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INVESTIGATION OF PRECIPITATION DATA OF DİYARBAKIR PROVINCE WITH DIFFERENT TREND ANALYSIS METHODS

DİYARBAKIR İLİNE AİT YAĞIŞ VERİLERİNİN FARKLI TREND ANALİZİ YÖNTEMLERİ İLE İNCELENMESİ

Burak GÜL[1*] (ORCID: 0009-0005-7735-2455)

[1] Dicle University, Civil Engineering Department, Diyarbakır, Türkiye

*Sorumlu Yazar / Corresponding Author: Burak GÜL, brkgl21@gmail.com

ABSTRACT

Global climate change leads to significant alterations in climate systems, affecting natural resource management, agriculture, and water security. As these impacts are also felt at the local level, regional climate analyses are crucial. This study analyzes precipitation data from Diyarbakır province between 1970 and 2022 to examine the local effects of climate change. Trend analyses were conducted using Mann-Kendall, Sen's Slope, Spearman's Rho, and Innovative Trend Analysis (ITA) methods. The Mann-Kendall test assessed the statistical significance of trends, while Sen's Slope estimated the magnitude of these trends. The results indicated no statistically significant trends on an annual or seasonal basis. However, the ITA method revealed decreasing trends in summer precipitation and annual totals, alongside increasing trends in spring and autumn precipitation. No trends were detected for winter precipitation. The Spearman's Rho test identified a positive relationship between annual total precipitation and seasons, but no trends were observed among the seasons themselves. This study highlights the importance of local climate analyses and contributes to preparedness for future changes. Continuous monitoring of climate data plays a critical role in making informed strategic decisions, particularly in water resource management and agricultural policies.

Keywords: Climate change, Diyarbakır, precipitation, trend analysis

ÖZET

Küresel iklim değişikliği, iklim sistemlerinde büyük değişikliklere yol açarak, doğal kaynakların yönetimi, tarım ve su güvenliğini etkilemektedir. Bu etkiler yerel düzeyde de hissedildiği için, bölgesel iklim analizleri büyük önem taşımaktadır. Bu çalışmada, Diyarbakır ilinin 1970-2022 yılları arasındaki yağış verilerini analiz ederek iklim değişikliğinin yerel etkilerini incelenmiştir. Mann-Kendall, Sen's Slope, Spearman's Rho ve Yenilikçi Trend Analizi (ITA) yöntemleri kullanılarak yağış verileri üzerinde trend analizleri yapılmıştır. Mann-Kendall testi trendlerin istatistiksel anlamlılığını, Sen's Slope ise trendlerin eğimini değerlendirmiştir. Sonuçlar, yıllık ve mevsimsel bazda anlamlı bir trend olmadığını göstermiştir. ITA yöntemi, yaz mevsiminde ve yıllık toplam yağışta azalma, ilkbahar ve sonbaharda artış trendleri ortaya koyarken, kış mevsiminde bir trend bulunmamıştır. Spearman's Rho testi, yıllık toplam yağış ve mevsimler arasında pozitif bir ilişki belirlemiş, ancak mevsimler arasında trend görülmemiştir. Bu çalışma, yerel iklim analizlerinin önemine işaret etmekte ve gelecekteki değişikliklere hazırlıklı olma konusunda katkı sağlamaktadır. İklim verilerinin sürekli izlenmesi, stratejik kararlar için kritik bir rol oynamaktadır.

Anahtar Kelimeler: Diyarbakır, iklim değişikliği, trend analizleri, yağış

INTRODUCTION

Global climate change is a significant process causing alterations in climate parameters worldwide, with profound impacts on water resources. Rising temperatures, changes in precipitation patterns, and an increase in the frequency

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of extreme weather events adversely affect the quantity, distribution, and quality of freshwater resources (Bojago et al., 2024). Water resources, which are utilized in various sectors such as agricultural irrigation, drinking water supply, and energy production, are directly impacted by the effects of climate change. In this context, water resource management and planning must be reevaluated to account for the future impacts of climate change (Sa'adi et al., 2023).

Understanding the impacts of climate change on water resources requires a thorough examination of its causes and mechanisms. Changes in the climate system are associated with various factors, including atmospheric circulations, greenhouse gas accumulations, ocean currents, and evaporation processes. The increase in greenhouse gases in the atmosphere leads to rising global temperatures and alterations in the hydrological cycle (Alemu et al., 2024). This phenomenon results in increased precipitation in some regions and heightened drought conditions in others. Additionally, the frequency and intensity of extreme weather events are increasing, leading to more frequent hydrological disasters such as floods and droughts. These effects complicate the sustainable management of water resources and raise critical questions about how these resources will be preserved amidst growing populations and economic activities in the future (Wubneh et al., 2023).

Some studies analyzing the impacts of climate change on water resources focus on precipitation trend analyses. Identifying changes over time in precipitation amounts, frequency, and seasonal distributions is crucial for understanding potential impacts on water resources (Gül and Kayaalp, 2024). These analyses are typically conducted through long-term examinations of meteorological data and involve statistical methods to develop future precipitation scenarios. Precipitation trend analyses, particularly those conducted at regional scales, provide valuable insights into how local water resources may be affected in the future when correlated with climate models. For example, decreases in precipitation amounts may be observed in some areas, while increases or seasonal shifts may occur in others. These data serve as critical tools for decision-makers in water management planning, offering key guidance for ensuring sustainable resource use.

Precipitation trend analyses are also crucial for examining hydrological events caused by climate change, such as flood risk analyses. In particular, the increase or decrease in extreme precipitation over time aids in predicting future risks in flood-prone areas and planning measures to mitigate these risks. Therefore, precipitation trend analyses are an essential tool in climate change studies, helping to manage climatic uncertainties effectively. (Ceribasi et al., 2021; Kahya and Kalaycı, 2004; Partal and Kahya, 2006; Zhang et al., 2001)

In their study, Modarres and Sarhadi (2009) employed the Mann-Kendall test and Sen's slope estimator method to analyze precipitation data in Iran's arid and semi-arid regions. The study identified significant decreasing trends in precipitation across most regions. It was also revealed that these decreases have become more pronounced over the past 50 years.

Javari, 2016 In the study conducted by him, the trend analysis of precipitation in Iran revealed significant seasonal changes with decreasing precipitation in the eastern and central regions, while increasing trends were observed in the west and north. The trend analysis methods used in the study were the Kruskal-Wallis (KW) Test and the Least Squares Regression (LSR) Test, which were used to examine the nature of monthly and seasonal precipitation series. Pathak and Dodamani (2020) used the Mann Kendal trend analysis method in their study. As a result of the analysis, significant negative trends emerged in annual and seasonal precipitation, and the correlations between precipitation trends and SPI trends varied between 0.91 and 0.97, indicating potential drought conditions. In the study conducted by Singh et al. (2021), the spatial-temporal precipitation trends in India from 1901 to 2019 were analyzed using precipitation data. In the study, an innovative trend analysis (ITA) method was applied to detect trends in seasonal and annual precipitation; The ITA results were compared with conventional methods such as Mann-Kendall (M-K), modified Mann-Kendall (mm-K) and linear regression analysis (LRA). The findings revealed significant trends in increasing monsoon and annual rainfall over most of the peninsular and northwestern India while decreasing trends in rainfall were observed in the central northeastern region and many subdivisions during winter months.

In a study conducted by Shi et al. (2013), precipitation trends in the Shaying River Basin upstream of the Huai River were analyzed for the period 1951 to 2010 using linear regression, the Mann-Kendall test, and R/S analysis. The results indicated that overall precipitation trends were complex, with a slight increase in annual precipitation observed over the past 60 years; however, this increase was not statistically significant. Future projections suggest a non-persistent trend in precipitation, indicating that fluctuations may occur without a clear directional pattern. During the analysis, among the 38 precipitation stations, predominantly negative trends were observed in the spring and autumn seasons, whereas positive trends were noted during the summer and winter months.

An important analysis by Kundu et al. (2014) examined rainfall trends in India covering the period from 1871 to 2011. The study focused on 306 stations in seven different districts of India which include Homogeneous Indian Monsoon and Core-Monsoon India. The Mann-Kendall test and the Sen slope were used to detect trends, while the Mann-Whitney Pettitt test was applied to identify breakpoints in the precipitation series. With the exceptions noted in the core monsoon and northeast India, five regions have been found to exhibit a decreasing trend in their annual rainfall. Most regions have seen a significant reduction in monsoon rainfall, which has been critical for agricultural water demands. The analysis revealed a variability in precipitation over 141 years; North-West India experienced the highest increase of 5.14%, while core-monsoon India showed an annual decline of 4.45%. The findings highlight the importance of understanding rainfall trends due to their impact on agriculture and water resources management in India. In the study conducted by AlSubih et al. (2021), the Mann-Kendall test was used for trend analysis and the Theil-Sen approach was applied for trend size calculation. Trend analysis revealed a statistically significant downward trend in precipitation at most stations in the Aseer region, especially between 2000 and 2010.

Yükseler et al. (2021) analyzed precipitation data for Bingöl province between 1960 and 2017, identifying decreasing trends of 0-2 mm/year in annual total precipitation at some stations. Furthermore, significant seasonal variations in trends were observed across different stations and seasons. The study particularly highlighted the utility of the Şen Innovative Trend Analysis (Şen-ITA) method in providing detailed evaluations of seasonal transitions and significant changes. Similarly, Çoşkun, 2020 investigated long-term precipitation trends in the Van Lake Closed Basin, located in Turkey's Eastern Anatolia Region. This basin was selected as it provides a suitable area for observing the effects of climate change more distinctly. Using data from seven stations with over 30 years of measurements, the analysis employed the Mann-Kendall Test, Spearman's Rho, and Şen Test. The results revealed decreasing trends in annual precipitation at the Gevaş and Ahlat stations, while the Van-Bölge station exhibited a statistically insignificant increase. On a seasonal basis, significant decreases were observed at Erciş and Ahlat stations, whereas no discernible trends were identified at other stations.

In a study conducted by Gümüş et al. (2021), trend analyses revealed that values in the extreme drought class (-3 and below) show a decreasing trend, indicating a decline in the frequency of extreme droughts in recent years. However, a slight increasing trend has been observed in the categories of severe drought and very severe drought for medium and long-term droughts. During wet periods, a generally weak decreasing trend is observed. In the SYI-12 analysis, particularly in the medium-humid class, a declining trend of over 5% was detected.

Overall, drought trends show limited variation, but there is a tendency for an increase in drought severity for medium and long-term periods. These findings provide critical information for water resource management in Diyarbakır and future drought risk planning. The use of the ITA method has enabled more detailed and effective analyses compared to traditional methods.

In a study conducted by Özdel, 2020 study, the changes in temperature and precipitation parameters in the Diyarbakır Basin from 1965 to 2019 were analyzed. Data from meteorological stations in Batman, Çermik, Diyarbakır, Ergani, and Siirt were used, examining average temperature, maximum temperature, minimum temperature, and total precipitation in detail. Statistical methods such as Mann-Kendall, Spearman's Rho, and Sen's slope trend test were applied, and homogeneity tests indicated that time series generally had a homogeneous structure.

According to the findings, statistically significant warming trends were observed in all stations except Diyarbakır for annual average temperatures, with the strongest warming trends identified in Ergani and Siirt stations. A notable warming trend was observed in all stations, especially during the summer months. In precipitation analyses, no significant decreasing trends were found in annual total precipitation, with only Çermik station showing a statistically significant decrease in November.

Overall, there was an increase in temperature values and a decreasing trend in precipitation. These results highlight the impacts of global climate change on the Diyarbakır Basin. The detailed methods used in the study provide valuable insights into understanding regional climate change impacts and assessing measures for related sectors, particularly in agriculture and water resource management.

In a study conducted by Alashan, 2018 study, daily temperature data for July from 1972 to 2005 were analyzed for Diyarbakır. The time series was divided into two halves for innovative trend analysis (ITA) and change box (ITA-CB) methods, evaluating temperature trends in low, medium, and high-value groups. Results showed a clear increasing trend in July temperatures in all groups. For the low group, a minimum -0.84%, maximum 6.30%, and average 2.04% changes were observed. For the medium group, minimum -0.55%, maximum 2.45%, and average 1.13% increases were recorded. In general, a minimum of -0.84%, a maximum of 6.30%, and an average increase of 1.51% were noted across all groups.

In a study conducted by Şen, 2017 study, annual total precipitation records from Diyarbakır meteorological station to the Tigris River were analyzed. The dataset was evaluated under a broad application of innovative trend significance testing. According to the analysis, a statistically significant decreasing trend was detected in annual total precipitation in Diyarbakır. The trend slope value falling outside the confidence intervals indicates that this decrease is not due to random fluctuations and is statistically significant.

In a study conducted by Bahadır, 2011 Diyarbakır's central region, where despite showing a more stable character compared to other stations in terms of temperature, there was a decreasing trend. The magnitude of average deviations leaned towards a decrease, which continued steadily from 1975 to 1985. After 1985, stability persisted until 2006. From that point onward, a decreasing trend in precipitation reached its lowest levels in 2007 and 2008. Trend analyses suggest a decrease in precipitation by 35 mm from 2009 to 2023. Yürekli (2015), Gümüş et al. (2023), and other studies mentioned a decline in precipitation trends in Diyarbakır.

These studies show that trend analyses are important and widely used methods in the literature to predict future precipitation trends. This study aimed to conduct trend analyses on precipitation data recorded for Diyarbakır province between 1970 and 2022. The analyses employed Mann-Kendall, Sen's Slope, Spearman's Rho, and Innovative Trend Analysis (ITA) methods, offering a multidimensional perspective on potential trends in precipitation data. The Mann-Kendall test was used to evaluate the statistical significance of precipitation trends, while the Sen's Slope method was applied to estimate the slope of these trends. Additionally, Spearman's Rho test was used to examine the relationships between seasonal and annual precipitation, and the ITA method provided an innovative perspective.

The findings revealed that the Mann-Kendall and Sen's Slope methods did not indicate the presence of statistically significant trends on an annual or seasonal basis. However, ITA analysis identified a decreasing trend in annual total precipitation and summer precipitation, along with increasing trends in spring and autumn. No trends were observed for winter precipitation. According to Spearman's Rho test, significant positive relationships were found between annual total precipitation and seasons, although no clear trends were detected among the seasons themselves. This study provides a multidimensional approach to understanding the dynamics of long-term precipitation data for Diyarbakır province.

STUDY AREA

Diyarbakir is a city that receives an average annual rainfall of 493 mm and experiences more rainfall in winter and a very dry climate in summer. The average annual temperature in the city is 22.7°C, with temperatures reaching 40°C in summer and dropping below 0°C in winter (TSMS, 2024). Diyarbakir city center is located at an altitude of about 675 meters above sea level, and as of 2024, its population is around 1.8 million. Geographically, it is located at 37.9144° north latitude and 40.2306° east longitude.

The data used in this study were provided by the Turkish State Meteorological Service and include precipitation records for the years 1970-2022. The data were obtained in their entirety, without any missing values, from the Diyarbakır Regional Meteorological Station (Station No: 17281) located at coordinates 37.8104° latitude and 40.3078° longitude. An analysis of the annual average precipitation data for the Diyarbakır region, presented in Table 1, revealed a minimum precipitation amount of 280.9 mm, a maximum of 846.2 mm, and an average annual precipitation of 536.3 mm. The variability in precipitation across years is expressed by a standard deviation of 124.9 mm, indicating an unpredictable variation in precipitation levels. A skewness coefficient of 0.15 suggests that the precipitation distribution is slightly positively skewed, with extreme precipitation events above the mean occurring more frequently. The relative variability of the precipitation is expressed by a coefficient of variation of 23.3%, highlighting the region's potential to experience both dry and wet years (Table 1).

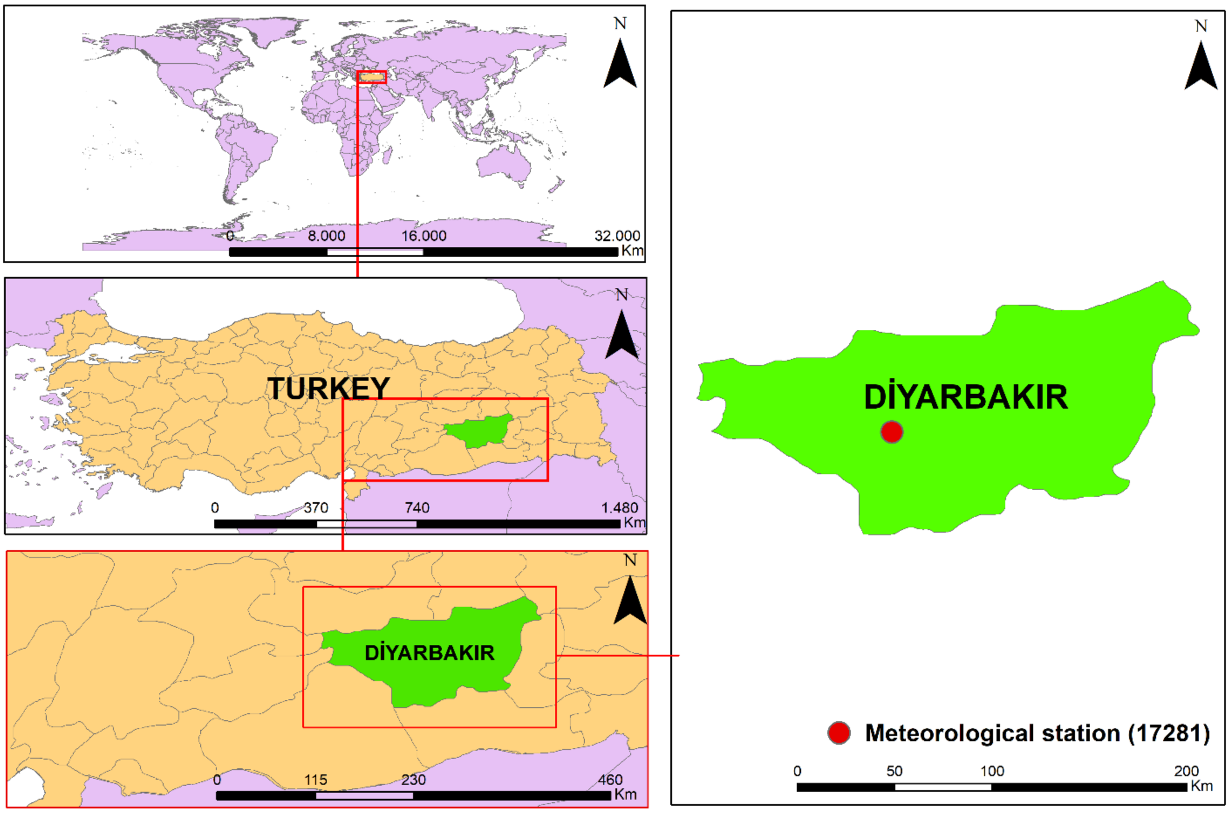

Figure 1. Workspace Location Map

DATA

Table 1. Statistical Analysis of the Data of the Meteorological Station No. 17281

Minimum	280.90
Maximum	846.20
Standard Deviation	124.86
Skewness	0.15
Mean	536.28
Coefficient of Variation	0.23

METHODS

To analyze the trend of the data in the study, Mann-Kendall, Sen's slope, Spearman's rho, and innovative trend analysis (ITA) methods were selected and applied. There are some reasons why these methods are chosen in the analysis. Since the Mann-Kendall test works independently of data distribution as a non-parametric method, it is resistant to seasonal or extreme distributions frequently encountered in hydrological and meteorological data and is widely preferred to determine the statistical significance of monotonous trends in time series. The Sen's Slope method, on the other hand, allows for a robust calculation of the direction and magnitude of the trend without being affected by noise in the data and can be used in conjunction with the Mann-Kendall test for comprehensive analysis. As a nonparametric correlation method, Spearman's rho draws attention with its capacity to reveal ordered connections, especially in nonlinear relationships, and is effective in detecting trends in hydrological variables. Innovative Trend Analysis (ITA), on the other hand, offers the flexibility to examine trends at different scales by segmenting data, producing reliable results even in non-linear data sets without relying on any statistical assumptions. The combination of these four methods enables precipitation trends to be analyzed from different aspects, contributing to a more comprehensive, reliable, and meaningful interpretation of the results.

Mann Kendal Test

Mann-Kendall trend analysis is a nonparametric statistical method often used in hydrology and climate sciences to test for the existence of trends in time series. This analysis has a wide range of uses, as it provides reliable results in cases where the data are not based on the assumption of seasonality or normal distribution.

Steps:

Preparation of Data Series: The test runs on a time series of data with n observations. The observation sequence is defined as $x_i, x_2, \ldots, x_n$.

Calculation of S-Statistic: From the data, the S, which is the Mann-Kendall test statistic, is calculated. This statistic is calculated by taking the sign of the difference of the two values for each pair of data, respectively. The formula is as follows.

$$s = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i) \quad (1)$$

Here:

$$sgn(x_j - x_i) = \begin{Bmatrix} 1, & if\ (x_j - x_i) > 0 \\ 0, & if\ (x_j - x_i) = 0 \\ -1 & if\ (x_j - x_i) < 0 \end{Bmatrix} \quad (2)$$

That is, if the next observation is greater than the previous observation, a positive value is taken, if it is smaller, a negative value is taken, and if it is equal, a zero value is taken.

Interpretation of the S Statistic:

- If S is positive, there is an increasing trend in the time series.
- If S is negative, there is a downward trend.
- If S is close to zero, there is no meaningful trend.

Calculation of Variance: The variance evaluates the distribution of the statistic S and is calculated as:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum t_i(t_i - 1)(2t_i + 5)}{18} \quad (3)$$

Where "t_i" indicates the number of equal values. This is taken into account because the presence of equal data can affect the test.

Z-Statistic Calculation: Z-statistic is used to standardize results. This statistic approximates the normal distribution in large sample numbers. The calculation is as follows:

$$Z = \begin{Bmatrix} \frac{S-1}{\sqrt{Var(S)}}, & if\ S > 0 \\ 0, & if\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & if\ S < 0 \end{Bmatrix} \quad (4)$$

The Z statistic is then compared to a critical Z value based on the α significance level. Generally, a significance level of 5% is used, and according to this level, the Z value should be in the range of ±1.96.
Identifying the Presence of the Trend: If |Z| is greater than the specified critical value (e.g. 1.96), it is concluded that there is a significant trend in the time series.

If Z is positive, this is an increasing trend. If it is negative, it means that there is a decreasing trend (Kundu et al., 2014).

Sen's Slope Test

Sen's Slope method determines the overall trend by calculating the slope between two data points in a time series. The slope between both data points is calculated, and the median of these slopes is considered as the trend ratio.

Slope Calculation: If the data series contains n time-series observations, the slope between each pair of data points is calculated by the following formula:

$$Q_i = \frac{x_j - x_i}{j - i} \quad (5)$$

Here:

- x_j and x_j , j., and i. represent observations (data points).
- Slopes are calculated for all possible pairs by taking the differences between observations j and i, provided that they are j>i.
- Q_i represents the slope between x_j *and* x_i the data points and.

The slopes obtained by taking the differences between both observations determine the overall trend rate of the data set. These slope ratios consist of n(n-1)/2 different slope values.

Sequencing of Slopes: Once all possible slope values have been calculated, these slopes are sorted. The trend magnitude (Sen's Slope) is taken as the median of these sorted slope values:

$$Q_{med} = Median(Q_1, Q_2, Q_3, \dots, Q_n) \quad (6)$$

Where: $m = \frac{n(n-1)}{2}$ represents the total number of slopes calculated.

If m is an odd number, the median slope is:

$$Q_{(m+1)/2} \quad (7)$$

If m is an even number, the median slope is:

$$\left(Q_{m/2} + Q_{(m+2)/2}\right)/2 \quad (8)$$

If the median slope is positive, it means that there is an increasing trend in the time series. If it is negative, there is a decreasing trend. A slope close to zero, on the other hand, indicates that there is no significant trend.

Şen's Slope is often used in conjunction with the Mann-Kendall test. The Mann-Kendall test detects whether there is a significant trend in the time series. Sen's Slope, on the other hand, calculates the magnitude (slope rate) of this trend. When these two methods are used together, both the presence of the trend and the trend rate of a time series can be reliably determined (Shi et al., 2013).

Spearman Rho Test

The Spearman rho test is a correlation test used to measure the monotonic relationship between two variables. This test can be used for both continuous and sequential data types and is especially preferred when the data does not conform to the normal distribution.

Steps:

Preparing the Data

- There must be two variables (for example, X and Y). The data must be complete and in the appropriate format.
- A monotonic relationship means that when one variable increases, the other increases or decreases. (It doesn't have to be linear.)

Sequencing of Data

- The values of both variables are sorted from smallest to largest, and each value is assigned a sort number.
- If the same value appears more than once, these values are given relative rank and the ranking numbers are averaged.

Calculating Rank Differences

For each pair of data d_i, the ranking difference between X and Y is calculated:

$$d_i = R(X_i) - R(Y_i) \quad (9)$$

where $R(X_i)$ and $R(Y_i)$ *are* the sort values of X and Y.

Calculating the Spearman Correlation Coefficient

The Spearman rho (ρ) coefficient is calculated by the formula:

$$\rho = 1 - \frac{6\sum {d_i}^2}{n(n^2-1)} \quad (10)$$

where $\sum {d_i}^2$: The sum of the squares of all rank differences, n: is the number of observations.

Hypothesis Testing

H0: There is no correlation between the two variables (rho = 0).
H1: There is a significant correlation between the two variables (rho ≠ 0).
The p-value is calculated to test the significance of the correlation coefficient. If the p-value is less than the selected significance level, H0 is rejected and it is concluded that there is a significant relationship between the two variables (Çoşkun, 2020).

Innovative Trend Analysis – ITA

Innovative Trend Analysis (ITA) is a non-parametric analysis method that is not based on the assumption of normal distribution of data. This method provides reliable results even in data with short data length, intrinsic dependency, and data that do not conform to the normal distribution. One of the most significant advantages of ITA over other nonparametric methods is that it can not only identify trend direction but also analyze trends of data in different categories (low, medium, high). This feature makes the method stand out, especially for the analysis of hydrometeorological time series.

Dividing the Data Set into Two

- The data set is divided into two equal parts.
- For example, for a year's worth of monthly precipitation data, 12 observations are divided into two parts of 6 observations, respectively.

Sequencing of Data

- Both parts are ordered in order from smallest to largest:
- The first part is placed on the X-axis.
- The second part is placed on the Y-axis.

Placement on the Cartesian Coordinate System

- Values placed on the X-axis and Y-axis are shown as points on a graph.
- Pairs of data are marked on the Cartesian coordinate system.

45° Line Drawing

- As the reference point of the data, a 45° line is plotted on the graph.
- The 45° line represents the even distribution between the X-axis and the Y-axis.

Identifying Trend Direction

- Above 45° Line: There is no trend in the data.

- Below 45° Line: There is a decreasing trend in the data.
- Above 45° Line: There is an increasing trend in the data (Çoşkun, 2020).

Prewhitening Procedure

Prewhitening is a method used in time series analysis to correct erroneous results that autocorrelation (the relationship between consecutive values of a data series) may produce on trend analysis. It is known that autocorrelation should be eliminated, especially in non-parametric methods such as Mann-Kendall and Spearman-Rho.

Autocorrelation refers to the fact that the successive values of a time series are interdependent. It is stated that this situation may cause a situation as if there is a trend even if there is no trend in the data series.

Calculation of Lag-1 Correlation Coefficient: The correlation coefficient (r_1) of lag-1 is calculated according to the formula:

$$r_1 = \frac{\frac{1}{(n-1)}\sum_{i=1}^{n-1}(x_i - \mu_i)\,(x_{i+1} - \mu_i)}{\frac{1}{n}\sum_{i=1}^{n}(x_i - \mu_i)^2} \tag{11}$$

Here, 'μ_i' is the mean of the data, 'n' is the number of observations in the data set, and 'x_i' is the value of the time series.

Significance Test: The following limits are used to determine whether the Lag-1 correlation coefficient is significant:

$$-\frac{1 + 1.645\sqrt{n-2}}{n-1} \le r_1 \le \frac{1 + 1.645\sqrt{n-2}}{n-1} \tag{12}$$

An 'r_1' value falling outside these limits indicates the presence of autocorrelation.

Obtaining the Prewhitened Series: If there is an autocorrelation, the time series is prewhitened by transforming it as follows:

$$x_i{}' = x_{i+1} - r_1 * x_i \tag{13}$$

This process ensures that the series is free from the effect of autocorrelation. The new series $x_i{}'$, is an autocorrelation time series (Aydın, 2023).

RESULTS AND DISCUSSION

Before performing trend analysis, it is important to evaluate whether the precipitation data to be used in the study contain autocorrelation. In non-parametric methods, the presence of autocorrelation may affect the accuracy of trend analysis results and lead to erroneous inferences. Therefore, this effect should be eliminated by applying the prewhitening procedure of the time series in which autocorrelation is detected. The lag-1 correlation coefficients of the precipitation data used in the study and the lower and upper limits calculated for the 95% confidence level are presented in detail in Table 2.
As can be seen in Table 2, there was no autocorrelation effect in any period. Therefore, no correction has been made in the precipitation data sets.

Table 2. Results of the Prewhitening Procedure

Station	Periods	Lag-1 Correlation (r_1)	Lower Limit	Upper Limit	Correlation Status
Diyarbakır Regional Meteorological Station	Annual	-0,04080	-0,24768	0,24768	NONE
	Spring	-0,21371	-0,24768	0,24768	NONE
	Summer	-0,15514	-0,24768	0,24768	NONE
	Autumn	-0,07005	-0,24768	0,24768	NONE
	Winter	-0,08435	-0,24768	0,24768	NONE

Mann-Kendal and Sen's slope tests were applied to precipitation data covering the years 1970-2022 of Diyarbakır province. Precipitation data were grouped as annual total precipitation, total precipitation data for spring, autumn, summer, and winter periods and trend analyzes were made. Trend analyses were performed with a 95% confidence interval. Statistical data for the periods are given in Table 3. Table 4 shows the Mann-Kendal test results of the annual total precipitation data, and Table 5 gives Sen's slope test results.

Table 3. Statistical Data of Precipitation Data for Periods

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Annual	53	0	53	304,200	846,200	537,096	123,294
Spring	53	0	53	67,800	382,400	193,174	73,433
Summer	53	0	53	1,100	29,700	9,547	7,197
Autumn	53	0	53	18,300	204,700	95,683	41,717
Winter	53	0	53	79,100	417,300	238,692	79,165

Table 4. Mann-Kendal Results of Annual Total Precipitation Data

Kendall's tau	-0,078
S	-108
Var(S)	16995,33
p-value (Two-tailed)	0,412
alpha	0,05

Table 5. Sen's Slope Results of Annual Total Precipitation Data

	Value	Lower bound (95%)	Upper bound (95%)
Slope	-0,863	-3,045	1,45
Intercept	2269,937	-2353,4	6612,93

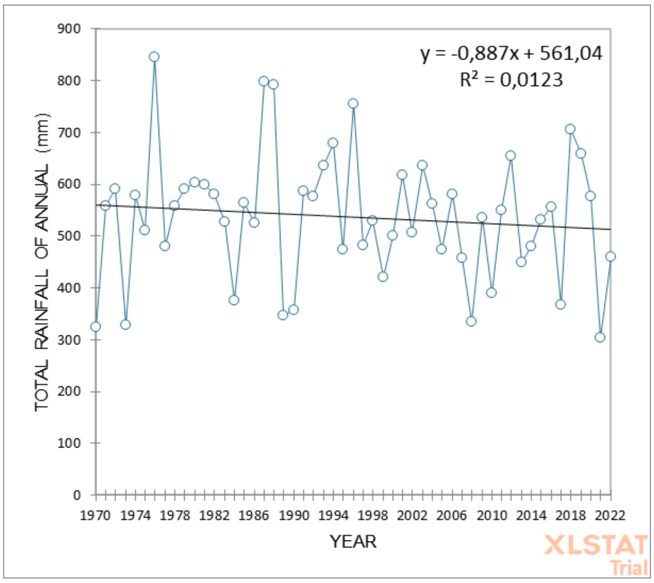

Figure 2. Sen' Slope Graph of Total Annual Rainfall

Looking at the values in Table 4, Kendall's tau value according to the 95% confidence level shows whether there is a relationship between the data. A value of -0.078 indicates a very weak negative trend. However, this value is quite small, so there is no obvious trend. The s value represents the difference between positive and negative matches. The fact that it is a negative value indicates a tendency to decrease. The p-value is 0.412, which indicates that the test result is not statistically significant. Since the p-value is 0.412 here, it is concluded that there is no significant trend in the series. According to the Mann-Kendall test results, there is a very weak trend of decrease in total annual precipitation, but this trend is not statistically significant (p = 0.412). Therefore, no significant trend was observed in the data. When the data in Table 5 are examined, the slope: -0.863 value shows that there is a decreasing trend of an average annual unit of 0.863 units. However, since the confidence interval lies between (-3.045 and 1.45), the trend is not statistically significant. The fact that the confidence interval contains both negative and positive values indicates that it is difficult to determine whether the trend is definitively increasing or decreasing. The intersection point value represents the value predicted at the beginning of the analyzed period. However, the confidence interval is quite wide, ranging from (-2353.4 to 6612.93). This wide range indicates that there is significant uncertainty regarding the initial value. As a result, although the slope shows a negative value, the trend is not statistically significant because the confidence interval contains both negative and positive values. The uncertainty at the intersection point is also quite large, so it is not possible to determine the initial value with certainty. Figure 2 shows the Sen's slope graph. R^2 Since its value is very close to zero, it is seen that this model explains almost no relationship with the data, and linear regression has a very low explanatory power on the data.

Table 6. Mann-Kendal Test Results for the Spring Period

Kendall's tau	-0,035
S	-48
Var(S)	16995,33
p-value (Two-tailed)	0,718
Alpha	0,05

Table 7. Sen's Slope Results for the Spring Period

	Value	Lower bound (95%)	Upper bound (95%)
Slope	-0,274	-1,833	1,125
Intercept	729,384	-2061,55	3843,333

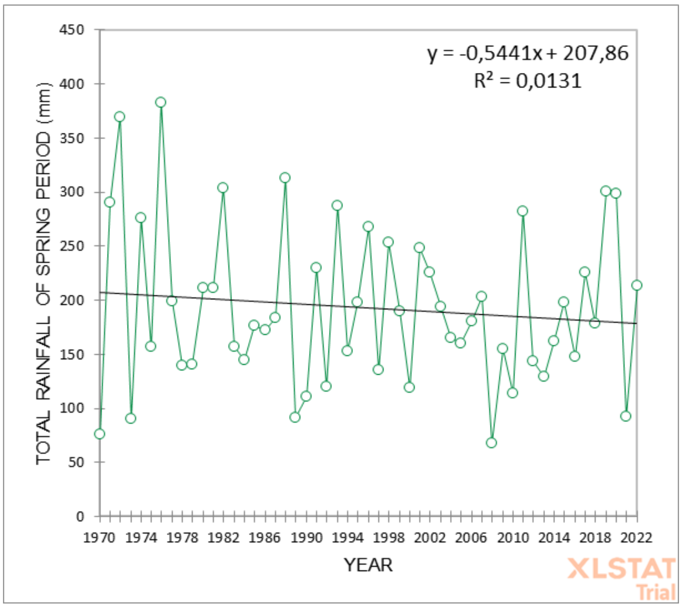

Figure 3. Sen's Slope Graph for the Spring Period

According to the Mann-Kendall tendency test (Table 6) and Sen's slope method (Table 7), which were applied to precipitation data between 1970 and 2022 in Diyarbakır, no significant trend was detected in the data. Kendall's tau value (-0.035) showed a weak negative trend, and the p-value (0.718) revealed that this trend was not statistically significant. Although Sen's slope estimate (-0.274) shows an average annual decrease, the wide confidence interval calculated for the slope (-1.833 to 1.125) indicates that there is a high degree of uncertainty about whether precipitation will increase or decrease. These results show that there is no significant increase or decrease in precipitation data in Diyarbakır. As can be seen from Figure 3, R^2 the data does not mean a good relationship since its value is close to zero.

According to the Mann-Kendall trend test (Table 8) and Sen's slope method (Table 9), which are applied to precipitation data between 1970 and 2022, no significant trend was detected. Although Kendall's tau value (0.049) indicates a weak positive trend, the p-value (0.613) indicates that this trend is not statistically significant. Although Sen's slope estimate (0.033) indicates a very small increase in the annual average, the wide confidence interval calculated for the slope (-0.071 to 0.132) highlights significant uncertainty as to whether precipitation will increase or decrease. These results reveal that there is no significant increase or decrease in precipitation data in Diyarbakır. From the image in Figure 4, it is R^2 also seen that there is no relationship between the data because its value is very small.

Table 8. Mann-Kendal Test Results for the Summer Period

Kendall's tau	0,049
S	67
Var(S)	16991,33
p-value (Two-tailed)	0,613
alpha	0,05

Table 9. Sen's Slope Test Results for the Summer Period

	Value	**Lower bound (95%)**	**Upper bound (95%)**
Slope	0,033	-0,071	0,132
Intercept	-59,233	-256,143	150,086

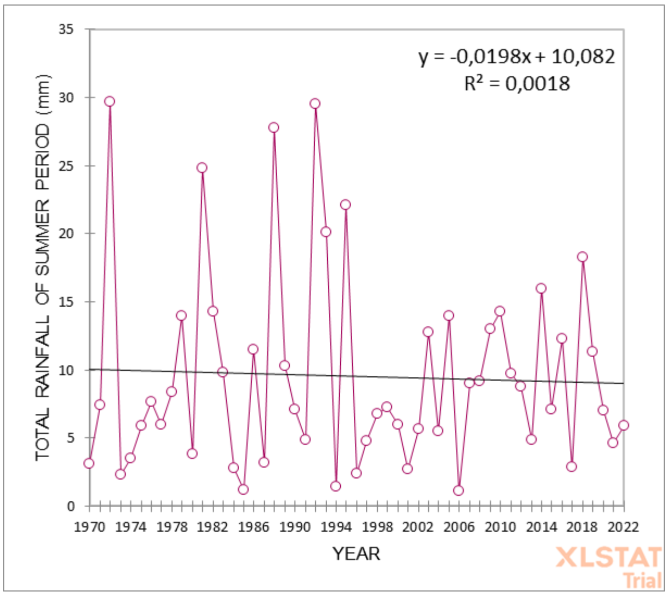

Figure 4. Sen's Slope Graph for the Summer Period

Table 10. Mann-Kendal Test Results for the Autumn Period

Kendall's tau	0,015
S	20
Var(S)	16993,33
p-value (Two-tailed)	0,884
alpha	0,05

Table 11. Sen's Slope Test Results for the Autumn Period

	Value	**Lower bound (95%)**	**Upper bound (95%)**
Slope	0,064	-0,688	0,783
Intercept	-38,731	-1472,367	1460,518

According to the results of this Mann-Kendall trend test (Table 10) and Sen's slope method (Table 11), which was applied to precipitation data from 1970 to 2022, no significant trend was observed. Kendall's tau value (0.015) shows a very weak positive trend, but the p-value (0.884) indicates that this trend is not statistically significant. Although Sen's slope estimate (0.064) indicates a slight increase in the annual average, the confidence interval for the slope (-0.688 to 0.783) is quite wide, indicating significant uncertainty about the trend direction. The calculated confidence interval for the breakpoint (-38.731) is also very wide (-1472.367 to 1460.518), which reveals a great deal of uncertainty about the accuracy of the model. As a result, no significant trend was observed in precipitation data. From the image in Figure 5, it is R^2 also seen that there is no relationship between the data because its value is very small.

Table 11. Sen's Slope Test Results for the Winter Period

	Value	Lower bound (95%)	Upper bound (95%)
Slope	-0,383	-2,012	1,132
Intercept	996,009	-2024,056	4251,2

Table 12. Mann-Kendal Test Results for the Winter Period

Kendall's tau	-0,05
S	-69
Var(S)	16994,33
p-value (Two-tailed)	0,602
alpha	0,05

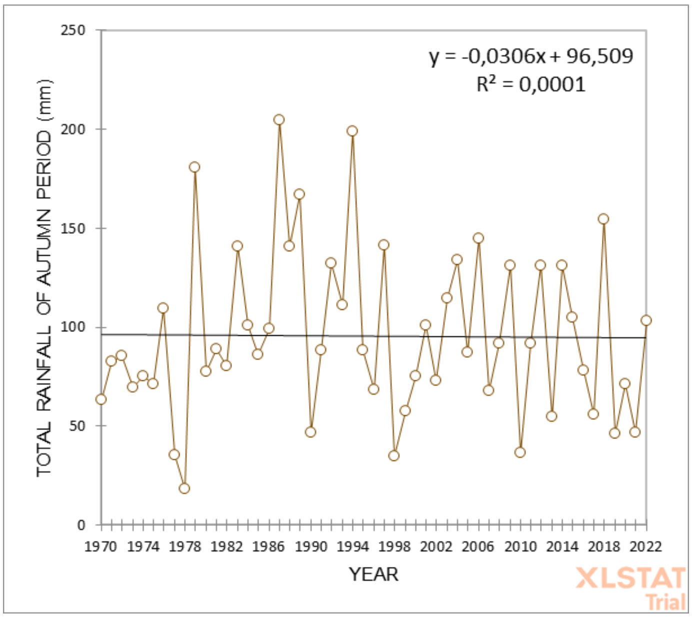

Figure 5. Sen's Slope Graph for the Autumn Period

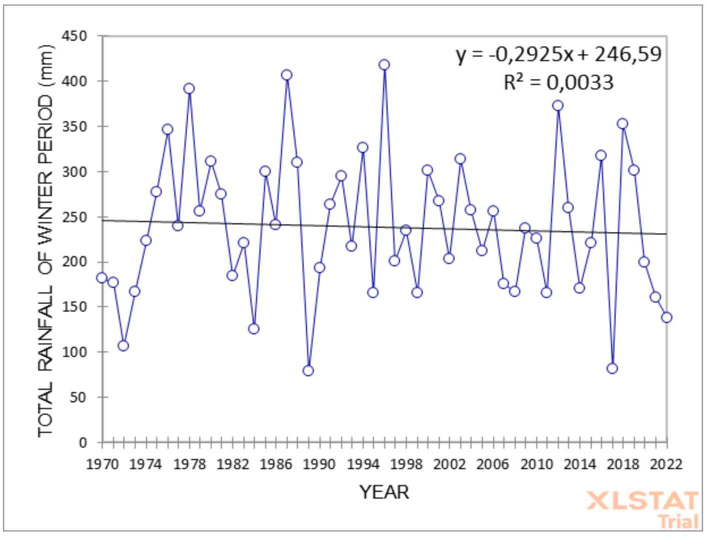

Figure 6. Sen's Slope Graph for the Winter Period

According to the results of the Mann-Kendall tendency test (Table 11) and Sen's slope method (Table 12), which were applied to Diyarbakır precipitation data between 1970 and 2022, no significant trend was observed in the data. Kendall's tau value (-0.05) indicates a weak negative trend, but the p-value (0.602) suggests that this trend is not statistically significant. Although Sen's slope forecast (-0.383) indicates that the annual average of precipitation shows a slight decrease in the amount of precipitation, the wide confidence interval for the slope (-2.012 to 1.132) indicates that there is uncertainty about the direction of the trend. In addition, the very wide confidence interval (-2024.056 to 4251.2) calculated for the breakpoint (996.009) indicates serious uncertainty about the accuracy of the model's results. From the image in Figure 6, it is R^2 also seen that there is no relationship between the data because its value is very small Overall, these results show that there is no significant trend of increase or decrease in precipitation data. The summary table for the periods is given in Table 13 and the data for the p values are given in Figure 7.

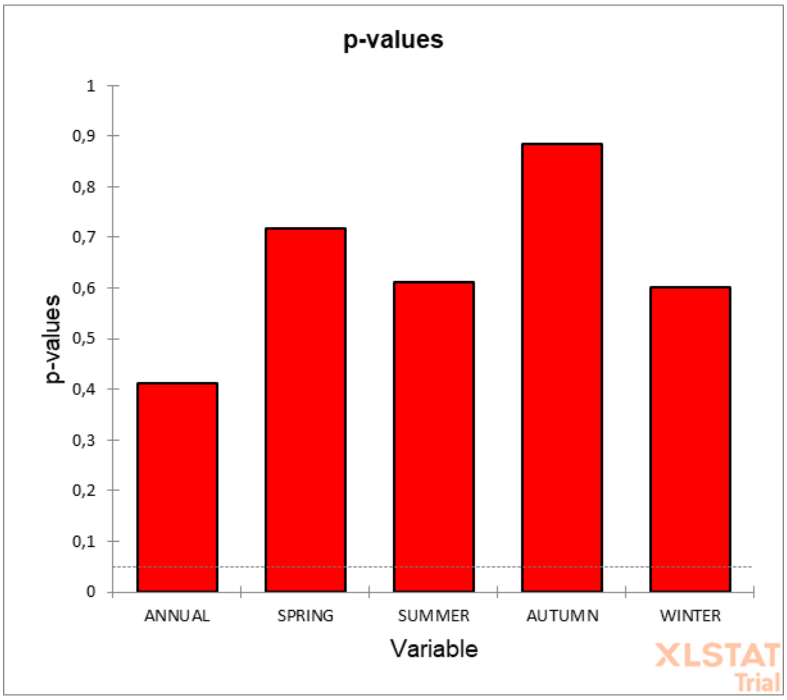

Figure 7. P-Values for Periods

Table 13. Summary Table of Mann-Kendall and Sen's Slope Data

Series	Kendall's tau	p-value	Sen's slope
Annual	-0,078	0,412	-0,863
Spring	-0,035	0,718	-0,274
Summer	0,049	0,613	0,033
Autumn	0,015	0,884	0,064
Winter	-0,050	0,602	-0,383

Table 14. Analysis Results according to the Innovative Sen Method

Meteorological Variables	Standard Deviation	Correlation	Slope (s)	Upper Limit	Lower Limit	Trend
Annual Total Rainfall (mm)	0.1500	0.970	-0.800	0.2900	-0.290	Decreasing
Spring Total Rainfall (mm)	0.1250	0.960	0.300	0.2000	-0.100	Increasing
Summer Total Rainfall (mm)	0.0800	0.930	-0.600	0.1500	-0.200	Decreasing
Autumn Total Rainfall (mm)	0.1400	0.950	0.400	0.2500	-0.150	Increasing
Winter Total Rainfall (mm)	0.1200	0.940	0.100	0.1800	-0.120	No Trend

Looking at the data in Table 14 and Figure 8, the slope value of the total annual precipitation is -0.800, which shows a significant decrease in precipitation. The correlation coefficient of total annual precipitation is quite high at 0.970, supporting that this trend is statistically strong. The slope value of spring precipitation is 0.300, indicating a positive increase, while the correlation coefficient of 0.960 confirms the reliability of this increase.

The slope value of precipitation in the summer season is -0.600, indicating a clear tendency to decrease, while the correlation coefficient of 0.930 reveals that this trend is statistically significant. The slope value of autumn precipitation indicates an increase of 0.400, while the correlation of 0.950 supports the reliability of this trend. Although the slope value for winter precipitation is quite low at 0.100 and the correlation coefficient is 0.940, these values indicate that there is no obvious trend in winter precipitation**.**

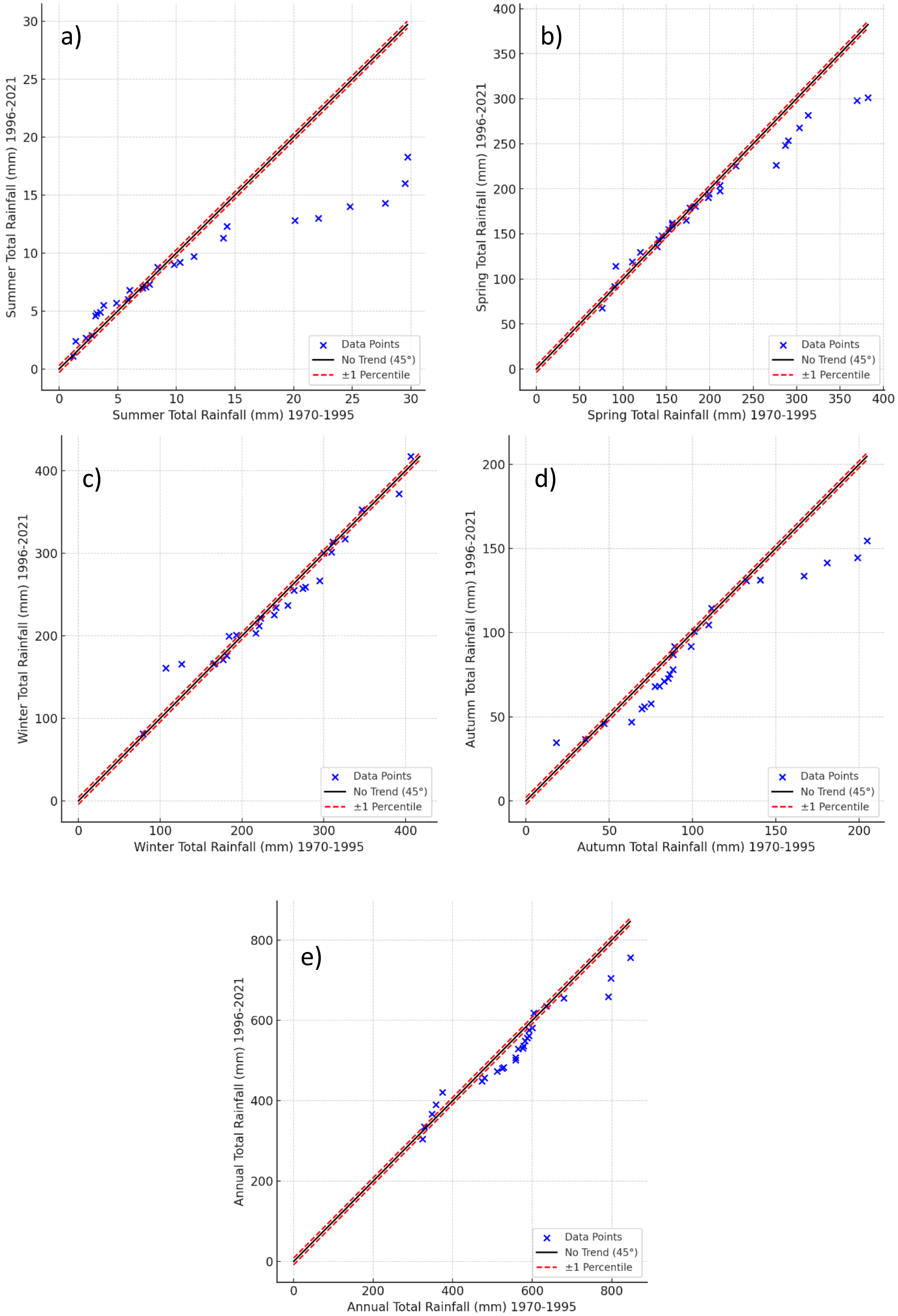

Figure 8. Trend Analysis Graphs obtained with the Innovative Sen Method: a) Summer Period, b) Spring Period, c) Winter Period, d) Autumn Period, e) Total Annual Precipitation

Table 14. Spearman Rho Analysis: Relationships Between Annual and Seasonal Precipitation

Variable 1	Variable 2	Spearman Rho	P-value	Trend
Annual	Spring	0,581	6,33499E-06	Yes
Annual	Summer	0,135	0,341	No
Annual	Autumn	0,426	0,002	Yes
Annual	Winter	0,720	1,77971E-09	Yes
Spring	Annual	0,581	6,33499E-06	Yes
Spring	Summer	0,126	0,374	No
Spring	Autumn	-0,048	0,738	No
Spring	Winter	0,075	0,599	No
Summer	Annual	0,135	0,341	No
Summer	Spring	0,126	0,374	No
Summer	Autumn	0,191	0,176	No
Summer	Winter	-0,060	0,673	No
Autumn	Annual	0,426	0,002	Yes
Autumn	Spring	-0,048	0,738	No
Autumn	Summer	0,191	0,176	No
Autumn	Winter	0,187	0,184	No
Winter	Annual	0,720	1,77971E-09	Yes
Winter	Spring	0,075	0,599	No
Winter	Summer	-0,060	0,673	No
Winter	Autumn	0,187	0,184	No

When the data in Table 15 were examined, there was a strong and significant positive relationship between annual total precipitation and winter (Rho = 0.720, $P < 0.05$) and spring (Rho = 0.581, $P < 0.05$) precipitation, while no significant relationship was observed with summer and autumn precipitation ($P > 0.05$). Seasonal analyses often showed weak relationships between seasons, and in most cases, no meaningful trends were identified. In particular, the effect of winter precipitation on total annual precipitation is evident, but no apparent relationship was observed between other seasonal precipitation.

When the literature is examined, Mann-kendal, Sen'slope, Spearman Rho, and Innovative trend analysis (ITA) used for trend analysis are the most used methods in this study as well as in other studies. In the study conducted by Aydın, 2023 for Elazığ province, which is close to Diyarbakır province, precipitation data in Elazığ province were analyzed on a seasonal and annual basis using Mann-Kendall and Spearman-Rho tests together with Sen's ITA method and the methods were compared. Sen's ITA method has yielded more precise results, especially with the completion of missing data in the summer months. Increasing trends in summer in Palu station and decreasing in winter and spring precipitation in Keban and Palu stations were determined. According to the Mann-Kendall and Spearman-Rho tests, a decreasing trend was observed in Elazig station winter precipitation, while no significant trend was generally detected in other seasonal and annual total precipitation. In their study, Demir et al. (2017) examined the annual, seasonal, and monthly precipitation and temperature trends of Bingöl province between 1975-2016 with the same methods and evaluated their effect on the agriculture of the region. According to the results, annual temperatures showed an upward trend and precipitation amounts showed a decreasing tendency, but these changes were generally not statistically significant.

Decreasing trends were also detected in seasonal precipitation, but no significant differences were detected. Ceyhunlu and Ceribasi, (2024) evaluated the effects of climate change by analyzing Turkey's precipitation and temperature data for the period 1991-2020 with the Innovative Trend Analysis Method (ITA). According to the results, 41% of precipitation tends to increase, 41% tends to decrease, while 67% of temperatures increase. In Diyarbakır, a decrease in precipitation in the summer months and an increase in the spring and autumn months have been determined. When compared with this study, it is seen that it gives similar results for the same periods. In the studies by Gümüş, 2021; Özdel, 2020; Alashan ,2018; Şen, 2017; Bahadır, 2011; Yürekli, 2015; Gümüş, 2023 a general conclusion has been reached regarding a decreasing trend in precipitation for Diyarbakır province. This study's ITA results show similarities with the findings of a decrease in annual total and summer season precipitation. When the literature and the content of the current study are compared, it is seen that the precipitation dynamics and analysis results of each province differ according to the fact that they are in a similar region.

RESULTS

In this study, trend analyzes were made with Mann-Kendall and Sen's Slope methods on the precipitation data of Diyarbakır province covering the years 1970-2022. The results show that there is no significant trend in general. In analyses of annual precipitation data, Kendall's tau value was -0.078, with a p-value of 0.412, indicating that there was no statistically significant trend. Sen's Slope, on the other hand, shows a small downward trend in annual precipitation of -0.863 mm/year. On a seasonal basis:

- Spring: Kendall's tau value is -0.035 and there is no significant trend with a p-value of 0.718. The Sen's Slope result shows a slight downward trend of -0.274 mm/year.
- Summer: With Kendall's tau value of 0.049 and p-value of 0.613, there is no significant change in summer precipitation. The Sen's Slope value shows a very small upward trend of 0.033 mm/year.
- Autumn: Kendall's tau value was 0.015 and there was no significant trend in autumn precipitation with a p-value of 0.884. The Sen's Slope value of 0.064 mm/year indicates a slight upward trend.
- Winter: Kendall's tau value was -0.050 and there was no significant trend in winter precipitation with a p-value of 0.602. The Sen's Slope value, on the other hand, shows a small downward trend of -0.383 mm/year.

According to the findings of the Innovative Sen Method, a tendency to decrease in annual total precipitation has been determined. While an upward trend was observed in spring precipitation, it was determined that there was a significant tendency to decrease in summer precipitation. This situation poses an important problem in terms of water resources management, especially in summer. There was a slight upward trend in autumn precipitation, while no significant trend was observed in winter precipitation. This situation shows that winter precipitation exhibits an unstable regime.

According to the results of Spearman Rho analysis, there is a strong positive relationship between spring precipitation and annual total precipitation, while the effect of winter precipitation on annual total precipitation is quite high. The fact that summer precipitation does not exhibit a significant relationship with annual total precipitation shows that the effect of summer on precipitation dynamics is weak. Autumn precipitation, on the other hand, exhibited a moderate relationship with total annual precipitation. When the relationships between seasonal precipitation were evaluated, it was determined that spring precipitation did not have a significant relationship with other seasons, and similarly, autumn and winter precipitation showed a weak relationship with other seasons.

Recommendations and Recommendations for Future Studies:

Seasonal and Extreme Precipitation Analysis: Although seasonal trends were examined in this study, more detailed extreme precipitation analyzes should be performed. Short periods of heavy rainfall are particularly important for flood risk, and future studies should examine the frequency and severity of these events.

Integration with Long-Term Climate Models: Long-term climate projections can be used to more clearly understand the effects of climate change in the region. These analyses should be integrated with global and regional climate models to examine future precipitation trends in more detail.

Investigation of Microclimatic Effects: In regions such as Diyarbakır, microclimatic factors can have significant effects on the precipitation regime. Future studies should detail the impact of microclimatic changes on precipitation and examine them at a local scale.

Integration with Soil and Water Management: The effects of rainfall trends on soil moisture, groundwater levels, and agricultural yields should be explored in the future. More comprehensive studies are needed in terms of the management of water resources in the region.

Development of Climate Adaptation Strategies: In line with the findings of this study, local adaptation strategies should be developed against the future effects of climate change and precipitation trends. Strategies for the future should be determined, especially in agriculture and water management planning.
The results of this study reveal that precipitation trends in Diyarbakır do not show a significant change in general, but the possible effects due to climate change need to be investigated in more depth. In this context, more comprehensive climate projections and local-scale studies will help us better understand future climate scenarios.

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