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Trend Analysis of Temperature Changes in the Trakya Region

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Abstract

*Monthly maximum, mean, and minimum long-term time series data (1960-2024) of air temperature from Edirne, Kırklareli, and Tekirdağ—located in the Trakya Peninsula (TP) of Türkiye—were tested by using the Mann-Kendall (MK), Şen trend and linear trend analysis tests in this study. The drought results determined in previous studies were compared with the results found in the study. The trend analysis outcomes revealed that the monthly air temperatures recorded at all stations have increased significantly at the 5% significance level according to the Şen trend test. The temperatures at all stations—except for the monthly maximum temperature in Kırklareli—showed statistically significant increasing trends at the 5% level according to the MK test (Edirne (+2.28, +2.17, +2.05); Kırklareli (1.43**, 2.16, 2.07); Tekirdağ (2.46, 2.07, 2.09)). Statistically significant upward trends in all air temperatures, except for the monthly maximum temperature in Kırklareli, under the 5% two-tailed hypothesis test, were seen according to the linear trend analysis. According to these analyses, it can be said that TP confirms the changing weather conditions and the increase in air temperatures in the natural balance between 1960 and 2024.*

Keywords
Mann-Kendall Trend Test, Şen Trend Test, Temperature, Trakya Peninsula

Trakya Bölgesi'nde Sıcaklık Değişimlerinin Trend Analizi

Özet

*Bu çalışmada, Trakya Yarımadası'nda (TY) yer alan Edirne, Kırklareli ve Tekirdağ'ın 1960-2024 yılları arasındaki aylık maksimum, ortalama ve minimum uzun süreli zaman serisi hava sıcaklığı verileri Mann-Kendall (MK), Şen eğilim ve doğrusal eğilim testleri kullanılarak analiz edilmiştir. Daha önceki çalışmalarda tespit edilen kuraklık çalışmaları sonuçları bu çalışmanın bulgularıyla karşılaştırılmıştır. Trend analizi sonuçları, tüm istasyonlarda kaydedilen aylık hava sıcaklıklarının Şen eğilim testine göre %5 anlamlılık düzeyinde istatistiksel olarak anlamlı bir artış gösterdiği görülmüştür. Kırklareli'ndeki aylık maksimum sıcaklık hariç tüm istasyonlardaki sıcaklıklar, MK testine göre %5 anlamlılık düzeyinde istatistiksel olarak anlamlı artış eğilimleri (Edirne (+2.28, +2.17, +2.05); Kırklareli (1.43**, 2.16, 2.07); Tekirdağ (2.46, 2.07, 2.09)) göstermiştir. Doğrusal eğilim analizine göre ise %5 çift taraflı hipotez testine göre, Kırklareli'ndeki aylık maksimum sıcaklık hariç, tüm hava sıcaklıklarında istatistiksel olarak anlamlı artış eğilimi görülmüştür. Bu analizlere göre, TY'nin 1960 ve 2024 yıllarında değişen hava şartları ve doğal dengedeki hava sıcaklıklarının artığını doğruladığı söylenebilir.*

Anahtar Sözcükler
Mann-Kendall Trend Testi, Şen Trend Testi, Sıcaklık, Trakya Yarımadası

1. Introduction

The air temperature is a critical variable that influences numerous processes in the universe and atmosphere. Every phenomenon occurring on Earth such as biological activities, plant growth, and physical and chemical formations, bears the imprint of temperature. Therefore, air temperature functions as a double-edged sword, exerting both beneficial and detrimental effects. Understanding climate change and natural climate variability has been the focus of many studies (Leroux, 2005; Garbrecht & Piechota, 2006; Blöschl & Montanari, 2010; Kadıoğlu, 2019; AghaKouchak et al., 2020; IPCC, 2021; Li & Rodell, 2023; Jensen et al., 2024; Masoudi et al., 2025). According to IPCC projections, the 20-year average global temperature is expected to exceed +1.5 °C in the early 2030s (Blöschl et al., 2019; Türkeş et al., 2020; Ay, 2021, 2022a, b; Chagas et al., 2024). Climate change and variability affect all living organisms through phenomena such as flooding, extreme heat, food and water scarcity, increased disease prevalence, and economic loss. These challenges directly influence the management and regulation of water resources (Katz & Brown, 1992; Aslan et al., 2016; Sivapalan & Blöschl, 2017; Díaz et al., 2018; Tabari, 2019; Ay, 2020; Şen, 2020a, b; Ay, 2022a, b; Güçlü, 2022; Kurnaz, 2023; Acar et al., 2025; Ercan et al., 2025; Xiong & Yang, 2025). In other words, such environmental changes increase labour and financial demands in areas such as cost, operation, and maintenance. Before these conditions reach a tipping point, greenhouse gas reduction strategies must be urgently implemented, and control mechanisms must provide more effective

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feedback, as emphasized in both national and international policy discussions. Although public institutions and organizations make various national and international efforts, an efficient operational mechanism that comprehensively integrates and monitors these efforts is still lacking in the world.

When examining studies on the air temperature variable in Türkiye (Sırdaş & Şen, 2003; Aksoy et al., 2008; Toros, 2012; Azlak, 2015; Bağdatlı & Bellitürk, 2016; Deveci, 2015; Öztürk, 2019; Azlak & Şaylan, 2019; Akçay et al., 2023; Eroğlu, 2022; Ciftci & Şahin, 2023; Acar 2024; Öz et al., 2024; MGM, 2024; Tuğrul & Hinis, 2024), it is seen that researchers have approached the topic from various perspectives and developed different methodological solutions. These studies have examined variables such as the relationship between the number of frost days and air temperature, air pollution parameters, minimum, maximum, mean, daily, and monthly air temperatures, streamflow, reference plant evapotranspiration, and drought indices. In general, these studies conclude that air temperature exhibits an increasing trend and that it affects the analysed variables either positively or negatively. This finding suggests a possible regional trend toward meteorological drought both spatially and temporally. At this point, rising air temperatures induce variations in other climatic and hydrological variables, leading to discrete and extreme measurements in the corresponding datasets (Türkeş et al., 2002; Tatlı, 2015; Abbasnia & Toros, 2020; Ay, 2022a, b; Yılmaz, 2023; Erlat & Güler, 2024; Stigter, 2024). The absence or decrease in water resources in the affected regions may indicate drought conditions; otherwise, such patterns might represent a temporary climatic phase within the TP. To accurately interpret these processes, measurement data such as precipitation, temperature, air and soil moisture, atmospheric pressure, solar radiation, and wind speed should be complemented with field observations related to land, plant, and soil characteristics (e.g., moisture, nitrogen, and organic matter). These factors must be evaluated together in order to obtain a holistic understanding (Tatlı et al., 2005; Bardsley & Hugo, 2010; Romm, 2011; Black et al., 2011; Toros, 2012; Azlak, 2015; Deveci, 2015; Tatlı, 2015; Gray et al., 2016; Cattaneo et al., 2019; Öztürk, 2019; Azlak & Şaylan, 2019; Mudelsee, 2019). In this study, inferences were made for the period of 1960-2024. Temporally, meteorological drought can trigger agricultural drought, which in turn represents a transition toward the most severe form, hydrological drought. The interconnections within this delicate chain directly affect both tangible and intangible aspects of regional productivity and quality of life (Miheretu et al., 2020; TAGEM, 2020; Pathakoti et al., 2021; Çamalan et al., 2021; Şen, 2022; Yıldırım, 2023; Chagas et al., 2024; Morovati & Karami, 2024). Unlike other studies, this study attempts to determine the trend exhibited by using minimum, average, and maximum data (1960-2024), considering the results of studies indicating monthly and seasonal temperature increases. An evaluation of extreme and outlier data is also conducted in the analysis. Accordingly, this study focused on the research queries:

1. What are the minimum, mean and maximum temperature trend patterns at three meteorological stations in the TP region from 1960 to 2024?
2. What are their spatiotemporal characteristics?
3. How do the results found in this study align with the conclusions stated in earlier studies?
4. What are the advantages and disadvantages of air temperatures in the TP region?
5. Has the air temperature in the TP region reached a potential tipping point?

To the best of our knowledge, long-term maximum, mean, and minimum air temperature datasets recorded between January 1960 and June 2024 were used for the first time in the TP. Trend analysis methods were used to evaluate the minimum, mean, and maximum monthly air temperature data. Accordingly, impacts of global warming on the TP were interpreted using the most up-to-date observational datasets. The results of this study can also serve as valuable information for decision makers and politicians in developing effective local adaptation and mitigation plans.

2. Study area and data

Türkiye, with an area of roughly 780043 km^2, has a subtropical climatic zone, which is vulnerable to climate changes and variability, and has 25 hydrological basins. This study includes the Eastern TP in the Marmara region (approximately 18794 km^2), as shown in Figure 1. Roughly 2 million people live in this region, and economic activities that make the region attractive increase anthropogenic stress in addition to natural effects (Aksoy et al., 2008; Şaylan et al., 2011; Bağdatlı & Bellitürk, 2016; Çamalan et al., 2021). The vast majority of land in the TP region consists of arable land. 12% of the country's wheat, 61% of sunflower and 54% of rice are carried out in the region. Wheat and sunflowers are common plant species in this region. Approximately 9.6% of Türkiye's surface water potential of 98 billion m^3, which is 9.46 billion m^3, constitutes the surface water potential of the region. 5.84 billion m^3 originated from the Meriç River. Approximately 3.2% of Türkiye's groundwater potential of 14 billion m^3 is also located in this region (MGM, 2024). For these reasons, the region has an important location and production outputs in both agricultural areas and animal husbandry. Winters are cold (January averages around 3.5 °C) and summers are hot (with highs of about 33 °C in July and August). Snow and frost can occur in winter, and heat waves may develop in summer. The region is also an important in Türkiye in term of location (Figure 1), and the Meriç-Ergene Basin consists of the drainage areas of the transboundary waters, Meriç, Arda, Kızıldeli River, Tunca and the national waters Ergene River. These rivers possess an international status and play a critical role in political relations, agricultural development, energy generation, and the provision of drinking water. Therefore, any a change in the upper stream of the region positively or negatively affects the downstream regions (Albut et al., 2007; Yıldız, 2010; Şaylan et al., 2011; Scheumann et al., 2011; Williams, 2011; Kankal & Uzlu, 2014; Ay

&Kişi, 2016; Dabanlı et al., 2016; TOB, 2018, 2019; Azlak & Şaylan, 2019; Kibaroglu, 2021; Deveci & Konukcu, 2024; Eroğlu, 2024). For this step, Prof. Dr. Fatih Konukçu and other project members launched a project called as İKLİMTRAK with other partners in the TP.

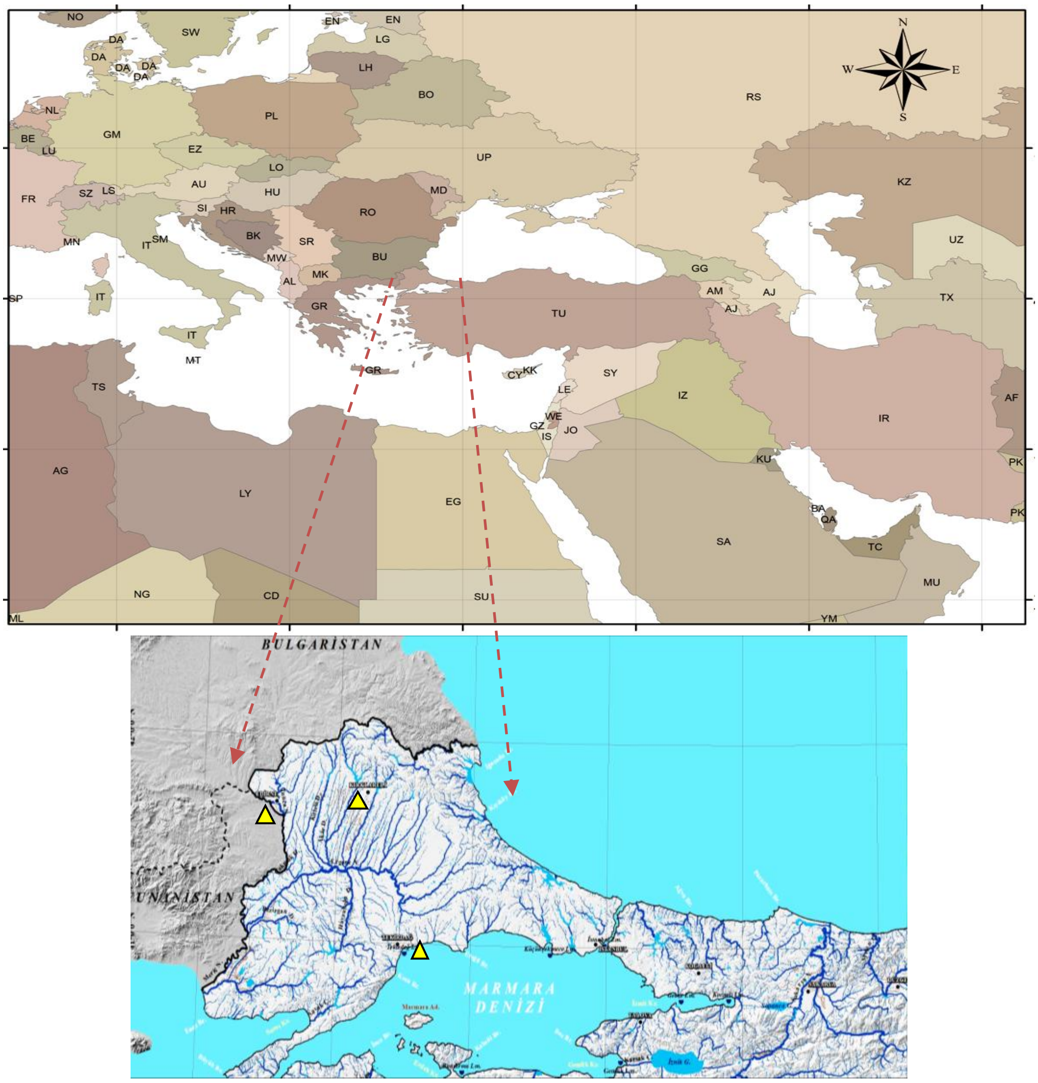

Figure 1: Locations of the meteorological stations (Edirne, Kırklareli and Tekirdağ) in the TP in Türkiye (SYGM, 2021)

The Edirne station (17050) is located in the provincial centre at an elevation of approximately 51 m above sea level, with historical daily climate data available back to at least the mid-20th century. This long dataset allows for robust analysis of temperature trends over extended periods. The Kırklareli station (17052), situated at about 232 m elevation in the provincial centre, also provides valuable climatic records that contribute to understanding regional climate variability. The Tekirdağ station (17056), located very close to sea level at approximately 4 m elevation, captures climate dynamics influenced by proximity to the Marmara Sea. Its record includes daily data dating back to the early 1960s, making it especially suitable for long-term trend analysis in coastal and near-coastal environments.

For this study, monthly records of the minimum, mean, and maximum temperatures were obtained from three stations maintained by the Turkish State Meteorological Service (TSMS). The basic statistics of the stations can be seen in Table 1-4. The station in Kırklareli province has missing data compared to other stations in previous years. The data here were taken to avoid statistical bias, and no data completion method was used. In Table 1, skewness coefficients have negative (left way) values except for Kırklareli (monthly mean temperature (°C) and Tekirdağ (monthly mean temperature (°C). Table 2, 3 and 4 also show some important results for the region. These tables show the monthly and annual temperatures of the provinces, respectively. The coefficients of variation of the monthly minimum temperatures (°C) of the stations had high values (Edirne (3.67), Kırklareli (3.03), and Tekirdağ (1.58) in Table 1. It can be said that these results can support the trend results in Table 8. The increase in the monthly minimum temperature values could also be another indication of the increase in air temperature. These arguments represent challenging issues in terms of nature activities in the TP. The box and whisker plots in Figure 2 show that there are no extreme and outlier data at the stations between 1960 and 2024. This result is also compatible with the skewness coefficients of the data in Table 1. A further significant result is the high coefficient of variation in monthly minimum temperatures of the stations, implying considerable changes between 1960 and 2024.

Table 1: Basic statistics of the monthly maximum, mean and minimum temperatures of the stations used in this study in the Trakya Peninsula (TP) in Türkiye (1960-2024)

Station codes and data range	Coordinates (Longitude and latitude)	Altitude (m)	Data types, 1960-2024 (°C)	N	Mean (°C)	Standard deviation (°C)	Coefficient of skewness	Coefficient of variation
Edirne-17050 (1960-2024)	41°67'67"N 26°55'08"E	51	Monthly maximum temperature	774	+27.17	7.85	-0.11	0.29
			Monthly mean temperature	774	+13.85	7.91	-0.02	0.57
			Monthly minimum temperature	774	+2.17	7.98	-0.06	**3.67**
Kırklareli-17052 (1960-2024)	41°73'82"N 27°21'78"E	232	Monthly maximum temperature	770	+25.92	8.02	-0.08	0.31
			Monthly mean temperature	771	+13.38	7.60	+0.01	0.57
			Monthly minimum temperature	744	+2.57	7.79	-0.02	**3.03**
Tekirdağ-17056 (1960-2024)	40°95'85"N 27°49'65"E	4	Monthly maximum temperature	774	+24.77	6.24	-0.08	0.25
			Monthly mean temperature	774	+14.19	6.90	+0.04	0.49
			Monthly minimum temperature	774	+4.89	7.73	-0.01	**1.58**

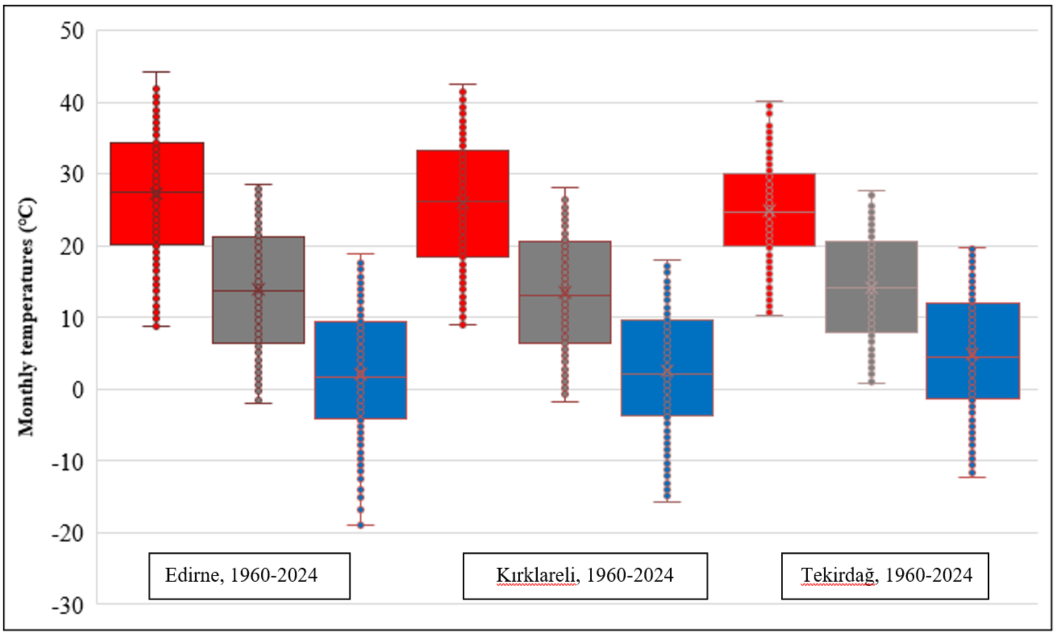

Figure 2: Box and whisker plots of the monthly minimum (blue boxes), mean (grey boxes) and maximum (red boxes) temperatures time series of Edirne, Kırklareli and Tekirdağ in Türkiye, 1960-2024

Table 2: Basic statistics of the temperatures (°C) in Edirne

EDİRNE (17050) (°C)	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Mean temperature	2.7	4.4	7.6	12.8	18	22.2	24.7	24.5	20.1	14.5	9.2	4.6	13.8
Mean maximum temperature	6.7	9.4	13.4	19.3	24.8	29.2	32	32	27.4	20.8	14.2	8.6	19.8
Mean minimum temperature	-0.5	0.5	2.9	7.1	11.7	15.5	17.4	17.3	13.5	9.3	5.3	1.4	8.5
Maximum temperature	20.5	23.3	28.0	33.5	37.1	42.6	44.1	41.9	39.9	35.8	28.0	22.9	44.1
Minimum temperature	-19.5	-19.0	-12.0	-4.1	0.7	6.0	8.0	8.9	0.2	-3.7	-9.4	-14.9	-19.5

Table 3: Basic statistics of the temperatures (°C) in Kırklareli

KIRKLARELİ (17052) (°C)	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Mean temperature	2.9	4.1	6.9	12.0	17.1	21.4	23.8	23.6	19.4	14.1	9.3	5.1	13.3
Mean maximum temperature	6.9	8.6	12.2	17.9	23.5	28.0	30.7	30.7	26.2	20.0	13.9	8.8	18.9
Mean minimum temperature	0.1	1.0	3.0	7.1	11.6	15.6	17.8	17.8	14.1	9.8	5.9	2.3	8.8
Maximum temperature	18.9	23.1	25.7	31.5	36.0	40.4	42.5	40.4	38.8	37.4	28.9	21.6	42.5
Minimum temperature	-15.8	-15.0	-11.8	-3.0	1.4	5.8	8.8	8.7	3.0	-3.4	-7.2	-11.1	-15.8

Table 4: Basic statistics of the temperatures (°C) in Tekirdağ

TEKİRDAĞ (17056) (°C)	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Mean temperature	4.9	5.5	7.3	11.7	16.7	21.1	23.7	23.9	20.3	15.7	11.3	7.3	14.1
Mean maximum temperature	8.1	9.0	11.0	15.7	20.6	25.3	28.1	28.3	24.5	19.5	14.8	10.5	18.0
Mean minimum temperature	2.0	2.5	4.1	8.1	12.7	16.7	19.1	19.4	16.2	12.1	8.2	4.4	10.5
Maximum temperature	23.9	24.7	28.1	34.3	33.8	40.2	38.4	39.4	39.7	35.1	28.2	23.5	40.2
Minimum temperature	-13.5	-13.3	-10.4	-1.2	2.7	8.6	10.9	11.0	3.7	-1.8	-7.8	-10.9	-13.5

3. Methodology

The Runs test is employed to determine the homogeneity of the data before analysis. Mann-Kendall (MK), Spearman's Rho (SR), Theil-Sen, and Şen tests are generally used non-parametric statistical monotonic trend tests. These methods have two main advantages. First, as non-parametric tests, they do not require the data to follow a normal distribution. Second, they are less sensitive to abrupt changes caused by an inhomogeneous time series. As with most statistical analyses, hypothesis testing was performed using confidence levels of 1%, 5%, and 10%. In these tests, the null hypothesis (H_0) assumes the absence of a trend, while the alternative hypothesis (H_1) assumes the presence of a trend. MK, Şen and linear trend tests were applied in this study, and more detail information can be seen below.

3.1. Homogeneity test

The Runs test is one of the most commonly used tests to determine the homogeneity of the data. In Eq. 1, Z is the test value, n is the number of data, N_a is the number of data smaller than the median, N_b is the number of data larger than the median, and r is the number of runs. If the calculated Z value is greater than the z test value of the two-tailed hypothesis test at a 95% confidence interval, H_0 is rejected; therefore, the H_1 hypothesis is accepted. It can be said that the examined time series is a statistically significant inhomogeneous series. It means that the homogenous datasets can be safely used in modeling, frequency analysis, and other statistical methods (Wald & Wolfowitz 1940; Swed & Eisenhart 1943; Güçlü et al., 2025)

$$Z = \frac{r - \frac{2*N_a*N_b}{N_a+N_b} - 1}{\sqrt{\frac{2*N_a*N_b(2*N_a*N_b-N)}{N^2(N-1)}}} \quad (1)$$

3.2. Trend tests

3.2.1 Mann-Kendall (MK) trend test

The MK test is a nonparametric statistical tool for determining whether a time series shows a monotonic upward or downward trend. Additional details can be obtained from previous studies (Mann, 1945; Kendall, 1975; Kottegoda, 1980; Gumus et al., 2022).

3.2.2 Şen trend test

Şen (2017) proposed a new procedure for this test was following an earlier graphical method introduced by Şen (2012, 2014). In the first phase of the procedure, a hydro-meteorological time series was divided into two equal halves in ascending order. After determining critical value (CL), comparison was performed using Equations 2-6 within the framework of the hypothesis test.

$$E(s) = \frac{2}{n}\left[E(\overline{y_2}) - E(\overline{y_1})\right] \quad (2)$$

$$\sigma_s{}^2 = \frac{4}{n^2}\left[E(\overline{y_2}^2) - 2E(\overline{y_2}\overline{y_1}) - E(\overline{y_1}^2)\right] \quad (3)$$

$$\rho_{\overline{y_2}\overline{y_1}} = \frac{E(\overline{y_2}\overline{y_1}) - E(\overline{y_2}) - E(\overline{y_1})}{\sigma_{\overline{y_2}}\sigma_{\overline{y_1}}} \quad (4)$$

$$\sigma_s = \frac{2\sqrt{2}}{n\sqrt{n}}\sigma\sqrt{\left(1 - \rho_{\overline{y_2}\overline{y_1}}\right)} \quad (5)$$

$$CL_{(1-\alpha)} = 0 \mp s_{critical}\sigma_s \quad (6)$$

$\overline{y_1}$ presents mean of the first half of the ordered data, $\overline{y_2}$ presents the mean of the second half of the ordered data; ρ denotes the correlation between them; s is the slope value; α indicates the significance levels (%10, %5, and %1); n is the number of data; σ is the standard deviation; σ_s is slope standard deviation, and $s_{critical}$ signifies the z critical values in the one-way hypothesis at 95% confidence interval. If the slope value (s) is outside the lower and upper confidence limits, the alternative hypothesis, H_1, is accepted. H_0, which is the null hypothesis, is accepted. The slope value (s) can be increasing (+) or decreasing (-) (Mann, 1945; Kendall, 1975; Helsel & Hirsch, 2002; Şen, 2014, 2017; Ay, 2022a, b).

4. Results and discussion

Spatial and temporal variations in air temperatures in the TP were evaluated using data covering the period from 1960 to 2024 (approximately 65-year). When formulating the hypotheses for the analyses, the critical Z-table values were taken into consideration, and H_0 hypothesis was determined as the null hypothesis. H_1 hypothesis was determined as the alternative hypothesis. The seasonal component in the monthly time series was evaluated, and the lag-1 autocorrelation coefficients were calculated after removing seasonality. Trend analyses were applied on these data series. As a result of these additional analyses, the main findings were given in terms of both trend direction and statistical significance. The calculated z values were smaller than the $z_{critical}$ (±1.96, %5 two-tailed hypothesis test) according to the Runs test' results; therefore, maximum, mean, and minimum monthly temperature of all stations had homogeneous time series. The time series plots illustrating the monthly maximum, mean, and minimum temperature values are presented in Figures 3, 4, and 5, respectively. These figures provide a visual representation of the temporal variability and long-term behaviour of the temperature records over the study period. The linear functions fitted to each dataset, as shown in the corresponding graphs, clearly indicate that all three-temperature series display a consistent upward tendency over time (1960-2024). This suggests a general warming pattern reflected across maximum, mean, and minimum temperature observations. According to the linear functions in the graphs, it is seen that the line of all data series exhibits an increasing trend. Whether the trend is statistically significant or not can be assessed according to the Student's t-test values. Table 5 indicates that only Kırklareli's monthly maximum temperature ($t_{cal.}$= +1.85) had a statistically insignificant increasing trend, while all other stations showed significant increases, with t values above the critical value (±1.97) according to the Student's t-test table.

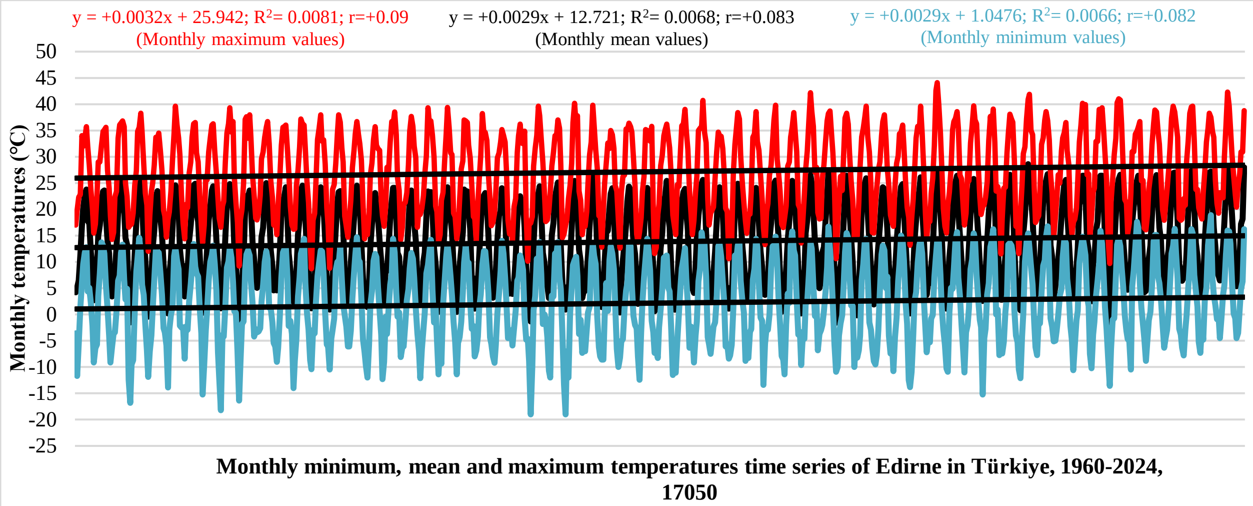

Figure 3: Monthly minimum, mean and maximum temperatures time series of Edirne in Türkiye

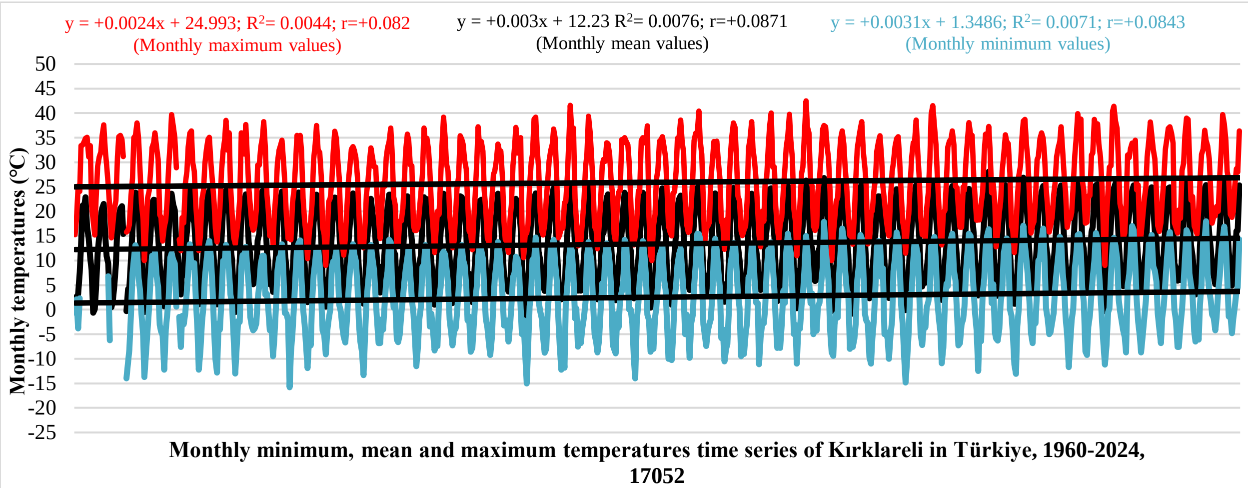

Figure 4: Monthly minimum, mean and maximum temperatures time series of Kırklareli in Türkiye

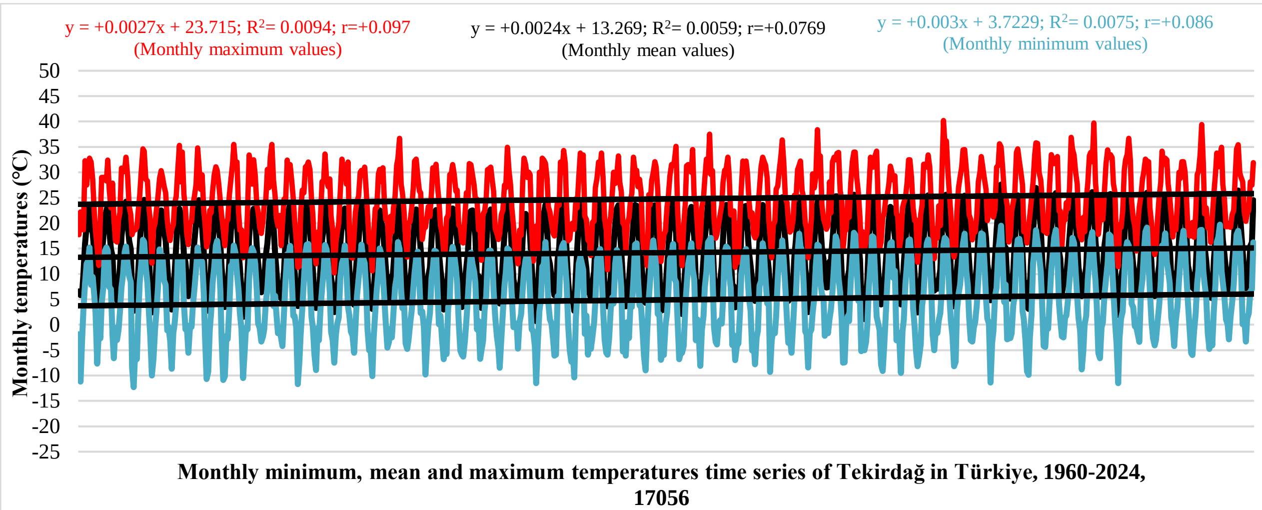

Figure 5: Monthly minimum, mean and maximum temperatures time series of Tekirdağ in Türkiye

Table 5: Student's t-test results for all stations according to the linear functions in the figures (3, 4, and 5)

Stations, dates and coordinates		Data	N	The linear functions of the time series data	Hypothesis H_1 or H_0	Trend statistically significant or not (+, -)	The calculated t value
Edirne-17050 (1960-2024)	41°67'67"N 26°55'08"E	Monthly maximum temperature (°C)	774	y = +0.0032x + 25.942 R^2= 0.0081 (r= +0.09)	H_1	*Yes (+)*	*+2.51*
		Monthly mean temperature (°C)	774	y = +0.0029x + 12.721 R^2= 0.0068 (r= +0.083)	H_1	*Yes (+)*	*+2.30*
		Monthly minimum temperature (°C)	774	y = +0.0029x + 1.0476 R^2= 0.0066 (r= +0.082)	H_1	*Yes (+)*	*+2.27*
Kırklareli-17052 (1960-2024)	41°73'82"N 27°21'78"E	Monthly maximum temperature (°C)	770	y = +0.0024x + 24.993 R^2= 0.0044 (r= +0.067)	**H_0**	**Statistically insignificant No (+)**	**+1.85***
		Monthly mean temperature (°C)	771	y = +0.003x + 12.23 R^2= 0.0076 (r= +0.0871)	H_1	*Yes (+)*	*+2.42*
		Monthly minimum temperature (°C)	744	y = +0.0031x + 1.348 R^2= 0.0071 (r= +0.0843)	H_1	*Yes (+)*	*+2.30*
Tekirdağ-17056 (1960-2024)	40°95'85"N 27°49'65"E	Monthly maximum temperature (°C)	774	y = +0.0027x + 23.715 R^2= 0.0094 (r= +0.097)	H_1	*Yes (+)*	*+2.71*
		Monthly mean temperature (°C)	774	y = +0.0024x + 13.269 R^2= 0.0059 (r= +0.0769)	H_1	*Yes (+)*	*+2.14*
		Monthly minimum temperature (°C)	774	y = +0.003x + 3.7229 R^2= 0.0075 (r= +0.086)	H_1	*Yes (+)*	*+2.42*

**$t_{critical}$ is ±1.97 according to the t-test table (N=770 and at 5% two-tailed hypothesis test). Trend is statistically insignificant at 5% two-tailed hypothesis test.*

The MK results can be seen in Table 6. Monthly temperatures recorded at all stations except for monthly maximum temperature of Kırklareli had an increased and were statistically significant at %5 significance level (α=5% and two-tailed test). Table 7 displays the results of the Şen trend test. All stations' z values were out of upper and lower critical limits for the 95% confidence interval (α=5% and one-tailed test); therefore, the H_1 hypothesis was accepted in all data. Table 8 displays an evaluation of the results of the tests. Table 8 indicates the Şen test provided same results with the MK and linear trend tests except for monthly maximum temperature of Kırklareli which is a statistically insignificant increasing trend. The trend tests have similar results for the TP and other previous studies (Türkeş et al., 2002; Türkeş & Sümer, 2004; Türkeş et al., 2016). In addition, the drought results and current TP conditions were compared with the findings of this study. It was observed the results of trend tests are consistent with the findings of the drought studies (Aksoy et al., 2008; Gönençgil, 2012; Altunay, 2016; Azlak & Şaylan, 2019; Eroğlu, 2021; Eroğlu, 2024). In other words, it is possible to say that the time of return interval of drought periods has shorten generally because all the stations have a statistically significant increasing trend except for monthly maximum temperature of Kırklareli. Moreover, magnitude of the significant trends found in this study can change according to the locations to locations in the region. Therefore, evapotranspiration (ET_0) values related to the air temperatures are generally increasing, which can be related with the drought cases of the TP. The results were also tested by querying society and the previous studies (Sırdaş & Sen, 2003; Oruc & Yalcin, 2021) in the TP. They specified that the region was hotter than before, rainfall was irregular and less than normal values, and the yield of products in the agricultural sector has been changing negatively (TOB, 2018, 2019, 2023a, b).

The rapid population growth and urbanization in the provinces have led to significant changes in land use and surface structure; these changes have caused natural surfaces to be transformed into artificial surfaces such as concrete and asphalt, creating effects on the local climate. The previous studies indicate that urbanization and increasing population density support the urban heat island, which raises air temperatures, particularly in urban areas compared to surrounding rural areas; this leads to increases in surface and air temperatures in regions with increased building density (Albut et al., 2007; Bağdatlı & Bellitürk, 2016; Oruc & Yalcin, 2021; Deveci & Konukcu, 2024; Eroğlu, 2024). Such cases are demonstrated in research conducted in Türkiye, showing that increasing population and changing land cover affect microclimatic characteristics, making temperatures higher in urban areas compared to rural areas. Furthermore, climate studies related to the TP reveal that regional temperature increase trends, which are compatible with this study, along with climate change, show that urbanization is altering the local climate; increased population and construction resulting from urbanization cause temperatures to rise in the TP, leading to more pronounced local microclimates and heat wave events. Studies indicate that rising temperatures and changing climate conditions in the TP have already influenced agricultural practices and crop patterns. Increased evapotranspiration, warmer conditions, and altered precipitation patterns affect water availability and crop water requirements, leading to shifts in the suitability and management of traditional crops such as wheat, canola, and sunflower. These climatic changes also influence the timing and methods of vegetable cultivation, prompting farmers to adjust sowing dates, crop selection, and agricultural practices in order to sustain productivity under evolving climatic conditions. Such evidences highlight the need for targeted adaptation strategies to maintain regional agricultural output in response to both urbanization-induced warming and broader climate change/variability trends (TOB, 2018, 2019, 2023a, b).

Table 6: Results of the MK trend test for the monthly maximum, mean and minimum temperatures (°C) in the Trakya Peninsula (TP) in Türkiye (1960-2024)

Parameters	Edirne-17050 (1960-2024)			Kırklareli-17052 (1960-2024)			Tekirdağ-17056 (1960-2024)		
	Monthly maximum temperature	Monthly mean temperature	Monthly minimum temperature	Monthly maximum temperature	Monthly mean temperature	Monthly minimum temperature	Monthly maximum temperature	Monthly mean temperature	Monthly minimum temperature
Data range	1960- 2024 (°C)	1960- 2024 (°C)	1960- 2024 (°C)	1960-2024 (°C)	1960-2024 (°C)	1960-2024 (°C)	1961-2024 (°C)	1960-2024 (°C)	1960-2024 (°C)
The number of data	774	774	774	770	771	744	774	774	774
Calculated ± Z value	+2.28	+2.17	+2.05	**+1.43***	+2.16	+2.07	+2.46	+2.07	+2.09
Z critical value (α=0.05 and two-tailed test)	±1.96	±1.96	±1.96	±1.96	±1.96	±1.96	±1.96	±1.96	±1.96
Type of trend (+, -)	Increasing trend(+)	Increasing trend(+)	Increasing trend(+)	**Statistically insignificant No trend (+)**	Increasing trend(+)	Increasing trend(+)	Increasing trend(+)	Increasing trend(+)	Increasing trend(+)
H_0, null hypothesis	Rejected	Rejected	Rejected	Accepted	Rejected	Rejected	Rejected	Rejected	Rejected

**Trend is statistically insignificant at 5% two-tailed hypothesis test ($z_{critical}$ is of ±1.96).*

Table 7: Results of the Şen trend test for the monthly maximum, mean and minimum temperatures (°C) in the Trakya Peninsula (TP) in Türkiye (1960-2024)

Parameters	Edirne-17050-(1960-2024)			Kırklareli-17052- (1960-2024)			Tekirdağ-17056-(1960-2024)		
	Monthly maximum temperature	Monthly mean temperature	Monthly minimum temperature	Monthly maximum temperature	Monthly mean temperature	Monthly minimum temperature	Monthly maximum temperature	Monthly mean temperature	Monthly minimum temperature
Unit	°C	°C	°C	°C	°C	°C	°C	°C	°C
The number of data, n	774	774	774	770	771	744	774	774	774
Slope, s (+ or -)	+0.0025	+0.0021	+0.0021	+0.0022	+0.0021	+0.0022	+0.0025	+0.0017	+0.0023
Z critical value (α=0.05 and one-tailed test)	±1.645	±1.645	±1.645	±1.645	±1.645	±1.645	±1.645	±1.645	±1.645
Hypothesis (H_0 or H_1)	H_1	H_1	H_1	H_1	H_1	H_1	H_1	H_1	H_1
Decision (Yes or No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Type of trend (Upward (+), downward (-) or no trend)	Upward (+)	Upward (+)	Upward (+)	Upward (+)	Upward (+)	Upward (+)	Upward (+)	Upward (+)	Upward (+)

Before some cases the results of climate change/variability in nature reach a tipping point, the necessary intangible and tangible actions should be taken all over the world. Everything has been known and discussed in the environmental and climate meetings held up to now (UNFCC, The European Climate Change Programme (ECCP), Conference of Parties (COP), IPCC, Kyoto, Paris Climate Agreement) but that is why it is high time we should conduct more detailed research in these arguments. While the decisions taken at the meetings focused on reducing greenhouse gas emissions, it can be seen that these decisions underwent a paradigm shift in the following years as adaptation to climate change. At this point, answers to the questions of what can be done to adapt to the changing climate/variability are found, while new strategies are also put forward. For example, the states need to reduce consumption with various regulations (e.g., carbon tax, if any), use resources economically, increase individual actions and make these more effective all over the world (Batan & Toprak, 2015; TOB, 2023a, b; Yıldız, 2024). Consequently, the amount of greenhouse gases in a region, waste management, water usage, and other significant environmental indicators should be closely monitored. Moreover, we should act with common future and sense. It can be said that if the increase in greenhouse gases and the motion of the world continues in this way, our generations will have to deal with more confusion, chaos, and disease in the future. Instead of saying that air temperature has a direct effect on climate variability and change, it would be more accurate to calculate how much climate change/variability affects the system globally and to determine how much climate change/variability affects which parts of the environment because land, soil uses, and the status of vegetation should also be considered and interpreted together in addition to the other variables listed above. Otherwise, there will be an incomplete phase for all systems.

Table 8: Comparison of the results of the trend tests for the monthly maximum, mean and minimum temperatures (°C) in the Trakya Peninsula (TP) in Türkiye (1960-2024)

Stations, dates and variables		Trend types for the annual data of the monthly temperature (°C), 1960-2024					
		Linear trend, the calculated t value	**Statistically significant or not (+, -)**	**MK trend test**	**The calculated z values**	**Şen trend test**	**The calculated slope values**
Edirne-17050-(1960-2024) (°C)	Monthly maximum temperature	*2.51*	Yes (+)	Increasing trend (+)	Statistically significant	(+)	Statistically significant
	Monthly mean temperature	*2.30*	Yes (+)	(+)	Statistically significant	(+)	Statistically significant
	Monthly minimum temperature	*2.27*	Yes (+)	(+)	Statistically significant	(+)	Statistically significant
Kırklareli-17052-(1960-2024) (°C)	Monthly maximum temperature	**1.85***	**Statistically insignificant No (+)**	**No Trend (+)**	**Statistically insignificant (+1.43)****	**Increasing Trend (+)**	**Statistically significant**
	Monthly mean temperature	*2.42*	Yes (+)	(+)	Statistically significant	(+)	Statistically significant
	Monthly minimum temperature	*2.30*	Yes (+)	(+)	Statistically significant	(+)	Statistically significant
Tekirdağ-17056-(1960-2024) (°C)	Monthly maximum temperature	*2.71*	Yes (+)	(+)	Statistically significant	(+)	Statistically significant
	Monthly mean temperature	*2.14*	Yes (+)	(+)	Statistically significant	(+)	Statistically significant
	Monthly minimum temperature	*2.42*	Yes (+)	(+)	Statistically significant	(+)	Statistically significant

**$t_{critical}$ is of ±1.97 according to the t-test table (N=770 and at 5% two-tailed hypothesis test). Trend is statistically insignificant at 5% two-tailed hypothesis test. **: Trend is statistically insignificant at 5% two-tailed hypothesis test ($z_{critical}$ is of ±1.96).*

On the other hand, while there are numerous published studies on the dangerous effects of climate change, there are a few studies done on positive effects of climate change. At this point, climate variability could have positive effects in one region and negative effects in another region. Benefits of climate change or variability may include longer growing seasons and milder temperatures, which could help agriculture (e.g., sugarcane, crops) and other sectors such as industries (e.g., electricity, natural gas) and energy. Rising temperatures may lead to lower heating needs and expanded tourism potential in regions such as the Arctic, Antarctic, Siberia, and other frozen parts of the world. In another example, snow that fell in the same region in the previous winter season fell in the higher altitude areas in the same region. Sunshine can also gain solar power, and strong winds can generate wind and wave powered energy. As another example, climate change/variability may also cause people/creatures living in cold regions to migrate to warmer regions. These situations can also be seen in the all regions; however, these issues need to be examined in detail on site (Friedlingstein et al., 2001; Albut et al., 2007; Aydinalp&Cresser, 2008; Tol, 2009; Batan & Toprak, 2015; Pearce-Higgins et al., 2015; USGCRP, 2017; Hoegh-Guldberg et al., 2018; Ruan et al., 2018; Cavus et al., 2021). However, the exact opposite cases of these situations can also be seen. Hence, some warming locations may start to cooling. In this case, the issues mentioned above may change the direction for possible situations (TOB 2023a, b) for each region in the world.

5. Conclusions

The monthly minimum, mean, and maximum temperature time series in the TP in Türkiye were scrutinised by using the MK, Şen, and linear trend test, as presented in Tables, 5, 6, 7 and 8. The statistically significant trends were detected in all air temperature series, except for the monthly maximum temperature at Kırklareli station, according to the linear trend test at the 5% level with a two-tailed hypothesis. According to the MK, the monthly temperatures in the stations, except the monthly maximum temperature at Kırklareli, exhibited statistically significant increases at 5% significance level (α=0.05 (5%), two-tailed test). Similarly, the Şen trend test indicated statistically significant increases in the monthly minimum, mean, and maximum temperatures at all stations at 5% significance level. These significant upward trends in air temperature correspond to an increased frequency of drought periods in Edirne, Kırklareli, and Tekirdağ. In line with this, the water levels and quality in the region's dams reached critical levels, which can be attributed to increased evaporation and/or reduced precipitation. Other atmospheric factors, including wind, humidity, radiation, and overall evaporation, also contribute to these conditions. These significant increases in the minimum, mean, and maximum temperatures have a direct impact on regional activities.

To mitigate these impacts, both regional and international solutions should be pursued. Adaptation strategies may include population planning, the implementation of recycling systems, changes in crop patterns, rainwater harvesting techniques, and the construction of groundwater storage facilities. These measures represent long-term and critical interventions for the TP (Albut et al., 2007; Aksoy et al., 2008; Deveci, 2015; Azlak & Şaylan, 2019; Candar et al., 2019; TOB, 2018, 2019; IPCC, 2021; Şen, 2022; Eroğlu, 2022; Dağ & Ay, 2024; Deveci & Konukcu, 2024; Jensen et al., 2024; MGM, 2024; Xiong & Yang, 2025). Furthermore, the conclusions of this present study are projected to supply valuable insights for stakeholders in the region, particularly regarding the interpretation of air temperature data recorded between 1960 and 2024. In addition to the results discussed above, the next inferences can be given:

1. This present study provides significant results based on historical climate data, indicating an increasing trend in the air temperature. These observed trends are consistent with the climate scenarios projected for the TP for the period 1960-2024.
2. To ensure reliability, these statistically significant increasing trends must be supported by evidence from field observations. For instance, declining agricultural yields in the region corroborate the observed increase in temperature increases (TOB, 2018, 2019, 2023a, b).
3. Addressing the question of whether air temperature in the TP has reached a tipping point involves consideration of complex underlying mechanisms. Although current evidence does not allow us to assert that temperatures in the region have reached a climatic tipping point, the results discussed above do reveal a clear upward trend in temperatures across the TP. To further substantiate these observations, it is necessary to analyse other relevant variables. Therefore, achieving a holistic understanding necessitates the consideration of additional variables, including precipitation, snowfall, relative humidity, soil moisture, atmospheric pressure, evaporation, surface winds, and solar radiation. Future studies should integrate these parameters to more robustly explain the climatic mechanisms operating over the TP.
4. Several ecological and natural processes, such as the nitrogen and carbon cycles, are altered as a result of rising temperatures. The cumulative effects of these changes enhance our understanding of climate variability and provide important visions into ecological sustainability for especially agricultural activities in the TP.

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References

Abbasnia, M., & Toros, H. (2020). Trend analysis of weather extremes across the coastal and non-coastal areas (A case study: Turkey). *Journal of Earth System Science., 129*, 95.

Acar, R. (2024). A comparison of the performance of different innovative trend assessment approaches for air temperature and precipitation data: an application to Elazıg Province (Turkey). *Journal of Water and Climate Change, 15(3)*, 1417-1437.

Acar, R., Akbas, E., Koycegiz, C., Esit, M. (2025). Rainfall trends in the transboundary Euphrates-Tigris River Basin. *Environ Earth Sci., 84*, 473.

AghaKouchak, A., Chiang, F., Huning, L. S., Love, C.A., Mallakpour, I., Mazdiyasni, O., Moftakhari, H., Papalexiou, S. M., Ragno, E., & Sadegh, M. (2020). Climate extremes and compound hazards in a warming world. *Annu Rev Earth Planet Sci., 48*, 519-548.

Akçay, F, Şan, M, Nacar, S, & Kankal, M. (2023). Annual Trends of Precipitation and Temperature in the Northwestern Part of Turkey Using Innovative Approaches: A Holistic and Partial Study. *Pure App Geoph., 180*, 3131-3156.

Aksoy, H., Unal, N.E., Alexandrov, V., Dakova, S., & Yoon, J. (2008). Hydrometeorological analysis of northwestern Turkey with links to climate change. *Int J Climatol., 28*, 1047-1060.

Albut, S., Istanbulluoglu, A., Konukcu, F., & Kocaman, I. (2007). Probable water crisis in Thrace and Istanbul in the near future and a sustainable strategy to overcome it. *Water Int., 32(4)*, 590-603.

Altunay, A. (2016). Investigation of climatological data in Turkey using Mann-Kendall and Şen trend method. [Master's Thesis, Çanakkale Onsekiz Mart University]. YÖK Ulusal Tez Merkezi. https://tez.yok.gov.tr/UlusalTezMerkezi.

Aslan, Z., Giden, F., Koyuncu, H., & Kalafat, A. (2016). İstanbul'un Asya ve Avrupa bölgeleri'nde hava sıcaklığı ve yağış miktarı değişimleri. *Doğal Afetler ve Çevre Dergisi, 2(1)*, 11-29.

Ay, M. (2021). Trend tests on maximum rainfall series by a novel approach in the Aegean region, Turkey. *Meteorol Atmos Phys., 133(4)*, 1041-1055.

Ay, M. (2022a). Trend of minimum monthly precipitation for the East Anatolia region in Turkey. *Theor Appl Climatol., 148*, 603-615.

Ay, M. (2022b, October 18-21). *Trends of monthly temperatures of Sivas in Turkey*. 10th ATMOS'22 (Symposium), Earth, climate, health and sustainability (Hybrid Presentation) [Konferans Bildirisi]. Poster Presentation (Online), Istanbul Technical University, İstanbul Turkey, October 18-21.

Ay, M. & Kişi, Ö. (2016). Debi ve sediment değişkenlerinin trend analizi. Dicle Üniversitesi Mühendislik Fakültesi Mühendislik Dergisi, 7(2), 169-180.

Aydinalp, C., & Cresser, M. S. (2008). The effects of global climate change on agriculture. *American-Eurasian J. Agric. & Environ. Sci., 3(5)*, 672-676.

Azlak, M. (2015). Possible effects of climate change on evaporation. [Master Thesis, Istanbul Technical University, Institute of Science, Istanbul, Turkey]. YÖK Ulusal Tez Merkezi. https://tez.yok.gov.tr/UlusalTezMerkezi.

Azlak, M., & Şaylan, L. (2019). İklim değişikliğinin Türkiye'de, Trakya bölgesinde referans evapotranspirasyona olan etkilerinin belirlenmesi. *Toprak Su Dergisi*, 77-85.

Bağdatlı, M. C., & Bellitürk, K. (2016). Water resources have been threatened in Thrace Region of Turkey. *Advances in Plants and Agriculture Research*, 4.

Bardsley, D. K., & Hugo, G. J. (2010). Migration and climate change: Examining thresholds of change to guide effective adaptation decision-making. *Population and Environment, 32,* 238-262.

Batan, M., & Toprak, Z. F. (2015). Positive effects of global climate change and the assessment in adaptation to climate change. *Dicle Üniversitesi Mühendislik Fakültesi, 6(2),* 93-102.

Black, R., Bennett, S. R. G., Thomas, S. M. & Beddington, J. R. (2011). Climate change: Migration as adaptation. *Nature, 478,* 447-449.

Blöschl, G., et al. (2019). Twenty-three unsolved problems in hydrology (UPH) – a community perspective. *Hydr Sci J., 64(10*), 1141-1158.

Blöschl, G., & Montanari, A. (2010). Climate change impacts-throwing the dice? *Hydrol. Process., 24,* 374-381.

Çamalan, G., Akgündüz, A. S., Çetin, S., & Doğan, H. (2021). *T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, Meteoroloji Genel Müdürlüğü, Türkiye Kuraklık Projeksiyonları.* Araştırma Dairesi Başkanlığı, Meteorolojik Afetler Şube Müdürlüğü, Ankara.

Candar, S., Alço, T., Yaşasın A. S., Korkutal, İ., Bahar, E. (2019). Türkiye Trakyası bağcılık iklim göstergelerindeki uzun süreli değişimlerin değerlendirilmesi. *COMU Journal of Agriculture Faculty, 7(2),* 259-268.

Cattaneo, C., Beine, M., Fro¨hlich, C. J., Kniveton, D., Martinez-Zarzoso, I., Mastroillo, M., Millock, K., Piguet, E., & Schraven, B. (2019). Human migration in the era of climate change (V1). University of Sussex.

Cavus, Y., Eris, E., Aksoy, H., Burgan, H.I., Aksu, H., & Boyacioglu, H. (2021). Spatio-temporal analysis of precipitation-based drought indices in Kucuk Menderes River Basin, Turkey, *EGU General Assembly 2021*, online, 19–30 Apr 2021, EGU21-1531.

Chagas, V. B. P., Chaffe, P. L. B. & Blöschl, G. (2024). Drought-rich periods are more likely than flood-rich periods in Brazil. *Water Resources Research, 60,* e2023WR035851.

Ciftci, N. D., & Sahin, A. D. (2023). Temperature and precipitation extremes' variability in Turkey. *Meteo Atmos Phys., 135,* 40.

Dağ, M., & Ay, M. (2024). Yağmur suyu hasadı hesabı: Çorum ili örneği. *Doğal Afetler ve Çevre Dergisi*, *10(2),* 334-343.

Dabanlı, İ., Şen, Z., Yeleğen, M.Ö., Şişman, E., Selek, B., & Güçlü, Y.S. (2016). Trend assessment by the Innovative-Şen method. *Water Resources Management, 30,* 5193-5203.

Deveci, H. (2015). Modeling the effects of climate change on surface water resources, soil moisture, and crop yield in the Thrace Region. [Tekirdağ Namık Kemal University, Institute of Science, Doctorate Thesis]. 210 pages. YÖK Ulusal Tez Merkezi. https://tez.yok.gov.tr/UlusalTezMerkezi.

Deveci, H., & Konukcu, F. (2024). Modelling the effect of climate change on evapotranspiration in the Thrace region. *Atmosphere, 15(10),* 1188.

Díaz, S., et al. (2018). Assessing nature's contributions to people. *Science, 359,* 270.

Ercan, C., Abu, Arra, A., & Şişman, E. (2025). Investigation of precipitation and temperature trends using classical and innovative approaches with corresponding frequencies in Antalya Basin, Türkiye. *Phys and Chem of the Earth, 139,* 103958.

Erlat, E., & Güler, H. (2024). Assessment of changes in absolute extreme temperatures in the Mediterranean region using ERA5-Land reanalysis data. *Theor Appl Climatol., 155,* 9051-9066.

Eroğlu, İ. (2021). Meriç Nehri Havzası'nda sıcaklık ve yağış değerlerinin dönemsel trend analizi. *Avrupa Bilim ve Teknoloji Dergisi, 23,* 750-760.

Eroğlu, İ. (2022). Trakya Yarımadası'nda ortalama hava sıcaklıklarının trend analizi. *Social Sciences Studies Journal, 8(102),* 3121-3144.

Eroğlu, İ. (2024). Trend Analysis of Precipitation in the Thrace Peninsula. *Coğrafya Dergisi*, *47*, 165-182.

Friedlingstein, P., Bopp, L., Ciais, P., Dufresne, J.L., Fairhead, L., LeTreut, H., Monfray, P., & Orr, J. (2001). Positive feedback between future climate change and the carbon cycle. *Geophys. Res. Lett., 28,* 1543-1546.

Garbrecht, J. D. & Piechota, T.C. (2006). *Climate variations, climate change and water resources engineering.* ASCE Publications: Reston.

Gönençgil, B. (2012, October 11-14). *Climate characteristics of Thrace and observed temperature - Precipitation Trends.* The Balkans at a Crossroads: Evaluating Past, Reading Present, Imagining Future Tirana. Bekir Çınar (Ed). Conference Proceeding Book, 2: 80-95.

Gray, B. R., Lyubchich, V., Gel, Y.R., Rogala, J.T., Robertson, D.M., Wei, X. (2016). Estimation of river and stream temperature trends under haphazard sampling. *Stat Methods Appl., 25,* 89-105.

Güçlü, Y.S. (2022). Trend stability identification by three-dimensional model. *Model. Earth Syst. Envir., 8*, 4333-4340.

Güçlü, Y.S., Acar, R., and Saplıoğlu, K. (2025). Seasonally adjusted periodic time series for Mann-Kendall trend test. *Physics and Chemistry of the Earth,* 138, Article 103848.

Gumus, V., Avsaroglu, Y., & Simsek, O. (2022). Streamflow trends in the Tigris River basin using Mann−Kendall and innovative trend analysis methods. *J Earth Syst Sci., 131*, 34.

Helsel, D. R., & Hirsch, R. M. (2002). *Statistical methods in water resources*. United States Geological Survey (USGS). Book 4, Chapter A3. U.S. Geological Survey, 522 pp.

Hoegh-Guldberg, O., Jacob, D., Taylor, M., Bindi, M., Brown, S., Camilloni, I. et al. (2018). *Impacts of 1.5°C Global Warming on Natural and Human Systems. https://www.ipcc.ch/sr15/chapter/chapter-3/*

IPCC, (2021). *Climate Change 2021: The Physical Science Basis.* Contribution of Working Group I to the Sixth Assessment Report of the IPCC [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, UK and NY, 2391 pp

Jensen, L., Gerdener, H., Eicker, A., Kusche, J., Fiedler, S. (2024). Observations indicate regionally misleading wetting and drying trends in CMIP6. Npj, *Clim Atmos Sci., 7*, 249.

Kadıoğlu, M. (2019). *Bildiğiniz Havaların Sonu.* 2. basım, 978-605-80178-7, 45101, 272 pp.

Kankal, M., & Uzlu, E. (2014). The status of transboundary rivers of Turkey. *Water Resources, 41*, 649-665.
Katz, R.W., & Brown, B.G. (1992). Extreme events in a changing climate: variability is more important than averages. *Climatic Change, 21*, 289-302.
Kendall, M.G. (1975). *Rank correlation methods.* Oxford University Press, New York.
Kibaroglu, A. (2021). *Turkey's water diplomacy: Analysis of its Foundations, Challenges and Prospects*.
Kottegoda, N.T. (1980). *Stochastic water resources technology*. Macmillan Press Ltd., London.
Kurnaz, M. L. (2023). İklim Değişikliği ve Uyum Süreçlerinde Türkiye. *Resilience, 7(1),* 199-208 (In Turkish).
Leroux, M. (2005). *Global Warming-Myth or Reality?* The Erring Ways of Climatology. Springer Praxis Books.
Li, B., & Rodell, M. (2023). How have hydrological extremes changed over the past 20 years? *Journal of Climate, 36(24),* 8581-8599.
Mann, H. B. (1945). Nonparametric tests against trend. *Econometrica, 13(3)*, 245-259.
Masoudi, M., Ghorbani, V. & Asrari, E. (2025). Evaluation of spatial warming trend in the Middle East using Geographic Information System. *Int. J. Environ. Sci. Technol., 22*, 4503-4510.
Meteoroloji Genel Müdürlüğü [MGM], (2024). *Sıcaklık ve yağış değerlendirmesi.* İklim ve Ziraî Meteoroloji Dairesi Başkanlığı Araştırma Dairesi Başkanlığı, Ekim 2024, 27 pages (In Turkish).
Miheretu, B. A. (2020). Temporal variability and trend analysis of temperature and rainfall in the Northern highlands of Ethiopia. *Physical Geography, 42(5),* 434-451.
Morovati, M., & Karami, P. (2024). Trend analysis of temperature and vegetation cover in the distribution range of Apis florea in Iran. *Int. J. Environ. Sci. Technol., 21*, 6745-6758.
Mudelsee, M. (2019). Trend Analysis of Climate Time Series: A review of methods. *Earth Sci. Rev., 190*, 310-322.
Oruc, S., & Yalcin, E. (2021). Extreme precipitation indices trend assessment over Thrace region, Turkey. *Acta Geophys. 69*, 307–321.
Öz, F.Y., Özelkan, E. & Tatlı, H. (2024). Comparative analysis of SPI, SPEI, and RDI indices for assessing spatio-temporal variation of drought in Türkiye. *Earth Sci Inform., 17*, 4473-4505.
Öztürk, İ. (2019). *TR21 Trakya Bölgesi'nde İklim Değişikliği ve Sürdürülebilir Tarımsal Üretim.* Trakya Tarımsal Araştırma Enstitüsü, Edirne.
Pathakoti, M., Santhoshi, T., Aarathi, M., Mahalakshmi, D.V., Kanchana, A.L., Srinivasulu, J., Raja Shekhar, S.S., Soni, K.V., Sesha Sai, M.V.R., Raja, P. (2021). Assessment of spatiotemporal climatological trends of ozone over the Indian region using machine learning. *Spatial Statistics, 43*, 100513.
Pearce-Higgins, J.W., Eglington, S.M., Martay, B., & Chamberlain, D.E. (2015). Drivers of climate change impacts on bird communities. *Journal of Animal Ecology, 84(4),* 943-954.
Romm, J. (2011). The next dust bowl. *Nature, 478*, 450-451.
Ruan, H. Y., Feng, P. Y., Wang, B., Xing, H. T., O'Leary, G., Huang, Z. G., Guo, H., & Liu, D. L. (2018). Future climate change projects positive impacts on sugarcane productivity in southern China. *Eur. J. Agron., 96*, 108-119.
Şaylan, L., Çaldağ, B., Bakanoğulları, F., Toros, H., Yazgan, M., Şen, O. & Özkoca, Y. (2011). Spatial variation of the precipitation chemistry in the Thrace Region of Turkey. *Clean Soil Air Water, 39*, 491-501.
Scheumann, W., Kibaroglu, A., & Kramer, A. (2011). *Trajectories of Turkey's water policy.* A. Kibaroglu, W. Scheumann and A. Kramer (Eds.).
Şen, Z. (2012). Innovative trend analysis methodology. *J of Hyd Eng., 17(9)*, 1042-1046.
Şen, Z. (2014). Trend identification simulation and application. *J of Hyd Eng., 19(3)*, 635-642.
Şen, Z. (2017). Innovative trend significance test and applications. *Theo and App Clima., 127*, 939-947.
Şen, Z. (2020a). Probabilistic innovative trend analysis. *International Journal of Global Warming, 20(2),* 93-105.
Şen, Z. (2020b). Water structures and climate change impact: A review. *Water Resour Manage., 34(13),* 4197-4216.
Şen, Z. (2022). *Renewable Energy, Climate Change and Water Resources.* Uyar, T.S., Javani, N. (eds) Renewable Energy Based Solutions. Lecture Notes in Energy, 87. Springer, Cham. pp 01-34.
Sırdaş, S., & Sen, Z. (2003). Spatio-temporal drought analysis in the Trakya region, Turkey. *Hyd Sci J., 48(5),* 809-820.
Sivapalan, M., & Blöschl, G. (2017). The growth of hydrological understanding: Technologies, ideas, and societal needs shape the field. *Water Resources Research, 53*, 8137-8146.
Stigter, T. Y. (2024). Groundwater, climate change, adaptation and mitigation. *Theor Appl Climatol., 155*, 9153-9155.
Swed, F.S., Eisenhart, C. (1943). Tables for testing randomness of grouping in a sequence of alternatives. *Ann. Math. Statist. 14(1),* 66-87.
Tarım ve Orman Bakanlığı (TOB), Su Yönetimi Genel Müdürlüğü (2018). *Meriç-Ergene Nehir Havzası Yönetim Planı, Havza Koruma Eylem Planlarının Nehir Havzası Yönetim Planlarına Dönüştürülmesi İçin Teknik Yardım*, TR2011/0327.21-05-01-001 (EuropeAid/134561/D/SER/TR).
Tarım ve Orman Bakanlığı (TOB), Su Yönetimi Genel Müdürlüğü, (2019). *TR21 Trakya Bölgesinde İklim Değişikliğinin Etkileri ve Uyum Stratejileri*, Yayın No: 2.08-027-0030/A-I, ISBN: 978-605-4265-57-2. Editörler: Fatih Konukcu, Selçuk Albut, Bahadır Altürk, Tekirdağ Namık Kemal Üniversitesi, Toprak Ofset-Tekirdağ, Türkiye.
Tarım ve Orman Bakanlığı (TOB), Su Yönetimi Genel Müdürlüğü, (2023a). *Climate Change Mitigation Strategy and Action Plan (2024-2030).* Ministry of Environment, Urbanization and Climate Change, Turkey. 230 pages.
Tarım ve Orman Bakanlığı (TOB), Su Yönetimi Genel Müdürlüğü, (2023b). *Climate Change Adaptation Strategy and Action Plan (2024-2030).* Ministry of Environment, Urbanization and Climate Change, Turkey. 261 pages.s
Tabari, H. (2019). Statistical analysis and stochastic modelling of hydrological extremes. *Water, 11(9),* 1861.
TAGEM, (2020). *2020 Tekirdağ Tarım Raporu,* Tekirdağ İl Tarım ve Orman Müdürlüğü, 57 pages.
Tatlı, H. (2015). Detecting persistence of meteorological drought via the Hurst exponent. *Meteo. Appl., 22(4),* 763-769
Tatlı, H., Dalfes, H.N., & Mentes, S.S. (2005). Surface air temperature variability over Turkey and its connection to large-scale upper air circulation via multivariate techniques. *Int. Journal of Climatology, 25(3),* 331-350.
Tol, R. S. J. (2009). The Economic effects of climate change. *Journal of Economic Perspectives, 23(2),* 29-51.
Toros, H. (2012). Spatio-temporal variation of daily extreme temperatures over Turkey. *Int J Clima., 32,*1047-1055.

Tuğrul, T., & Hinis, M.A. (2024). Trend analysis of hydrological and meteorological drought in Apa Dam, Türkiye. *Environmental Earth Science, 83*, 502.

Türkeş, M., & Sümer, U.M. (2004). Spatial and temporal patterns of trends and variability in diurnal temperature ranges of Turkey. *Theor Appl Climatol, 77*, 195-227.

Türkeş, M., Sümer, U. M., & Demir, İ. (2002). Re-evaluation of trends and changes in mean, maximum and minimum temperatures of Turkey for the period 1929-1999. *Int J Climatol., 22,* 947-977.

Türkeş, M., Turp, M. T. An, N., Ozturk, T., & Kurnaz, M. L. (2020). *Impacts of Climate Change on Precipitation Climatology and Variability in Turkey*. Springer Nature Switzerland AG 2020 N.B. Harmancioglu, D. Altinbilek (eds.), Water Resources of Turkey, World Water Resources 2, 10.1007/978-3-030-11729-0_14.

Türkeş, M., Yozgatlıgil, C., Batmaz, İ., İyigün, C., Koc, E. K., Fahmi, F. M., & Aslan, S. (2016). Has the climate been changing in Turkey? Regional climate change signals based on a comparative statistical analysis of two consecutive time periods, 1950-1980 and 1981-2010. *Climate Research, 70(1),* 77-93.

USGCRP, (2017). *Climate Science Special Report: Fourth National Climate Assessment*, Volume 1 [Wuebbles, D. J., D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, and T. K. Maycock (eds.)]. U.S. Global Change Research Program, USA, 470 pp.

Wald, A., &Wolfowitz, J. (1940). On a test whether two samples are from the same population. *Ann. Math Statist. 11*, 147-162.

Williams, P.A. (2011). *Turkey's Water Diplomacy: A Theoretical Discussion.* Kramer A, Kibaroglu A, Scheumann W.(eds) Turkey's Water Policy. Springer.

Xiong, J., & Yang, Y. (2025). Climate change and hydrological extremes. *Curr Clim Change Rep., 11*, 1.

Yıldırım, E. A. (2023). *Investigation of the effects of climate change on reference plant water consumption values in Tekirdağ conditions.* [Biosystems Engineering, Master Thesis, Namık Kemal Üniversitesi, 67 pages]. YÖK Ulusal Tez Merkezi. https://tez.yok.gov.tr/UlusalTezMerkezi

Yıldız, D. (2010). *Su'dan Savaşlar*. Truva Yayınları, 365 sayfa.

Yıldız, D. (2024). *Hydropolitics Newsletter, 63*, November 2024.

Yılmaz, M. U. (2023). Keşif kuraklık indeksi ve standartlaştırılmış yağış indeksi kullanılarak Kırklareli ilinde kuraklığın eğilimi ve zamansal değişkenliği. *Doğal Afetler ve Çevre Dergisi, 9(2),* 341-364.