962
1963	1.66	1.29	1.20	1.09	1.61	1.77	1.56	1.63	1.70	1.09	1.11	1.24	1963
1964	0.32	0.52	0.55	0.10	-0.04	-0.30	-0.18	0.21	0.79	0.50	1.05	0.53	1964
1965	0.56	1.16	0.80	1.25	1.11	1.23	1.34	1.24	0.36	0.69	0.77	0.28	1965
1966	1.00	-0.49	0.14	0.16	-0.09	0.17	-0.20	0.04	0.03	-0.03	-0.63	-0.38	1966
1967	-0.14	0.42	-0.15	-0.36	-0.23	-0.35	-0.14	-0.69	-0.67	0.04	0.46	0.63	1967
1968	1.08	0.96	1.03	0.66	0.41	0.45	0.34	0.86	1.68	1.43	1.53	1.36	1968
1969	0.69	0.83	0.69	1.31	1.37	1.42	1.55	1.18	0.05	-0.40	-0.84	-0.33	1969
1970	-0.43	0.08	-0.10	-0.36	0.22	0.16	-0.16	-0.12	0.29	0.85	1.20	1.41	1970
1971	1.08	0.40	1.04	0.74	0.32	0.27	0.52	0.60	0.30	0.25	0.31	0.15	1971
1972	0.26	-0.15	-1.07	-0.86	-0.60	-0.50	-0.63	-0.35	0.17	0.53	0.62	-0.16	1972
1973	-0.08	0.32	0.64	1.00	1.03	1.26	1.16	1.12	0.29	0.25	0.63	1.36	1973
1974	1.44	1.12	1.05	0.77	1.12	0.83	0.89	0.87	1.15	0.56	0.42	0.59	1974
1975	0.70	0.93	0.94	0.60	0.49	0.89	0.70	0.32	-0.18	0.28	0.14	0.13	1975
1976	0.20	-0.27	-0.69	-0.63	-0.77	-0.98	-0.68	-0.37	0.03	0.25	0.06	0.14	1976
1977	-0.08	-0.35	-0.13	0.24	-0.23	-0.45	-0.71	-1.22	-1.35	-1.45	-1.09	-0.94	1977
1978	-0.57	0.04	-0.08	-0.15	0.11	0.09	0.17	0.38	1.06	1.09	0.66	0.26	1978
1979	0.29	-0.08	-0.55	-0.69	-0.63	-0.73	-0.65	-0.62	-1.18	-1.26	-1.11	-1.20	1979
1980	-0.87	-0.62	0.29	0.24	0.36	0.75	0.80	0.55	0.41	0.33	0.64	1.19	1980
1981	1.31	1.28	0.87	0.39	0.88	0.53	0.67	0.69	1.11	1.20	0.98	1.36	1981
1982	1.16	1.02	0.93	1.67	1.48	1.59	1.73	1.85	1.21	1.01	0.81	-0.05	1982
1983	-0.31	0.16	-0.24	-0.73	-1.06	-0.76	-1.13	-1.06	-0.83	-0.58	0.13	0.00	1983
1984	-0.16	-0.67	0.05	0.55	0.46	0.32	0.73	0.65	0.30	0.03	-0.41	-0.59	1984
1985	-0.56	-0.39	-0.88	-1.49	-1.43	-1.42	-1.80	-1.87	-1.62	-1.16	-0.94	-0.85	1985
1986	-0.66	-0.58	-0.83	-0.80	-0.82	-0.51	-0.57	-0.69	-0.84	-0.95	-1.38	-0.60	1986
1987	-0.25	-0.99	-0.15	0.06	0.42	0.29	0.42	0.78	0.70	0.80	1.06	1.07	1987
1988	-0.14	0.11	-0.22	-0.12	-0.44	-0.70	-0.97	-1.26	-1.10	-1.10	-0.82	-1.33	1988
1989	-1.31	-1.64	-1.88	-2.27	-2.17	-2.04	-1.81	-1.70	-1.57	-0.92	-1.21	-1.18	1989
1990	-1.33	-0.81	-0.72	-0.03	0.27	0.13	0.39	0.37	0.75	0.13	0.25	0.54	1990
1991	0.52	0.42	0.33	0.97	1.34	1.41	1.24	1.25	1.34	1.26	0.64	0.32	1991
1992	0.33	0.55	1.02	0.14	-0.58	-0.26	-0.14	-0.27	-0.82	-0.61	-0.22	0.18	1992
1993	0.42	0.18	-0.28	-0.15	0.07	-0.44	-0.60	-0.45	-0.25	-0.78	-0.64	-1.00	1993
1994	-1.24	-1.24	-1.28	-1.46	-1.70	-1.11	-1.17	-1.04	-1.39	-1.05	-1.06	-0.69	1994
1995	0.10	-0.46	0.55	1.05	0.80	0.12	0.40	0.27	0.65	0.56	0.65	0.30	1995
1996	-0.63	0.04	-0.32	-0.16	0.01	0.02	-0.28	-0.53	-0.17	0.23	-0.55	-0.46	1996
1997	-0.66	-0.75	-0.97	-0.53	-0.45	-0.20	0.16	0.91	0.30	0.85	1.15	1.66	1997
1998	1.73	1.87	2.06	1.14	1.69	1.73	1.57	0.85	1.16	0.93	1.27	0.93	1998
1999	0.91	1.37	1.07	1.08	0.17	0.46	0.16	0.28	-0.27	-0.74	-0.84	-1.16	1999
2000	-0.60	-1.22	-0.65	0.22	0.48	0.22	0.35	0.31	0.72	1.07	0.70	0.79	2000
2001	-0.01	-0.41	-1.29	-1.58	-1.18	-1.45	-1.56	-1.51	-1.58	-2.17	-1.67	-0.41	2001
2002	0.16	-0.17	0.29	0.73	0.55	0.72	1.03	1.13	1.35	1.82	1.61	0.43	2002
2003	0.33	0.88	0.58	0.52	0.42	0.20	-0.09	-0.45	-0.42	-0.29	-0.33	0.25	2003
2004	1.02	0.70	0.74	0.07	0.00	0.38	0.45	0.73	0.05	-0.61	-0.46	-0.81	2004
2005	-1.04	-1.00	-0.81	-0.89	-0.76	-0.82	-0.40	-0.73	-0.09	0.28	0.44	0.81	2005
2006	0.20	0.61	0.34	0.07	-0.17	0.12	-0.25	-0.40	-0.46	-0.48	-0.54	-0.94	2006
2007	-0.91	-1.86	-1.70	-1.54	-1.57	-1.83	-1.81	-1.74	-1.96	-1.78	-1.76	-0.94	2007
2008	-1.34	-0.99	-0.57	-0.56	-0.30	-0.41	-0.39	-0.45	0.52	0.19	-0.46	-1.04	2008
2009	-0.64	0.28	0.38	0.42	0.36	0.21	0.20	0.28	-0.28	-0.20	-0.03	0.22	2009
2010	0.49	0.53	0.42	0.64	0.71	1.63	1.69	1.63	1.49	2.86	2.83	2.56	2010
2011	2.40	2.03	1.87	2.04	1.98	1.40	1.18	1.61	1.50	-0.50	-0.45	-0.60	2011
2012	-0.14	0.74	0.91	0.87	1.16	0.99	0.92	0.60	0.38	-0.32	-0.14	0.42	2012
2013	0.22	-0.27	-0.47	-0.79	-1.30	-0.72	-0.41	-0.52	-0.49	0.45	0.65	-0.20	2013
2014	-1.01	-1.56	-1.59	-1.09	-0.32	0.15	-0.07	0.26	1.15	0.68	0.82	1.70	2014
2015	2.08	2.43	2.69	2.64	2.17	1.93	1.92	1.77	1.36	1.30	1.08	-0.37	2015
2016	-0.32	-0.44	-0.57	-1.32	-1.06	-1.35	-1.41	-1.36	-1.52	-1.94	-1.92	-1.35	2016
2017	-1.99	-2.13	-2.19	-1.89	-1.83	-1.49	-1.31	-1.28	-1.34	-0.98	-1.17	-1.35	2017
2018	-1.81	-1.22	-0.50	-0.89	-0.85	-1.02	-0.99	-1.07	-0.82	-0.69	-0.68	-0.62	2018
2019	-0.78	-0.93	-1.58	-1.21	-1.49	-1.74	-1.53	-1.26	-1.35	-1.63	-1.95	-2.67	2019

Similar results in studies conducted for other regions in our country, an increase in drought has also been observed. Ilgar (2010) examined the drought situation and trends in Çanakkale Province with the SPI method and observed an increase in the annual drought conditions of the province. Arslan et al. (2016) calculated the SPI values within the Kızılırmak for 1, 3, 6, 9, 12, and 60-month periods. They showed significant increases in the drought periods in the Kızılırmak in terms of 12 and 60-month periods compared with the droughts in the past years. Karaer et al. (2018) conducted a drought analysis of Bilecik Province with the SPI method in 1, 3, 6, 12, and 24-month periods in their study. They found that drought is felt in 6 and 12 periods, and drought is generally seen in summer. Camalan et al. (2017) calculated the SPEI drought index in 1, 3, and 12-month time periods, examined the temporal and spatial incidence of drought and evaluated the climatological trend of the drought that may occur in the future.

CONCLUSIONS

This study carried out trend analysis and drought analysis using temperature and precipitation data from the Bursa Province between 1960 and 2019. When the temperature and precipitation trend analysis results for Bursa Province were examined, an increasing trend was found for all time intervals in temperature data. Still, a statistically significant trend could not be obtained in precipitation data.

Considering the annual average precipitation results, although there is a general increase, it was observed that there was a decrease in precipitation of -4.19 mm/year for the years 2010 – 2019. These studies are critical to predicting precipitation and temperature anomalies for the future. It is of great importance to increase such studies nationally and regionally and to establish a data bank in order to take precautions for extreme weather events that will mostly affect agricultural production and food safety, such as excessive precipitation, floods, and hail.

When the results of drought analysis of SPI and SPEI indices in 12 months are examined, drought was generally at normal levels. According to the annual evaluation results for the period considered, various drought periods were observed according to the SPI index, but no periodic integrity was found. According to the SPEI index, it could be said that the period between 2016 and 2019 was dry. In this study, it was observed that the SPEI index was more sensitive in detecting drought. Still, similar values could be obtained for both indices according to the annual evaluation results. By using drought indices, a data bank can be created with the data obtained from temperature and precipitation data for many years and the forecasts made, and necessary precautions can be taken against this natural disaster, which will affect all living things, especially agricultural activities and water resources.

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