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Trend Analysis of Precipitation in the Thrace Peninsula

Trakya Yarımadası'nda Yağışların Trend Analizi

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ABSTRACT
This study focuses on the Thrace Peninsula located in the Marmara Region, comprising the territories of the provinces of Edirne, Kırklareli, Tekirdağ, İstanbul, and Çanakkale. The Thrace Peninsula is within the Mediterranean macroclimate region, where the regions receiving rainfall of over 600 mm cover the largest area. The highest and lowest annual average precipitation are observed in the municipalities of Sarıyer (819.3 mm) and Çorlu (576.6 mm), respectively. This study utilized the long-term precipitation data of 13 meteorological stations located in and around the Thrace Peninsula between 1937 and 2021. Trend analyses of monthly, seasonal (winter, spring, summer, fall), semiannual (October–March, April–September), and annual total precipitation averages of the water year were performed using the Mann–Kendall test, Kendall's tau test, and Sen's slope test at a confidence interval of 95% and statistical significance level of α = 0.05. The results of the monthly precipitation analysis show a significant negative trend in August, November, and February in Lüleburgaz, Tekirdağ, and Ipsala, and a significant positive trend in June and October, September, and June in Sarıyer, Malkara, and Çanakkale. In terms of seasonal average precipitation on the Thrace Peninsula, a statistically significant and positive trend was observed in Saryer in the summer and in Kumköy and Sarıyer in the fall. In terms of semiannual and annual precipitation averages, a statistically significant and positive trend was observed in Kumköy, Çorlu, and Sarıyer between April and September and in Kumköy and Sarıyer annually. In terms of monthly maximum precipitation, a positive and significant trend was observed in orlu, Saryer, and Malkara. This study is expected to help in the formulation of plans and implementation of measures to address potential water-related issues in the Thrace Peninsula, given the increasing demand for water and its resources.
Keywords: Thrace Peninsula, Precipitation, Trend analysis

ÖZ
Bu çalışmanda araştırma alanını Marmara Bölgesi'nde Edirne, Kırklareli, Tekirdağ, İstanbul ve Çanakkale illerinin topraklarının yer aldığı Trakya Yarımadası oluşturmaktadır. Akdeniz makroklima alanı içinde kalan Trakya Yarımadası'nda 600 mm üzerinde yağış alan yerler en geniş sahayı kaplamaktadır. En yüksek yıllık ortalama yağış Sarıyer'de (819,3 mm) ve en düşük yıllık ortalama yağış Çorlu'da (576,6 mm) görülmektedir. Araştırmada Trakya Yarımadası ve çevresinde bulunan 13 meteoroloji istasyonunun 1937-2021 yılları arasında değişen yağış verilerinden yararlanılmıştır. Aylık, mevsimlik (kış, ilkbahar, yaz, sonbahar), su yılının altı aylık (ekim-mart, nisan-eylül) ve yıllık toplam yağış ortalamalarının, %95 güven aralığında ve istatistiki olarak α=0,05 önem seviyesinde Mann-Kendall Testi, Kendall'ın Tau Testi ve Sen'in Eğim Testi kullanılarak trend analizleri yapılmıştır. Aylık yağış analizlerine göre Lüleburgaz'da ağustos, Tekirdağ'da kasım ve İpsala'da şubat ayında negatif yönlü anlamlı bir trend, Sarıyer'de haziran ve ekim aylarında, Malkara'da eylül ve Çanakkale'de haziran ayında pozitif yönlü anlamlı bir trend olduğu sonucuna ulaşılmıştır. Öte yandan yine Trakya Yarımadası'ndaki ortalama yağışlarda yaz mevsiminde Sarıyer, sonbahar mevsiminde Kumköy ve Sarıyer, nisan-eylül arasındaki dönemde Kumköy, Çorlu, Sarıyer ve yıllık yağışlarda Kumköy ve Sarıyer'de istatistiksel olarak anlamlı ve pozitif yönlü bir trend bulunmuştur. Aylık maksimum yağışlarda Kumköy, Çorlu, Sarıyer ve Malkara'da pozitif yönlü ve anlamlı bir trend olduğu sonucuna ulaşılmıştır. Bu çalışmanın Trakya Yarımadası'nda suya ve su kaynaklarına olan ihtiyacın her geçen gün arttığı düşüncesinden hareketle yaşanması olası sorunlarla ilgili olarak alınacak önlemlere ve yapılacak planlamalara katkı sağlayacağı düşünülmektedir.
Anahtar kelimeler: Trakya Yarımadası, Yağış, Trend Analiz

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1. INTRODUCTION

Global warming and climate change are among the most challenging problems of today's world. Increases in temperature, changes in precipitation patterns, melting of glaciers, rise of sea levels, and changes in river flows are among the main indicators of climate change (Hanedar et al., 2019). Fluctuations in precipitation values due to climate change cause increases or decreases at regional or local scales or trends in these aspects. In the analysis of precipitation trends in any study area, statistical methods are used to determine the aspects of changes that occur due to decreases or increases in the time series data (Gönençgil and İçel, 2010; Avcı and Esen, 2019; Eroğlu, 2021; Kocaoğlu and Çağlıyan, 2022, Karakuş and Güler, 2022).

Recent analyses of temperature and precipitation trends in Turkey show that temperatures and precipitation are increasing and decreasing, respectively (Partal, 2003; Türkeş, 2012; Karakuş and Güler, 2022). However, seasonal and annual precipitation trends are not as strong as the trends observed in air temperatures (Türkeş, 2012; Türkeş, 2016). Significant trends in the direction of increase in temperature averages currently measured in the Thracian Peninsula are in line with this trend (Eroğlu, 2022).

Climate model studies have revealed that global warming will lead to climate change in and around Turkey (Önol and Semazzi, 2009), and temperatures and precipitation will increase and decrease (Demir, Kılıç and Coşkun, 2008; Türkeş, 2011). According to the MPI-ESM-MR model RCP4.5 scenario results in the TR21 Region covering the provinces of Tekirdağ, Edirne, and Kırklareli, it was emphasized that the changes in total precipitation amounts between 2015 and 2100 depending on location and time are expected to decrease in general (Hanedar et al., 2019). There is a relationship between the positive and negative periods of the North Atlantic Oscillation (NAO) and precipitation changes in Turkey (Erlat, 2002; Türkeş and Erlat, 2005; Karakoç and Tağıl, 2014; Erlat, 2016; Sezen and Partal, 2019); thus, this factor should also be considered in evaluating the interannual climate patterns and water potential (Karabörk, Kahya and Karaca, 2000).

The Thrace Peninsula is one of the most socioeconomically significant areas in Turkey (Figure 1). The changes in the amount and regime of precipitation may lead to the emergence of significant challenges in the Thrace Peninsula, such as shortage of water resources, water scarcity, or drought. Therefore, identifying the trends of increase or decrease in precipitation in the Thracian region considering the current data would significantly contribute to future planning against possible challenges. Various studies have focused on the amount of precipitation, distribution, regime characteristics, and trend analysis of precipitation in the Thrace Peninsula (Kurter, 1974–1977; Türkeş,1996; Erlat, 2000; Türkeş, Sümer and Kılıç, 2002; Partal, 2003; Türkeş and Erlat, 2005; Türkeş, Koç, and Sarış, 2007; Sarış, Hannah, and Eastwood, 2010; Gönençgil and İçel, 2010; Aydınözü, 2010; Türkeş, 2011; Türkeş, 2012; Türkeş, 2016; Topuz, Feidas, and Karabulut 2020; Kocaoğlu and Çağlıyan, 2022). The trend analyses of monthly, seasonal, semiannual, and annual precipitation averages of the Thrace Peninsula were performed using the Mann–Kendall test (Mann, 1945; Hirsch & Slack, 1984), Kendall's tau test, and Sen's slope test (Sen, 1968) by utilizing data from 13 meteorological stations located in and around the Thrace Peninsula.

This study aims to clearly reveal the increasing or decreasing trends in precipitation amounts due to climate change in the Thrace Peninsula, which is located in the Mediterranean macroclimate area, and to contribute to the sustainability of human–natural environment relations in this area from a geographical perspective. For this purpose, trend analyses of monthly, seasonal (winter, spring, summer, fall), semiannual (October–March, April–September), and annual total precipitation amounts of the water year were performed.

1.1. Research Area

The Thrace Peninsula in northwestern Turkey was determined as the research area. It forms the territory of the Marmara Region on the European continent and is surrounded by the Bosporus and the Sea of Marmara to the east; the Sea of Marmara, the Dardanelles, and the Aegean Sea to the south; Greece and Bulgaria to the west; and Bulgaria and the Black Sea to the north (Figure 1). Some of the provincial lands of İstanbul and Çanakkale and all of the provincial lands of Tekirdağ, Kırklareli, and Edirne are within the borders of the Thrace Peninsula, which has a surface area of 23.854 km² (Özşahin ve Eroğlu, 2018).

Agriculture, industry, and trade sectors are the most developed sectors in the Thrace Peninsula. A wide variety of agricultural products are grown using modern methods on large and fertile agricultural lands, constituting an area with a significant population potential. As of 2022, the total population living in the Thrace Peninsula is 12,220,690 (Edirne, Kırklareli, Tekirdağ, Eceabat, Gelibolu, and İstanbul's districts having 414,714 residents, 369,347 residents, 1,142,451 residents, 8,684 residents, 43,984 residents, and 10,241,510 residents, respectively) (TUİK (2023)).

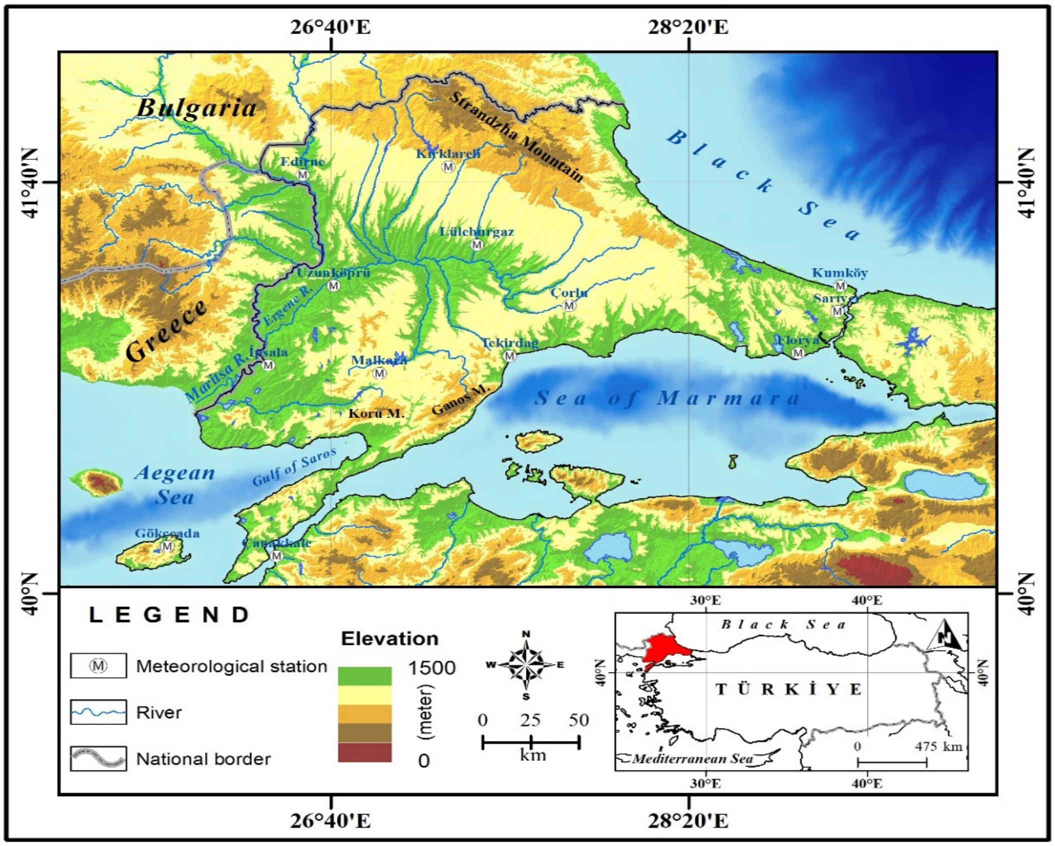

Figure 1: Location map of the research site.

The monthly precipitation averages of the meteorological stations in the Thrace Peninsula show that the rainiest month is December in all stations, and the months with the least precipitation are July in Kumköy, Sarıyer, and Florya and August in other meteorological stations (Table 1, Figure 2). The monthly precipitation regime of the Thrace Peninsula is characterized by a rapid onset of the December peak, a rainy winter season, and a gradual transition to dry summer (Sarış, Hannah, and Eastwood, 2010).

The average annual precipitation of meteorological stations in the Thrace Peninsula is 583.4 mm in Kırklareli, 607.3 mm in Edirne, 605.9 mm in Lüleburgaz, 666.2 mm in Uzunköprü, 790 mm in Kumköy, 576.6 mm in Çorlu, 819.3 mm in Sarıyer, 639.9 mm in Florya, 580.9 mm in Tekirdağ, 610.2 mm in İpsala, 668.3 mm in Malkara, 736.4 mm in Gökçeada, and 610.3 mm in Çanakkale (Table 2). The highest precipitation is observed in the meteorological stations of Gökçeada (329.3 mm) in winter, Gökçeada (171 mm) in spring, Sarıyer (108.8 mm) in summer, Sarıyer (251.3 mm) in fall, Gökçeada (572.8 mm) in October–

Table 1: The monthly average precipitation of meteorological stations in the Thracian Peninsula.

Meteorology Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Kırklareli	66,3	50,5	49,6	44,0	49,8	53,5	27,6	21,1	32,6	52,9	64,9	70,6	583,4
Edirne	67,1	52,2	51,9	48,5	53,0	47,3	32,2	23,7	35,6	56,8	67,6	71,3	607,3
Lüleburgaz	69,0	54,2	56,4	46,1	44,3	47,5	32,6	15,9	33,7	58,5	70,0	79,3	605,9
Uzunköprü	75,2	64,9	69,5	49,4	42,1	40,5	27,4	19,0	33,7	67,8	84,2	90,8	666,2
Kumköy	96,5	72,5	71,0	45,6	37,4	32,5	25,5	43,9	68,8	87,5	94,2	115,1	790,5
Çorlu	62,8	52,5	50,3	42,7	45,5	44,6	25,1	17,0	35,5	56,3	67,1	77,1	576,6
Sarıyer	106,2	78,7	69,4	45,0	35,4	34,7	34,5	39,6	63,9	85,9	101,5	124,4	819,3
Florya	84,7	70,1	60,1	45,6	30,8	27,6	20,6	22,6	37,3	64,6	79,4	96,7	639,9
Tekirdağ	68,6	54,3	53,8	42,0	37,5	38,0	25,0	15,6	32,6	60,6	72,0	80,9	580,9
İpsala	66,9	62,3	62,4	44,2	37,9	36,0	20,7	14,2	32,0	61,8	81,0	90,8	610,2
Malkara	75,3	62,4	67,3	48,1	44,0	48,8	24,0	11,1	39,6	65,4	86,8	97,8	668,3
Gökçeada	110,9	92,2	83,2	53,7	34,1	21,2	14,3	9,3	31,0	59,4	100,9	126,2	736,4
Çanakkale	91,4	70,0	66,1	45,6	30,3	25,8	13,9	8,3	24,5	55,5	82,7	106,1	610,3

March, and Kumköy (253.7 mm) in April–September and of Sarıyer (819.3 mm) in annual precipitation. The lowest precipitation is observed in Kırklareli (187.4 mm) in winter, Tekirdağ (133.3 mm) in spring, Çanakkale (42.1 mm) in summer, Kırklareli (150.3 mm) in fall, Kırklareli (354.8 mm) in October–March, and Çanakkale (140.4 mm) in April–September and Çorlu (576.6 mm) in annual precipitation.

The areas in the Thrace Peninsula are categorized as medium precipitation areas in terms of precipitation amount and intensity (Erlat, 2000). In these areas, the Mediterranean precipitation regime is observed in the northern part of the Saros Gulf, and the Marmara transition-type precipitation regime is observed in the Mediterranean to the Black Sea, which is characterized as very rainy in all seasons with a hot and less rainy summer season in other areas (Türkeş, 1996; Türkeş, 1998; Türkeş et al., 2002; Türkeş et al. 2007; Türkeş et al. 2009). Furthermore, the Thrace Peninsula was classified with a costal regime pattern, as observed in the Marmara, Aegean, and Mediterranean coasts of Turkey due to its significant December precipitation (Sarış, Hannah, and Eastwood, 2010).

According to the Erinç Precipitation-Effectiveness Index, a semi-humid climate is observed in Kırklareli (I:30.9), Edirne (I:30.8), Lüleburgaz (I:30.8), Uzunköprü (I:33.8), Çorlu (I:32), Florya (I:34.8), Tekirdağ (I:32.5), İpsala (I:31), Malkara (I:35.5), Gökçeada (I:38.4), and Çanakkale (I:31). On the other hand, a humid climate is observed in Kumköy (I:44.2) and Sarıyer (I:46.6). the Erinç Precipitation-Effectiveness Index values shows that the Black Sea coast of the Thrace Peninsula is humid, while the other areas remain in the semi-humid climate zone (Aydın et al., 2019). In the annual precipitation series of the

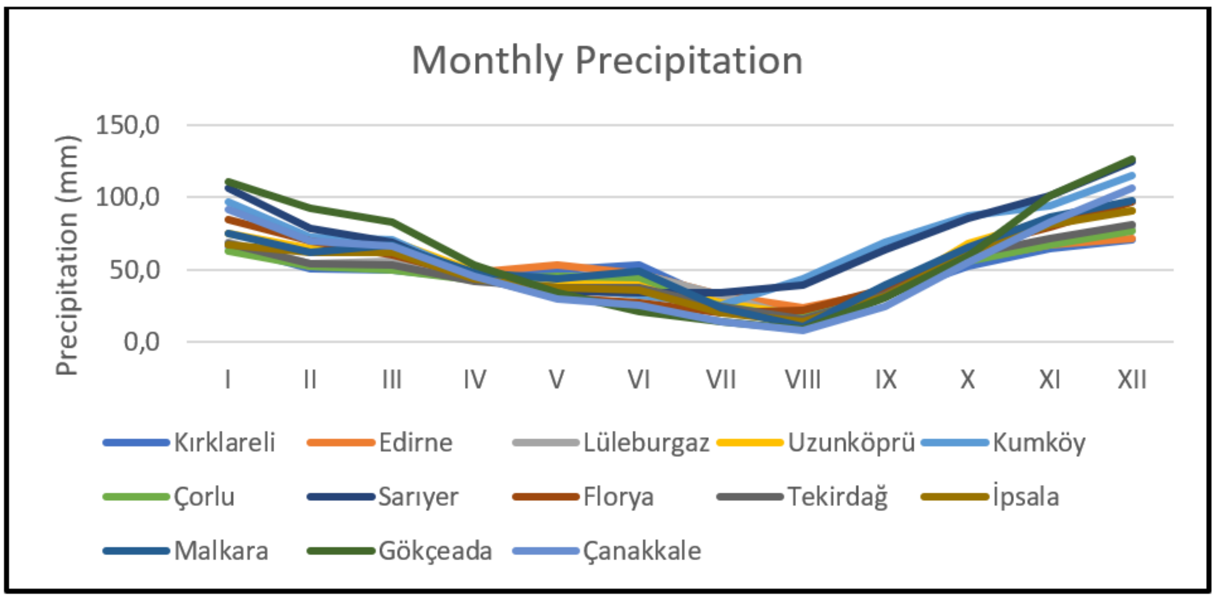

Figure 2: Figure of the monthly average precipitation of the meteorological stations in the Thracian Peninsula.

Table 2: Average precipitation values of meteorological stations in Thrace Peninsula.

Meteorology Station	Winter	Spring	Summer	Fall	October- March	April- September	Annual
Kırklareli	187,4	143,4	102,2	150,3	354,8	228,6	583,4
Edirne	190,7	153,5	103,2	160	367,1	240,2	607,3
Lüleburgaz	202,4	146,7	94,6	161,8	387,4	218,1	605,9
Uzunköprü	230,9	161	86,9	185,7	452,5	212,1	666,2
Kumköy	284,1	153,9	102	250,4	536,8	253,7	790,5
Çorlu	192,4	138,5	86,7	159	366,2	210,4	576,6
Sarıyer	309,4	149,9	108,8	251,3	566,2	253,1	819,3
Florya	251,6	136,5	70,5	181,2	455,6	184,2	639,9
Tekirdağ	203,8	133,3	78,6	165,3	390,2	190,7	580,9
İpsala	220	144,5	71	174,7	425,1	185,1	610,2
Malkara	235,5	159,5	81,6	191,8	455	213,4	668,3
Gökçeada	329,3	171	44,2	191,3	572,8	163,1	735,9
Çanakkale	267,5	141,9	42,1	158,7	469,9	140,4	610,3

Reference: General Directorate of Meteorology.

Thrace Peninsula, significant dry conditions were found in Kırklareli in 1989–1997, Tekirdağ in 1992–1993 and 1989–1990, and Çorlu in 1992–1994. (Gönençgil 2012).

2. MATERIALS AND METHODS

The data of this study are based on the monthly precipitation values of Kırklareli, Edirne, Lüleburgaz, Uzunköprü, Kumköy, Çorlu, Sarıyer, Florya, Tekirdağ, İpsala, Malkara, Gökçeada, and Çanakkale meteorological stations obtained from the General Directorate of Meteorology of the Ministry of Environment, Urbanization, and Climate Change (Table 3). This study also utilized the long-term precipitation measurement data from Çanakkale (17112) and Gökçeada (17110) meteorological stations to enrich the results of the field analysis and obtain more accurate results. The longest and shortest periods evaluated in the precipitation trend analysis are found in Florya (84 years (1937–2020)) and Malkara (42 years (1980–2021)) meteorological stations, respectively. Among the other meteorological stations, this study analyzed precipitation data of Kırklareli (covering 63 years (1959–2021)), Edirne (70 years (1952–2021)), Lüleburgaz (67 years (1955–2021)), Uzunköprü (57 years (1965–2021)), Kumköy (70 years (1951–2020)), Çorlu (64 years (1958–2021)), Sarıyer (67 years (1954–2020)), Florya (84 years (1937–2020)), Tekirdağ (82 years (1940–2021)), İpsala (58 years (1964–2021)), Malkara (42 years (1980–2021)), Gökçeada (56 years (1965–2020)), and Çanakkale (84 years (1937–2020)).

Monthly precipitation data were organized as seasonal (winter, spring, summer, fall), semiannual (October–March, April–September) periods of the water year, and annual total precipitation series. The homogeneity of each dataset was tested at a 99% confidence interval according to the results of Pettitt's test (Pettitt, 1979), standard normal homogeneity test (SNHT), Buishand's test, and von Neumann's test in XLSTAT (2022) package program. Parametric and nonparametric trend tests are conducted to analyze the trends in hydrometeorological variables (Karakuş, 2017). In this study, the Mann–Kendall test (Mann, 1945; Hirsch, & Slack, 1984), Kendall's tau test, and Sen's slope test (Sen, 1968) were used to investigate the trend analysis of precipitation time series at a 95% confidence interval and statistical significance level $\alpha = 0.05$. The Mann–Kendall test, also known as Kendall's tau, and Sen's slope test are the nonparametric tests used to analyze climatological and hydrometeorological data (Partal, 2003). In Sen's slope test, a negative and a positive value indicate a decreasing and an increasing trend, respectively (Kocaoğlu and Çağlıyan, 2022). XLSTAT (2022) package program was used for the trend and homogeneity analyses. A geographic information system (GIS) ArcGIS 10.8 program was used to draw the maps. Inverse distance weighting (IDW) method was used to obtain precipitation distribution maps based on the average precipitation values of the meteorological stations presented in Table 2. Study maps showing the precipitation distribution and precipitation trend status were formed by adding signs indicating the trend status of the stations to these maps. IDW is an interpolation method commonly preferred for determining the cell values of unknown points using the values of known sample points. The cell value is calculated by examining the various points away from the relevant cell and depending on the increase in distance. This method involves surface interpolation based on the weighted average of the sample points (İlker et al., 2019).

2.1. Mann–Kendall Test

In the Mann–Kendall test, the H0 hypothesis states that observations x1, ..., xn, which are time independent and similarly

Table 3: Meteorological stations used in the study and their characteristics.

Meteorology Station	Meteorology Station	Latitude	Longitude	Altitude (m)	Observation Years	Data Length (Years)
Kırklareli	17052	41.7382 N	27.2178 E	232	1959-2021	63
Edirne	17050	41.6767 N	26.5508 E	51	1952-2021	70
Lüleburgaz	17631	41.3513 N	27.3108 E	46	1955-2021	67
Uzunköprü	17608	41.2726 N	26.7056 E	45	1965-2021	57
Kumköy	17059	41.2505 N	29.0384 E	38	1951-2020	70
Çorlu	17054	41.1798 N	27.8160 E	145	1958-2021	64
Sarıyer	17061	41.1464 N	29.0502 E	59	1954-2020	67
Florya	17636	40.9758 N	28.7865 E	37	1937-2020	84
Tekirdağ	17056	40.9585 N	27.4965 E	4	1940-2021	82
İpsala	17632	40.8900 N	26.3900 E	81	1964-2021	58
Malkara	17634	40.8873 N	26.9080 E	207	1980-2021	42
Gökçeada	17110	40.1910 N	25.9075 E	79	1965-2020	56
Çanakkale	17112	40.1410 N	26.3993 E	6.0	1937-2020	84

Reference: General Directorate of Meteorology.

distributed random variables, are time sorted. Meanwhile, the H1 hypothesis states that for all (k, j ≤ n), where (k ≠ j), the distributions of xk and xj in the series are not identical. Equation (1) is used to derive the statistic S of the Mann–Kendall. Equation (2) gives the value of (xj-xk) in this equation (Terzi and İlker, 2021).

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

$$\text{sgn}(x_j - x_k) = \begin{cases} (x_j - x_k) > 0 \Rightarrow +1 \\ (x_j - x_k) = 0 \Rightarrow 0 \\ (x_j - x_k) < 0 \Rightarrow -1 \end{cases} \quad (2)$$

The variance of the test statistic *S* is obtained as follows:

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

Equation (4) is used if similar variables are present in the time series ("tie condition"):

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_i^r t_i(t_i-1)(2t_i+5)}{18} \quad (4)$$

The significance of the Mann–Kendall test, for which the variance value is determined, is compared with the critical Z value of the standard normal variable Z calculated in the equation. The numbers 1 in the numerator are continuous correction units.

$$Z = \begin{cases} \dfrac{S-1}{[\text{Var}(S)]^{\frac{1}{2}}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \dfrac{S+1}{[\text{Var}(S)]^{\frac{1}{2}}} & \text{if } S < 0 \end{cases} \quad (5)$$

If the α significance level $|z| \leq z\alpha/2$, the null hypothesis H0 is supported. Otherwise, it is rejected. A positive and a negative S value indicate the presence of an increasing and a decreasing trend, respectively (Yu et al., 1993; Partal, 2003; Yüce et al.2018; Terzi and İlker, 2021).

2.2. Sen's Slope Test

Sen's slope test is a nonparametric trend test proposed by Hirsch (1982) and developed by Sen (1968). It is not affected by data errors and extreme values. This test indicates that if the trend ($X_1, X_2 \ldots, Xn$) is time-sorted data, the values of X_j and X_k, (being the data at any j and k times, provided that (j>k)) are found using the following relation.

$$\beta = \frac{X_j - X_k}{j-k}$$

The number of all β values found is N. N=n(n + 1)/2 data are sorted from smallest to largest. The median value of these sorted data gives us the change per unit of time (Partal, 2003).

3. FINDINGS

3.1. Homogeneity Analysis

Pettitt's test (Pettitt, 1979), SNHT (Alexandersson, 1986), Buishand's test (Buishand, 1982), and von Neumann's test (Von Neumann, 1941) were utilized for homogeneity analysis of annual precipitation data of meteorological stations in the Thrace Peninsula (Table 4). These tests were conducted with a 99% confidence interval. Based on the homogeneity analysis results, all the tests performed at Kırklareli, Edirne, Uzunköprü, Kumköy, Çorlu, Tekirdağ, Malkara, and Gökçeada stations showed homogeneity. Although the SNHT, Pettitt's test, and von Neumann' test in Lüleburgaz, Florya, İpsala, and Çanakkale respectively, are rejected, the annual precipitation data are considered homogeneous. On the other hand, the annual precipitation data is considered doubtful in Sarıyer as the SNHT and Buishand's test are rejected (Wijngaard, Klein Tank, & Konnen, 2003).

3.2. Trend Analysis of Monthly Precipitation

The significant trend in monthly precipitation in the Thrace Peninsula is observed at Lüleburgaz, Sarıyer, Tekirdağ, İpsala, Malkara, and Çanakkale stations (Table 5, Figure 3). No significant trend is observed in the monthly precipitation of other stations. A significant negative trend is found in August, November, and February in Lüleburgaz, Tekirdağ, and İpsala, respectively. On the other hand, a significant positive trend is observed in June and October in Sarıyer, September in Malkara, and June in Çanakkale. In other words, a significant increasing trend in monthly precipitation is found in Sarıyer, Malkara, and Çanakkale, and a decreasing trend is noted in Lüleburgaz, Tekirdağ, and İpsala.

On the other hand, there is a statistically increasing trend in October precipitation with 1 significant station and 12 insignificant stations, in June precipitation with 2 significant stations and 9 insignificant stations, in September precipitation with 1 significant station and 8 insignificant stations, and in July precipitation with 9 insignificant stations. One station has a significant negative trend and 9 stations have an insignificant trend in November precipitation, and 11 stations have a insignificant decreasing trend in December precipitation.

Table 4: The results of the homogeneity tests of the annual precipitation data of the meteorological stations in the Thracian Peninsula.

Meteorology Station	Name of the Test	P Value	Year of Change	Meteorology Station	Name of the Test	P Value	Year of Change
Kırklareli	Pettitt	0.375	2004	Florya	Pettitt	**0.019**	1957
	SNHT	0.145	2008		SNHT	0.590	2018
	Buishand	0.095	2004		Buishand	0.976	1957
	Von Neumann	0.433	-		Von Neumann	0.341	-
Edirne	Pettitt	0.713	2004	Tekirdağ	Pettitt	0.357	1994
	SNHT	0.364	2008		SNHT	0.087	1940
	Buishand	0.261	1994		Buishand	0.763	1994
	Von Neumann	0.211	-		Von Neumann	0.100	-
Lüleburgaz	Pettitt	0.121	1971	İpsala	Pettitt	0.894	2015
	SNHT	**0.046**	1966		SNHT	0.071	2016
	Buishand	0.060	1971		Buishand	0.374	2015
	Von Neumann	0.050	-		Von Neumann	**0.001**	-
Uzunköprü	Pettitt	0.440	1981	Malkara	Pettitt	1.000	1994
	SNHT	0.579	1981		SNHT	0.169	1993
	Buishand	0.362	1981		Buishand	0.069	1994
	Von Neumann	0.237	-		Von Neumann	0.097	-
Kumköy	Pettitt	0.051	1973	Gökçeada	Pettitt	0.619	1993
	SNHT	0.103	1973		SNHT	0.582	1993
	Buishand	0.051	1973		Buishand	0.257	1993
	Von Neumann	0.200	-		Von Neumann	0.095	-
Çorlu	Pettitt	0.734	1994	Çanakkale	Pettitt	0.386	1981
	SNHT	0.222	2008		SNHT	0.394	1981
	Buishand	0.247	2008		Buishand	0.143	1981
	Von Neumann	0.188	-		Von Neumann	0.031	-
Sarıyer	Pettitt	0.083	1967				
	SNHT	**0.037**	1967				
	Buishand	**0.042**	1995				
	Von Neumann	0.078	-				

3.1. Trend Analysis of Winter Precipitation

When the winter season precipitation in the Thrace Peninsula is analyzed, no statistically significant increasing or decreasing trend at $\alpha = 0.05$ significance level is found in any of the stations used in the study (Table 6, Figures 4 and 8). A positive trend in winter precipitation is observed in Edirne, Kumköy, Sarıyer, and Malkara stations, and a negative trend is found in Kırklareli, Lüleburgaz, Uzunköprü, Çorlu, Florya, Tekirdağ, İpsala, Gökçeada, and Çanakkale stations.

3.2. Trend Analysis of Spring Precipitation

In the spring season, no statistically significant increase or decrease in the trend of precipitation is found at any of the stations used in the study (Table 7, Figures 5 and 8). On the other hand, the number of stations with an increasing trend is increasing in the spring. Kumköy, Sarıyer, and Malkara stations, where a positive trend is observed in winter precipitation, are accompanied by Çorlu, Florya, Gökçeada, and Çanakkale stations in spring precipitation. Again, Edirne, which shows an increasing trend in the winter season, follows a decreasing trend in the spring. Kırklareli, Lüleburgaz, Uzunköprü, Tekirdağ, and İpsala are other stations with negative trends in precipitation during this season. Although statistically insignificant, it is understood that the number of stations showing a positive trend in spring precipitation in the Thrace Peninsula has increased compared to the winter season.

3.3. Trend Analysis of Precipitation in Summer

In the Thrace Peninsula, a statistically significant and positive trend in summer precipitation is detected only at Sarıyer station (Table 8, Figures 6 and 8). A positive but insignificant trend in summer precipitation is found in Kırklareli, Edirne, Uzunköprü, Kumköy, Çorlu, Florya, Tekirdağ, İpsala, Malkara, Gökçeada, and Çanakkale, and a negative and also insignificant trend in summer precipitation is noted in Lüleburgaz. The fact that the trend in summer precipitation is positive in almost all of the stations shows that a more notable trend is present in summer precipitation in the Thrace Peninsula compared to winter and s

3.4. Trend Analysis of Precipitation in Fall

In the fall season, a positive and significant precipitation trend is detected in Kumköy and Sarıyer stations (Table 9, Figures 6 and 8). A positive but insignificant precipitation is

Table 5: Trend values of monthly precipitation.

Meteorology Station	Test Name	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Kırklareli	Mann-Kendall	0,598	0,873	0,877	0,427	0,991	0,182	0,717	0,396	0,644	0,031	0,618	0,257
	Kendall's Tau	0,046	0,014	-0,014	-0,069	-0,002	0,116	0,032	-0,074	0,040	0,187	0,044	-0,098
	Sen's Slope	0,185	0,026	-0,027	-0,118	-0,005	0,283	0,046	-0,088	0,069	0,529	0,139	-0,405
Edirne	Mann-Kendall	0,788	0,749	0,808	0,543	0,612	0,693	0,144	0,546	0,887	0,475	0,510	0,792
	Kendall's Tau	0,022	-0,027	0,020	-0,050	-0,042	-0,033	0,120	0,050	-0,012	0,059	-0,054	0,022
	Sen's Slope	0,070	-0,049	0,052	-0,091	-0,119	-0,079	0,194	0,057	-0,014	0,209	-0,178	0,069
Lüleburgaz	Mann-Kendall	0,384	0,713	0,799	0,649	0,910	0,677	0,436	**0,001**	0,426	0,788	0,074	0,299
	Kendall's Tau	-0,073	-0,031	0,022	0,038	0,010	-0,035	-0,066	-0,290	-0,067	0,024	-0,150	-0,087
	Sen's Slope	-0,227	-0,070	0,042	0,100	0,023	-0,071	-0,087	-0,288	-0,109	0,059	-0,463	-0,320
Uzunköprü	Mann-Kendall	0,522	0,731	0,836	0,449	0,620	0,491	0,601	0,720	0,885	0,655	0,055	0,433
	Kendall's Tau	0,059	-0,032	-0,019	-0,07	-0,046	0,063	0,048	-0,033	0,014	0,041	-0,175	-0,072
	Sen's Slope	0,259	-0,107	-0,045	-0,191	-0,121	0,166	0,056	-0,022	0,013	0,161	-0,874	-0,421
Kumköy	Mann-Kendall	0,800	0,475	0,939	0,400	0,530	0,423	0,367	0,364	0,147	0,325	0,757	0,516
	Kendall's Tau	-0,021	0,059	0,007	0,069	0,052	0,066	0,074	0,075	0,119	0,081	0,026	0,053
	Sen's Slope	-0,072	0,152	0,008	0,125	0,087	0,078	0,095	0,107	0,420	0,302	0,079	0,242
Çorlu	Mann-Kendall	0,505	0,899	0,972	0,945	0,391	0,092	0,835	1,000	0,566	0,075	0,411	0,066
	Kendall's Tau	-0,058	0,011	0,003	0,006	0,074	0,145	0,018	0,000	0,050	0,153	-0,071	-0,158
	Sen's Slope	-0,192	0,029	0,007	0,021	0,154	0,407	0,024	0,000	0,108	0,419	-0,187	-0,541
Sarıyer	Mann-Kendall	0,914	0,168	0,626	0,642	0,414	**0,012**	0,582	0,363	0,211	**0,014**	0,426	0,927
	Kendall's Tau	0,009	0,116	0,041	-0,039	0,069	0,211	0,047	0,077	0,105	0,205	0,067	-0,008
	Sen's Slope	0,042	0,321	0,125	-0,069	0,117	0,313	0,059	0,119	0,364	0,788	0,273	-0,031
Florya	Mann-Kendall	0,899	0,626	0,705	0,625	0,393	0,162	0,671	0,920	0,624	0,905	0,358	0,391
	Kendall's Tau	-0,010	0,036	-0,028	0,036	0,064	0,104	-0,032	-0,008	-0,037	0,009	-0,069	-0,064
	Sen's Slope	-0,016	0,083	-0,054	0,050	0,061	0,116	-0,011	0,000	-0,060	0,012	-0,161	-0,164
Tekirdağ	Mann-Kendall	0,234	0,321	0,493	0,981	0,608	0,838	0,634	0,416	0,583	0,363	**0,028**	0,234
	Kendall's Tau	-0,090	0,075	-0,052	-0,002	0,039	0,016	0,036	0,062	0,042	0,069	-0,165	-0,051
	Sen's Slope	-0,209	0,167	-0,096	-0,003	0,063	0,025	0,040	0,032	0,050	0,171	-0,443	-0,150
İpsala	Mann-Kendall	0,742	**0,013**	0,904	0,634	0,825	0,717	0,200	0,177	0,243	0,215	0,469	0,515
	Kendall's Tau	0,030	-0,225	-0,012	-0,044	-0,021	0,033	0,116	0,123	-0,106	0,113	-0,066	-0,059
	Sen's Slope	0,142	-0,705	-0,025	-0,110	-0,033	0,062	0,208	0,100	-0,230	0,445	-0,227	-0,308
Malkara	Mann-Kendall	0,530	0,269	0,828	0,957	0,721	0,410	0,182	0,845	**0,011**	0,089	0,087	0,488
	Kendall's Tau	0,069	0,120	0,024	-0,007	0,040	0,090	-0,145	0,022	0,275	0,184	-0,185	-0,075
	Sen's Slope	0,527	0,496	0,067	-0,017	0,141	0,300	-0,217	0,004	0,738	1,008	-1,311	-0,496
Gökçeada	Mann-Kendall	0,899	0,296	1,000	0,938	0,238	0,189	0,146	0,205	0,932	0,055	0,400	0,719
	Kendall's Tau	-0,012	-0,097	0,000	0,008	-0,109	0,122	-0,138	-0,121	0,008	0,177	-0,078	-0,034
	Sen's Slope	-0,090	-0,499	0,000	0,029	-0,189	0,146	-0,056	-0,003	0,000	0,680	-0,436	-0,246
Çanakkale	Mann-Kendall	0,155	0,694	0,61	0,494	0,932	**0,027**	1.000	0,861	0,737	0,449	0,221	0,299
	Kendall's Tau	-0,106	-0,030	-0,038	0,051	-0,007	0,165	0,000	-0,014	0,025	0,057	-0,091	-0,077
	Sen's Slope	-0,395	-0,083	-0,074	0,089	-0,012	0,163	0,000	0,000	0,010	0,122	-0,282	-0,329

found in Kırklareli, Edirne, Çorlu, Florya, Malkara, Gökçeada, and Çanakkale stations. Moreover, a negative and insignificant precipitation is noted in Lüleburgaz, Uzunköprü, Tekirdağ, and İpsala stations. Kırklareli and Edirne, which show a negative trend in spring, have a positive trend in fall.

Meteorology Station	Test Name	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Kırklareli	Mann-Kendall	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
	Kendall's Tau	Increase	Increase	Decrease	Decrease	Decrease	Increase	Increase	Decrease	Increase	Increase	Increase	Decrease
	Sen's Slope	Increase	Increase	Decrease	Decrease	Decrease	Increase	Increase	Decrease	Increase	Increase	Increase	Decrease
Edirne	Mann-Kendall	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
	Kendall's Tau	Increase	Decrease	Increase	Decrease	Decrease	Decrease	Increase	Increase	Decrease	Increase	Decrease	Increase
	Sen's Slope	Increase	Decrease	Increase	Decrease	Decrease	Decrease	Increase	Increase	Decrease	Increase	Decrease	Increase
Lüleburgaz	Mann-Kendall	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Significant	Insignificant	Insignificant	Insignificant	Insignificant
	Kendall's Tau	Decrease	Decrease	Increase	Increase	Increase	Decrease	Decrease	Decrease	Decrease	Increase	Decrease	Decrease
	Sen's Slope	Decrease	Decrease	Increase	Increase	Increase	Decrease	Decrease	Decrease	Decrease	Increase	Decrease	Decrease
Uzunköprü	Mann-Kendall	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
	Kendall's Tau	Increase	Decrease	Decrease	Decrease	Decrease	Increase	Increase	Decrease	Increase	Increase	Decrease	Decrease
	Sen's Slope	Increase	Decrease	Decrease	Decrease	Decrease	Increase	Increase	Decrease	Increase	Increase	Decrease	Decrease
Kumköy	Mann-Kendall	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
	Kendall's Tau	Decrease	Increase	Increase	Increase	Increase	Increase	Increase	Increase	Increase	Increase	Increase	Increase
	Sen's Slope	Decrease	Increase	Increase	Increase	Increase	Increase	Increase	Increase	Increase	Increase	Increase	Increase
Çorlu	Mann-Kendall	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
	Kendall's Tau	Decrease	Increase	Increase	Increase	Increase	Increase	Increase	Increase	Increase	Increase	Decrease	Decrease
	Sen's Slope	Decrease	Increase	Increase	Increase	Increase	Increase	Increase	Increase	Increase	Increase	Decrease	Decrease
Sarıyer	Mann-Kendall	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Significant	Insignificant	Insignificant	Insignificant	Significant	Insignificant	Insignificant
	Kendall's Tau	Increase	Increase	Increase	Decrease	Increase	Increase	Increase	Increase	Increase	Increase	Increase	Decrease
	Sen's Slope	Increase	Increase	Increase	Decrease	Increase	Increase	Increase	Increase	Increase	Increase	Increase	Decrease
Florya	Mann-Kendall	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
	Kendall's Tau	Decrease	Increase	Decrease	Increase	Increase	Increase	Decrease	Decrease	Decrease	Increase	Decrease	Decrease
	Sen's Slope	Decrease	Increase	Decrease	Increase	Increase	Increase	Decrease	Increase	Decrease	Increase	Decrease	Decrease
Tekirdağ	Mann-Kendall	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Significant	Insignificant
	Kendall's Tau	Decrease	Increase	Decrease	Decrease	Increase	Increase	Increase	Increase	Increase	Increase	Decrease	Decrease
	Sen's Slope	Decrease	Increase	Decrease	Decrease	Increase	Increase	Increase	Increase	Increase	Increase	Decrease	Decrease
İpsala	Mann-Kendall	Insignificant	Significant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
	Kendall's Tau	Increase	Decrease	Decrease	Decrease	Decrease	Increase	Increase	Increase	Decrease	Increase	Decrease	Decrease
	Sen's Slope	Increase	Decrease	Decrease	Decrease	Decrease	Increase	Increase	Increase	Decrease	Increase	Decrease	Decrease
Malkara	Mann-Kendall	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Significant	Insignificant	Insignificant	Insignificant
	Kendall's Tau	Increase	Increase	Increase	Decrease	Increase	Increase	Decrease	Increase	Increase	Increase	Decrease	Decrease
	Sen's Slope	Increase	Increase	Increase	Decrease	Increase	Increase	Decrease	Increase	Increase	Increase	Decrease	Decrease
Gökçeada	Mann-Kendall	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
	Kendall's Tau	Decrease	Decrease	Increase	Increase	Decrease	Increase	Decrease	Decrease	Increase	Increase	Decrease	Decrease
	Sen's Slope	Decrease	Decrease	Increase	Increase	Decrease	Increase	Decrease	Decrease	Increase	Increase	Decrease	Decrease
Çanakkale	Mann-Kendall	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Significant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
	Kendall's Tau	Decrease	Decrease	Decrease	Increase	Decrease	Increase	Increase	Decrease	Increase	Increase	Decrease	Decrease
	Sen's Slope	Decrease	Decrease	Decrease	Increase	Decrease	Increase	Increase	Increase	Increase	Increase	Decrease	Decrease

Significant Insignificant Decrease Increase

Figure 3: Trend values of monthly precipitation.

Table 6: Trend values of precipitation in winter.

Meteorology Station	Mann-Kendall P (Value) (α=0,05)		Kendall's Tau		Sen's Slope	
Kırklareli	0,780	●	-0,025	▬	-0,083	▬
Edirne	0,765	●	0,025	✚	0,065	✚
Lüleburgaz	0,124	●	-0,129	▬	-0,873	▬
Uzunköprü	0,393	●	-0,061	▬	-0,177	▬
Kumköy	0,656	●	0,037	✚	0,088	✚
Çorlu	0,215	●	-0,107	▬	-0,241	▬
Sarıyer	0,566	●	0,048	✚	0,120	✚
Florya	0,648	●	-0,034	▬	-0,053	▬
Tekirdağ	0,662	●	-0,033	▬	-0,067	▬
İpsala	0,341	●	-0,087	▬	-0,250	▬
Malkara	0,965	●	0,006	✚	0,011	✚
Gökçeada	0,385	●	-0,081	▬	-0,324	▬
Çanakkale	0,094	●	-0,124	▬	-0,741	▬

● Significant ● Insignificant ▬ Decrease ✚ Increase

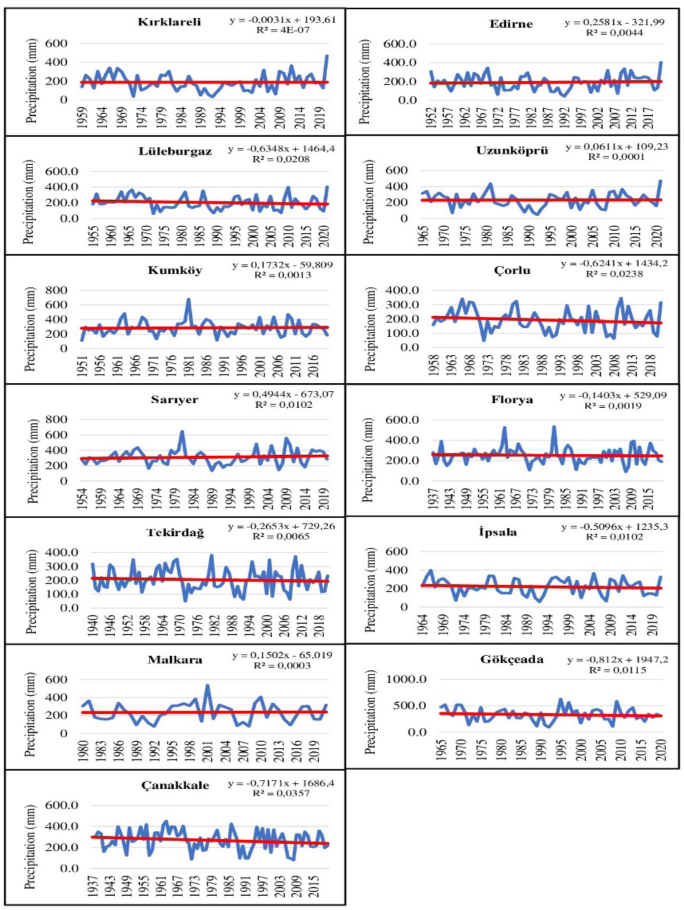

Figure 4: Year by year change in winter precipitation.

3.5. Trend Analysis of Precipitation During the October–March Period

In the Thrace Peninsula, no statistically significant upward or downward trend is observed in any of the meteorological stations in the October–March period (Table 10, Figures 9 and 11). On the other hand, an insignificant positive trend is observed in Kırklareli, Edirne, Kumköy, Çorlu, Sarıyer, and Florya stations,

Table 7: Trend values of precipitation in spring season.

Meteoro-logy Station	Mann-Kendall P (Value) (α=0,05)		Kendall's Tau		Sen's Slope	
Kırklareli	0,731	●	-0,030	▬	-0,040	▬
Edirne	0,843	●	-0,017	▬	-0,027	▬
Lüleburgaz	0,720	●	-0,030	▬	-0,120	▬
Uzunköprü	0,863	●	-0,016	▬	-0,028	▬
Kumköy	0,757	●	0,026	✚	0,046	✚
Çorlu	0,451	●	0,065	✚	0,081	✚
Sarıyer	0,983	●	0,002	✚	0,003	✚
Florya	0,637	●	0,035	✚	0,029	✚
Tekirdağ	0,701	●	-0,029	▬	-0,031	▬
İpsala	0,979	●	-0,003	▬	-0,003	▬
Malkara	0,879	●	0,017	✚	0,033	✚
Gökçeada	0,697	●	0,036	✚	0,065	✚
Çanakkale	0,920	●	0,008	✚	0,024	✚

● Significant ● Insignificant ▬ Decrease ✚ Increase

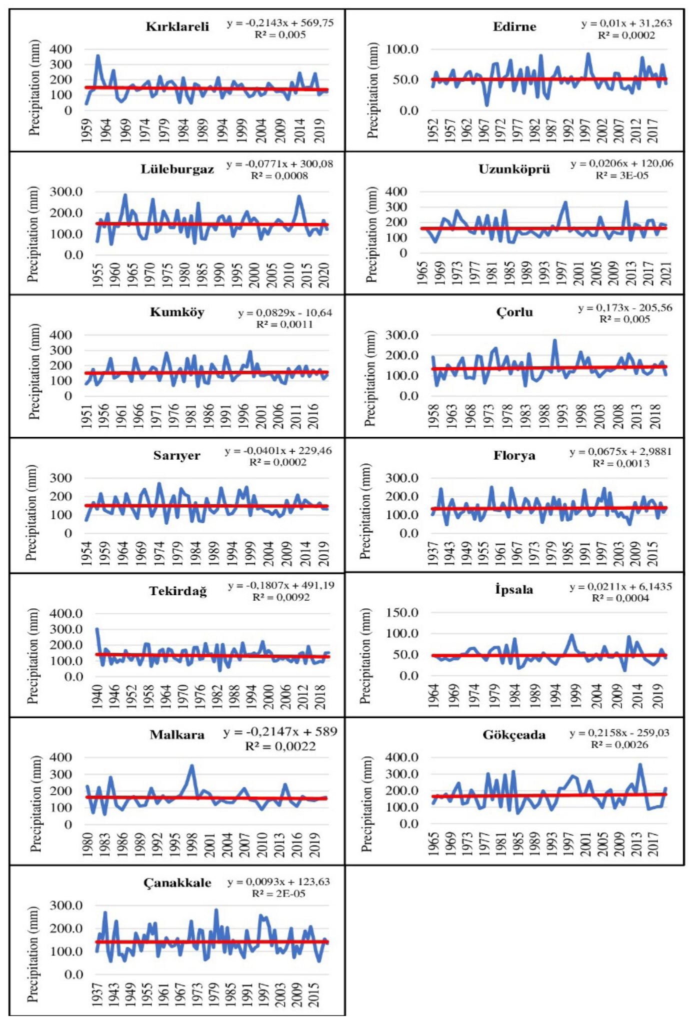

Figure 5: Trend graphs of precipitation in spring season.

Table 8: Trend values of precipitation in summer.

Meteorology Station	Mann-Kendall P (Value) (α=0,05)		Kendall's Tau		Sen's Slope	
Kırklareli	0,370	🔴	0,078	✚	0,122	✚
Edirne	0,453	🔴	0,062	✚	0,085	✚
Lüleburgaz	0,574	🔴	-0,047	▬	-0,207	▬
Uzunköprü	0,587	🔴	0,050	✚	0,064	✚
Kumköy	0,400	🔴	0,069	✚	0,098	✚
Çorlu	0,107	🔴	0,138	✚	0,174	✚
Sarıyer	**0,016**	🟢	0,202	✚	0,275	✚
Florya	0,629	🔴	0,036	✚	0,023	✚
Tekirdağ	0,433	🔴	0,059	✚	0,049	✚
İpsala	0,222	🔴	0,111	✚	0,119	✚
Malkara	0,803	🔴	0,028	✚	0,041	✚
Gökçeada	0,235	🔴	0,110	✚	0,102	✚
Çanakkale	0,406	🔴	0,062	✚	0,112	✚

🟢 Significant 🔴 Insignificant ▬ Decrease ✚ Increase

Table 9: Trend values of precipitation in fall.

Meteorology Station	Mann-Kendall P (Value) (α=0,05)		Kendall's Tau		Sen's Slope	
Kırklareli	0,137	🔴	0,129	✚	0,217	✚
Edirne	1,000	🔴	0,000	✚	0,000	✚
Lüleburgaz	0,274	🔴	-0,092	▬	-0,422	▬
Uzunköprü	0,125	🔴	-0,140	▬	-0,325	▬
Kumköy	**0,010**	🟢	0,211	✚	0,438	✚
Çorlu	0,407	🔴	0,071	✚	0,125	✚
Sarıyer	**0,005**	🟢	0,234	✚	0,558	✚
Florya	0,985	🔴	0,002	✚	0,001	✚
Tekirdağ	0,911	🔴	-0,009	▬	-0,015	▬
İpsala	0,629	🔴	-0,044	▬	-0,114	▬
Malkara	0,278	🔴	0,117	✚	0,271	✚
Gökçeada	0,977	🔴	0,003	✚	0,009	✚
Çanakkale	0,948	🔴	0,005	✚	0,023	✚

🟢 Significant 🔴 Insignificant ▬ Decrease ✚ Increase

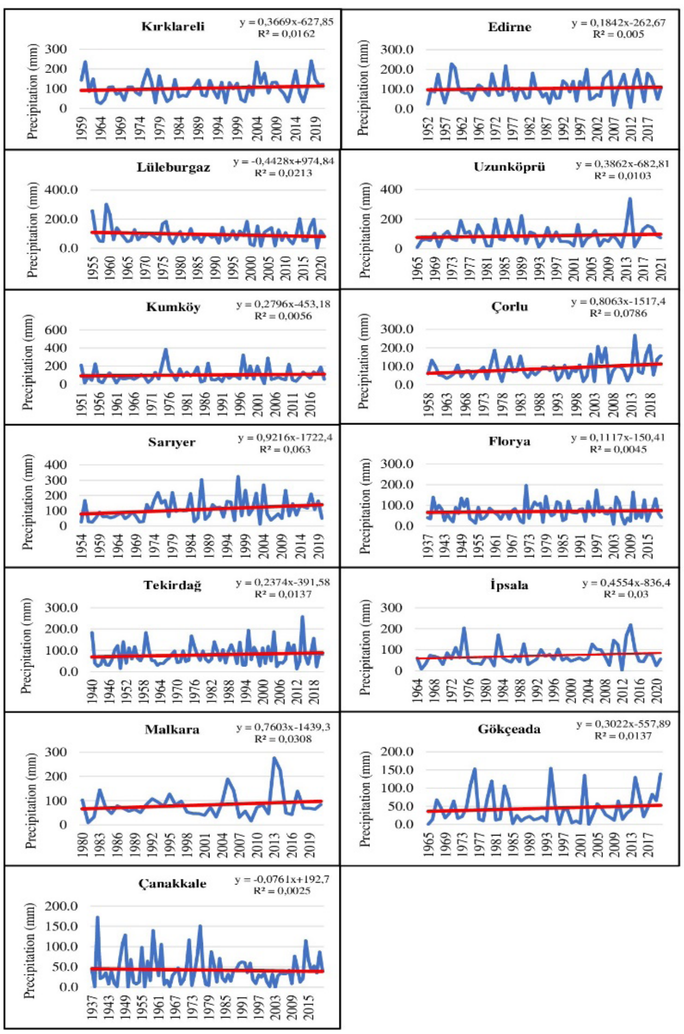

Figure 6: Trend graphs of precipitation in summer.

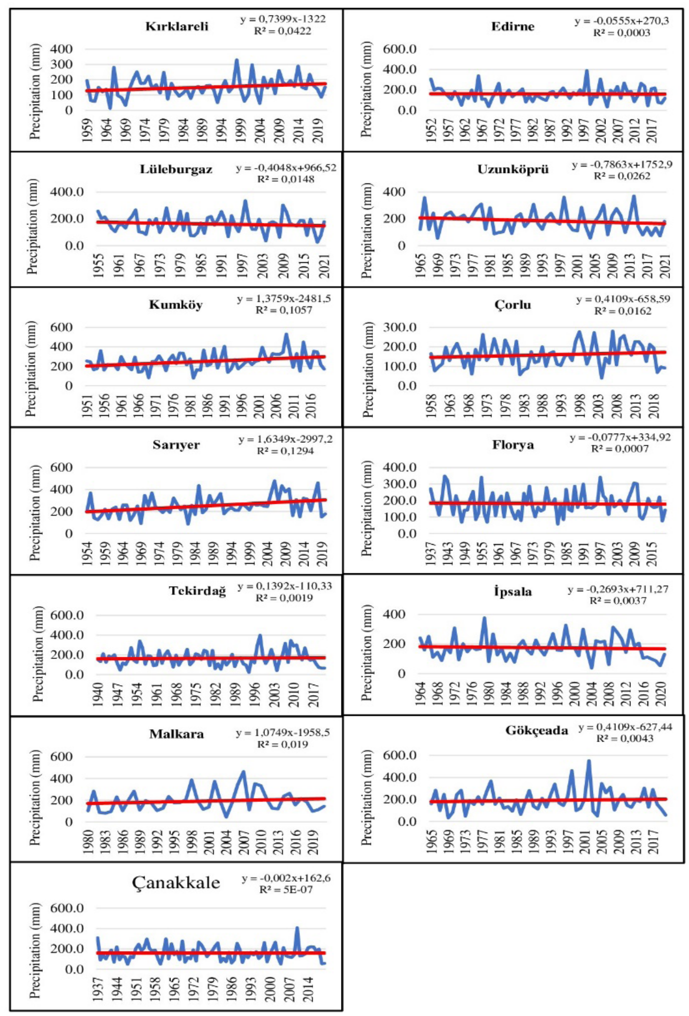

Figure 7: Trend graphs of precipitation in fall.

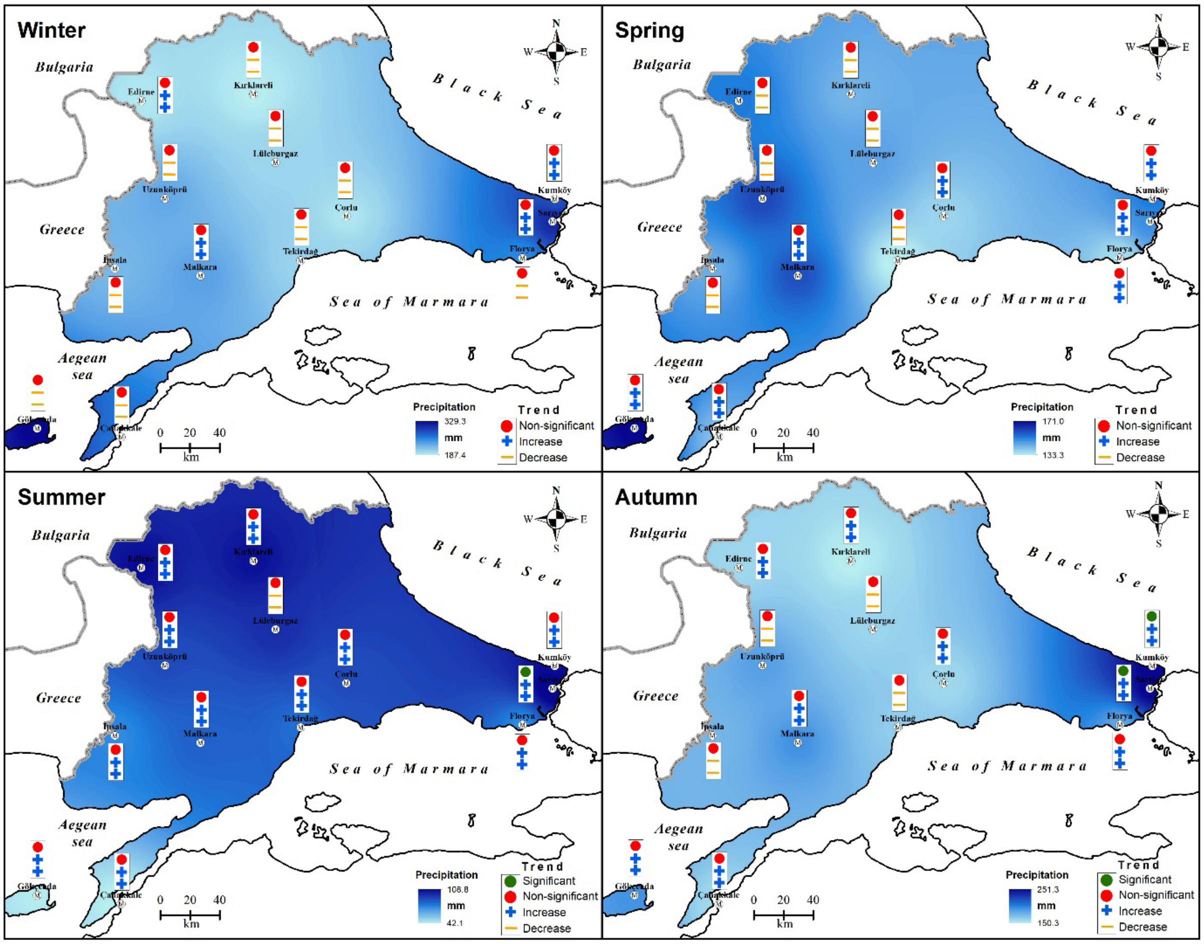

Figure 8: Results of trend analysis for (a) winter, (b) spring, (c) summer and (d) autumn precipitation totals.

Table 10: Trend values of precipitation during the October-March period.

Meteorology Station	Mann-Kendall P (Value) (α=0,05)		Kendall's Tau		Sen's Slope	
Kırklareli	0,700	Insignificant	0,034	Increase	0,046	Increase
Edirne	0,693	Insignificant	0,033	Increase	0,058	Increase
Lüleburgaz	0,225	Insignificant	-0,102	Decrease	-0,955	Decrease
Uzunköprü	0,640	Insignificant	-0,043	Decrease	-0,091	Decrease
Kumköy	0,626	Insignificant	0,040	Increase	0,064	Increase
Çorlu	0,451	Insignificant	0,065	Increase	0,081	Increase
Sarıyer	0,122	Insignificant	0,130	Increase	0,190	Increase
Florya	0,637	Insignificant	0,035	Increase	0,029	Increase
Tekirdağ	0,309	Insignificant	-0,077	Decrease	-0,092	Decrease
İpsala	0,687	Insignificant	-0,037	Decrease	-0,075	Decrease
Malkara	0,931	Insignificant	-0,010	Decrease	-0,022	Decrease
Gökçeada	0,783	Insignificant	-0,026	Decrease	-0,071	Decrease
Çanakkale	0,137	Insignificant	-0,111	Decrease	-0,871	Decrease

● Significant ● Insignificant — Decrease ✚ Increase

and a negative trend is observed in Lüleburgaz, Uzunköprü, Tekirdağ, İpsala, Malkara, Gökçeada, and Çanakkale stations.

3.6. Trend Analysis of Precipitation During the April–September Period

A statistically significant and positive trend in precipitation is observed in Kumköy, Çorlu, and Sarıyer stations in the April–September period (Table 11, Figures 10 and 11). A positive and insignificant trend is observed in Kırklareli, Edirne, Florya, Tekirdağ, İpsala, Malkara, Gökçeada, and Çanakkale, and a negative and insignificant trend is observed in Lüleburgaz and Uzunköprü.

3.7. Trend Analysis of Annual Precipitation

Based on the trend analysis of the total annual precipitation values of the stations in the Thrace Peninsula, a significant and positive trend is found in Kumköy and Sarıyer (Table 12, Figures 12 and 13). On the other hand, positive and insignificant trends are observed in Kırklareli, Çorlu, and Malkara stations, and negative and insignificant trends are detected in Edirne, Lüleburgaz, Uzunköprü, Florya, Tekirdağ, İpsala, Gökçeada, and Çanakkale stations.

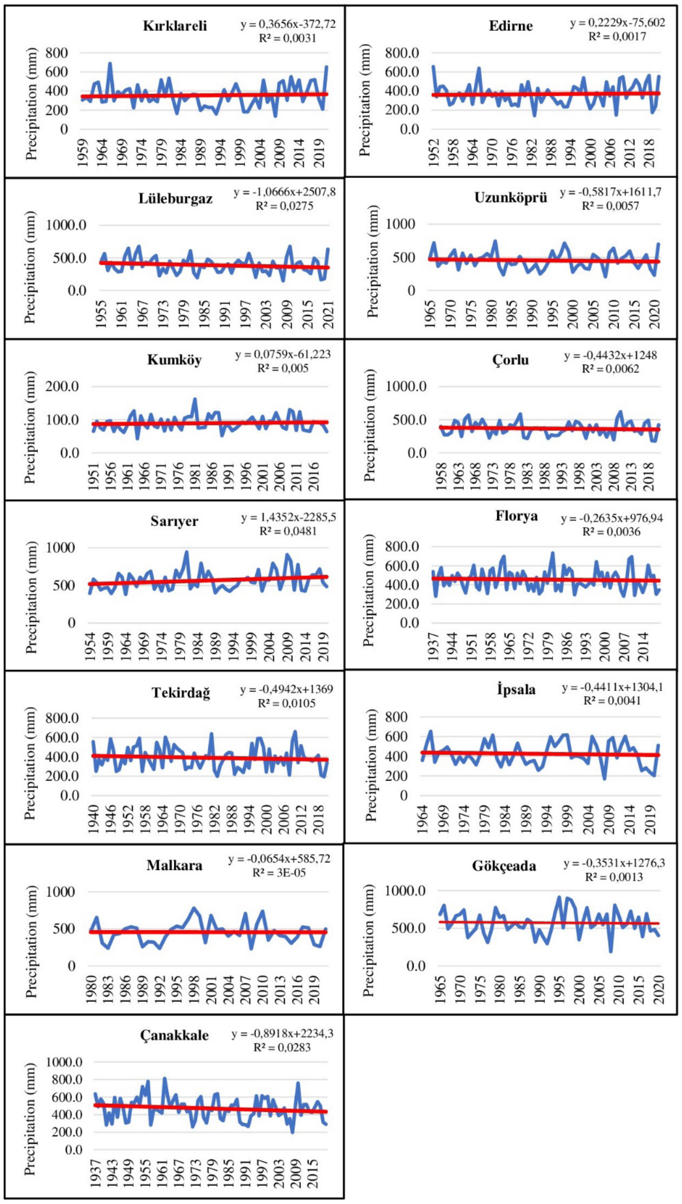

Figure 9: Trend graphs of precipitation during the October-March period.

3.10. Trend Analysis of Monthly Maximum Precipitation

In the trend analysis of monthly maximum precipitation, a positive and significant trend is found in Kumköy, Çorlu, Sarıyer, and Malkara stations located on the Thrace Peninsula (Table 13, Figure 14). Among the stations where a statistically insignificant trend was determined, the trend in monthly maximum precipitation in Lüleburgaz, Uzunköprü, and Florya stations follows a negative direction, whereas the trend in Kırklareli, Edirne, Tekirdağ, İpsala, Gökçeada, and Çanakkale stations follows a positive direction.

Table 11: Trend values of precipitation during the April-September period.

Meteoro-logy Station	Mann-Kendall P (Value) (α=0,05)		Kendall's Tau		Sen's Slope	
Kırklareli	0,308	🔴	0,089	✚	0,077	✚
Edirne	0,570	🔴	0,047	✚	0,031	✚
Lüleburgaz	0,221	🔴	-0,103	–	-0,509	–
Uzunköprü	0,956	🔴	-0,006	✚	-0,011	✚
Kumköy	**0,035**	🟢	0,172	✚	0,219	✚
Çorlu	**0,021**	🟢	0,198	✚	0,180	✚
Sarıyer	**0,010**	🟢	0,216	✚	0,273	✚
Florya	0,985	🔴	0,002	✚	0,001	✚
Tekirdağ	0,476	🔴	0,054	✚	0,035	✚
İpsala	0,648	🔴	0,042	✚	0,028	✚
Malkara	0,083	🔴	0,187	✚	0,270	✚
Gökçeada	0,821	🔴	0,021	✚	0,017	✚
Çanakkale	0,743	🔴	0,025	✚	0,096	✚

🟢 Significant 🔴 Insignificant – Decrease ✚ Increase

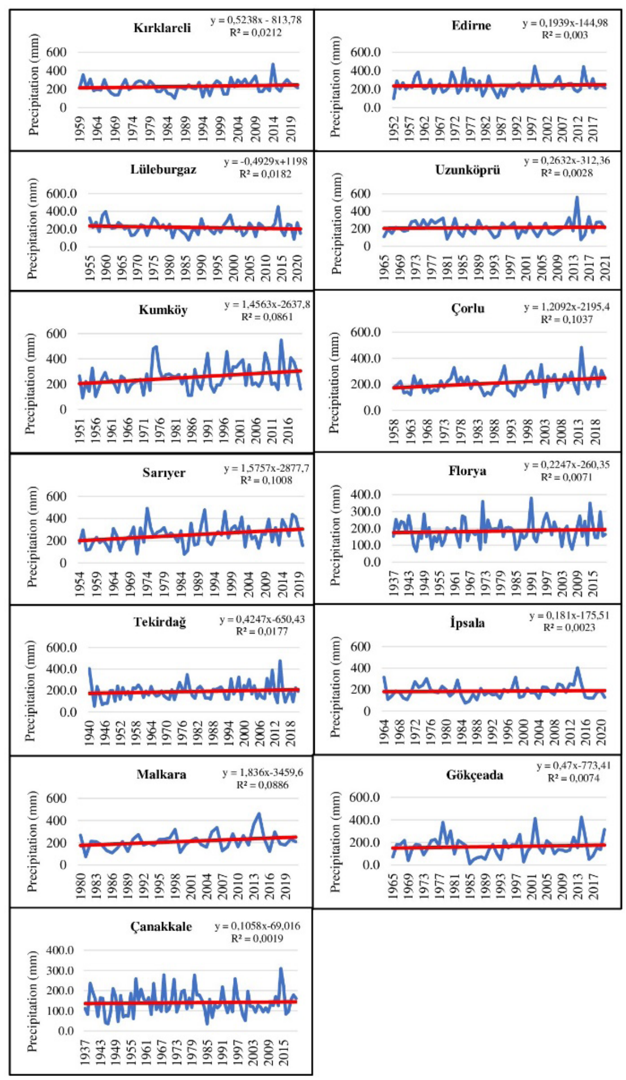

Figure 10: Trend graphs of precipitation during the April-September period.

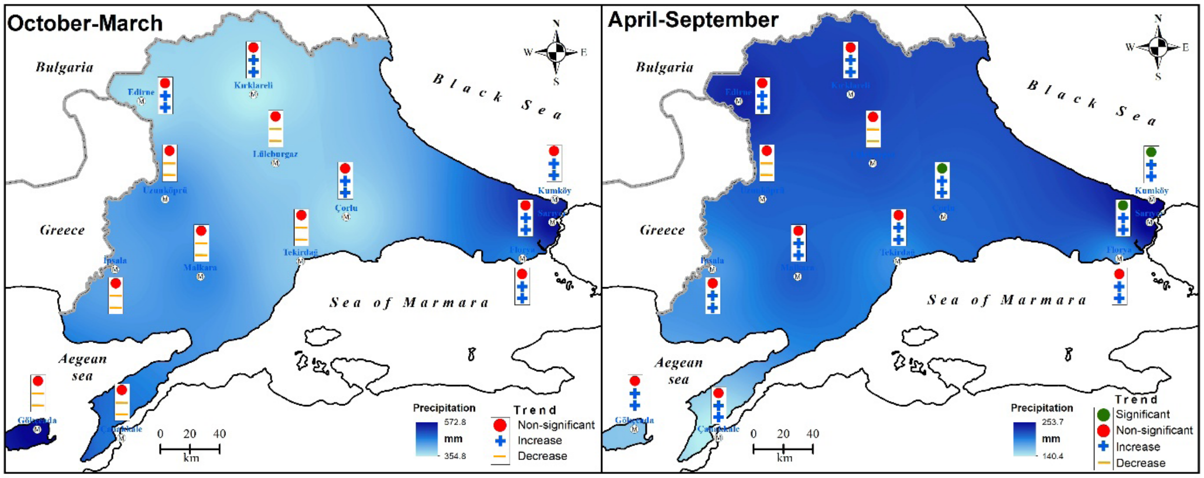

Figure 11: Trend maps of precipitation during the October-March and the April-September periods.

Table 12: Trend values of annual precipitation.

Meteorology Station	Mann-Kendall P (Value) (α=0,05)		Kendall's Tau		Sen's Slope	
Kırklareli	0,644	Insignificant	0,040	Increase	0,600	Increase
Edirne	0,911	Insignificant	-0,010	Decrease	-0,106	Decrease
Lüleburgaz	0,096	Insignificant	-0,140	Decrease	-1,697	Decrease
Uzunköprü	0,615	Insignificant	-0,046	Decrease	-0,742	Decrease
Kumköy	**0,014**	Significant	0,201	Increase	1,971	Increase
Çorlu	0,434	Insignificant	0,067	Increase	0,675	Increase
Sarıyer	**0,002**	Significant	0,262	Increase	3,498	Increase
Florya	0,802	Insignificant	-0,019	Decrease	-0,126	Decrease
Tekirdağ	0,958	Insignificant	-0,004	Decrease	-0,025	Decrease
İpsala	0,511	Insignificant	-0,060	Decrease	-0,848	Decrease
Malkara	0,308	Insignificant	0,110	Increase	2,376	Increase
Gökçeada	0,916	Insignificant	-0,010	Decrease	-0,115	Decrease
Çanakkale	0,233	Insignificant	-0,089	Decrease	-0,820	Decrease

● Significant ● Insignificant — Decrease ✚ Increase

4. DISCUSSION and CONCLUSION

According to the Mann–Kendall test, Kendall's tau, and Sen's slope test, a significant negative trend in monthly precipitation values in the Thrace Peninsula is found in August, November, and February in Lüleburgaz, Tekirdağ, İpsala, respectively. Moreover, a significant positive trend is observed in June and October in Sarıyer, September in Malkara, and June in Çanakkale. Regarding the seasons, a positive and statistically significant trend is detected in Sarıyer in summer and Kumköy and Sarıyer in autumn. In addition, positive and statistically significant trend is noted in Kumköy, Çorlu, and Sarıyer in the April–September and in Kumköy and Sarıyer in annual precipitation. No significant trend in precipitation is detected between the winter and spring seasons and during the October–March period. An insignificant decreasing trend is also found in winter, during October–March, and annual precipitation, whereas an insignificant increasing trend is found in spring, summer, fall,

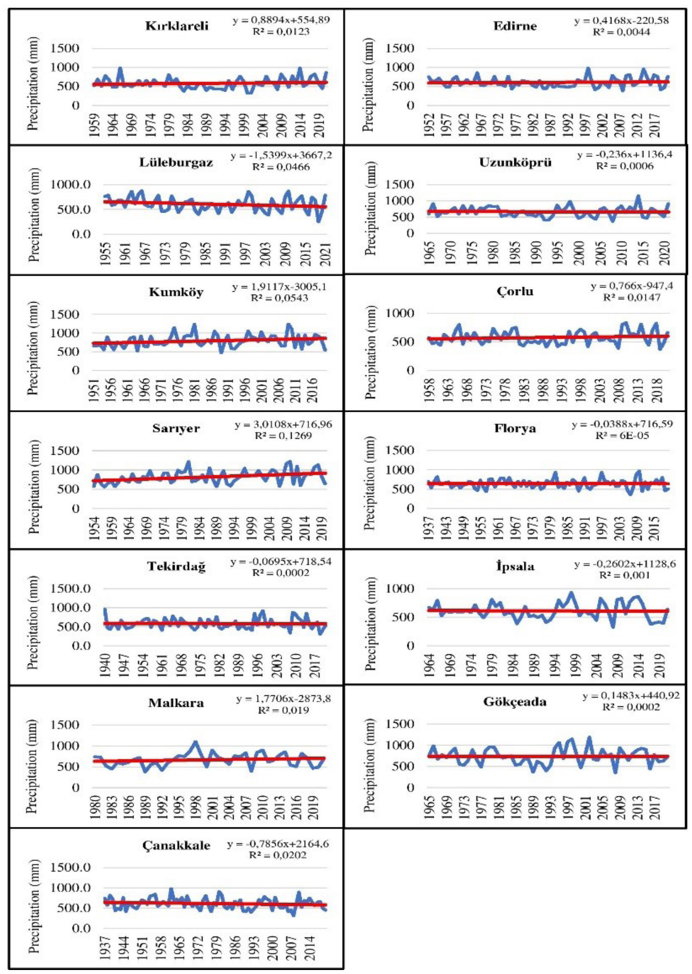

Figure 12: Trend graphs of annual precipitation.

and during April–September precipitation. In terms of monthly maximum precipitation, a positive and significant trend is found in Kumköy, Çorlu, Sarıyer, and Malkara.

The findings obtained in this study are mostly consistent with

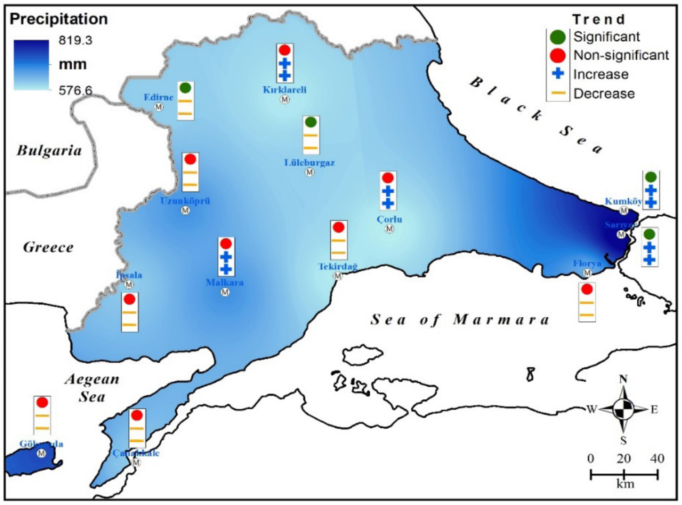

Figure 13: Trend map of annual precipitation.

Table 13: Trend values of monthly maximum precipitation.

Meteoro-logy Station	Mann-Kendall P (Value) (α=0,05)		Kendall's Tau		Sen's Slope	
Kırklareli	0,865	🔴	0,015	✚	0,017	✚
Edirne	0,070	🔴	0,150	✚	0,161	✚
Lüleburgaz	0,795	🔴	-0,022	▬	-0,043	▬
Uzunköprü	0,713	🔴	-0,034	▬	-0,035	▬
Kumköy	**0,001**	🟢	0,278	✚	0,379	✚
Çorlu	**0,012**	🟢	0,219	✚	0,235	✚
Sarıyer	**0,020**	🟢	0,197	✚	0,298	✚
Florya	0,383	🔴	-0,066	▬	-0,057	▬
Tekirdağ	0,224	🔴	0,092	✚	0,090	✚
İpsala	0,409	🔴	0,076	✚	0,144	✚
Malkara	**0,026**	🟢	0,243	✚	0,639	✚
Gökçeada	0,117	🔴	0,146	✚	0,349	✚
Çanakkale	0,147	🔴	0,109	✚	0,135	✚

🟢 Significant 🔴 Insignificant ▬ Decrease ✚ Increase

those of previous studies. Alexandrov et al. (2004) stated that the trends in annual precipitation in Bulgaria for the 1901–2000 period were insignificant at the 95% probability level. Topuz et al. (2020) found no statistically significant trend in annual and winter precipitation in Turkey for the 1955–2013 period. Türkeş (2012) found an increasing trend in annual total precipitation in Tekirdağ and İstanbul regions. Furthermore, Gönençgil (2012) found that annual total precipitation showed a decreasing trend at all stations, except Edirne and Kirecburnu. In this study, no statistically significant trend in winter precipitation was found, but a significant positive trend in annual precipitation was observed only in Kumköy and Sarıyer.

Gönençgil (2012) concluded that the July precipitation series showed an increasing trend at Edirne (significant) and Kırklareli stations and a decreasing trend at Tekirdağ, Kirecburnu, and

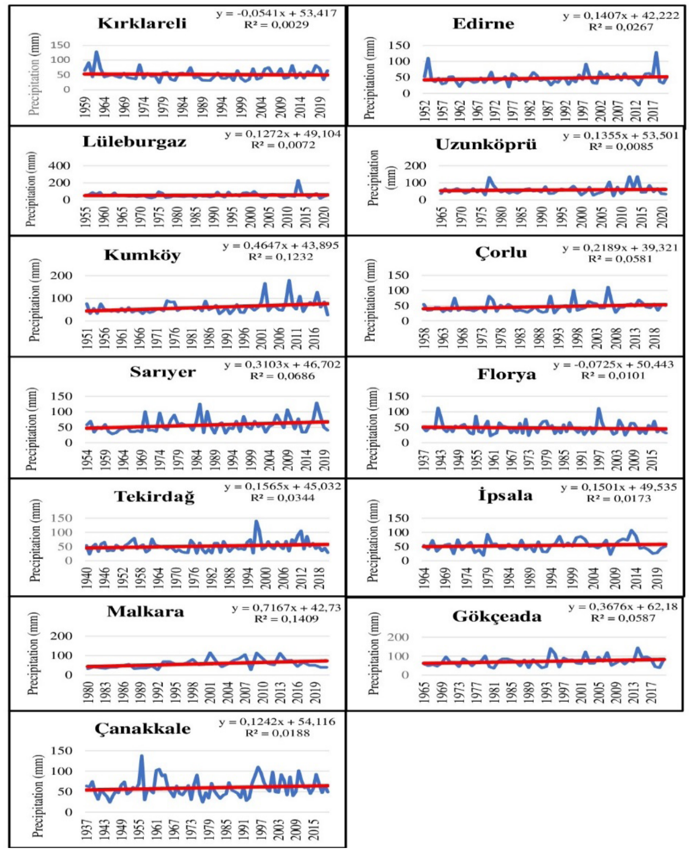

Figure 14: Trend graphs for monthly maximum precipitation.

Çorlu stations, especially after the 1990s. In this study, although the trend direction of summer precipitation is increasing, a statistically significant increase is observed only in Sarıyer station.

In the periodic trend analysis of annual precipitation averages in the Meriç River Basin Eroğlu (2021) determined that there was a significant negative trend at Ipsala in the 1965–1990 period, a significant positive trend at Kırklareli station in the 1991–2015 period, and no statistically significant trend at any station in the basin area in the 1965–2015 period. No statistically significant trend was also found in annual average precipitation at any station in the Meriç River Basin in this study.

From the analysis of precipitation trends in the Thrace Peninsula within the scope of meteorological stations, significant positive trends are detected in Sarıyer, Kumköy, Çorlu, Malkara, and Çanakkale stations, whereas significant negative trends are found in Lüleburgaz, Tekirdağ, and İpsala stations only in monthly precipitation. Moreover, no statistically significant results are found in Kırklareli, Edirne, Uzunköprü, Florya, and Gökçeada stations.

Out of 117 analyses performed for 13 meteorological stations in the Thrace Peninsula to determine the effects of global climate change on temperature averages, 107 (91.5%) were found to have a statistically positive and significant trend (Eroğlu, 2022). This trend in air temperatures would cause an increase in the amount of evapotranspiration (ET). Due to population growth, urbanization, and industrialization, the need for water and water resources in this area is increasing day by day. It is also emphasized the change in the global climate has resulted in the escalation of problems, such as flooding and water insufficiency, water quality deterioration, and ecosystem problems in the Thrace Peninsula in recent years (Turoğlu and Uludağ, 2013), where water resources and groundwater are important (Aykut, 2021).

On the other hand, the average rainy days in Sarıyer, Kumköy, Çorlu, Florya, Edirne, Uzunköprü, Kırklareli, Tekirdağ, Malkara, Ipsala, Lüleburgaz, Gökçeada, and Çanakkale are 131, 124, 123, 118, 108.5, 99, 98.5, 98, 98, 96, 90, 88, and 86 days, respectively. Accordingly, the number of rainy days in the Thrace Peninsula varies between 131 and 86 days. Sarıyer and Çanakkale are the stations with highest and lowest number of rainy days, respectively. The rainfall Trakya is distributed according to precipitation intensity classes, where light rains below 10 mm constitute 80% of the total rainfall. On the other hand, the proportion of heavy and very heavy rain showers is <1% (Erlat, 2000).

The maximum monthly precipitation during the observation periods of the meteorological stations was 227.4 mm, 179.4 mm, 144.4 mm, 140.1 mm, 137.8 mm, 131.8 mm, 128.9 mm, 128.5 mm, 128.3 mm, 115.1 mm, 112.5 mm, 111.3 mm, and 93.2 mm in Lüleburgaz (2013, April), Kumköy (2009, September), Gökçeada (2014, May), Tekirdağ (1997, October), Çanakkale (1956, November), Uzunköprü (1977, December), Sarıyer (2017, September), Edirne (2018, November), Kırklareli (1960, January), Malkara (2001, December), Florya (1942, November), Çorlu (2006, July), and Ipsala (1979, November), respectively. From these data, it can be understood that the monthly maximum rainfall in Edirne, Sarıyer, Gökçeada, Lüleburgaz, Kumköy, Çorlu, Malkara, and Tekirdağ decreased between 1997 and 2018. Similarly, the monthly maximum rainfall in İpsala, Uzunköprü, Kırklareli, Çanakkale, and Florya decreased during the period from 1942 to 1979.

This study examined the impact of global climate change on precipitation trends in the Thrace Peninsula. The data obtained contribute to the future planning of water resources, water use, and management. Nevertheless, it is relevant to note that a large number of detailed scientific studies are necessary to reach more diverse findings regarding the climatological and precipitation characteristics of the Thrace Peninsula.

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