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# TREND ANALYSIS OF METEOROLOGICAL PARAMETERS & DROUGHT ANALYSIS IN THE MURAT RIVER BASIN

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## ABSTRACT

Recognizing hydro-meteorological trends and monitoring drought are crucial for evaluating climate change and variability at basin and regional levels. In this Study,The Standard Precipitation Index (SPI) was used to assess drought in the Murat River Basin, analyzing monthly data from seventeen stations over various time periods. Wallis and Moore's test was used to analyze the homogeneity of the obtained monthly data from 17 rainfall stations and 18 temperature stations ,while Mann-Kendal tests were used to assess trends. The study analyzing data from 17 meteorological stations in the Murat River Basin found a lack of rainfall and severe droughts in 2014 and 2018. The Mann-Kendall test showed a decreasing trend in monthly precipitation data from 17 stations. Temperature data from 18 stations showed a rising trend, except for station 4025, with most showing a rise. The study suggests that rising temperatures and decreasing precipitation will lead to a decline in water supply in the future, affecting socioeconomic life by reducing water resources and soil moisture.

***Keywords:*** *Climate Change, Trend Analysis, Drought Analysis, Murat River Basin, Standard Precipitation Index (SPI)*

# MURAT NEHRİ HAVZASINDA METEOROLOJİK PARAMETRELERİN TREND ANALİZİ VE KURAKLIK ANALİZİ

## ÖZET

Hidro-meteorolojik eğilimlerin tanınması ve kuraklığın izlenmesi, havza ve bölgesel düzeyde iklim değişikliği ve değişkenliğinin değerlendirilmesi için çok önemlidir. Bu çalışmada, Murat Nehri Havzası'ndaki kuraklığı değerlendirmek için Standart Yağış İndeksi (SPI) kullanılmış ve çeşitli zaman dilimlerinde on yedi istasyondan alınan aylık veriler analiz edilmiştir. Elde edilen 17 yağış ve 18 sıcaklık istasyonlarının aylık verilerinin homojenliğini analiz etmek için Wallis ve Moore testi kullanılırken, eğilimleri değerlendirmek için Mann-Kendal testleri kullanılmıştır. Murat Nehri Havzası'ndaki 17 meteoroloji istasyonundan elde edilen verilerin analiz edildiği çalışmada, 2014 ve 2018 yıllarında yağış eksikliği ve şiddetli kuraklık tespit edilmiştir. Mann-Kendall testi, 17 istasyondan alınan aylık yağış verilerinde bir azalma eğilimi olduğunu göstermiştir. 18 istasyondan alınan sıcaklık verileri, 4025 numaralı istasyon hariç, artış eğilimi göstermiştir. Çalışma, artan sıcaklıklar ve azalan yağışların gelecekte su arzında düşüşe yol açacağını, su kaynaklarını ve toprak nemini azaltarak sosyo-ekonomik yaşamı etkileyeceğini öne sürmektedir.

***Anahtar Kelimeler:*** *İklim Değişikliği, Trend Analizi, Kuraklık Analizi, Murat Nehri Havzası, Standart Yağış Endeksi (SPI)*

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## 1. Introduction

Water and oxygen are the only ingredients that could support life on Earth, which is the only planet we know of in this universe.[1] For life on earth to survive, water is essential. It is impossible for anyone to survive even a single day without water. In addition, there is a limited amount of clean water accessible for human consumption. In order to ensure the future of pure water, we should conserve it. [2] It is impossible for life on Earth to exist without water. On our planet, water plays a pivotal role, serving as the lifeblood that sustains various essential activities. From dawn to dusk, water is harnessed for a multitude of purposes. [3] It is consumed for drinking, utilized in cooking, employed for cleaning and laundering, and essential for nurturing plants. [4] Additionally, water serves as a critical resource for agricultural cultivation, industrial operations, and the generation of electricity in hydroelectric power plants. [5] Its significance reverberates across diverse sectors, making it an indispensable element in our daily lives.

Drought is a natural phenomenon resulting from abnormally low rainfall. Meteorological droughts are caused by increased temperatures and lower humidity, while hydrological droughts occur when river flow and underground water decrease.[6] Turkey is currently experiencing a severe meteorological drought from 2013-2014, which is progressing from a meteorological drought to an agricultural and hydrological drought due to a significant reduction in winter precipitation.[7] Global climate changes are causing increased frequency and severity of meteorological droughts, making drought a normal part of daily life. [8] Turkey needs to plan for its drinking water needs, meet its hydroelectric energy demand, and implement drought-resistant agricultural irrigation methods.

A study carried out by V. Gumus and Y. Avsaroglu evaluates historical droughts in the Tigris basin of Turkey between 1965 and 2020 using the Standardized Precipitation Index (SPI) method for 3-, 6-, and 12-month time scales. Three periods are considered: 1965-1983, 1983-192001, and 2001-2020. The mean peak drought indices in the basin increased significantly from FP to TP for all time scales. Extreme and severe drought occurrences in SPI-3 and SPI-6 increased from the past to the present.[9] In SPI-12, although there is a significant decrease in extreme drought occurrence at FP and SP, it increases considerably at TP. The trend analysis results show an increase in decreasing trend stations in the basin, and a considerable increase in stations with decreasing trends in almost all drought classes in SPI-6 and SPI-12.

M. I. Yuce and M. Esit examines the use of 10 drought indices (SPI, SPEI, scPDSI, CZI, MCZI, RAI, RDI, DI, PNI, and ZI) to monitor drought events in the Ceyhan Basin, Turkey. Eight meteorological stations were used to evaluate the applicability and effectiveness of these indexes during previous droughts.[10] The indices show strong correlations for 1-month time scales, but low correlations for longer time scales. The study found a significant increasing trend in annual maximum, minimum, and average temperature time series in all seven stations, with a decreasing trend in five stations and an increasing trend in three stations, indicating that droughts will likely occur in the Ceyhan Basin.

A study conducted by Yuce İ. and Eşit M. uses the Standardized Precipitation Index (SPI) and Standardized Precipitation Evapotranspiration Index (SPEI) to analyze droughts in Samsun province. The analysis examines the effects of climate change on precipitation, temperature, relative humidity, and evaporation. The study finds an increasing trend in temperature data but no trend in precipitation, relative humidity, and evaporation data.[11] A strong relationship is found between SPI and SPEI in 1-month time series and 3-, 6-, 9-, 12-, and 24-month time series with decreasing $R^2$ value. The normal drought category is the most common, while extreme drought is the least common. Little difference is observed between the two indices.

R. Yadav and S. Tripathi conducted a study focuses on the changing trends of rainfall and temperature in thirteen districts of Uttarakhand, located on the southern slope of the Himalayan range. The climate and vegetation vary greatly with elevation, from glaciers at high elevations to subtropical forests at lower elevations. The study analyzes the most important climatic variables, including precipitation and temperature, using daily rainfall data from 1971 to 2011 and temperature data from 1971 to 2007. The Mann-Kendall Test and Sen's Slope Estimator are used to determine trend and slope magnitude.[12] The results show increasing and decreasing trends in precipitation and temperature in some months, suggesting overall insignificant changes in the area.

This study involves the use of data from meteorological stations in the Murat River Basin. Before using rainfall and temperature data for detecting any trend and analyzing drought in the basin, the row data's homogeneity has been checked by conducting the Wallis-Moore test. Homogeneous data was used with care to get more accurate findings. In this respect, R Studio software has been used to estimate the hydro-meteorological condition of the basin utilizing trend analysis. Is there a hydro-meteorological trend in the Murat River Basin that may be utilized for this purpose? Will there be any drought effecting water resources resulted in difficulty of supplying water? In this research, answers to these questions were sought.

## 2. Methodology

### *2.1. Homogenity by The Wallis-Moore Test for precipitation and temperature*

A number of methods have been developed for confirming that meteorological series are homogeneous [13] Normally, homogeneity is determined by one of two methods: the absolute method or the relative method. Each station is assessed separately in the first method. Furthermore, nearby reference stations can also be used as part of the second method of testing [14]. There is, however, difficulty in locating reference stations with a high correlation and homogeneous structure in vast regions. Thus, in our study, homogeneity was determined by the absolute technique [15]. The Wallis-Moore test was conducted to analyze the inhomogeneity in global annual precipitation data from gauging stations.

Using the phase frequency test (1941), Wallis and Moore evaluated a sequence of values X1, X2,..., Xn for randomness. X1, X2, X1,..., Xn. Sign-difference (- or +) tests are performed with Xn1. Indication sequences occurring at the beginning and end of phases are not taken into account. The total number of phases is determined by H [16]. The hypothesis that H is typically disturbed may be tested fairly effectively when continuity correction is applied and n is less than 10. It is not necessary to apply the correction when n is less than 25.

$$E[H] = \frac{1}{3}(2n - 7) \tag{1}$$

$$var[H] = \frac{1}{90}(16n - 29) \tag{2}$$

$$z = \frac{H - E[H]}{\sqrt{\left(\frac{1}{90}(16n - 29)\right)}} \tag{3}$$

### *2.2. Trend test by Mann-Kendall test for precipitation and temperature Test*

It relies on the relationship between a time series' rankings and sequences to determine the Mann-Kendall trend test [17]. A given time series Xi, I = 1, 2..., n is independently distributed according to the null hypothesis H0, while a monotonic trend is maintained by the alternative hypothesis H1.Accordingly, test statistic is calculated as follows.

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \quad (4)$$

Where n represents the number of data and x represents the data at times i and j (j> i) [18]. The signal function is defined as follows:

$$sgn(x_j - x_k) = \begin{cases} 1 & (x_j - x_k) > 0 \\ 0 & (x_j - x_k) = 0 \\ -1 & (x_j - x_k) < 0 \end{cases} \quad (5)$$

When n ≥ 10, variance of the S value is calculated as follows:

$$Var(S) = \frac{n(n-1)(2n+5)}{18} \quad (6)$$

Variance is calculated as follows if there are equal observations in the series:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_i^T t_i(t_i-1)(2t_i+5)}{18} \quad (7)$$

Z test statistic for n> 10 is calculated as follows.

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & S > 0 \\ 0 & S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & S < 0 \end{cases} \quad (8)$$

Positive values of z indicate an upward trend, while negative values indicate a downward trend. According to the statistics, the crucial test statistical values for unique significant cases were 1.64 and 1.96 at 90% and 95% probability levels, respectively.

### *2.3. Standardied Precipitation Index (SPI)*

In various periods of time, the SPI is used to measure precipitation deficits. During these times, different sources of water have been affected by drought. In response to anomalous precipitation patterns, soil moisture levels fluctuate in the short term. Streamflow and reservoir storage are affected by longer-term precipitation anomalies [19]. Long-term rainfall statistics are used to calculate the SPI for every unique site. It is necessary to fit this long-term data to a probability distribution, and then transform it into a normal distribution, in order to ensure that the mean SPI is zero during the relevant time period [20]. The SPI value that is negative represents below-average precipitation, while the SPI value that is positive represents above-average precipitation. Since the SPI is normalized, wet and dry conditions may be displayed similarly [19] When the SPI is consistently negative and reaches an intensity of -1.0 or below, then a drought has occurred. In the event that the SPI is positive, the event is over. As a result, each drought event has a duration and strength based on its beginning and end dates. The "magnitude" of the drought is calculated by adding the SPIs during all months of the drought. The SPI index can be seen in Table 1.

**Table 1.** SPI (standardized precipitation index) classification [19]

| SPI Index | Category |
|---|---|
| 2.0+ | Extremely wet |
| 1.5 to 1.99 | Very wet |
| 1.0 to 1.49 | Moderately wet |
| -.99 to .99 | Near normal |
| -1.0 to -1.49 | Moderately dry |
| -1.5 to -1.99 | Severely dry |
| -2 and less | Extremely dry |

In order to calculate the standardized precipitation index (SPI), you divide the percentage change in precipitation from the mean by the standard deviation for the relevant time period.

$$\mathrm{SPI} = \frac{\mathrm{Xij} - \mathrm{Xim}}{\sigma} \tag{9}$$

SPI: Standard Precipitation Index

Xij: Observed Precipitation (mm)

Xim: Average of Precipitation Series (mm)

σ: Standard deviation of the series

SPI indices for the 1-, 3-, 6-, 9-, 12-, and 24-month timescales are utilized for each measuring station. The amount of rainfall deficit, or the total amount of time that negative SPI values preceded and succeeded by positive SPI values, is what is used to determine how long a drought lasts (Figure 1).[21] Any drought period's intensity, beginning at the i$^{th}$ month, is described as:

$$S = \sum_{i=1}^{D} |-SPI_i| \tag{10}$$

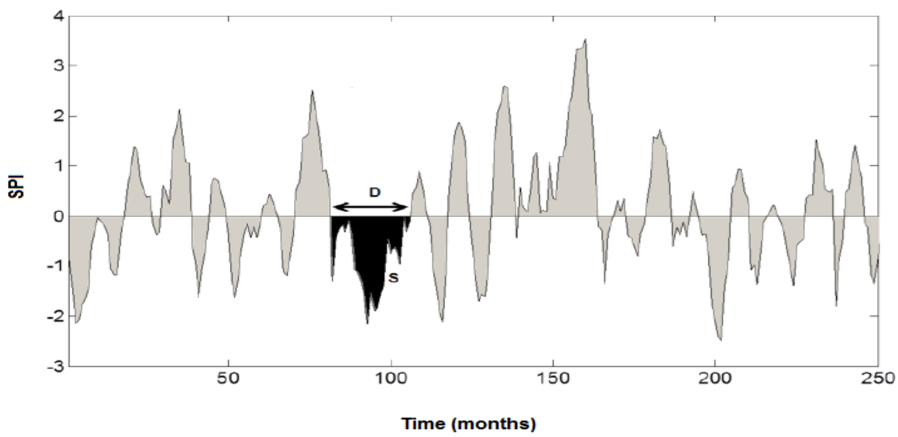


**Figure 1**:The severity S and duration D of a drought episode are determined using the drought index SPI.[7]

Meteorological and agricultural soil moisture conditions respond to precipitation anomalies over relatively short time periods, ranging from 1 to 6 months, unlike streamflow, reservoirs, and groundwater [22]. As a result, meteorological drought applications may require a 1- to 2-month SPI, agricultural drought applications may require a 1- to 6-month SPI, and hydrological drought applications may require a 6- to 24-month SPI or longer. From 2013 to 2014, Turkey suffered from a severe drought. Drought conditions are changing from meteorological to agricultural and hydrological due to a significant decrease in winter precipitation. The increased frequency and intensity of meteorological droughts in Turkey are likely to be related to changes in the worldwide climate [23]. We can assume that drought will increasingly affect daily life as a result of global climate change.

## 3. Study Area And Data

It is one of Western Asia's longest and most significant rivers, both in terms of catchment area and length. Turkey, Syria, and Iraq occupy the vast majority of the basin. Saudi Arabia and Kuwait only have tiny portions inside their borders. There are approximately 2786 kilometers of river along its length. About 440 000 people live in the catchment area of the river, of which 28%, or 123 000, live in Turkey. Most of the water for the Euphrates comes from the Murat River, also known as the Eastern Euphrates. Around 40.000 people live along its 720 kilometers of hilly terrain in Turkey's mountainous region near Mount Ararat at around 3520 meters above sea level [24];[25]. A warm and dry summer is characteristic of the Murat River Basin, while a cold and rainy winter is also characteristic.[26] With a combination of rain and snow, autumn, winter, and spring are the wettest seasons in mountainous headwater regions. Autumn and spring are relatively brief transitional periods [27]. In the winter, the most precipitation occurs between November and April. In the Murat River Basin, as shown in Figure 2, annual precipitation varies from 350 to 1010 mm, depending on the region.


**Figure 2.** Location area, Murat Basin

A location near the intersection of the NAF (North Anatolian Fault) and EAF (Eastern Anatolian Fault) in eastern Anatolia has been strongly impacted by neotectonic deformations since the middle Miocene. From the Turkish-Iranian-Caucasus orogen to the Himalayan-Tibetan orogen, the Eastern Anatolian plateau forms the westernmost border of the world's largest continental collision belt.[28] Combined with the collision of Arabia, India, and Eurasia, the Central Anatolian plateau has created this situation. In Eastern Anatolia (EA), multiple E-W extended basins were formed as a result of compressional tectonic activity. In the current study, we select the Muş Basin as the research area, which has the characteristics of an intermontane press [29]. Several studies have been conducted on the Murat

River, which is the main branch of the Euphrates River. It is mostly located in the geological depression of the Muş Basin on the East Anatolian plateau [30]. As for the second region, it experiences an average annual temperature of 9.5°C and rainfall of 700–750 mm (General Directorate of Meteorology).

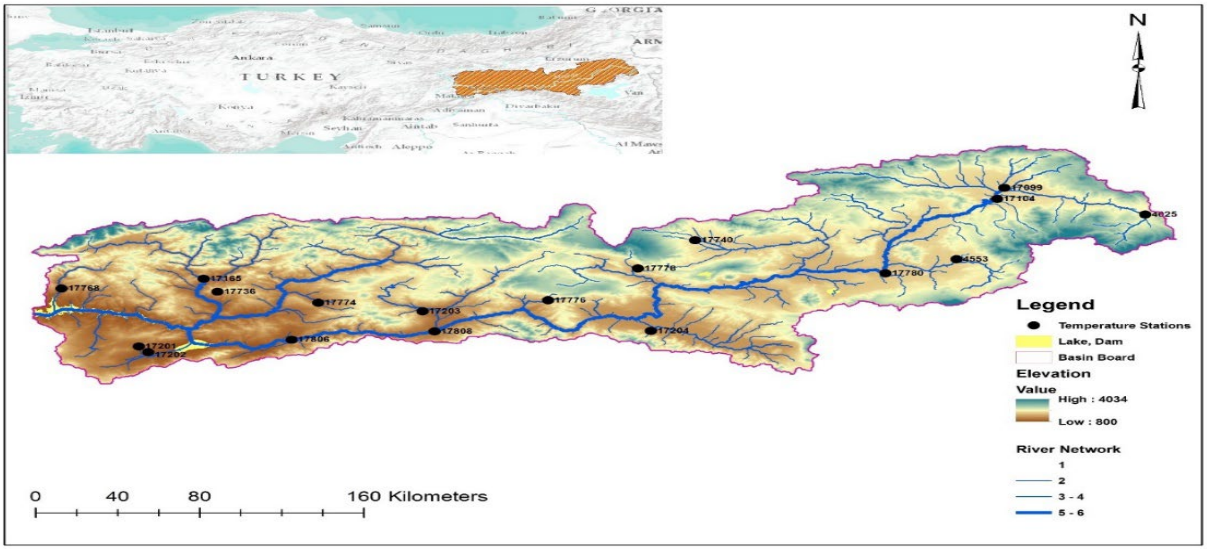


**Figure 3.** Temperature stations in the Murat River Basin

A total of 17 hydro-meteorological stations were used in this study to obtain average monthly precipitation data. Furthermore, precipitation data were provided by the General Directorate of Meteorology (MGM), as illustrated in Table 2 and Figure 3. Throughout the Murat River Basin, the data of 18 different temperature stations (can be seen in the figure 4) were examined in this research. Data for stations were obtained from the General Directorate of Meteorology.

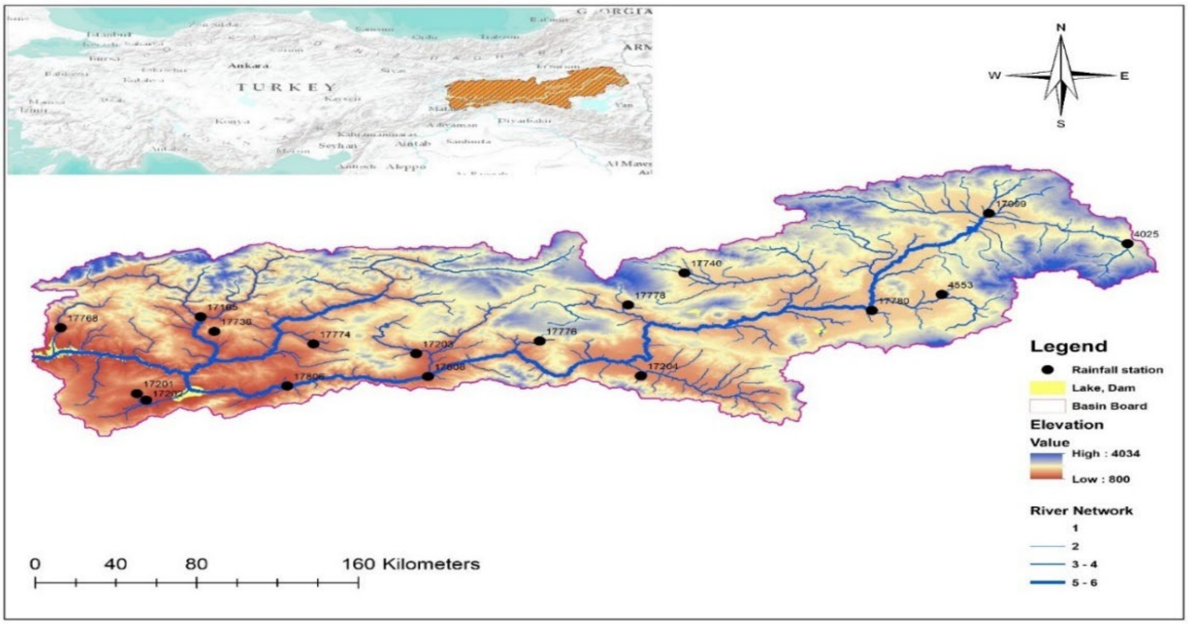


**Figure 4.** Rainfall Stations of the Murat River Basin

**Table 2.** Georgraphical values of Murat River Basin, Precipitation and Temperature Stations (*Station number 17104 is only temperature station)

| Station ID | Observation year | Location name | Elevation(m) | Average Temperature (°C) | Longitude | Latitude |
|---|---|---|---|---|---|---|
| **17778** | 1977-2020 | Varto | 1650 | 7.8 | 414.452 | 391.764 |
| **17204** | 1964-2020 | Muş Merkez | 1320 | 9.7 | 415.023 | 387.509 |
| **17780** | 1959-2020 | Malazgirt | 1666 | 7.3 | 425.308 | 391.436 |
| **4553** | 1976-2002 | Patnos | 1650 | 7.5 | 428.420 | 392.394 |
| **4025** | 1977-1994 | Diyadin | 1900 | 5.2 | 436.694 | 395.436 |
| **17104*** | 2001-2020 | Ahmed-i Hani Havaalanı | 1645 | 9.36 | 430.200 | 396.500 |
| **17099** | 1940-2020 | Ağrı | 1632 | 6.2 | 430.522 | 397.253 |
| **17203** | 1961-2020 | Bingöl Merkez | 1177 | 12.1 | 405.007 | 388.847 |
| **17776** | 1965-2020 | Solhan | 1366 | 10.4 | 410.503 | 389.597 |
| **17808** | 1979-2020 | Genç | 1250 | 12 | 405.528 | 387.477 |
| **17806** | 1965-2020 | Palu | 1000 | 13.7 | 39.926 | 386.907 |
| **17202** | 2001-2020 | Elazığ | 884 | 13.5 | 392.973 | 386.058 |
| **17201** | 1938-2020 | Elazığ Bölge | 990 | 13.1 | 392.561 | 386.443 |
| **17740** | 1960-2020 | Hınıs | 1716 | 6.5 | 416.957 | 393.688 |
| **17774** | 1979-2020 | Karakoçan | 1580 | 11.1 | 400.428 | 389.425 |
| **17736** | 1981-2020 | Mazgirt | 1100 | 11.3 | 396.015 | 390.180 |
| **17165** | 1960-2020 | Tunceli | 940 | 12.7 | 395.408 | 391.058 |
| **17768** | 1968-2020 | Çemişgezek | 953 | 13.6 | 389.177 | 390.401 |

## 4. Results

### *4.1. Precipitation and temperature results of Homogenity by The Wallis-Moore Test*

In general, when test findings are reviewed in depth, the rainfall data series are homogeneous, as illustrated in (Table 3). There is a nonhomogeneity in the data series from 4025 stations, 4553 stations, and 17778 stations when analysis findings are reviewed at 90% and 95% confidence intervals. In 17774 stations, the data series are homogeneous at a 90% confidence interval, but in the same station, the data series for precipitation are nonhomogeneous.

**Table 3.** The Results of Wallis and Moore Homogeneity Test for Precipitation Data

| Wallis and Moore Test Results | | | | |
|---|---|---|---|---|
| **Station ID** | **p-value** | **Z value** | **0.90 (+-1.64)** | **0.95 (+-1.96)** |
| **4025** | 0,024 | 2,260 | Non-homogeneous | Non-homogeneous |
| **4553** | 0,015 | 2,442 | Non-homogeneous | Non-homogeneous |

| | | | | |
|---|---|---|---|---|
| **17099** | 0,534 | 0,622 | Homogeneous | Homogeneous |
| **17165** | 0,304 | 1,028 | Homogeneous | Homogeneous |
| **17201** | 0,792 | 0,263 | Homogeneous | Homogeneous |
| **17202** | 0,781 | -0,278 | Homogeneous | Homogeneous |
| **17203** | 0,407 | 0,829 | Homogeneous | Homogeneous |
| **17204** | 0,395 | 0,851 | Homogeneous | Homogeneous |
| **17736** | 0,609 | 0,512 | Homogeneous | Homogeneous |
| **17740** | 0,304 | 1,028 | Homogeneous | Homogeneous |
| **17768** | 1,000 | 0,000 | Homogeneous | Homogeneous |
| **17774** | 0,081 | 1,746 | Non-homogeneous | Homogeneous |
| **17776** | 0,519 | 0,644 | Homogeneous | Homogeneous |
| **17778** | 0,028 | 2,191 | Non-homogeneous | Non-homogeneous |
| **17780** | 0,126 | 1,529 | Homogeneous | Homogeneous |
| **17806** | 0,334 | 0,967 | Homogeneous | Homogeneous |
| **17808** | 0,318 | 0,998 | Homogeneous | Homogeneous |

**Table 3.** Continue

The study used temperature data from 18 meteorological stations in the Murat River Basin to assess homogeneity. The results showed that the data series was not homogeneous at 90%, but homogeneity was observed at a 95% confidence level. Station 17202 had a p-value of 0.058 and a Z-value of 1.894, indicating it was not homogeneous. Station 17204 had a Z-value of 1.809 and a p-value of 0.070, indicating it was not homogeneous with 90% confidence (Table 4).

**Table 4.** Wallis and Moore Homogeneity Results of Test for Temperature Data

| **Wallis and Moore Test Results** | | | | |
|---|---|---|---|---|
| **Station ID** | **p-value** | **Z value** | **0.90 % (+-1.64)** | **0.95 % (+-1.96)** |
| **4025** | 0.922 | 0.098 | Homogeneous | Homogeneous |
| **4553** | 0.937 | -0.079 | Homogeneous | Homogeneous |
| **17099** | 0.477 | 0.711 | Homogeneous | Homogeneous |
| **17104** | 0.781 | 0.278 | Homogeneous | Homogeneous |
| **17165** | 0.681 | 0.411 | Homogeneous | Homogeneous |
| **17201** | 0.599 | 0.526 | Homogeneous | Homogeneous |
| **17202** | 0.058 | 1.894 | Non-homogeneous | Homogeneous |
| **17203** | 0.147 | 1.451 | Homogeneous | Homogeneous |
| **17204** | 0.07 | 1.809 | Non-homogeneous | Homogeneous |
| **17736** | 0.898 | 0.128 | Homogeneous | Homogeneous |
| **17740** | 0.918 | 0.103 | Homogeneous | Homogeneous |
| **17768** | 0.74 | 0.331 | Homogeneous | Homogeneous |
| **17774** | 0.383 | 0.873 | Homogeneous | Homogeneous |
| **17776** | 0.519 | 0.644 | Homogeneous | Homogeneous |
| **17778** | 0.715 | 0.365 | Homogeneous | Homogeneous |
| **17780** | 0.292 | 1.055 | Homogeneous | Homogeneous |
| **17806** | 1.000 | 0 | Homogeneous | Homogeneous |
| **17808** | 0.383 | 0.873 | Homogeneous | Homogeneous |

### 4.2. Precipitation and temperature results by Mann-Kendall test

The Mann-Kendall test was used to analyze monthly rainfall data from stations in the Murat River basin. The results showed a decreasing trend at the 90% confidence interval and no trend at the 95% confidence interval for stations 4025, 4553, 17099, 17165, 17201, 17202, 17203, 17204, 17736, 17774, and 17780. Station 17768 showed a statistically significant decreasing trend, while Station 17778 showed a statistically significant trend. Station 17736 showed a statistically significant trend, while Station 17740 showed a statistically significant no trend (Table 5). The results suggest that the precipitation trend in the Murat River basin are not uniformly distributed across different stations.

**Table 5.** Mann-Kendall Trend Analysis Results

| Mann-Kendall Test Results | | | | | |
|---|---|---|---|---|---|
| **Station ID** | **p-value** | **Var S** | **Z value** | **Trend (90%)** | **Trend (95%)** |
| **4025** | 0,36 | 697,00 | -0,91 | No trend | No trend |
| **4553** | 0,71 | 2301,00 | -0,38 | No trend | No trend |
| **17099** | 0,88 | 60119,00 | -0,15 | No trend | No trend |
| **17165** | 0,23 | 25823,33 | -1,20 | No trend | No trend |
| **17201** | 0,61 | 64657,00 | -0,51 | No trend | No trend |
| **17202** | 0,31 | 950,00 | -1,01 | No trend | No trend |
| **17203** | 0,85 | 24582,33 | -0,19 | No trend | No trend |
| **17204** | 0,74 | 21102,67 | 0,34 | No trend | No trend |
| **17736** | 0,40 | 7365,67 | -0,84 | No trend | No trend |
| **17740** | 0,05 | 25822,33 | -1,94 | Decreasing | No trend |
| **17768** | 0,01 | 16995,33 | -2,55 | Decreasing | Decreasing |
| **17774** | 0,18 | 8513,33 | -1,35 | No trend | No trend |
| **17776** | 0,08 | 20020,00 | -1,76 | Decreasing | No trend |
| **17778** | 0,01 | 9774,33 | -2,75 | Decreasing | Decreasing |
| **17780** | 0,98 | 27104,33 | -0,02 | No trend | No trend |
| **17806** | 0,06 | 20020,00 | -1,87 | Decreasing | No trend |
| **17808** | 0,01 | 8513,33 | -2,74 | Decreasing | Decreasing |

The study used the Mann-Kendall test to analyze monthly data from temperature stations in the Murat River basin. The results showed a trend towards an increase at nearly all 18 stations. The analysis showed a trend towards an increasing trend at a 90% confidence interval and a 95% confidence interval for stations 4553, 17099, 17165, 17201, 17202, 17203, and 17204. At 90% and 95% confidence levels, Station 4025 showed no statistically significant trend in temperature with a p-value of 0.111, a variance Var (S) of 695, and a standardized test statistic (Z) of -1.593 (Table 6). On the other hand, Station 17104 showed an increasing trend with a p-value of 0.060, a variance Var (S) of 949.00, and a standardized test statistic (Z) of 1.883. The study provides a comprehensive analysis of temperature trends in the Murat River basin.

**Table 6.** Mann-Kendall Trend Analysis Results

| **Mann-Kendall Test Results** | | | | | |
|---|---|---|---|---|---|
| **Station ID** | **p-value** | **Var S** | **Z value** | **Trend (90%)** | **Trend (95%)** |
| **4025** | 0.111 | 695.000 | -1.593 | No trend | No trend |
| **4553** | 0.016 | 2.289.333 | 2.403 | Increasing | Increasing |
| **17099** | 0.022 | 60.028.000 | 2.290 | Increasing | Increasing |
| **17104** | 0.06 | 949.000 | 1.883 | Increasing | No trend |
| **17165** | 0 | 25.723.667 | 4.714 | Increasing | Increasing |
| **17201** | 0.002 | 64.456.000 | 3.131 | Increasing | Increasing |
| **17202** | 0.002 | 7.883.000 | 3.131 | Increasing | Increasing |
| **17203** | 0.014 | 24.504.000 | 2.447 | Increasing | Increasing |
| **17204** | 0 | 21.066.333 | 4.671 | Increasing | Increasing |
| **17736** | 0.001 | 7.343.667 | 3.454 | Increasing | Increasing |
| **17740** | 0 | 25.761.667 | 4.822 | Increasing | Increasing |
| **17768** | 0 | 16.917.667 | 5.305 | Increasing | Increasing |
| **17774** | 0.033 | 8.485.667 | 2.128 | Increasing | Increasing |
| **17776** | 0.001 | 19.970.000 | 3.319 | Increasing | Increasing |
| **17778** | 0.006 | 9.746.333 | 2.755 | Increasing | Increasing |
| **17780** | 0.001 | 22.149.333 | 3.272 | Increasing | Increasing |
| **17806** | 0 | 19.957.333 | 3.745 | Increasing | Increasing |
| **17808** | 0.002 | 8.469.333 | 3.140 | Increasing | Increasing |

### *4.3. Results of SPI*

The study used the SPI index to analyze data from seventeen meteorological stations in the Murat River Basin over periods of 1, 3, 6, 9, 12, and 24 months. The severity and duration of droughts were crucial, with the SPI index determining the maximum drought severity at stations on a one-month time scale. In 1989, severe droughts occurred at stations 4025, 4553, 17099, 17165, 17201, 17203, 17204, 17736, and 17780. Station 17780 experienced the highest absence of precipitation in 1989, with an intensity of 12.8 and a duration of nine months. Station 17202 experienced the highest drought magnitude and duration in 2004, while the SPI 24 index measured a maximum drought magnitude and duration of 35.1 and 27 months. Stations 17740, 17774, and 17778 experienced the most severe droughts in 2012, with the highest lack of precipitation observed in 17778. Station 17808 had the highest maximum drought in 2018 with a magnitude of 22.97 and a duration of 24 months (Table 7 and Table 8).

**Table 7.** According to six different time series, the maximum, average, and minimum drought severity and drought duration (month)

| | | SPI 1 | | SPI 3 | | SPI 6 | | SPI 9 | | SPI 12 | | SPI 24 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Station N.** | **Index** | **S** | **D** | **S** | **D** | **S** | **D** | **S** | **D** | **S** | **D** | **S** | **D** |
| 4025 | **Min.** | 0.1 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| | **Av.** | 0.4 | 1.7 | 0.4 | 3.1 | 0.4 | 5.0 | 0.4 | 6.4 | 0.3 | 5.8 | 0.3 | 5.7 |
| | **Max.** | **9.96 (1989)** | 7.0 | 13.4 | 9.0 | 17.3 | 14.0 | 21.2 | 17.0 | 27.1 | 22.0 | 50.1 | 35.0 |
| 4553 | **Min.** | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.2 | 1.0 | 0.1 | 1.0 | 0.0 | 1.0 |
| | **Av.** | 0.4 | 1.8 | 0.4 | 3.0 | 0.4 | 5.9 | 0.4 | 7.6 | 0.4 | 7.3 | 0.4 | 8.1 |
| | **Max.** | **10.78 (1989)** | 7.0 | 15.9 | 13.0 | 41.5 | 30.0 | 49.8 | 33.0 | 55.0 | 32.0 | 74.5 | 66.0 |
| 17099 | **Min.** | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| | **Av.** | 0.4 | 2.1 | 0.4 | 4.2 | 0.4 | 7.1 | 0.4 | 7.6 | 0.4 | 10.3 | 0.4 | 11.7 |
| | **Max.** | **10.92 (1989)** | 9.0 | 17.6 | 19.0 | 34.1 | 40.0 | 41.6 | 41.0 | 48.1 | 58.0 | 79.3 | 71.0 |
| 17165 | **Min.** | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| | **Av.** | 0.4 | 2.0 | 0.4 | 3.7 | 0.4 | 6.9 | 0.4 | 9.6 | 0.4 | 13.1 | 0.4 | 34.2 |
| | **Max.** | **12.52 (1989)** | 10.0 | 18.2 | 14.0 | 20.3 | 26.0 | 45.8 | 50.0 | 49.7 | 49.0 | 66.2 | 80.0 |
| 17201 | **Min.** | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.1 | 1.0 | 0.0 | 1.0 |
| | **Av.** | 0.4 | 1.8 | 0.4 | 3.6 | 0.4 | 6.5 | 0.4 | 7.8 | 0.4 | 9.6 | 0.4 | 11.4 |
| | **Max.** | **9.72 (1989)** | 7.0 | 13.2 | 12.0 | 38.3 | 31.0 | 46.1 | 34.0 | 51.5 | 47.0 | 67.1 | 62.0 |
| 17202 | **Min.** | 0.1 | 1.0 | 0.2 | 1.0 | 0.1 | 1.0 | 0.1 | 1.0 | 0.0 | 1.0 | 0.7 | 2.0 |
| | **Av.** | 0.4 | 1.7 | 0.4 | 3.7 | 0.4 | 6.2 | 0.4 | 6.5 | 0.4 | 13.0 | 0.4 | 12.9 |
| | **Max.** | **6.27 (2004)** | 4.0 | 12.1 | 13.0 | 26.2 | 22.0 | 31.4 | 23.0 | 34.7 | 39.0 | 35.1 | 27.0 |
| 17203 | **Min.** | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| | **Av.** | 0.4 | 1.9 | 0.4 | 3.7 | 0.4 | 5.6 | 0.4 | 6.4 | 0.4 | 8.6 | 0.4 | 12.0 |
| | **Max.** | **10.35 (1989)** | 8.0 | 18.1 | 17.0 | 26.3 | 31.0 | 28.0 | 31.0 | 30.9 | 35.0 | 69.4 | 68.0 |
| 17204 | **Min.** | 0.0 | 1.0 | 0.0 | 1.0 | 0.1 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| | **Av.** | 0.4 | 1.8 | 0.4 | 3.4 | 0.4 | 5.6 | 0.4 | 7.1 | 0.4 | 8.3 | 0.4 | 16.3 |
| | **Max.** | **9.52 (1989)** | 7.0 | 15.2 | 16.0 | 30.8 | 25.0 | 38.6 | 34.0 | 42.9 | 34.0 | 75.0 | 62.0 |

**Table 8.** According to six different time series, the maximum, average, and minimum drought severity and drought duration (month)

| | | **SPI 1** | | **SPI 3** | | **SPI 6** | | **SPI 9** | | **SPI 12** | | **SPI 24** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Station ID** | **Index** | **S** | **D** | **S** | **D** | **S** | **D** | **S** | **D** | **S** | **D** | **S** | **D** |
| 17736 | **Min.** | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.1 | 1.0 |
| | **Av.** | 0.4 | 2.0 | 0.4 | 3.2 | 0.4 | 5.4 | 0.4 | 8.1 | 0.4 | 9.8 | 0.4 | 13.5 |
| | **Max.** | **11.63 (1989)** | 8.0 | 16.5 | 16.0 | 19.0 | 24.0 | 22.1 | 26.0 | 57.8 | 50.0 | 78.4 | 66.0 |
| 17740 | **Min.** | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| | **Av.** | 0.4 | 1.9 | 0.4 | 4.0 | 0.4 | 5.9 | 0.4 | 8.6 | 0.4 | 10.6 | 0.2 | 16.4 |
| | **Max.** | **15.25 (2012)** | 11.0 | 24.7 | 30.0 | 60.7 | 35.0 | 72.6 | 45.0 | 76.7 | 46.0 | 23.9 | 37.0 |
| 17768 | **Min.** | 0.1 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| | **Av.** | 0.4 | 2.0 | 0.4 | 3.2 | 0.4 | 4.6 | 0.4 | 6.3 | 0.4 | 8.2 | 0.4 | 9.8 |
| | **Max.** | **15.76 (2014)** | 11.0 | 25.7 | 13.0 | 52.8 | 37.0 | 61.2 | 38.0 | 76.8 | 57.0 | 149.6 | 100.0 |
| 17774 | **Min.** | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| | **Av.** | 0.4 | 1.9 | 0.3 | 3.6 | 0.4 | 5.6 | 0.4 | 7.0 | 0.4 | 6.3 | 0.4 | 7.4 |
| | **Max.** | **11.47 (2012)** | 9.0 | 22.4 | 18.0 | 57.3 | 40.0 | 67.2 | 38.0 | 73.5 | 43.0 | 91.8 | 50.0 |
| 17776 | **Min.** | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| | **Av.** | 0.4 | 1.9 | 0.4 | 3.6 | 0.4 | 5.8 | 0.4 | 7.3 | 0.4 | 8.2 | 0.4 | 10.5 |
| | **Max.** | **14.05 (2014)** | 12.0 | 25.8 | 21.0 | 70.1 | 47.0 | 82.2 | 45.0 | 89.3 | 42.0 | 134.4 | 94.0 |
| 17778 | **Min.** | 0.0 | 1.0 | 0.0 | 1.0 | 0.1 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.2 | 1.0 |
| | **Av.** | 0.4 | 2.4 | 0.4 | 3.4 | 0.4 | 6.4 | 0.4 | 9.1 | 0.4 | 9.2 | 0.3 | 11.5 |
| | **Max.** | **17.13 (2012)** | 13.0 | 35.5 | 17.0 | 46.0 | 31.0 | 70.5 | 39.0 | 75.4 | 42.0 | 90.2 | 47.0 |
| 17780 | **Min.** | 0.0 | 1.0 | 0.1 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| | **Av.** | 0.4 | 2.0 | 0.4 | 4.4 | 0.4 | 7.6 | 0.4 | 8.9 | 0.4 | 10.8 | 0.3 | 23.7 |
| | **Max.** | **12.08 (1989)** | 9.0 | 18.1 | 18.0 | 43.5 | 37.0 | 49.5 | 38.0 | 45.8 | 39.0 | 83.2 | 124.0 |
| 17806 | **Min.** | 0.1 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| | **Av.** | 0.4 | 1.9 | 0.4 | 3.6 | 0.4 | 5.8 | 0.4 | 7.4 | 0.4 | 7.7 | 0.4 | 11.7 |
| | **Max.** | **18.9 (2014)** | 12.0 | 32.3 | 16.0 | 38.7 | 31.0 | 43.6 | 45.0 | 47.5 | 45.0 | 62.1 | 51.0 |
| 17808 | **Min.** | 0.0 | 1.0 | 0.0 | 1.0 | 0.1 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| | **Av.** | 0.4 | 2.1 | 0.4 | 3.3 | 0.4 | 5.3 | 0.4 | 6.7 | 0.4 | 11.1 | 0.4 | 17.2 |
| | **Max.** | **22.97 (2018)** | 24.0 | 36.1 | 24.0 | 45.9 | 28.0 | 55.1 | 36.0 | 67.3 | 53.0 | 137.6 | 85.0 |

## 5. Conclusion

The study analyzed data from seventeen meteorological stations in the Murat River Basin using the SPI method, revealing a lack of rainfall with severe droughts occurring in 2014 and 2018. The study conducted on 17 precipitation stations in the Murat River Basin used the Wallis and Moore homogeneity test, Mann-Kendall trend analysis test to analyze monthly precipitation data sets, using 95% and 90% confidence intervals. The Mann-Kendall test showed a decreasing trend in monthly precipitation data from 17 Murat River basin stations. A total of 18 temperature stations throughout the Murat River Basin were used to collect the monthly temperature data series. There have been two tests performed on these temperature data series: the Wallis and Moore homogeneity test, the Mann-Kendall trend analysis test in order to analyze these data series, 90% and 95% confidence intervals were used. The results have showed us that a rising trend in temperature data from 18 stations except for station 4025 which shows no trend, with most showing a rise in temperature. The data homogeneity calculated by the Wallis and Moore test was not significant factors in determining the trend.

The results of this research, which were based on data collected from stations in the Murat River Basin, showed that there was a rising trend in temperature data as well as drought in the precipitation data of the previous years for the SPI 1, SPI 3, SPI 6, SPI 9, SPI 12, and SPI 24-month periods.

Drought negatively impacts socioeconomic life by reducing water resources, soil moisture, and other factors. [31];[32].A study using data from Murat River Basin stations found a rising trend in temperature data and drought in precipitation data. This suggests that rising temperatures and decreasing precipitation will lead to a decline in water supply in the Murat River Basin in the future. The findings recommend that competent authorities take significant measures to address the issue and ensure the safety of the water supply.

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