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Research Article

Trend Analysis of Precipitation and Temperatures in the Black Sea Region Using the Innovative Trend Analysis

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Abstract: To assess the climatic characteristics of the Black Sea Region, trend analyses were performed with Innovative Trend Analysis (ITA) using precipitation and temperature data obtained from the General Directorate of Meteorology (MGM) for 13 provinces (Amasya, Artvin, Bolu, Giresun, Gümüşhane, Kastamonu, Ordu, Rize, Samsun, Sinop, Tokat, Trabzon and Zonguldak). The findings show that there is a general upward trend in both precipitation and temperature. However, the fact that the temperature trend shows a more pronounced increase than precipitation increases the likelihood that the Black Sea Region will face drought risk in the future. Graphical analysis reveals that Rize, Samsun, Sinop, and Trabzon stations show a steady upward trend in precipitation data. Although the graph of Tokat station does not show a clear trend, statistical analysis shows a low increasing trend. On the other hand, temperature trend analyses show a clear and significant increasing trend in all stations, which is clearly demonstrated in the graphs. This finding emphasizes that the temperature increase in the region is widespread and significant. The fact that the precipitation in Tokat station is almost in a constant trend while the temperature is in a significantly increasing trend indicates that important measures should be taken in terms of drought risk. The study provides important outputs for future studies, local administrators and decision-makers.

Keywords: Black sea region, temperature, trend analysis, precipitation, innovative trend analysis

Araştırma Makalesi

Karadeniz Bölgesinin Yenilikçi Şen Yöntemi Kullanılarak Yağış ve Sıcaklıklarının Trend Analizi

Öz: Karadeniz Bölgesi'nin iklimsel özelliklerini değerlendirmek amacıyla 13 il (Amasya, Artvin, Bolu, Giresun, Gümüşhane, Kastamonu, Ordu, Rize, Samsun, Sinop, Tokat, Trabzon ve Zonguldak) için Meteroloji Genel Müdürlüğü (MGM)'nden temin edilen yağış ve sıcaklık verileri kullanılarak Yenilikçi Şen Yöntemi (ITA) ile trend analizleri gerçekleştirilmiştir. Bulgular hem yağış hem de sıcaklıkta genel bir artış eğilimi olduğunu göstermektedir. Ancak, sıcaklık eğiliminin yağışa göre daha belirgin bir artış göstermesi, Karadeniz Bölgesi'nin gelecekte kuraklık riskiyle karşı karşıya kalma olasılığını artırmaktadır. Grafiksel analiz, Rize, Samsun, Sinop ve Trabzon istasyonlarının yağış verilerinde istikrarlı bir artış trendi gösterdiğini ortaya koymaktadır. Tokat istasyonu grafiği, belirgin bir trend göstermese de istatistiksel analizler düşük bir artış eğilimi olduğunu göstermektedir. Sıcaklık trend analizleri ise tüm istasyonlarda belirgin ve önemli bir artış eğilimi tespit etmiş, bu durum grafiklerle açıkça ortaya konmuştur. Bu bulgu, bölgedeki sıcaklık artışının yaygın ve belirgin olduğunu vurgulamaktadır. Tokat istasyonunda yağışın neredeyse sabit bir trendde seyrederken, sıcaklığın belirgin bir artış eğiliminde olması, kuraklık riski açısından önemli tedbirlerin alınması gerektiğini işaret etmektedir. Çalışma, gelecekte yapılacak çalışmalara, yerel yöneticilere ve karar vericilere önemli çıktılar sunmaktadır.

Anahtar Kelimeler: Karadeniz bölgesi, sıcaklık, trend analizi, yağış, yenilikçi şen yöntemi

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1. Introduction

The Black Sea Region is located in the north of Turkey and attracts attention with its natural beauties, biodiversity, and economic potential. Agriculture, fisheries, tourism, and energy sectors have an important place in the region [1]. However, climate change and related environmental factors directly affect economic activities and living conditions in the region. Therefore, a detailed analysis of climate data in the Black Sea Region is of great importance for determining sustainable development and environmental management strategies [2].

In recent years, urban floods have been occurring due to factors such as the increase in impervious areas with urbanization and short-term and heavy rainfall [3], [4]. In addition to the frequent occurrence of such disasters in the Black Sea Region, the region with the highest rainfall in Turkey, increasing temperatures with climate change also increase the risk of drought. Therefore, it is very important to determine the trends of precipitation and temperature along with drought analysis of the region. There are many methods in the literature for trend analysis. One of them is ITA. ITA is a modern method used to detect and analyze trends in time series data. ITA provides more flexible and sensitive results than traditional trend analysis methods [5]. This method has a wide range of applications in various fields such as climate change studies, water resources management, agricultural productivity, and environmental analysis.

The main purpose of ITA is to make predictions about the trends of data sets by determining the temporal changes of data at certain time intervals. In doing so, it provides analysis results in two different methods: the graphical method and the statistical method. The ITA method is especially preferred for analyzing long-term meteorological data. Drought analysis was performed using precipitation data measured between 1929-2016 in Diyarbakır. Drought index values were determined at 1, 3, 6, and 12-month time scales with the Standardized Precipitation Index. Drought trends were analyzed using ITA and the driest periods were determined as 8, 18, 21 and 53 months in 1, 3, 6, and 12-month time scales, respectively. As a result of the analysis, it was found that extreme dry periods have decreased in recent years and there is a tendency to decrease by more than 5% in moderately humid periods [6]. Monthly evaporation data from Gaziantep, Şanlıurfa, and Mardin were analyzed by the Mann-Kendall test and ITA. At Şanlıurfa station, significant increasing trends were detected at 95% confidence intervals in May and September and 90% confidence intervals in October. In May, this increase was calculated as 0.98%/year. The ITA method showed the presence of trends at low, medium, and high values. As a result, it was determined that the ITA method can be an alternative to monotonic trend analysis with its ease of calculation and ability to present graphical results [7]. Monthly and annual streamflow drought indices of 7 streamflow observation stations in the Yeşilırmak basin were trend analyzed. In the analyses performed using the Mann-Kendall, ITA, and Thiel-Sen Approach, trend-free pre-whitening was applied to remove serial dependencies. In the results evaluated according to 1% and 5% significance levels, it was observed that ITA was more sensitive and graphically superior compared to the Mann-Kendall test. The study showed that increasing hydrological drought trends dominate in the region [8]. Using monthly precipitation data from nine meteorological stations in the Tigris Basin, drought analysis was performed with the Standardized Precipitation Index at time scales of 3, 6, 12, and 24 months. In the trend analysis with ITA, the longest dry period was observed at the Cizre station with 158 months in the SYI-24time scale. The highest drought rate was determined as 58% at Yüksekova station in SYI-12. In addition, a "very strong" decreasing trend was detected at Maden station on all time scales [9]. Temperature trends of 14 provinces in the Eastern Anatolia Region were analyzed and Mann-Kendall test and ITA were used. According to the results of the analysis, a positive trend was found in 12 provinces and a downward trend in Erzurum. No trend was found in Bitlis at a 95% confidence interval. The results of the three methods largely supported each other within a 95% confidence interval [10].

This study aims to determine the climatic trends of the Black Sea Region by using annual average temperature and precipitation data between 1962 and 2023. This analysis using ITA aims to reveal the temporal dynamics of climate changes in the region. The datasets to be used in the study were obtained from MGM and this dataset includes annual average temperature and precipitation data. In the analysis process, it is aimed to identify trends in temperature and precipitation data, to evaluate the statistical significance of these trends, and to provide predictions about the future climatic dynamics of the region. The findings will contribute to the development of sustainable agriculture, water resources management, and environmental protection policies in the Black Sea Region. It will also shed light on the strategic planning necessary for the adaptation of the region to climate change. In this context, the results of the study are expected to provide important information for decision-makers and policymakers in the region.

2. Materyal ve Metot

2.1. Study area

In this study, the provinces of Amasya, Artvin, Bolu, Bolu, Giresun, Giresun, Gümüşhane, Kastamonu, Ordu, Rize, Samsun, Samsun, Sinop, Tokat, Trabzon and Zonguldak in the Black Sea Region were determined as the study area to perform trend analysis. In this context, total precipitation and average temperature data for the monthly time period between 1962-2023 were obtained from MGM. The locations of the provinces and meteorological observation stations determined as study areas in Turkey are given in Figure 1.

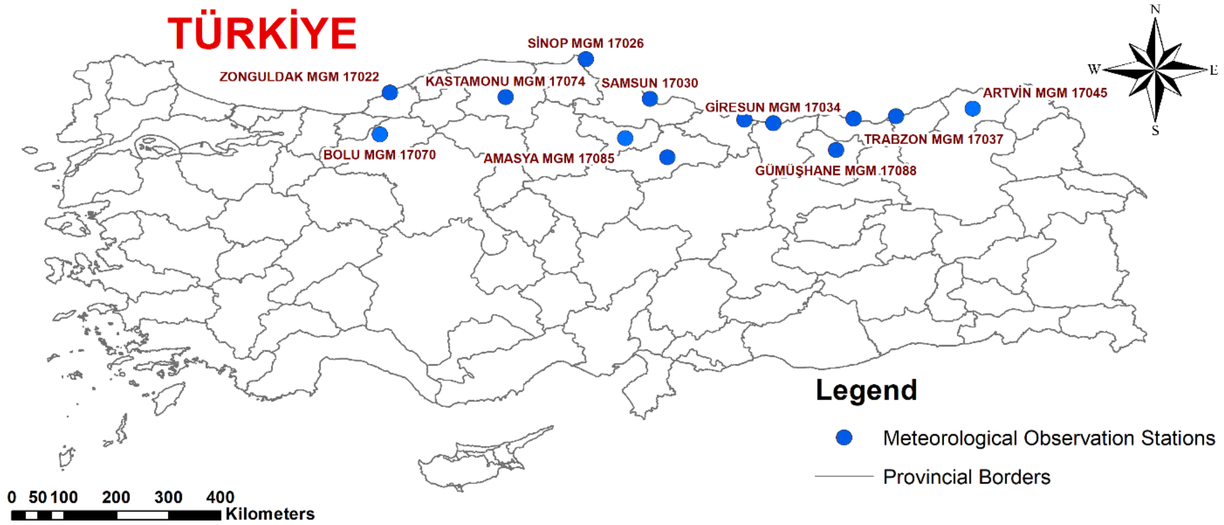


Figure 1. Black Sea region and meteorological observation stations

The number, basin, and altitude values of the meteorological observation stations are shown in Table 1.

Table 1. Characteristics of Meteorological Observation Stations

Station Number	Station name	Basin name	Station Altitude
17085	Amasya	Yeşilırmak	409
17045	Artvin	Çoruh	613
17070	Bolu	Batı Karadeniz	743
17034	Giresun	Doğu Karadeniz	38
17088	Gümüşhane	Doğu Karadeniz	1,216
17074	Kastamonu	Kızılırmak	800
17033	Ordu	Doğu Karadeniz	5
17040	Rize	Doğu Karadeniz	3
17030	Samsun	Yeşilırmak	4
17026	Sinop	Batı Karadeniz	32
17086	Tokat	Yeşilırmak	611
17037	Trabzon	Doğu Karadeniz	25
17022	Zonguldak	Batı Karadeniz	135

2.2. ITA

In this study, the ITA method proposed by Şen [2] is used to perform trend analysis. The main advantage of ITA, unlike other trend analyses, is that it does not require any assumptions or control of the distribution [11], [12]. In addition, ITA is widely used as it allows to identify in which region the trends are concentrated with a graphical technique [13]. The main purpose of ITA is to estimate the trends of data belonging to the same time series. The time series is divided into two equal periods, the first half-time series and the second half-time series. The data sets of both half-time series are sorted from smallest to largest. The sorted data set of the first half-time series is positioned on the x-axis in the coordinate system and the sorted data set of the second half-time series is positioned on the y-axis in the coordinate system. And then the x=y line is drawn. According to whether the marked data sets are above or below this line, predictions such as decreasing, increasing, or no trend can be made [14].

ITA's graphical method process steps are as follows;

- Time series with n number of data

$(x_1, x_2, .., x_n)$, $\{y_{1,n/2}\}$=$\{x_1, x_2, .., x_{n/2}\}$ ve $\{y_{2,n/2}\}$=$\{x_{n/2+1}, x_{n/2+2}, .., x_n\}$

is separated according to two simultaneous times.

- The data are sorted from smallest to largest;

  $\{r_1\}$=$\{$min$(y_{1,n/2})$, . . . , y_i, . . . , max$(y_{1,n/2})\}$ (1 < i < n/2)

  $\{r_2\}$=$\{$min$(y_{2,n/2})$, . . . , y_j, . . . , max$(y_{2,n/2})\}$ (1 < j < n/2)

  $\{r_1\}$=$\{$maks$(y_{1,n/2})$, . . . , y_i, . . . , min$(y_{1,n/2})\}$ (1 < i < n/2)

  $\{r_2\}$=$\{$maks$(y_{2,n/2})$, . . . , y_j, . . . , min$(y_{2,n/2})\}$ (1 < j < n/2)

  as new series are obtained.

- The values in clusters $\{r_1\}$ and $\{r_2\}$ are matched in pairs and shown in the scatter diagram. In the graph, the same scale is used on the horizontal and vertical axes and the smallest values of $\{r_1\}$ and $\{r_2\}$ are matched. Similarly, the largest values of $\{r_1\}$ and $\{r_2\}$ are also matched and these points have coordinates [min$(y_{1,n/2})$, min$(y_{2,n/2})$], ... , [max$(y_{1,n/2})$, max$(y_{2,n/2})$]. In this case, the $\{r_1\}$ data represents the first half of the series on the horizontal axis, and the $\{r_2\}$ data represents the second half of the series on the vertical axis.
- The 1:1 line is drawn.
- A 1:1 line represents perfect correlation. The trend can be interpreted by looking at whether the data is above or below this line. If the majority of the data lies above the line, this indicates an upward trend; if the majority lies below the line, this indicates a downward trend. If a data point is just above the line, it can be said that there is no upward or downward trend for this data [15].

In the graphical method; if the data sets are clustered above the 1:1 line, it indicates an increasing trend, and if they are clustered below, it indicates a decreasing trend. In some cases, the graphical method does not give clear results about the direction of the trend. Therefore, the results should be checked statistically [16]. The equations used for this are as follows:

$$\sigma_s^2 = \frac{4}{n^2}\left(E\left(\bar{y_2^2}\right) - 2E(\bar{y_2}\bar{y_1}) + E\left(\bar{y_1^2}\right)\right) \tag{1}$$

$$\rho_{\bar{y_1}\bar{y_2}} = \frac{\left(E(\bar{y_1}\bar{y_2}) - E(\bar{y_2}) - E(\bar{y_1})\right)}{\sigma_{\bar{y_1}}\sigma_{\bar{y_2}}} \tag{2}$$

$$\sigma_s^2 = \frac{8}{n^2}\frac{\sigma^2}{n}\left(1 - \rho_{\bar{y_2}\bar{y_1}}\right) \tag{3}$$

$$\sigma_s^2 = \frac{2\sqrt{2}}{n\sqrt{n}}\sigma\sqrt{1 - \rho_{\bar{y_2}\bar{y_1}}} \tag{4}$$

$$CL_{(1-\alpha)} = 0 \mp s_{critical}\sigma_s \tag{5}$$

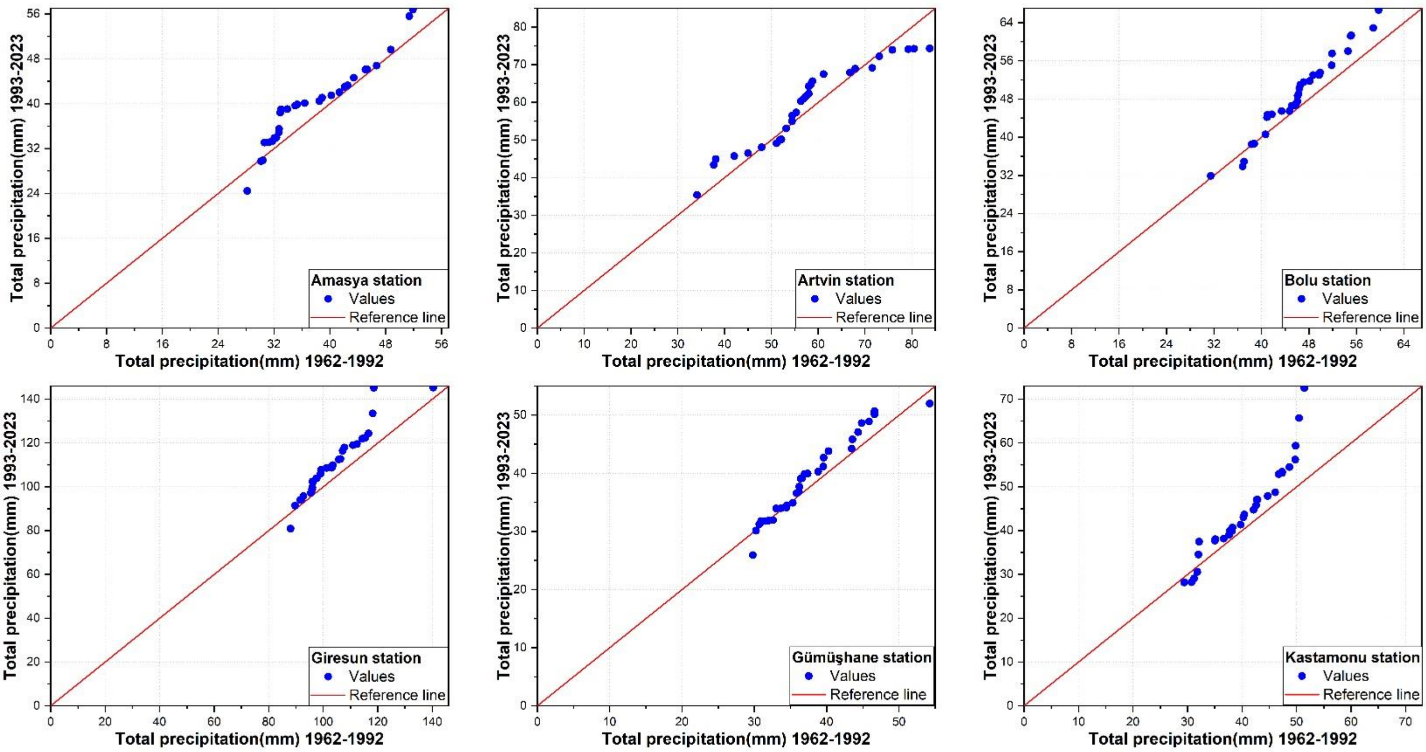
In the equations, $(\bar{y_1})$ is the mean of the first data, $(\bar{y_2})$ is the mean of the second data, (ρ) is the correlation between the first and second data, s is the slope value, n is the number of data, σ is the standard deviation of all data, and σ_s is the standard deviation of the slope [17].

$s_{critical}$ refers to the Z critical values for a one-way hypothesis (e.g. at the 95% confidence level). The critical upper and lower limit values calculated in the last step of the statistical check are established to determine the limits of the hypothesis test. If the trends of the data obtained from individual stations are outside the upper and lower confidence limits of the critical s value, it can be said that a trend is present in the data analyzed. To determine whether this trend is increasing or decreasing, the sign of the critical s is examined. A positive slope value s indicates an upward trend in the data, while a negative slope value indicates a downward trend [16].

3. Results and discussion

Trend analysis is often used to determine the climatic characteristics of a region. Although it cannot give as clear results as drought indices, knowing the trends of temperature and precipitation provides a strong estimate of the drought status of the region. ITA, which has gained a place in the existing studies in the literature, has some important advantages over other trend analysis methods. One of these advantages is that it offers a statistical solution together with the graphical method.

In the graphical method, clustering of the data in the upper region of the trend line indicates an increasing trend, clustering in the lower region indicates a decreasing trend, and clustering above the trend line indicates that there is no clear trend. For 13 provinces in the Black Sea Region (Amasya, Artvin, Bolu, Giresun, Giresun, Gümüşhane, Kastamonu, Ordu, Rize, Samsun, Sinop, Tokat, Trabzon and Zonguldak), trend analyses were carried out with the ITA method using precipitation and temperature data obtained from MGM. As a result of these analyses, it was determined that, in general, precipitation and temperature values have an increasing trend. However, the fact that the temperature increase shows a higher trend compared to the precipitation increase increases the risk of the Black Sea Region facing drought in the future. As a result of the analysis, the trend graph of precipitation data is given in Figure 2 and the trend graph of temperature data is given in Figure 3.



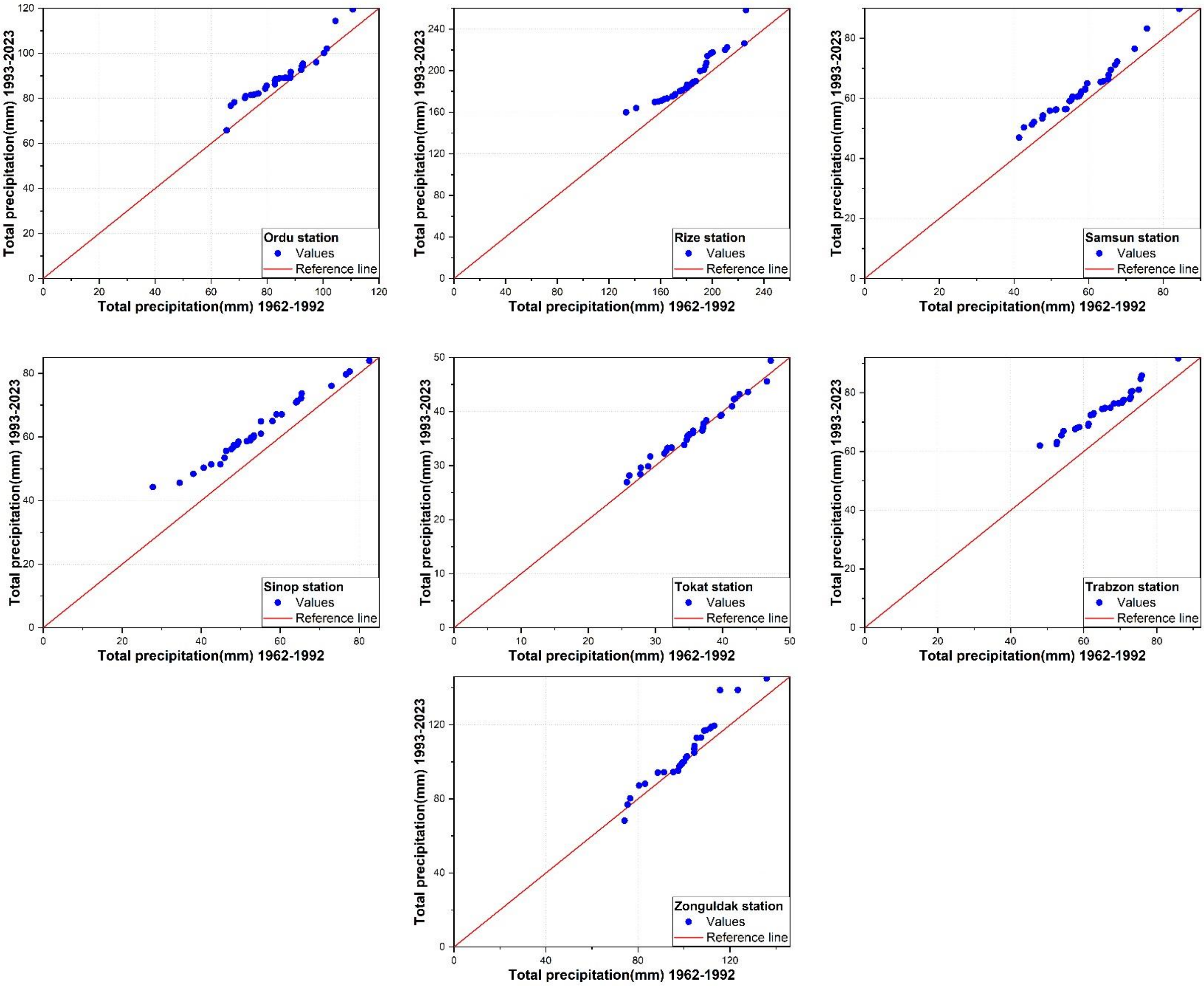


Figure 2. Analysis of precipitation records according to ITA

As a result of the precipitation analysis, the evaluations made by using the graphical method reveal that the values of Rize, Samsun, Sinop, and Trabzon stations are all located above the trend line, indicating a steady increase in precipitation. When the graph of the landlocked Tokat station is examined, it is observed that many points are clustered on the trend line. Although this implies that there is no clear trend, the analysis by statistical methods shows that the slope value (0.01365) is greater than the Scritic value (0.01129). This reveals that there is an upward trend, albeit at a very low rate. In their study, Partal and Yavuz [18] conducted a trend analysis of precipitation data in the Central Black Sea and Eastern Black Sea Region with the ITA method. As a result of this study, they observed that there is an increasing trend in all stations. In this respect, their findings are similar to this study.

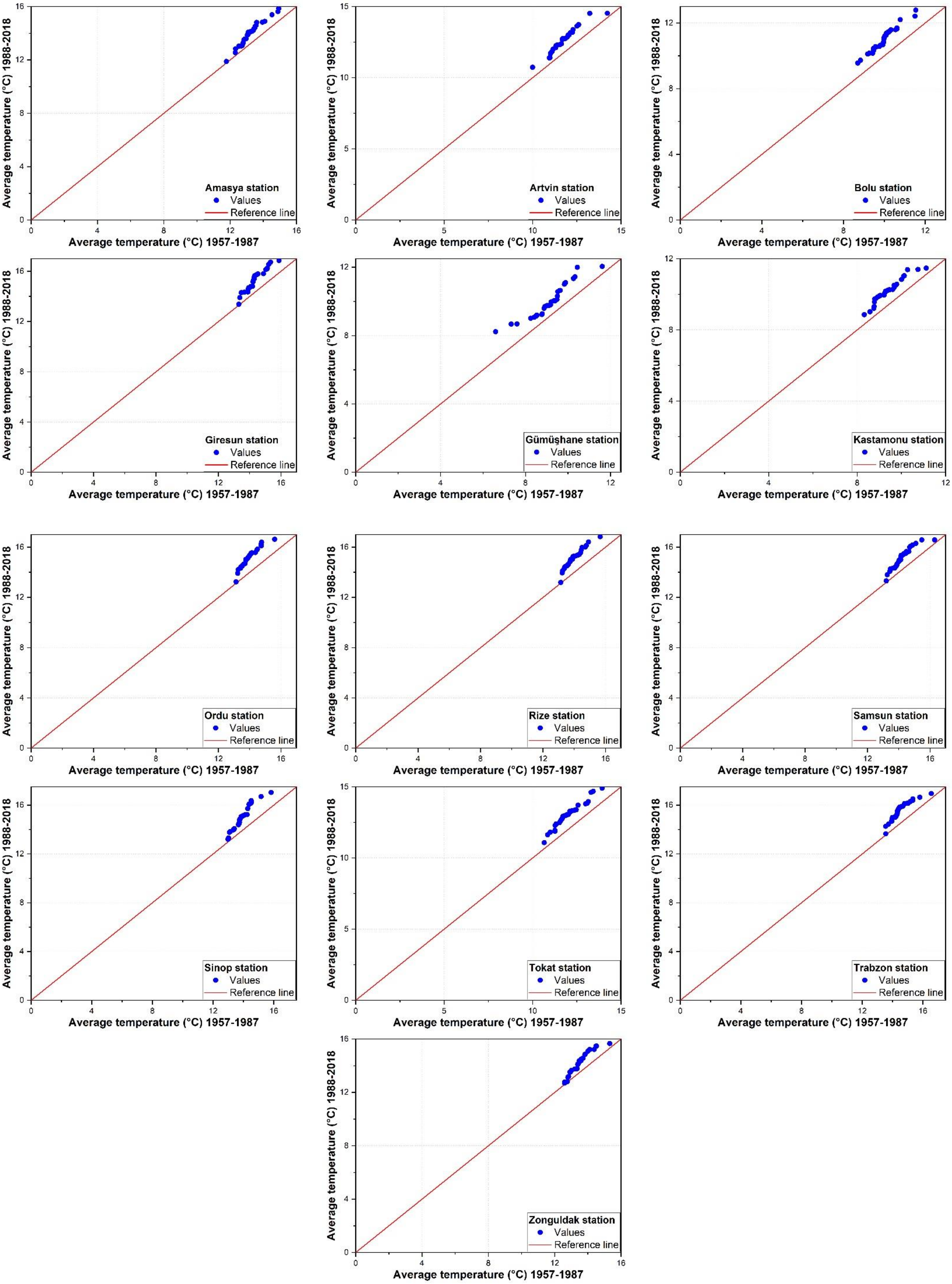


Figure 3. Analysis of temperature records according to ITA

According to the results of temperature trend analyses, significantly increasing trends were detected in all stations. Examination of the graphs clearly revealed this situation and there was no need to resort to statistical methods. This clear and consistent increase in the graphs clearly shows that the temperature values have increased at a high rate at each station. This finding reveals how significant and widespread the temperature increase in the region is. The fact that the precipitation at Tokat station is almost in a constant trend while the temperature is in a significant upward trend indicates that important measures should be taken in terms of drought risk. Tokgöz and Partal [17] conducted trend analyses using precipitation and temperature data for the Black Sea Region using Mann-Kendall and ITA methods. While an increase in precipitation and temperature was observed according to the results of the ITA method, it was stated that this increase was not observed in all stations according to the Mann-Kendall method. The analyses they obtained as a result of their study gave similar results with this study.

4. Conclusions

This study analyzed precipitation and temperature data with ITA to understand the climatic dynamics of the Black Sea Region and revealed the future climatic risks of the region. The findings generally show increasing trends in both precipitation and temperature values. In particular, the fact that the increase in temperature is more pronounced than the increase in precipitation indicates that the Black Sea Region may face the danger of drought in the future. This situation indicates that the region has become more vulnerable to the impacts of climate change.

The results of the graphical analyses revealed a steady increase in precipitation in coastal provinces such as Rize, Samsun, Sinop, and Trabzon, while in Tokat province, the precipitation trend was not evident but showed a statistically low increasing trend. This finding suggests that climate change impacts in inland areas may be more complex. Analysis of temperature data showed a clear and significant increasing trend in all stations. Although the precipitation trend in Tokat province remains constant, the increasing trend of temperature suggests that there may be an increase in the severity of drought. However, an examination of the geological structure of the region will contribute to a more accurate and comprehensive conclusion on this issue.

In conclusion, this study shows how increasing temperature trends and precipitation changes in the Black Sea Region affect the climatic balance of the region and emphasizes the need to take measures against future climate risks. The development of regional climate strategies, water resources management, and drought mitigation policies should become an urgent priority in light of these findings. The continuation of such studies will help us better understand the impacts of climate change at the local level and develop regional adaptation strategies.

Author Contribution Rate

Methodology, B.Ç. and İ.T.; Software, İ.T.; Validation, B.Ç.; Investigation, B.Ç. and İ.T.; Writing – Review & Editing B.Ç., İ.T. and R.A.; Supervision, R.A. All authors have read and accepted the published version of the manuscript.

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Conflict of Interest Statement

The authors declare no conflict of interest.

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