International Journal of Weather, Climate Change and Conservation Research, 12(1),43-81, 2026
Print ISSN: ISSN 2059-2396 (Print)
Online ISSN: ISSN 2059-240X (Online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

Investıgatıon of Drought Effect in Down Fırat Basın by Usıng Trend Analysıs Methods

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doi: https://doi.org/10.37745/ijwcccr.15/vol12n14381 Published July 27, 2026

Citation: Karahan S., and Kılıç Z. (2026) Investıgatıon of Drought Effect in Down Fırat Basın by Usıng Trend Analysıs Methods, *International Journal of Weather, Climate Change and Conservation Research*, 12(1),43-81

Abstract: *In this study, trend analyses of annual mean temperature and annual total precipitation data were conducted at ten meteorological stations within the Lower Euphrates Basin for the period 1965–2025 years. The analyses employed the Mann-Kendall Test, Spearman's Rho Correlation Test, Sen's Slope Method, Innovative Trend Analysis (ITA), and Statistical Trend Analysis (IPTA). Temperature analyses revealed a statistically significant (p < 0.001) positive warming trend at all stations. The highest warming rate was observed at Gaziantep Merkez station (Sen's slope: 0.0502 °C/year; Rho: 0.82), while the lowest was recorded at Şanlıurfa Birecik station (Sen's slope: 0.0226 °C/year; Rho: 0.60). ITA/IPTA graphs confirmed that warming occurred homogeneously and systematically across low, medium, and high temperature quantiles at all stations.Precipitation data exhibited notable differences among stations. The highest negative trend value was observed at Malatya Doğanşehir station (Sen's slope: -0.1762 mm/year; p = 0.017), representing the strongest aridification signal in the study. This was followed by Şanlıurfa Birecik (Sen's slope: -0.1625 mm/year; p = 0.012), Şanlıurfa Haliliye (Sen's slope: -0.1572 mm/year; p = 0.089), Elazığ Palu (Sen's slope: -0.1424 mm/year; p = 0.080), and Elazığ Keban (Sen's slope: -0.1082 mm/year; p = 0.104). Malatya Yeşilyurt station also exhibited a statistically significant decreasing trend (Sen's slope: -0.0955 mm/year; p = 0.047). In contrast, Elazığ Merkez showed near-stationary conditions (Sen's slope: 0.03 mm/year; p = 0.686), while Şanlıurfa Siverek displayed a slight decline (Sen's slope: -0.0634 mm/year; p = 0.677). Adıyaman Merkez (Sen's slope: -0.0824 mm/year; p = 0.502) and Gaziantep Merkez (Sen's slope: -0.0732 mm/year; p = 0.448) also showed decreasing tendencies, though these trends were not statistically significant.The most critical finding of the study is that stations where temperature increases coincide with precipitation decreases in Malatya Doğanşehir, Şanlıurfa Birecik, Şanlıurfa Haliliye, Elazığ Palu, and Elazığ Keban, face an increasing thermal stress on the hydrological water budget and a heightened risk of aridification. In particular, the precipitation decline of -0.1762 mm/year at Malatya Doğanşehir and the Spearman's Rho coefficient of -0.32 at Şanlıurfa Birecik indicate that the aridification trend at these stations has gained a systematic character. In conclusion, a pronounced warming trend is occurring in the Lower Euphrates Basin due to climate change, with statistically significant decreases in precipitation regimes, particularly in the southern and eastern parts of the basin. This situation underscores the urgent need for strategic measures in water resources management and agricultural sustainability in the region.*

Keywords: lower euphrates basin, trend analysis, Mann-Kendall, ITA/IPTA, drought, climate change

INTRODUCTION

Climate change is one of the most important causes of global warming and drought. Drought, which occurs with a long-term lack of precipitation, is one of the natural disasters, and its impact has been increasing in recent years, also reducing the quality of socioeconomic life (Yıldız, 2019). Due to climate change, increases and imbalances in evaporation and precipitation, melting of glaciers, rising sea levels, and natural events such as hurricanes, typhoons, floods, and droughts are being observed more frequently. Scientific studies on the subject indicate that global warming and climate changes will reduce water resources and trigger drought (Fıstıkoğlu and Biberoğlu, 2008). In addition, climate changes have effects on hydrological cycle elements. Since data in the hydrological cycle are of a changing nature, periodic investigation of the trend of these data requires the use of special methods (Karahan and Kılıç, 2024).

Water is one of the most valuable treasures and riches bestowed upon all living beings by the Creator; there is no life without water (Kılıç, 2020). The importance of sufficient clean water is enormous for the productive, satisfying, high-quality, and abundant production activities of states and the public. The living standards of societies with sufficient clean water and abundant production activities rise. If states want to reduce their dependence on other countries and strengthen their economies, they must use all natural resources, including water resources, in a sustainable manner and with serious ownership. If water is not used sustainably, if necessary measures are not taken urgently, and if people's water literacy level is not increased, accessing already scarce water resources will become even more difficult (Kılıç and Karahan, 2024). The protection of water resources, their planned operation, and the fight against drought have always been among the current issues of humanity. It is important to know the current status of our river resources and to check them periodically in order to survive drought with minimal damage and to take necessary measures in a timely manner. A downward trend in our rivers is an important indicator for determining the effect of drought in that area. In this context, remembering the past conditions of our basin and rivers, determining their current and future conditions is necessary to somewhat reduce the economic and social damages of possible drought. Planning of water resources, development of operating technologies, periodic control, and protection are essential. This thesis study has the characteristics to contribute to the aforementioned purposes. Furthermore, such research, which is important for regions like Adıyaman where climatic conditions are hot, evaporation is high, agricultural irrigation is intensive, and rivers and dams are abundant, has the potential to provide specific information for water management practices and sustainable use of water.

For the sustainable use of water and efficient planning on the subject, hydrological observations are needed; however, making these observations and measuring data in accordance with standards is difficult and time-consuming. For these reasons, in today's world where technological systems are highly developed, statistical methods and new approaches are needed for data that may have difficulties and deficiencies in measurement. One of these current methods, artificial intelligence methods, are widely used in hydrology and water resources systems, in engineering studies dealing with water science, in determining water levels in dams and flow regimes in rivers, and in modeling complex nonlinear phenomena, and continue to be used. Today, water-related problems have increased, and this situation requires planned use of water and timely and accurate evaluation and operation of parameters related to data. Otherwise, water-related problems will increase further in the future. We need hydrological observations and data for planning water resources, determining water levels, determining river flow regimes, project design, operation, and safety. However, the measurements and experiments conducted to make hydrological observations and obtain the necessary data are quite costly, laborious, and time-consuming. Furthermore, since these data can change frequently in short intervals, it is also difficult to measure them in accordance with standards using classical methods. Therefore, to facilitate work, obtain data close to standards, and save time, statistical methods and new approaches and models are needed for data that cannot be measured, are missing, or are incorrectly measured.

In order to take precautions when the water level in rivers decreases and to prevent the formation of river irregularity, water storage reservoirs need to be constructed. For this purpose, having accurate and reliable data is important, and data estimation studies for input and output of the system to determine river flow, lake and dam water levels are widely carried out today using artificial intelligence methods (Özel, 2018). Water level determination processes in past years were mostly based on traditional statistical methods. Today, since expected results can be achieved, consistent results can be obtained, and the probability of error is lower, different methods within the framework of artificial intelligence techniques are used for hydrological modeling (Katipoğlu and Acar, 2021; Taşkolu, 2023). The distribution of the current water potential of rivers over time generally does not match the status of people's water needs over time. For these needs to be met in a planned manner, dam reservoir and river flow regime planning must be carried out. Dam reservoirs perform water storage and elevation functions, but the amount of water and flow in rivers vary according to precipitation and climate changes. Therefore, while drought can occur in rivers, floods can also occur due to excessive precipitation. To prevent damages arising from these situations, it is important to plan dam reservoirs well during construction, improve them over time, accurately estimate reservoir volume changes, and determine river flow regimes (Gümüşcan, 2017).

The Euphrates-Tigris Basin, one of Türkiye's twenty-five water basins, is located in the eastern and southeastern region of Türkiye. Since it encompasses the Euphrates and Tigris Rivers and their surroundings, this basin has a quite large area. The ratio of the Euphrates-Tigris Basin to Türkiye's area is 22.69%, with a total area of 184,918 km². A total of 469 settlements, including 22 provinces, 157 districts, 224 towns, and 88 villages, are within the basin boundaries. The basin ends at the Eastern Black Sea mountains in the north and the Syria-Iraq border in the south. With an annual average flow of 52.94 km³, its potential contribution rate is 28.5%, ranking first among Türkiye's basins in terms of hydraulic potential (https://www.tarimorman.gov.tr). Considering their widespread use in research worldwide and their reliable results, the methods predominantly used within the scope of this study are Mann-Kendall, Sen's Trend Slope Method, Mann-Kendall Rank Correlation Test, and Şen's Innovative Trend Analysis. By using these methods together in this study, it was possible to cross-verify the results with one another. In this study, the trends of minimum flows obtained from streamflow observation stations established on the rivers of the Lower Euphrates Basin, which is a sub-basin of the Tigris-Euphrates Basin, were examined, the results were evaluated in terms of drought, and comparisons were made. In the basin where widespread agricultural lands are located and drought is frequently experienced, the design of irrigation systems, and the changes in resources in the region from past to present for adequate resource supply were also examined, and evaluations and recommendations were made.

This study is expected to contribute to similar studies and provide guidance on matters such as irrigation/drinking water resource supply, water management planning, transmission facility design, determination of hydropower plant installation locations, and turbine selection in the region.

MATERIAL

Research Area

The Lower Euphrates Basin encompasses a vast geographical area located at the junction of Southeastern and Eastern Anatolia, along the Euphrates River, and includes the provinces of Gaziantep, Kilis, Şanlıurfa, and Adıyaman. Its western and southern borders are with Syria. The basin is approximately 2,800 km long and covers an area of approximately 20,204 km², representing about 2.58% of Türkiye's total land area. This basin forms the backbone of the Southeastern Anatolia Project (GAP), Turkey's largest regional development project. In this study, trend analyses were conducted using average precipitation and average temperature data obtained from the General Directorate of Meteorology at ten stations: 17265-Adıyaman, 17201-Elazığ, 17804-Keban, 17806-Palu, 17261-Gaziantep, 17872-Doğanşehir, 17199-Yeşilyurt, 17270-Şanlıurfa, 17966-Birecik and 17912-Siverek.

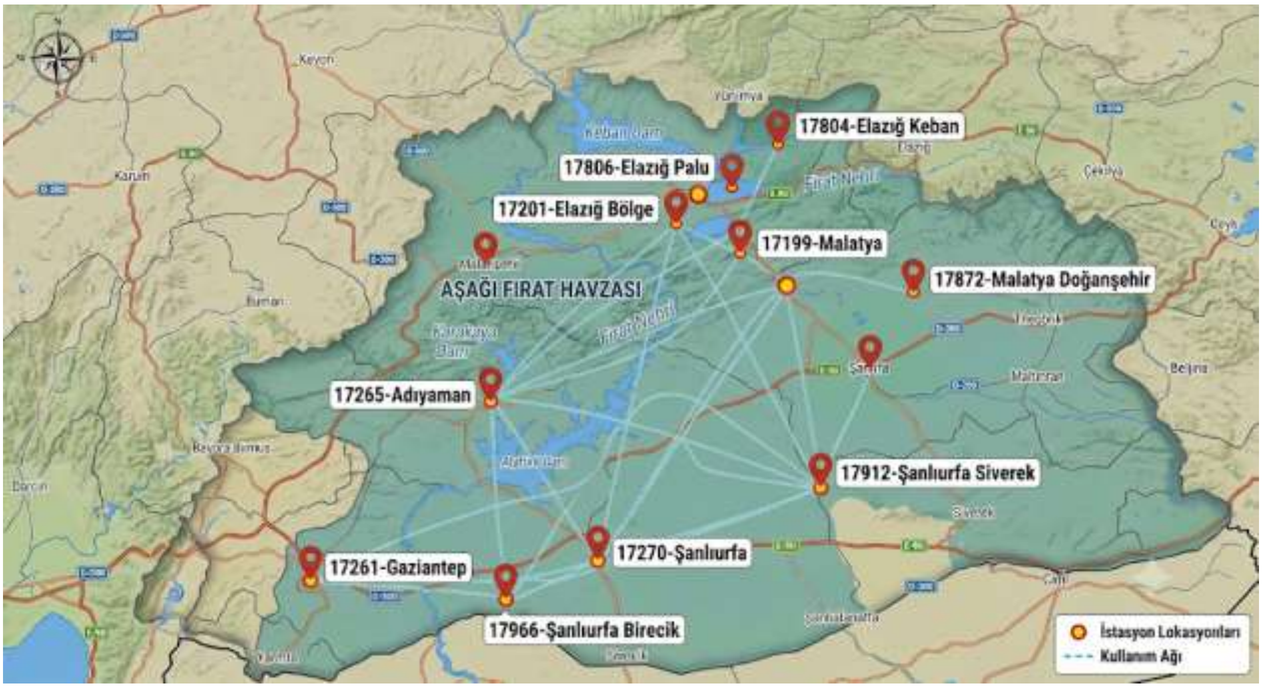

Figure 1. Location of Observation Ten Stations in The Low Euphrates Basin

Obtaining Study Data

The station data used in the trend analysis of the Lower Euphrates Basin were obtained using precipitation and temperature data from 10 meteorological stations of the General Directorate of Meteorology (MGM). We studied period as the range 1965-2025 years, and data belonging to this period were compiled from the relevant MGM station records precipitationa and temperature (Table 1).

Table 1. Meteorological Observation and Station Information

City	Station Name	Station No	Observation Years (Precipitation)	Observation Years (Temperature)
Adıyaman	Adıyaman	17265	1965-2025	1965-2025
Elazığ	Elazığ Center	17201	1965-2025	1965-2025
	Palu	17806	1965-2025	1965-2025
	Keban	17804	1965-2025	1965-2025
Gaziantep	Gaziantep	17261	1965-2025	1965-2025
Malatya	Malatya	17199	1965-2025	1965-2025
	Doğanşehir	17872	1965-2025	1965-2025
Şanlıurfa	Siverek	17912	1965-2025	1965-2025
	Şanlıurfa	17270	1965-2025	1965-2025
	Birecik	17966	1965-2025	1965-2025

Determination of Study Area

Precipitation and Temperature Data

For each station used in the study, summary statistics (mean, maximum and minimum values, standard deviation, etc.) of the annual average precipitation and annual average temperature series were calculated in the first stage.

Subsequently, missing years were identified for trend analyses, and missing data were completed using appropriate regression techniques. Descriptive statistical values of precipitation and temperature data for the stations are presented in Tables 2 and 3.

Tablo 2. Statistical Values of Precipitation Data (mm)

City	Station Name	Station No	Highest Precipt. Year	Annual Total Precipt.	Max Precipt.	Minimum Precipt.	Average Precipt.	Standard deviation
Adıyaman	Adıyaman	17265	2012	768	333.5	0	97.49	119.88
Elazığ	Elazığ Center	17201	1976	733	166.8	0	61.08	51.09
	Palu	17806	1967	798.3	132.6	2.8	66.53	49.96
	Keban	17804	1967	656.9	101	0	54.74	36.64
Gaziantep	Gaziantep	17261	1996	994	247.4	0	82.83	82.00
Malatya	Malatya	17199	1988	597.4	129.5	0.1	49.78	43.10
	Doğanşehir	17872	1976	788	160.5	0	65.67	56.43
Şanlıurfa	Siverek	17912	1976	893	169	0	74.42	63.63
	Şanlıurfa	17270	1996	854.7	297.4	0	71.23	92.74
	Birecik	17966	1996	614	176.9	0	51.17	57.09

Data Completion

Missing years and gaps identified in the datasets were filled using a completion method employing long-term correlations and linear regression models obtained from neighboring stations located in the same region. During the missing data completion stage; first stations in the closest geographical location to the station with missing data were identified, than correlation relationship between these stations was statistically checked, and the missing years were completed by establishing appropriate linear regression models. The series before and after the completion process were checked visually and statistically, and this process was limited to eliminating only obvious data gaps in a way that would not deteriorate the trend characteristics of the series.

Table 3. Statistical Values of Temperature Data (°C)

City	Station Name	Station No	Highest Temp Year	Annual Total Temp.	Maximum Temp.	Minimum Temp.	Average Temp.
Adıyaman	Adıyaman	17265	2010	33.2	6.9	19.325	9.29
Elazığ	Elazığ Center	17201	2018	28.8	3.8	15.73	9.02
	Palu	17806	2018	29.3	4.2	16.25	8.93
	Keban	17804	2010	30.8	4.7	17.06	9.56
Gaziantep	Gaziantep	17261	2024	30.3	6.3	17.74	9.38
Malatya	Malatya	17199	2010	30.1	3	16.33	9.73
	Doğanşehir	17872	2024	25.6	1.1	13.075	9.18
Şanlıurfa	Siverek	17912	2010	32.4	6.5	18.76	9.33
	Şanlıurfa	17270	2010	34	8.2	20.69	9.35
	Birecik	17966	2010	32.5	8.7	19.76	8.97

METHOD

Flow data are generally interpreted in three different forms—maximum, average, and minimum flows—considering the times decided upon in literature studies. In this study, minimum flow data obtained from meteorological stations located in the Lower Euphrates Basin were used. For the analyses, the Mann-Kendall Rank Correlation Test, Mann-Kendall Test, and Sen's Trend Slope Method were used. Missing data were completed using regression analysis. The regression analysis method is widely used in hydrological studies conducted in basins together with flow duration curves.

Figure 2. Türkiye's River Basins And The Geographical Location of the Euphrates Basin

Mann Kendall (MK) Trend Test Method

To determine whether a trend in time series data is statistically significant, the Mann-Kendall (MK) trend test, which is the most commonly used method that is not sensitive to outliers and does not require normal distribution, was employed. The MK test was preferred due to reasons such as its high resistance to outliers. The ρ values obtained from the test allow us to evaluate whether the trend in the data is random, within the framework of a 0.05 significance level. The null hypothesis (H_0) established within the scope of the study assumes that the time series of the relevant meteorological parameter does not show a statistically significant trend. As a result of comparing the calculated p-values with the 0.05 significance level (alpha = 0.05), a $\rho < 0.05$ situation indicates the presence of a statistically significant trend, while a $\rho > 0.05$ situation indicates that the observed changes are random fluctuations.

Şen’s Slope Trend

To quantitatively calculate the magnitude of the trend and the annual rate of change, Şen's slope method was applied. This method enables the calculation of the slope coefficient in the time series, covering non-linear trends in the data as well. In order to quantitatively reveal the magnitude of the trend identified by this test, Sen's Slope Estimator method, calculated over the median of the slopes of all data pairs in the series, was applied.

Spearman’s Rho Test

Spearman's Rho test, unlike the Pearson correlation coefficient, is a correlation measure that eliminates the requirement for data to show a normal distribution and evaluates the continuously increasing or decreasing, but not necessarily linear, relationship between variables. It is preferred when data are on an ordinal scale or when they are continuous but violate the normal distribution assumption.

ITA ve IPTA Trend Analysis

To overcome the limitations of classical trend tests based on the homogeneity of data in the time series, the Innovative Trend Analysis (ITA) methodology proposed by Şen was used. This approach divides the time series into two equal subgroups and enables visualization on a 1:1 line in the Cartesian coordinate system. The ITA method provides a unique analytical framework for identifying trend sub-types that classical tests might overlook, by separating asymmetric changes in the low, medium, and high value segments of the data. In order to geometrically express multi-dimensional changes in the temporal distribution of data, the Innovative Polygon Trend Analysis (IPTA) method was utilized. IPTA calculates the deviations between polygon areas formed by the values of the series in two different periods and graphically maps the direction (increase/decrease) and intensity of the trend, along with non-linear changes in the data and frequency changes, reflecting the spatial and numerical correlation of temporal dynamics within statistical integrity.

RESULT AND DISCUSSION

In this study, minimum flow data from 10 meteorological stations (17265-Adıyaman, 17201-Elazığ, 17804-Keban, 17806-Palu, 17261-Gaziantep, 17872-Doğanşehir, 17199-Yeşilyurt, 17270-Şanlıurfa, 17966-Birecik, 17912-Siverek) located within the boundaries of the Lower Euphrates Basin were used. A comprehensive study was conducted on the trend analyses of annual average precipitation series and annual average temperature data using the Mann-Kendall, Innovative Şen, Spearman Rho, Time Series Analysis (ITA), and Statistical Trend Analysis (IPTA) methods.

Precipitation and Temperature Analysis of Adıyaman Central Station

As a result of the analyses, the average temperature and average precipitation data of the Adıyaman Meteorology Station for the years 1965-2025 were examined using both time series trend analysis and Innovative Trend Analysis (ITA/IPTA) methods, thus revealing the climatic change dynamics of the province. It is observed that during the study period, there is a statistically significant increasing trend in average temperature data, while in the precipitation regime, a variability structure accompanied by high fluctuations, though not as pronounced as in temperature, is dominant.

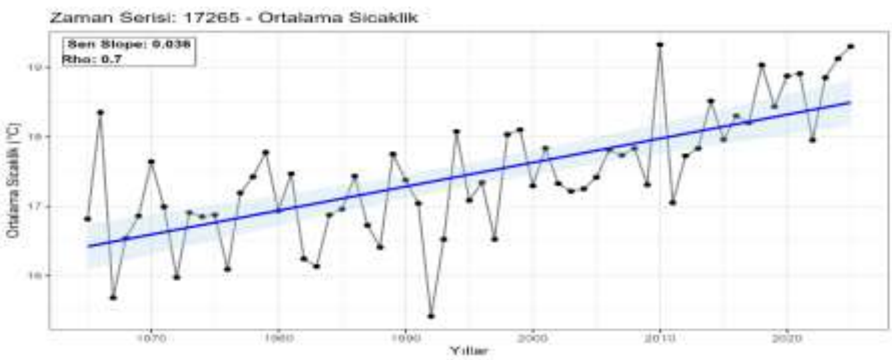

Figure 3. Average Temperature ITA/IPTA Analysis of Adıyaman Station
Figure 4. Time Series Analysis of Average Temperature at Adıyaman Station

The time series temperature data graph in Figure 4 shows Sen slope value of 0.036, indicating a positive trend in temperature. The Spearman's Rho value of 0.7 indicates a very strong correlation in the temperature data, suggesting a significant warming trend at the station. These findings are also confirmed in figure 3, where the points in the ITA/IPTA data graph are positioned entirely on the 1:1 (red dashed) line. This proves that all temperature values are low, medium, and high increase over time.

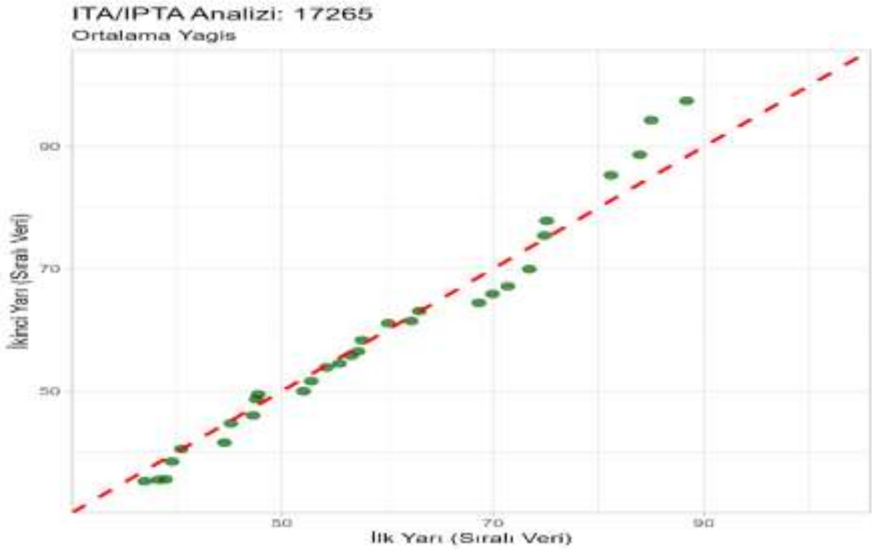

Figure 5. Average Precipitation ITA/IPTA Analysis for Adıyaman Station

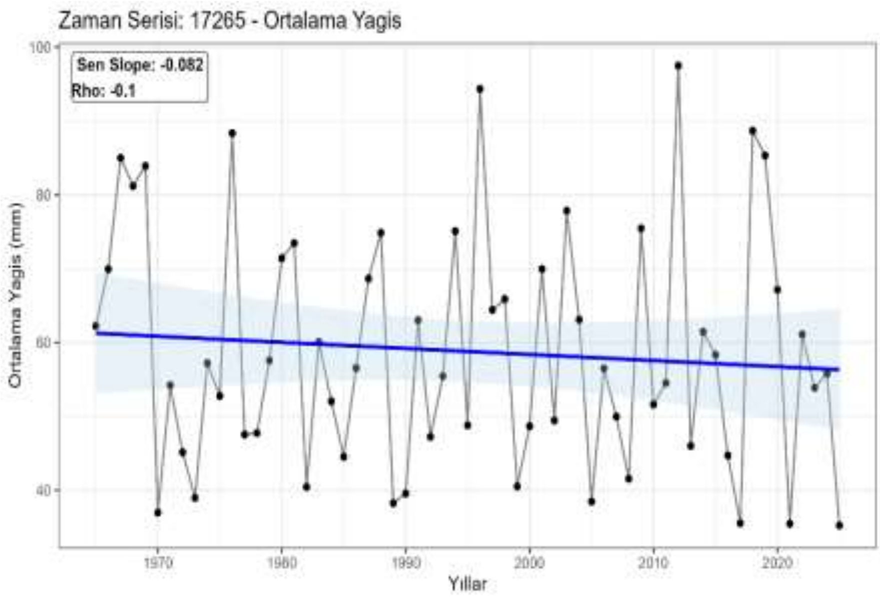

Figure 6. Average Precipitation Time Series Analysis for Adıyaman Center Station

As seen in figure 6, the time series Sen slope value of -0.082 in the precipitation data graph shows a slight decreasing trend in precipitation. However, the Rho value of -0.1 indicates that this decrease is very weak and does not form a statistically significant strong trend. This suggests that rather than a systematic change in the precipitation characteristics of the region, the existing variability continues to be maintained. The graph in figure 5 supports this interpretation, and the data distribution shows a distribution very close to the ITA/IPTA 1:1 line, both above and below it. This indicates a slight increase or stability during low-precipitation periods and a significant decrease or variability during high-precipitation periods, showing that the overall precipitation regime does not exhibit as sharp and unidirectional a change as temperature. The time series and Innovative Trend Analysis (ITA) results for the period 1965-2025 at the Adıyaman station indicate a significant change in the climatic dynamics of the region. The strong and statistically significant increasing trend detected in average temperature data at all quantile levels (low, medium, high) using both non-parametric tests (Sen slope: 0.036, Spearman's Rho: 0.7) and the ITA method indicates that the region is directly affected by the global warming trend. This finding is consistent with Türkeş's (1999) warming projections for a large part of Türkiye and the significant temperature increases detected by Dabanlı (2017) in the Akarçay Basin. Furthermore, the success of the ITA method in revealing trend differences, especially at low and high values, has been emphasized in hydrological drought studies conducted in different basins by Deger et al. (2025), as well as in this study. On the other hand, a trend as sharp as that observed in temperature was not seen in the average precipitation regime. The very low SEN slope value (-0.082) and Spearman's Rho coefficient (-0.1) indicate that there is no statistically significant decreasing trend in precipitation; on the contrary, a high variability structure prevails. The scattered pattern of the points around the 1:1 line in the ITA/IPTA graph supports the idea that this variability is a reflection of existing climatic fluctuations rather than a structural transformation. This situation is also parallel to studies conducted in the literature for the Southeastern Anatolia Region. For example, Gümüş et al. (2016), in their SPI analysis at the Şanlıurfa station, detected the existence of periodic dry and wet periods without a distinct trend in precipitation, while Özfidaner and Topaloğlu (2020) drew attention to the irregularity in the temporal distribution of precipitation in the same region. These findings are critical in showing that the precipitation regime in Adıyaman, despite the warming in temperature, has not yet entered a systematic dryness trend, but that variability is increasing. Despite the significant increase in temperature, this stagnant pattern in precipitation should be carefully considered, especially in terms of water resource planning; because increasing temperatures can increase evaporation losses, reducing the contribution of existing precipitation to the water budget. This potential hydrological effect is also frequently emphasized in the drought studies conducted by Esit and Yuce (2023) and Yuce et al. (2025) in different basins.

Elazığ Central Station Precipitation and Temperature Analysis

Time series analysis of meteorological data from 1965-2025 at Elazığ Central Station, using ITA/IPTA methods across different time scales, reveals climatic change trends in the region. The results of the ITA/IPTA method, conducted to examine the homogeneity of the series, are visualized in Figure 7. Looking at the graph in Figure 7, the positioning of the data above the 1:1 line (red dashed line) indicates that temperature values in the second half of the series are higher than in the first half, meaning a positive trend is dominant in the series. The systematic deviation of the data from the 1:1 line shows that the observed temperature increases are not coincidental and that the series exhibits a characteristic warming trend.

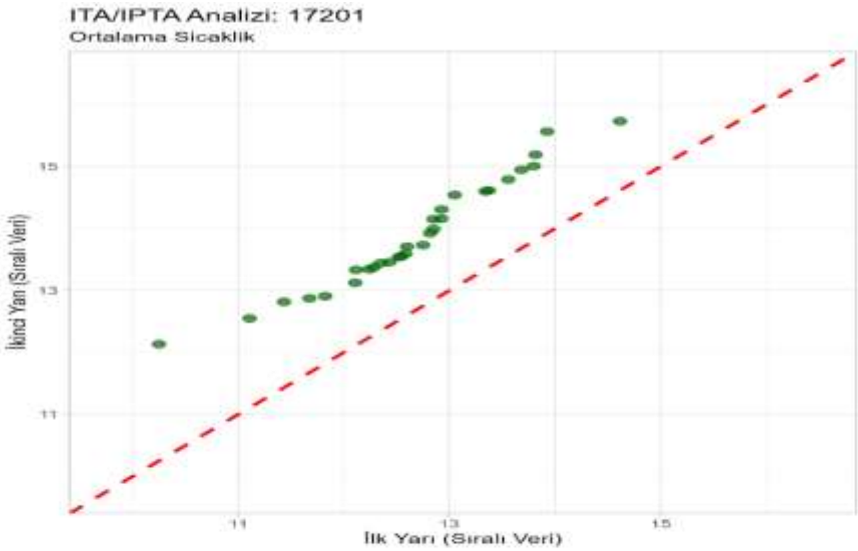

Figure 7. Average Temperature ITA/IPTA Analysis for Elazığ Center Station

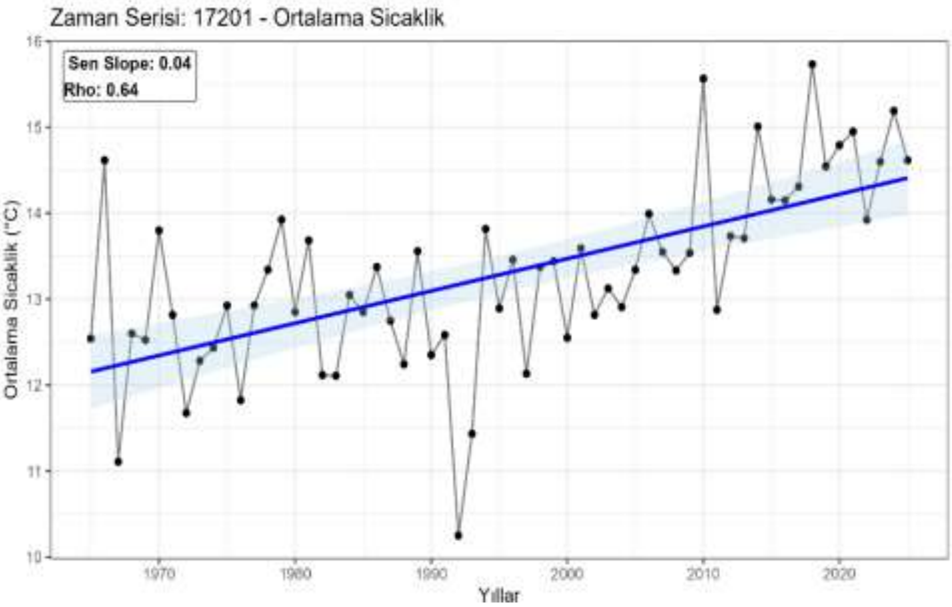

Figure 8. Time Series Analysis of Average Temperature at Elazığ Center Station

According to the graph in Figure 8, the temporal variation graph of the data shows a significant warming trend in the data from the relevant stations. The Spearman's rho value obtained from the Mann-Kendall test was determined as 0.64; this value indicates a strong positive correlation between the data. The S-slope coefficient of 0.04 shows a significant increasing trend in the average temperature data on an annual basis. When the temperature data obtained from the Elazığ Center Meteorological Station are examined in terms of both temporal variation and homogeneity tests, they point to a strong warming trend in the region, confirming the regional effects of climate change.

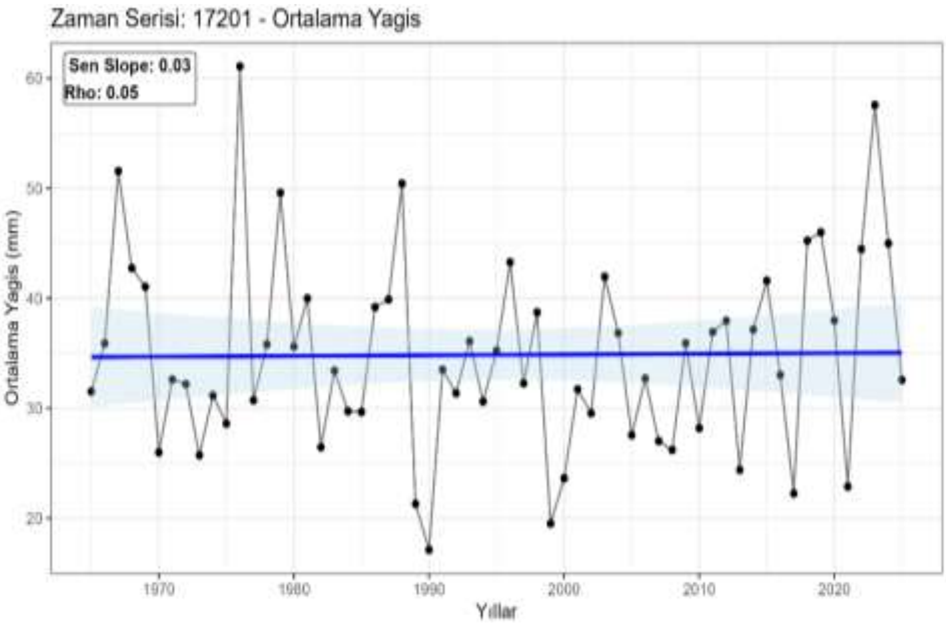

Figure 9. Average Precipitation Time Series Analysis for Elazığ Center Station

Figure 9, a time series graph, shows no significant trend in precipitation values during the period under review. The Spearman's rho coefficient of 0.05, obtained from the Mann-Kendall test, indicates that there is no statistically significant linear correlation in the series.

The fact that the Spearman's rho coefficient remains at a very low value of 0.03 and the trend line follows a horizontal course proves that temporal variability is more prominent than a long-term increase or decrease trend in average annual precipitation.

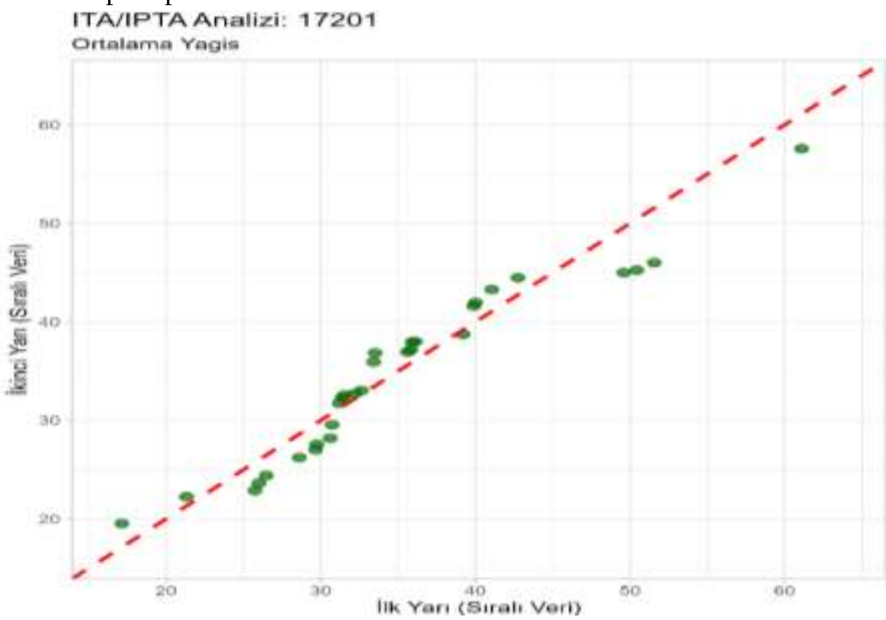

Figure 10. Average Precipitation ITA/IPTA Analysis for Elazığ Center Station

The ITA/IPTA results shown in figure 10 support the time series findings. The clustering of the vast majority of data on or very close to the 1:1 line indicates that there is no significant difference between the two halves of the series and that the data exhibits a homogeneous distribution. Although there are limited deviations from the 1:1 line at the extremes where high precipitation values are observed, this does not create a dominant trend change in the overall character of the series. Average precipitation data for the Elazığ station, in contrast to the significant warming trend observed in temperature data, exhibits a stationary structure and indicates that the precipitation regime in the region has not entered a long-term changing trend. The analyses performed at the Elazığ station revealed significant findings that largely parallel those of the Adıyaman station, but also contain some nuances. The Spearman's Rho value of 0.64 and the Sen slope coefficient of 0.04 obtained from the Mann-Kendall test on average temperature data prove the existence of a statistically significant and distinct warming trend in Elazığ, although not as strong as in Adıyaman (Rho=0.7). The positioning of the data points on the 1:1 line in the ITA/IPTA graph indicates that this warming occurs in all temperature quanta (low, medium, high) and that the series systematically deviates from a homogeneous structure. This situation reveals that both stations are affected by the same regional climate change signal and that temperature increases have become widespread in the area encompassing the Eastern Mediterranean and Southeastern Anatolia regions. This finding is consistent with the drought trend identified by Çelik et al. (2018) in their seasonal drought analysis for the Eastern Anatolia Region, and with the warming projections presented by Türkeş (1999) for Turkey as a whole. When evaluated in terms of precipitation regime, the Elazığ station exhibits a more pronounced stability compared to Adıyaman. While the SEN slope value in Adıyaman shows a slight decreasing trend with -0.082, this value is very close to zero in Elazığ, at 0.03. The Spearman's Rho coefficient of 0.05 definitively shows that there is no statistically significant trend in the series. The clustering of the majority of points on or very close to the 1:1 line in the ITA/IPTA graph indicates that the precipitation regime in Elazığ has maintained a homogeneous structure for many years, and even the high fluctuations observed in Adıyaman are not significant at this station. This finding is consistent with the findings of Katipoğlu and Acar (2021) in their meteorological and hydrological drought mapping study in the Euphrates Basin, which showed that the area around Elazığ exhibits a relatively more stable character in terms of precipitation variability. The absence of a sharp trend in precipitation patterns, similar to that in temperature, at both stations, but the more pronounced stable pattern in Elazığ compared to the fluctuating pattern in Adıyaman, indicates that microclimatic differences and topographical effects can play a decisive role in precipitation patterns, even under the same regional climate change pressures. This suggests that, from a water resources management perspective, precipitation patterns in Elazığ may remain a relatively reliable component, but variability in precipitation in Adıyaman should be considered a more critical factor in management planning.

Precipitation and Temperature Analysis at Elazığ Keban Station

The analysis conducted on the Elazığ Keban station reveals a statistically significant warming trend over the last half-century. The calculated Sen's Slope coefficient of 0.035 documents a steady increase in average annual temperatures (Figure 12). The ITA/IPTA method, used to support this finding, confirmed the homogeneity of the data and detected a systematic deviation in the positive direction from the 1:1 reference line (Figure 11). This deviation indicates that the temperature values measured in the second half of the series are significantly higher compared to the first half. Combined with the correlation value of $\rho = 0.63$, this shows that the region's climatic parameters are in high agreement with global climate change signals, that the warming trend maintains its dominant character, and that the warming trend in the region is statistically consistent and reliable.

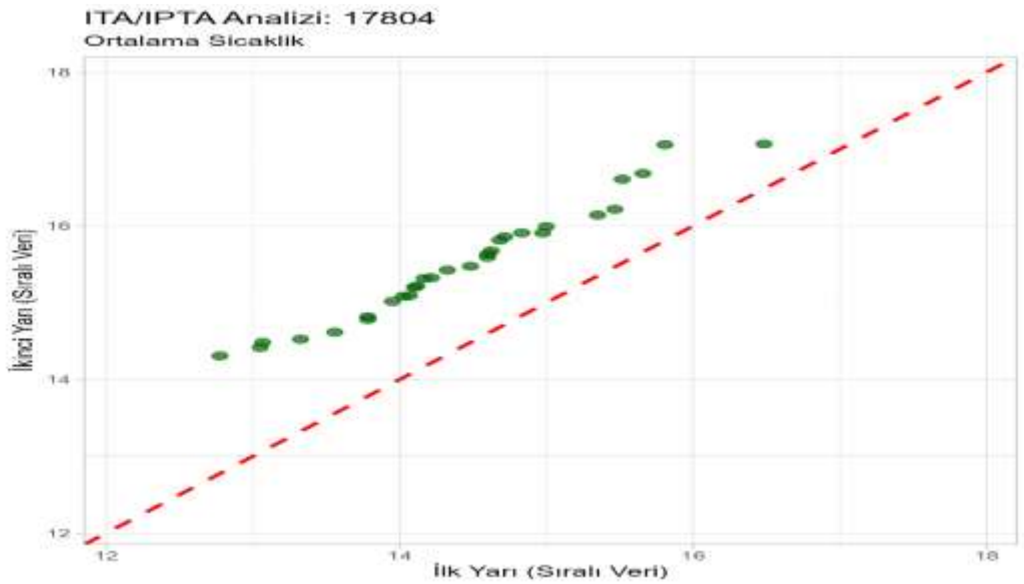

Figure 11. Average Temperature ITA/IPTA Analysis of Elazığ Keban Station

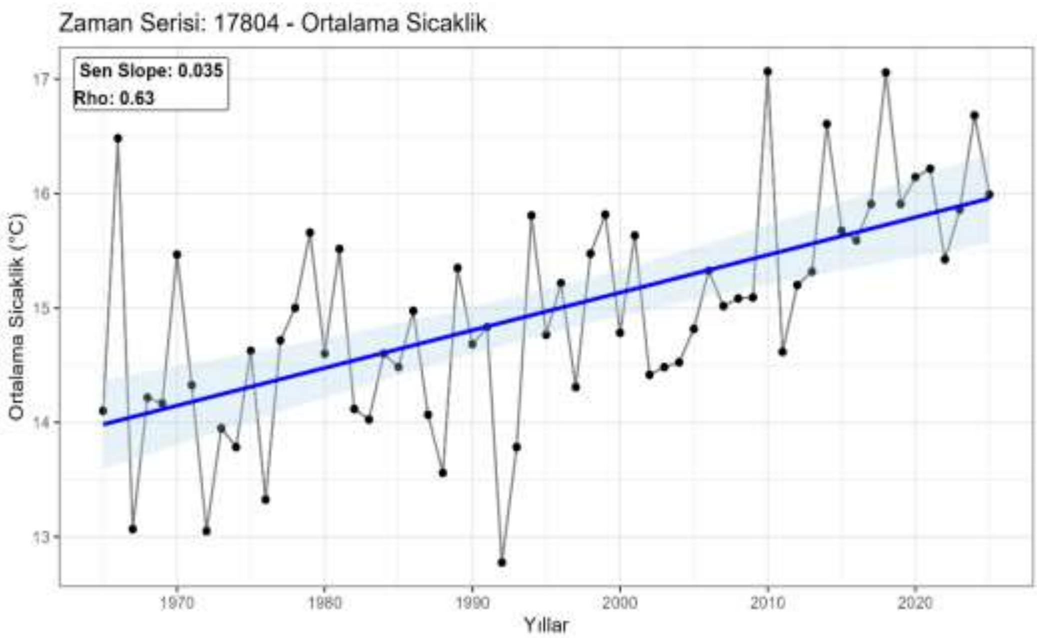

Figure 12. Time Series Analysis of Average Temperature at Elazığ Keban Station

The average temperature analyses show that the climatic data from Elazığ-Keban stations support each other using both the Sen's Slope and ITA methods. These two methods provide methodological robustness to the study's findings and demonstrate that the warming trend in the region is statistically logical.

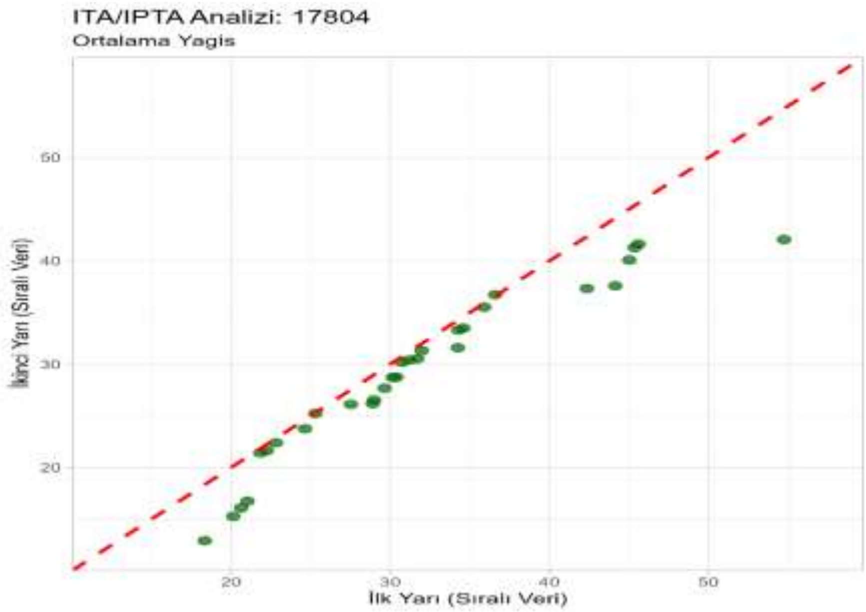

Figure 13. Average Precipitation ITA/IPTA Analysis for Elazığ Keban Station

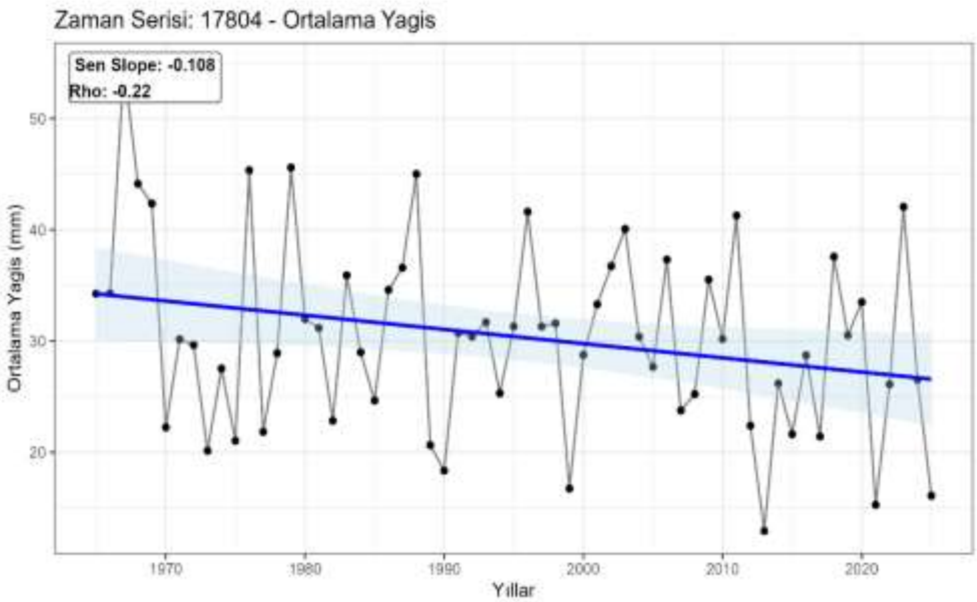

Figure 14. Average Rainfall Time Series Analysis for Elazığ Keban Station

Average precipitation analyses reveal a long-term negative trend in the precipitation regime of the region, as shown in the graph. The -0.108 Sen Slope value observed in figure 14 numerically confirms the systematic decrease in annual precipitation. When these findings are analyzed with figure 13, the clustering of the vast majority of data below the 1:1 reference line methodologically proves that precipitation amounts decreased significantly in the second half of the series. Consequently, this decreasing trend, supported by a Spearman Rho value of -0.22, indicates that the region is moving towards a drier period from a hydrological perspective. Analyses conducted at the Elazığ Keban station reveal a warming trend consistent with the Adıyaman and Elazığ Central stations in terms of temperature regime, while exhibiting a significantly different picture in terms of precipitation regime. The calculation of the Sen slope value as 0.035 and Spearman's Rho coefficient as 0.63 in the average temperature data proves the existence of a statistically significant and strong warming trend at the Keban station. The systematic positioning of the data points on the 1:1 line in the ITA/IPTA graph shows that this warming is valid for all temperature quanta and that the homogeneous structure of the series is significantly disrupted in the second half. These findings indicate that the temperature increase has acquired a widespread and consistent character on a regional scale in all three stations, thus showing that the most prominent effect of global climate change in the Eastern and Southeastern Anatolia Region is manifested in the temperature regime. This situation is in complete agreement with Türkeş's (1999) warming projections for Turkey as a whole and Çelik et al. (2018)'s drought trend due to temperature increase in the Eastern Anatolia Region. However, when evaluated in terms of precipitation regime, the Keban station differs strikingly from the other two stations. While Adıyaman shows a slight decreasing trend in precipitation (Sen slope: -0.082) and high fluctuations, Elazığ Merkez exhibits almost complete stagnation (Sen slope: 0.03). In contrast, the calculated Sen slope value of -0.108 and Spearman's Rho coefficient of -0.22 at Keban station reveal a statistically more significant and systematic decreasing trend in precipitation. The clustering of the majority of data points below the 1:1 line in the ITA/IPTA graph methodologically proves that precipitation amounts in the second half of the series decreased significantly compared to the first half.

This finding demonstrates that even within the same basin, the precipitation regime does not exhibit a homogeneous structure, and that topographic factors and microclimatic conditions play a decisive role in the temporal distribution of precipitation. This significant decreasing trend at Keban station is of critical importance, particularly for the water budget of dam reservoirs located in the upper reaches of the Euphrates Basin. Indeed, in the study conducted by Katipoğlu and Acar (2021) in the Euphrates Basin, it was emphasized that the severity of drought varies in different regions of the basin and that the risk of hydrological drought may be higher, especially in the upper basin sections. This decreasing trend detected at the Keban station once again demonstrates that regional differences should be taken into account in water resource planning, as highlighted by Rossi et al. (1992) in their studies on regional drought estimation and analysis. It is assessed that this decreasing trend in precipitation, combined with increasing temperatures, will further increase evaporation losses and may negatively affect the operating conditions of strategic water structures, especially the Keban Dam.

Precipitation and Temperature Analysis at Elazığ Palu Station

The analyses conducted show that the data from the Elazığ Palu station demonstrate a high level of statistical and methodological confidence in the climate warming occurring in the region. The annual increase coefficient of 0.036 obtained from the graph data in figure 16 determines the rate of warming, while the systematic shift observed in figure 15 confirms that this warming has a shift character. The complementary results of these two methods constitute concrete academic evidence that the region's climate system is experiencing a persistent, deterministic warming phase that is difficult to reverse.

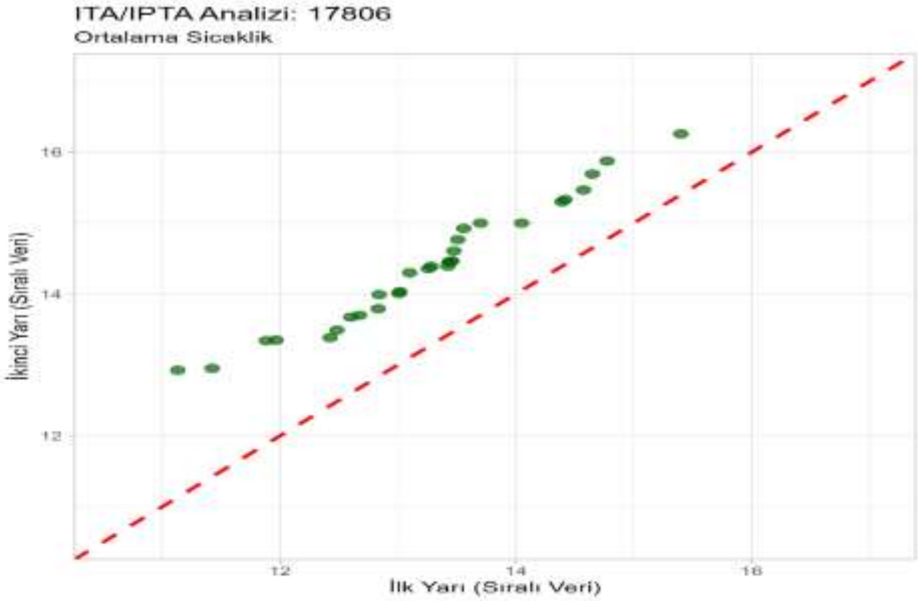

Figure 15. ITA/IPTA Analysis of Average Temperature at Elazığ Palu Station

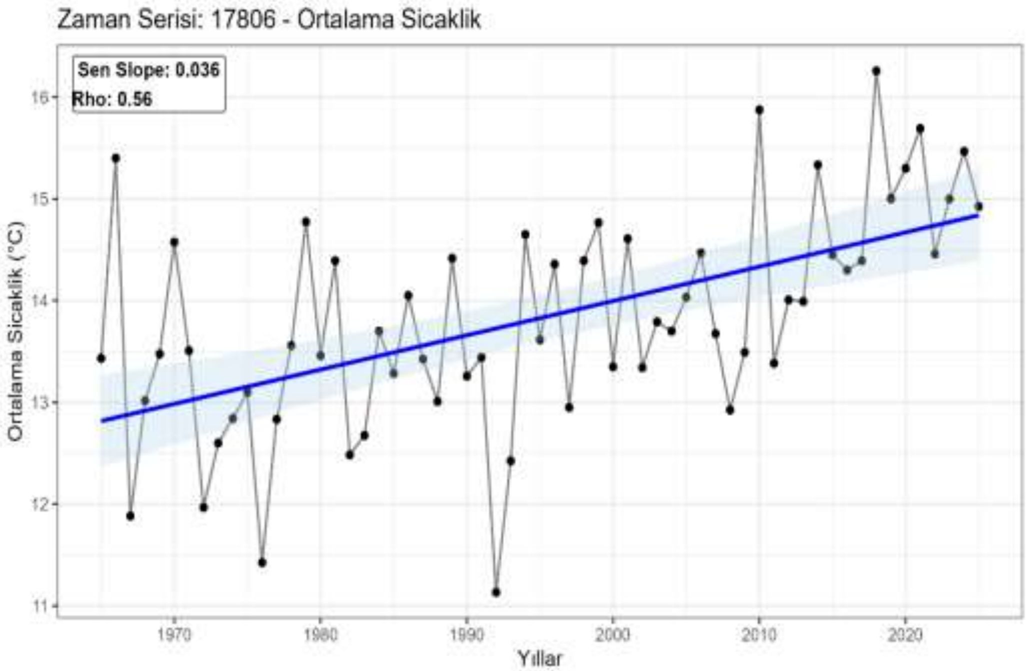

Figure 16. Time Series Analysis of Mean Temperature at Elazığ Palu Station

Average temperature analysis data from the Elazığ Palu station indicates that the region is highly sensitive to the effects of global warming and that thermal balance factors will increase.

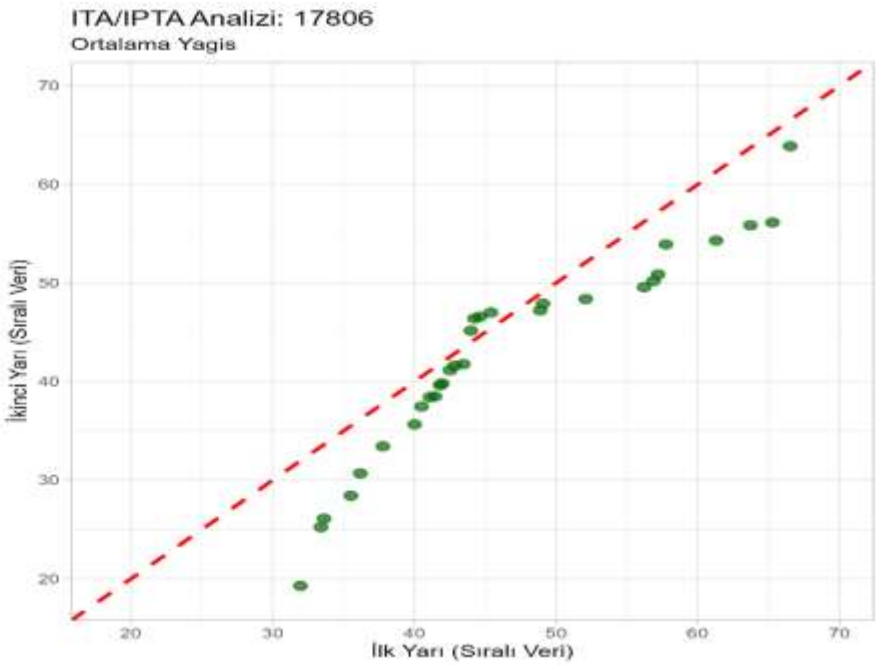

Figure 17. Average Precipitation ITA/IPTA Analysis for Elazığ Palu Station

The ITA/IPTA analysis data in figure 17 presents a comparative distribution by dividing the dataset into two sub-periods. The clustering of the majority of green data points below the 1:1 reference line demonstrates that precipitation values in the second period are lower compared to the first period. This systematic deviation from the reference line indicates a decreasing trend in precipitation intensity, particularly in the middle and upper quartiles.

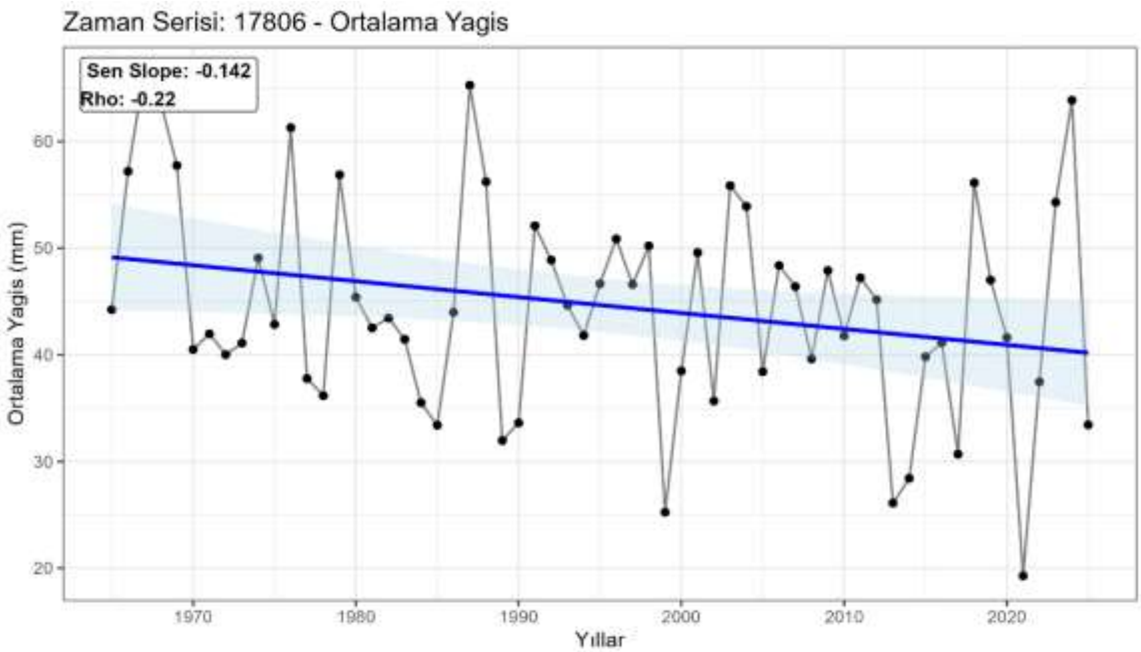

Figure 18. Time Series Analysis of Average Rainfall at Elazığ Palu Station

Figure 18 shows a statistically significant negative trend in the annual average precipitation data. The calculation of the S&R slope value as -0.142 numerically confirms the existence of a systematic decrease in the series on an annual basis. Furthermore, the Spearman correlation coefficient (Rho) of -0.22 indicates a weak but consistent inverse correlation between the time variable and precipitation amount. These findings point to a long-term hydrological decline process in the studied region. The average precipitation analysis data for the Elazığ Palu station indicate a potential long-term risk of drought. The analyses conducted at the Elazığ Palu station show complete agreement with the other three stations (Adıyaman Merkez, Elazığ Merkez, Elazığ Keban) in the temperature regime, while revealing a significant decreasing trend in the precipitation regime, similar to the Keban station. The calculation of the Sen slope value as 0.036 in the average temperature data indicates a warming rate that almost perfectly matches the Adıyaman (0.036) and Elazığ Merkez (0.04) stations. The systematic shift of the data points above the 1:1 line in the ITA/IPTA graph shows that this warming is valid for all temperature quanta and that the homogeneous structure of the series is significantly disrupted in the second half. This finding confirms once again that the temperature increase has acquired a homogeneous and widespread character on a regional scale, and therefore, the most significant and consistent effect of global climate change in the Eastern and Southeastern Anatolia Region is on the temperature regime. This situation is in complete agreement with the warming projections for Turkey as a whole predicted by Türkeş (1999) and the drying trend due to temperature increase detected in the Eastern Anatolia Region by Çelik et al. (2018). In terms of precipitation regime, the Palu station, unlike the stationary structure in Elazığ Merkez station, exhibits a significant decreasing trend parallel to the Keban station. The calculated Sen slope value of -0.142 represents the highest negative trend among the four stations, indicating a more significant rate of decrease than the -0.108 value at the Keban station. The calculation of Spearman's Rho coefficient as -0.22 shows the exact same correlation level as the Keban station, demonstrating the consistency of the inverse relationship between time and precipitation. The clustering of the majority of green data points below the 1:1 reference line in the ITA/IPTA graph methodologically proves that precipitation intensity is decreasing, particularly in the middle and upper quartiles. These findings show that even within Elazığ province, the precipitation regime does not exhibit a homogeneous structure; while precipitation remains relatively stable in the central district, it shows a significant decreasing trend in rural and upper basin areas such as Keban and Palu. This situation once again reveals the decisive influence of topographic factors and microclimatic conditions on the precipitation regime. Indeed, in the study conducted by Özfidaner and Topaloğlu (2020) in the Southeastern Anatolia Region, it was emphasized that the variability in the precipitation regime shows regional differences and that it is difficult to speak of a homogeneous drought trend. This significant decreasing trend detected at the Palu station, as in the drought analysis conducted by Yaltı and Aksu (2019) for Iğdır province, reveals the importance of station-based assessments when planning water resources at the regional scale. Combined with increasing temperatures, this decrease in precipitation is considered to pose serious hydrological drought risks, especially in rural areas with an agricultural-based economic structure such as Palu, in terms of agricultural irrigation and drinking water supply.

Gaziantep Central Station Precipitation and Temperature Analysis

As a result of the analyses, average temperature and precipitation data from the Gaziantep Central Meteorological Station for the years 1965-2025 were examined using both time series trend analysis and Innovative Trend Analysis (ITA/IPTA) methods. The findings statistically demonstrate a significant warming trend in the region.

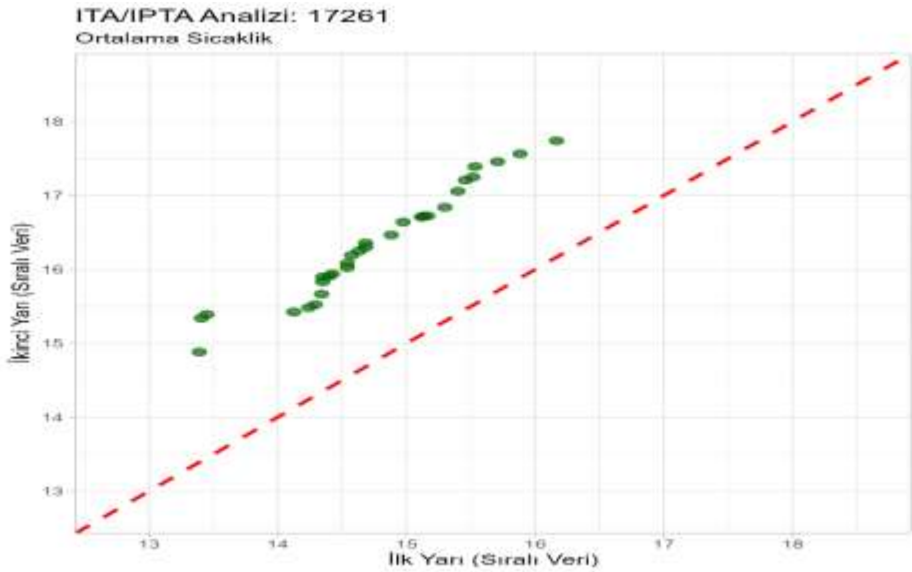

Figure 19. Average Temperature ITA/IPTA Analysis of Gaziantep Station

All average temperature data from the Gaziantep Station clustered above the 1:1 reference line. This indicates that the observations constituting the second half of the data series have statistically higher values than their counterparts in the first half. The systematic deviation of the data points from the reference line reveals that the warming regime is not limited to increases at the extremes, but rather shows a homogeneous and consistent increase across all temperature ranges comprising the data set.

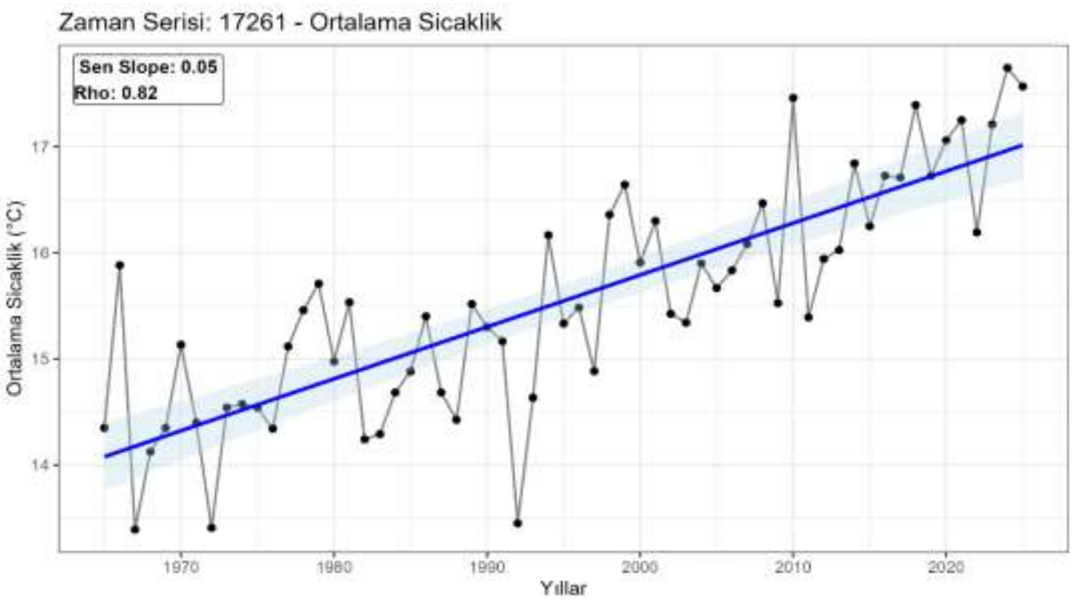

Figure 20. Time Series Analysis of Average Temperature at Gaziantep Station

The coefficient of 0.05 in Sen's slope graph shows a systematic warming trend of 0.05 °C on an annual basis in average annual temperatures, as shown in Figure 20. The Spearman Correlation Coefficient of 0.82 reveals a high degree of positive correlation between temporal progression and temperature increase. This finding indicates a high level of statistical reliability in the warming trend.

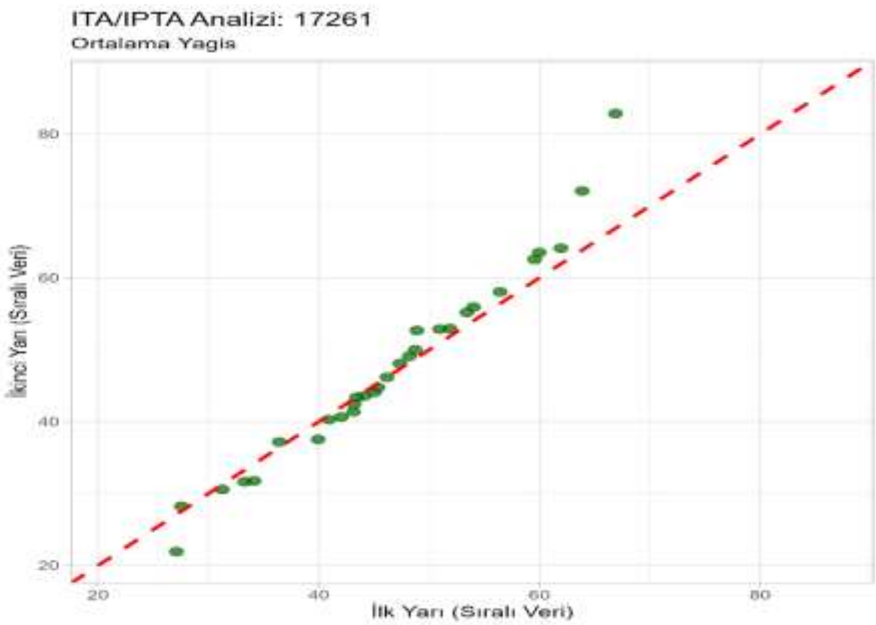

Figure 21. Average Precipitation ITA/IPTA Analysis for Gaziantep Station

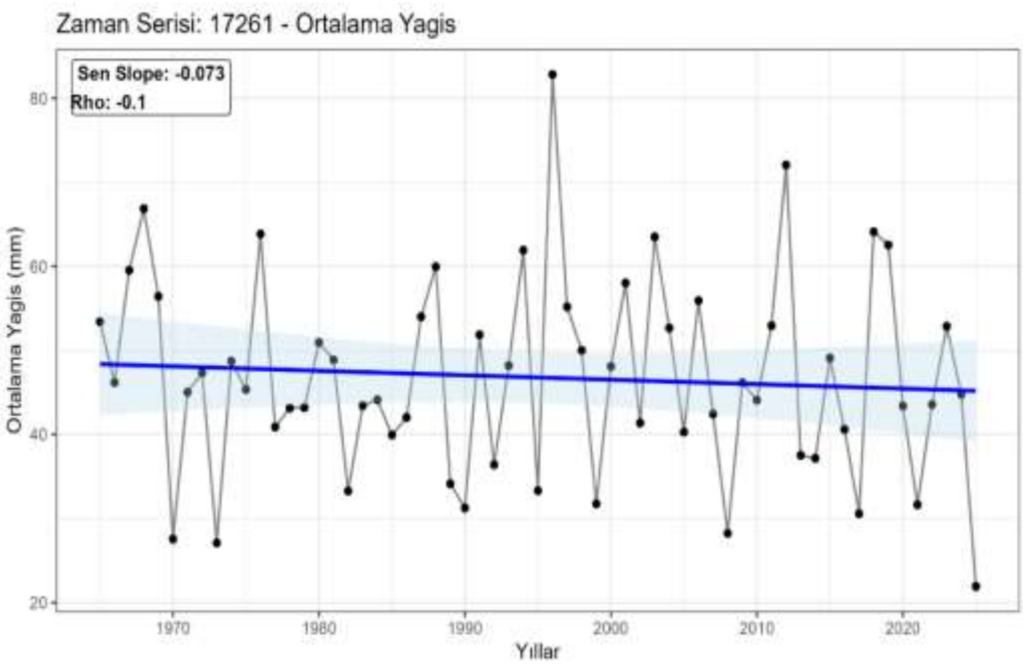

Figure 22. Average Rainfall Time Series Analysis for Gaziantep Station

When the data from the Gaziantep Central Station is examined, the Sen Slope value of 0.073 observed in the time series analysis shows a very slight downward trend in precipitation (Figure 22). The ITA/IPTA graph shows that this trend exhibits a homogeneous structure, but deviations occur from time to time, especially at the extreme values (Figure 21). The low Rho value obtained (-0.1) reveals that the precipitation regime in the region has a structure characterized by high variability rather than a clear statistical trend. The analyses performed at the Gaziantep Central Station reveal the most significant and strong warming trend among all stations examined to date (Adıyaman, Elazığ Central, Elazığ Keban, Elazığ Palu) in terms of temperature regime. The calculation of the Sen slope value as 0.05 indicates a higher warming rate compared to the values in the range of 0.035-0.04 in other stations. Even more remarkable is the fact that Spearman's Rho coefficient takes a very high value of 0.82; this value is considerably higher than that of Adıyaman (0.70) and Elazığ Merkez (0.63) stations, indicating that the temporal consistency and statistical reliability of the temperature increase in Gaziantep are much higher. The clustering of all data points above the 1:1 reference line in the ITA/IPTA graph proves that this warming is occurring homogeneously and systematically in all temperature ranges: low, medium, and high. These findings directly coincide with the findings of Kılıç (2026) in his study on spatiotemporal drought and soil moisture dynamics in the Southeastern Anatolia Project (GAP) Region, which indicated that the region is evolving towards drier conditions due to the increasing temperature trend. Furthermore, this strong warming signal is consistent with Dabanlı's (2017) study in the Akarçay Basin and Çelik et al. This is consistent with the temperature increases detected in the Eastern Anatolia Region by (2018), showing that the warming trend is becoming increasingly pronounced in the southern and eastern regions of Türkiye. In terms of precipitation regime, the Gaziantep station exhibits a similar character to the Adıyaman station. The S&R value of -0.073 is close to the -0.082 value in Adıyaman, placing it between the stationary structure in Elazığ Center (0.03) and the significant decreasing trends in Keban (-0.108) and Palu (-0.142). The Spearman's Rho coefficient of -0.1 is exactly the same as in Adıyaman, indicating that this decreasing trend is statistically weak and that a high variability structure, rather than a distinct trend, is dominant in the precipitation regime. The distribution of points around the 1:1 line both above and below the ITA/IPTA graph visually confirms this variability structure. This situation confirms that the characteristic feature of the precipitation regime in the Southeastern Anatolia Region is high seasonal variability, as highlighted in the SPI analyses conducted in Şanlıurfa by Tonkaz and Çetin (2005) and in the drought studies carried out in the same region by Gümüş et al. (2016). Kılıç (2026), in his analyses conducted throughout the GAP Region, emphasizes that this variability in the precipitation regime directly affects soil moisture dynamics and poses significant risks, especially in terms of agricultural irrigation planning. In a rapidly growing industrial and agricultural city like Gaziantep, the combination of the strong increase in temperature trend with variability in precipitation can increase evaporation losses, put pressure on the water budget, and make dependence on groundwater resources even more critical.

Precipitation and Temperature Analysis at Malatya Yeşilyurt Station

As a result of the analyses, the average temperature and precipitation data of the Malatya Yeşilyurt Meteorological Station covering the years 1965-2025 were examined within the framework of classical trend analysis and ITA/IPTA methodologies. The analysis performed using the ITA/IPTA method, shown in Figure 23, indicates that all temperature values of the Malatya Central station show a systematically increasing trend in the second half of the series and do not include any cooling period.

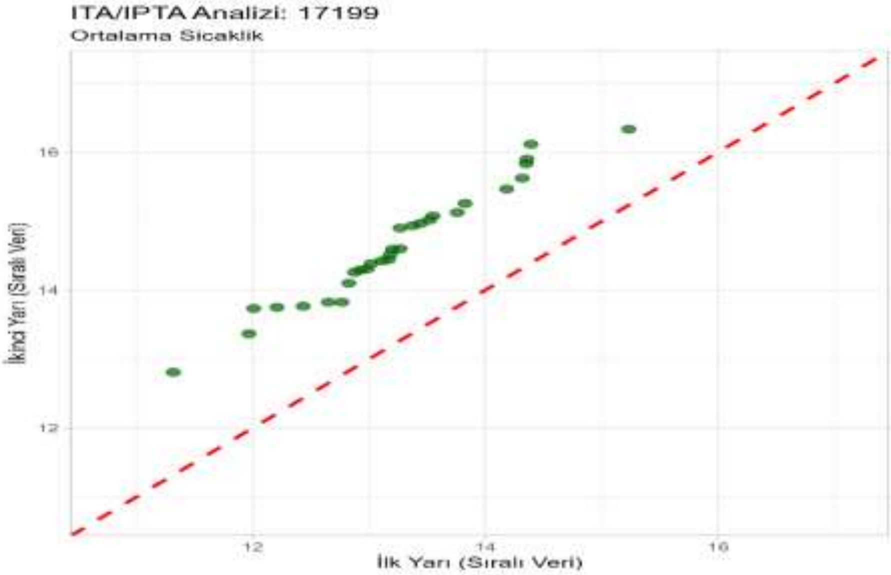

Figure 23. Average Temperature ITA/IPTA Analysis of Malatya Yeşilyurt Station

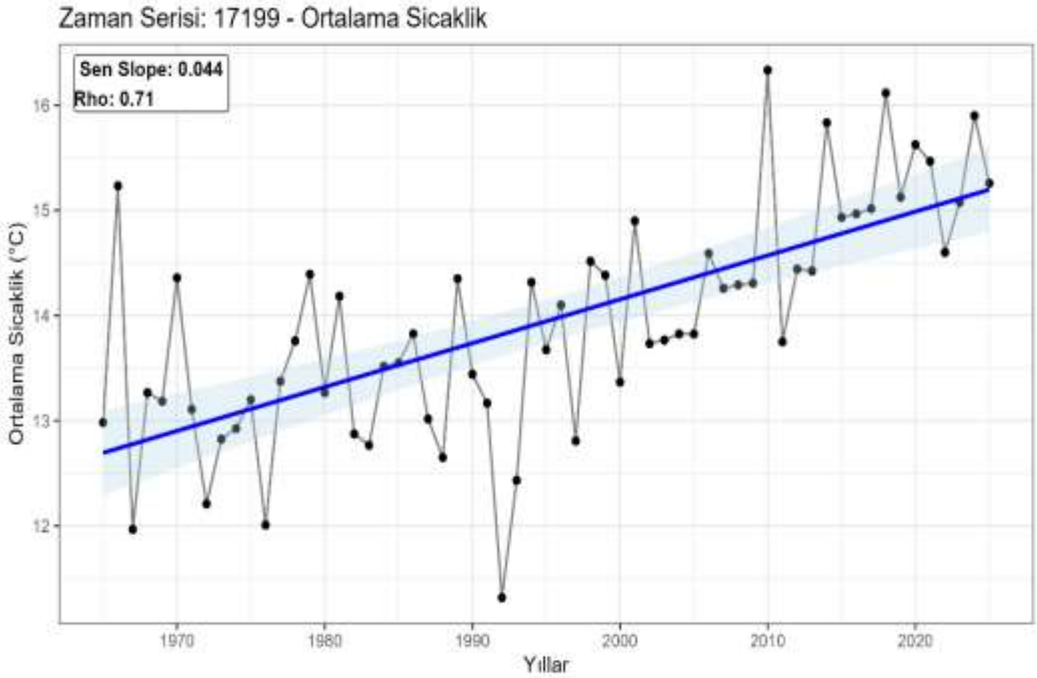

Figure 24. Time Series Analysis of Average Temperature at Malatya Yeşilyurt Station

The slope coefficient of 0.044 °C provides quantitative evidence that thermal values in the region have increased by an average of 0.044 °C annually. Furthermore, the Rho coefficient of 0.71 indicates a statistically strong and significant correlation between time and temperature change, suggesting that the warming trend is not random but has a directional character (Figure 24).

The average temperature data from the Malatya Yeşilyurt station confirms the speed and direction of warming (0.044 °C annually), while the ITA/IPTA graph confirms that this warming is a persistent and systematic change spread across the entire dataset.

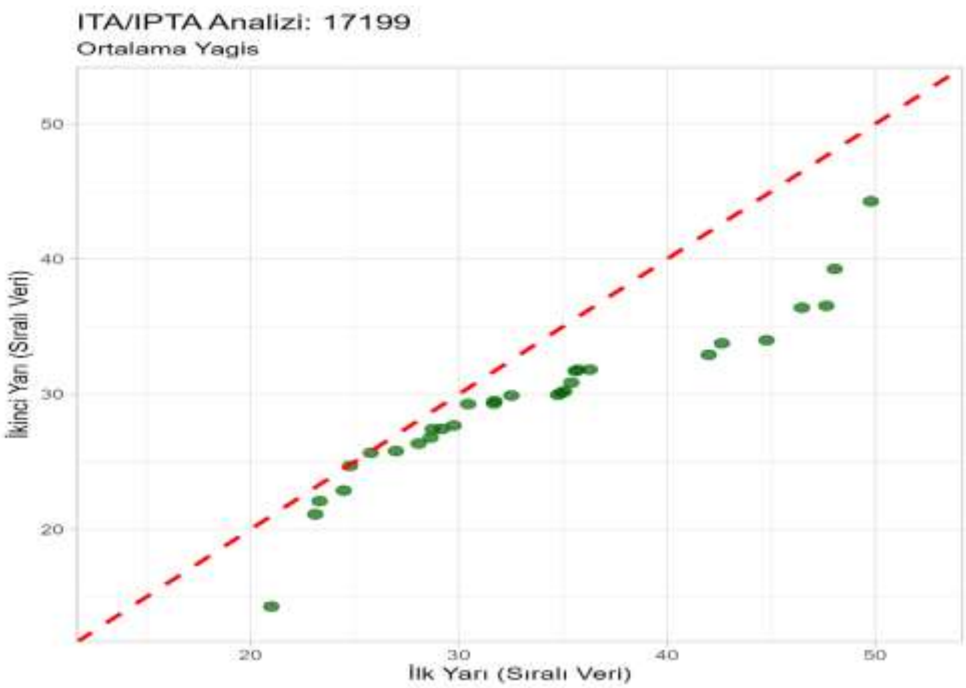

Figure 25. Average Precipitation ITA/IPTA Analysis for Malatya Yeşilyurt Station

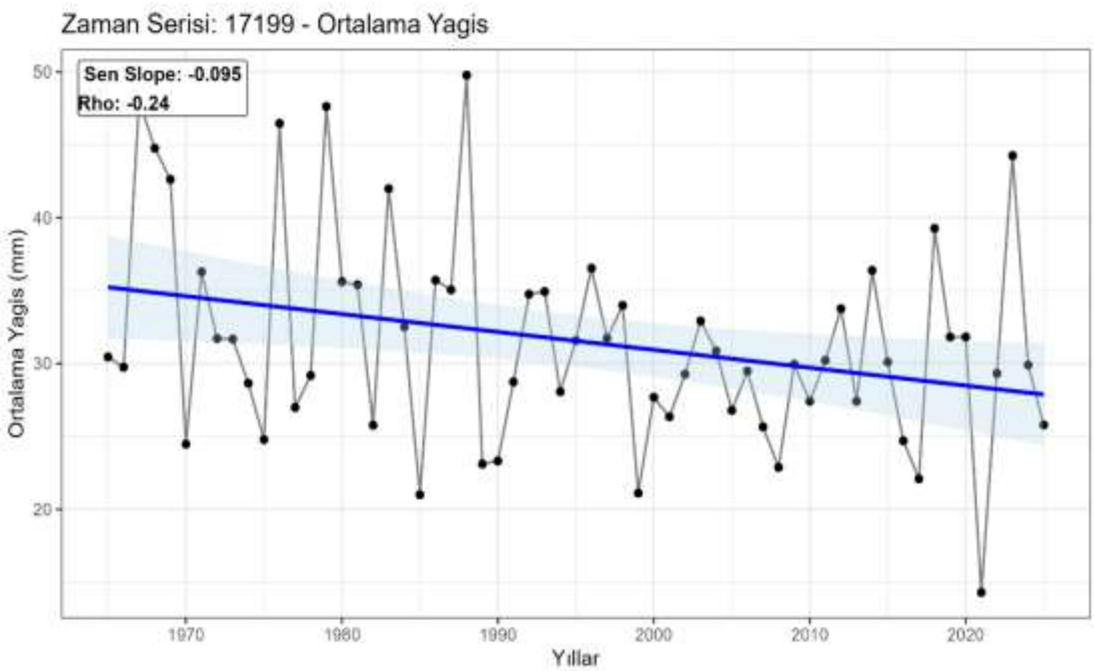

Figure 26. Time Series Analysis of Average Rainfall at Malatya Yeşilyurt Station

Trend and distribution analyses applied to data from the Malatya Yeşilyurt station show a significant change in the climatic characteristics of the region. The Sen slope value (-0.095), supported in figure 26, reveals a long-term decrease in precipitation, while the ITA/IPTA graph in figure 25 confirms that this decrease is a stable and systematic process extending across the entire series. These findings provide strong evidence that the risk of drought is increasing at the local level and that meteorological parameters exhibit a decreasing trend consistent with climate change scenarios.

Precipitation and Temperature Analysis at Malatya Doğanşehir Station

Time series analysis of meteorological data from the Malatya Doğanşehir station, covering different time scales between 1965 and 2025, and ITA/IPTA analyses show a significant warming trend in the region's climatic parameters. Data in Figure 28 supports an annual average temperature increase of 0.042 °C, while figure 27 demonstrates that this warming exhibits a systematic pattern throughout the series. This data provides strong statistical evidence that the studied region is under the influence of global climate change.

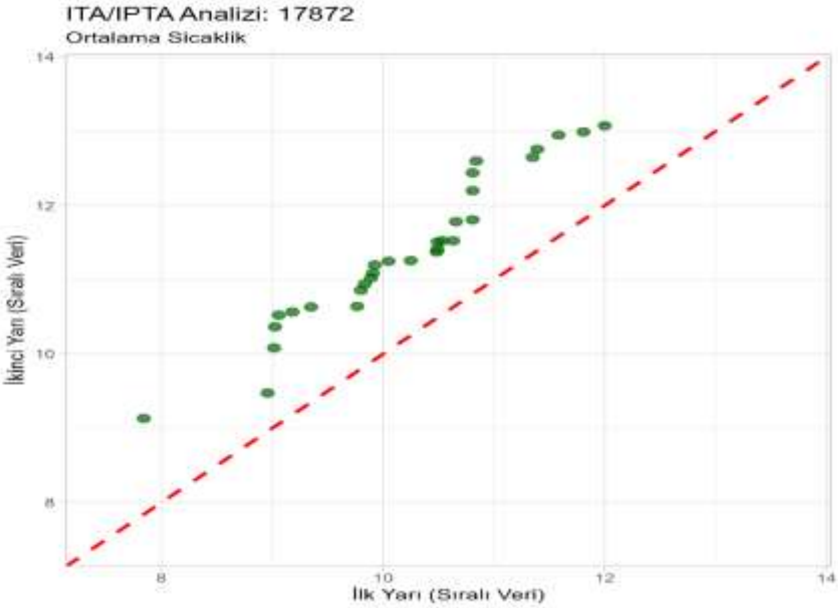

Figure 27. ITA/IPTA Analysis of Average Temperature at Malatya Doğanşehir Station

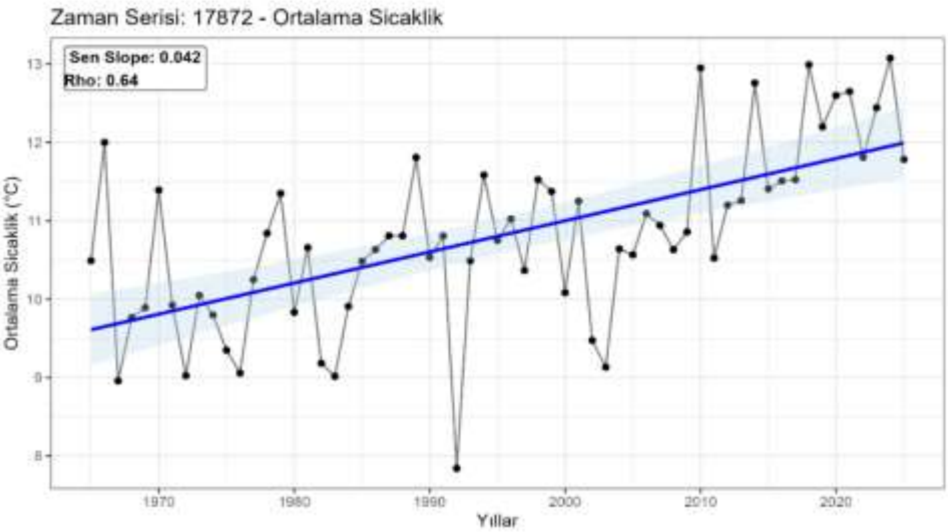

Figure 28. Time Series Analysis of Average Temperature at Malatya Doğanşehir Station

Statistical analyses applied to precipitation data from the Malatya Doğanşehir station reveal a significant trend of decreasing precipitation in the region. The Sen slope value (-0.176) obtained in Figure 30 numerically supports the annual decrease in precipitation amounts, while Figure 29 confirms that this decrease is systematic and extends throughout the entire series. These findings are considered key evidence supporting the trend of increasing drought in local climatic processes.

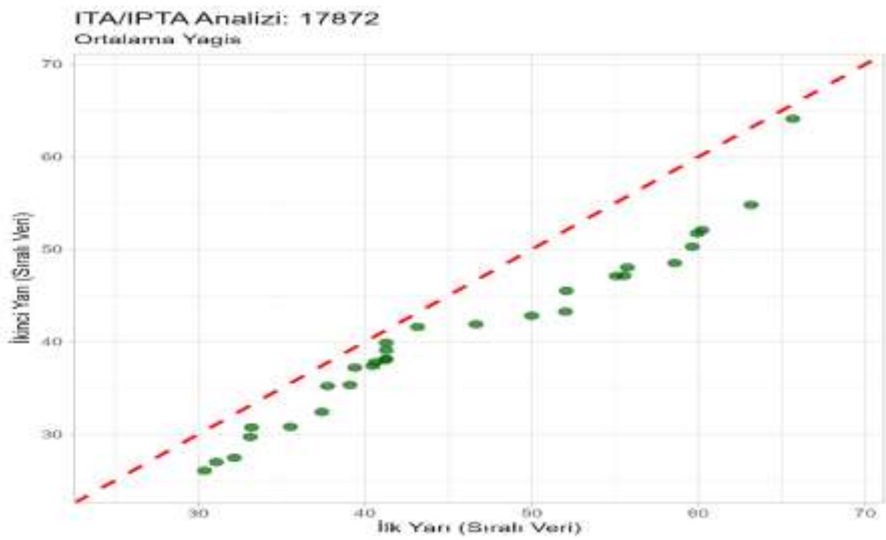

Figure 29. Average Precipitation ITA/IPTA Analysis for Malatya Doğanşehir Station

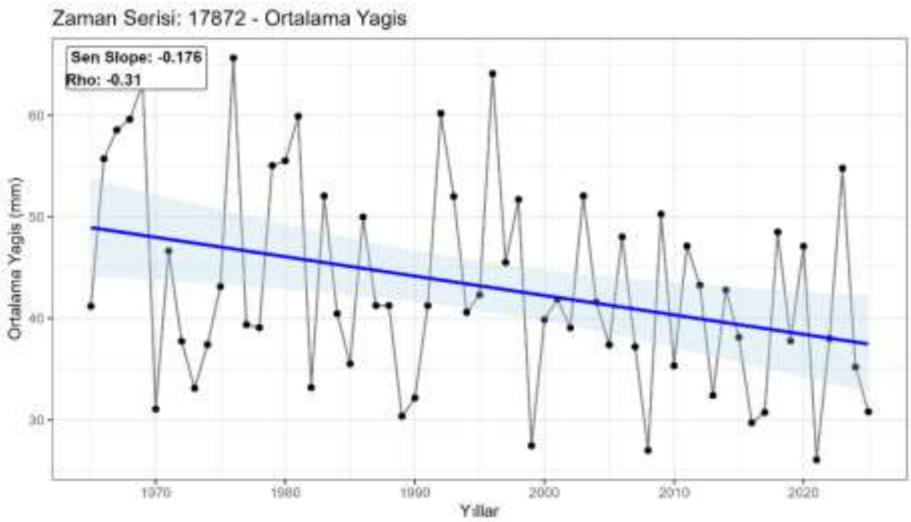

Figure 30. Time Series Analysis of Average Rainfall at Malatya Doğanşehir Station

Analyses conducted at the Yeşilyurt and Doğanşehir stations in Malatya strongly confirm a regional warming trend in the temperature regime, while revealing the highest negative trend value in the precipitation regime, particularly at the Doğanşehir station. The calculation of a Sen slope value of 0.044 and a Spearman's Rho coefficient of 0.71 at the Yeşilyurt station indicates a very strong and statistically significant warming trend, similar to the Adıyaman (0.036; Rho=0.70) and Gaziantep (0.05; Rho=0.82) stations. At the Doğanşehir station, the similar Sen slope value of 0.042 and Rho coefficient show that the warming rate and reliability are similar at both stations.

The clustering of all data points on the 1:1 reference line in the ITA/IPTA graphs at both stations proves that warming is occurring homogeneously and systematically across all temperature levels: low, medium, and high. The ITA method developed by Şen (2012), when used alongside the classical Mann-Kendall test as in this study, provides the advantage of visually revealing trend differences in the lower and upper quantiles of the series. These findings demonstrate that the warming trend highlighted by Türkeş (2012) for the Eastern Anatolia Region is also valid for Malatya, and that the region is strongly affected by global climate change. Furthermore, the findings of Çelik et al. (2018) in their seasonal drought analysis of the Eastern Anatolia Region, which indicated that temperature increases during summer months exacerbate drought severity, directly coincide with this strong warming signal at the Malatya stations.

In terms of precipitation regime, the Malatya stations present one of the most critical findings of the study. The calculation of the Sen slope value as -0.095 at the Yeşilyurt station indicates a significant decreasing trend, similar to the Elazığ Keban (-0.108) and Palu (-0.142) stations. At Doğanşehir station, the -0.176 SEN slope value is higher than that of Şanlıurfa Birecik (-0.163) and Haliliye (-0.157) stations, representing the highest negative trend value among all stations included in the study. This finding indicates that Doğanşehir is undergoing a faster drying process in its precipitation regime than all other stations. The clustering of data points below the 1:1 line in both stations in the ITA/IPTA graphs confirms that this decrease has gained a systematic character in the second half of the series. This situation is consistent with the decreasing precipitation and increasing drought severity trend identified in the study conducted by Dabanlı (2017) in the Akarçay Basin, and reveals the sensitivity of Malatya, located in the transition zone between Central and Eastern Anatolia, to climate change. In particular, the -0.176 mm/year decrease trend in Doğanşehir, combined with increasing temperatures, will further increase evaporation losses and may put serious pressure on agricultural production and water resources in the region.

As highlighted by Mishra and Singh (2010), the risk of meteorological drought turning into agricultural drought is of strategic importance in terms of its economic consequences in a region like Malatya, which is a world leader in apricot production. Similarly, in the study conducted by Kılıç (2026) in the GAP Region, it was emphasized that the decreasing trend in the rainfall regime increases the demand for agricultural irrigation water and that sustainable water management policies are necessary. In the case of Malatya, these findings show that drought risk management plans should be urgently implemented, especially in high-altitude and rain-dependent agricultural production areas such as Doğanşehir.

Precipitation and Temperature Analysis of Şanlıurfa Haliliye Station

Analyses performed on temperature data from the Şanlıurfa Haliliye station show a stable warming trend in the region's climatic parameters. The Sen slope value (0.041) in figure 32 numerically reveals the annual rate of warming, while figure 31 confirms that this warming is not coincidental, and that all observation values systematically increased in the second half of the series. These findings provide strong statistical evidence supporting local climate change indicators in the region.

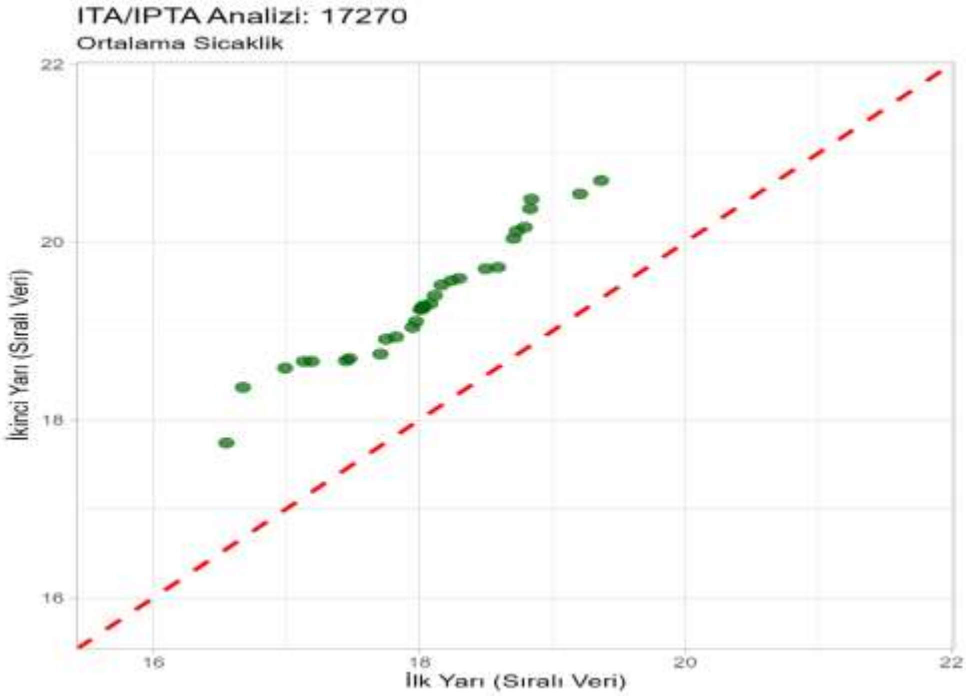

Figure 31. Average Temperature ITA/IPTA Analysis of Şanlıurfa Haliliye Station

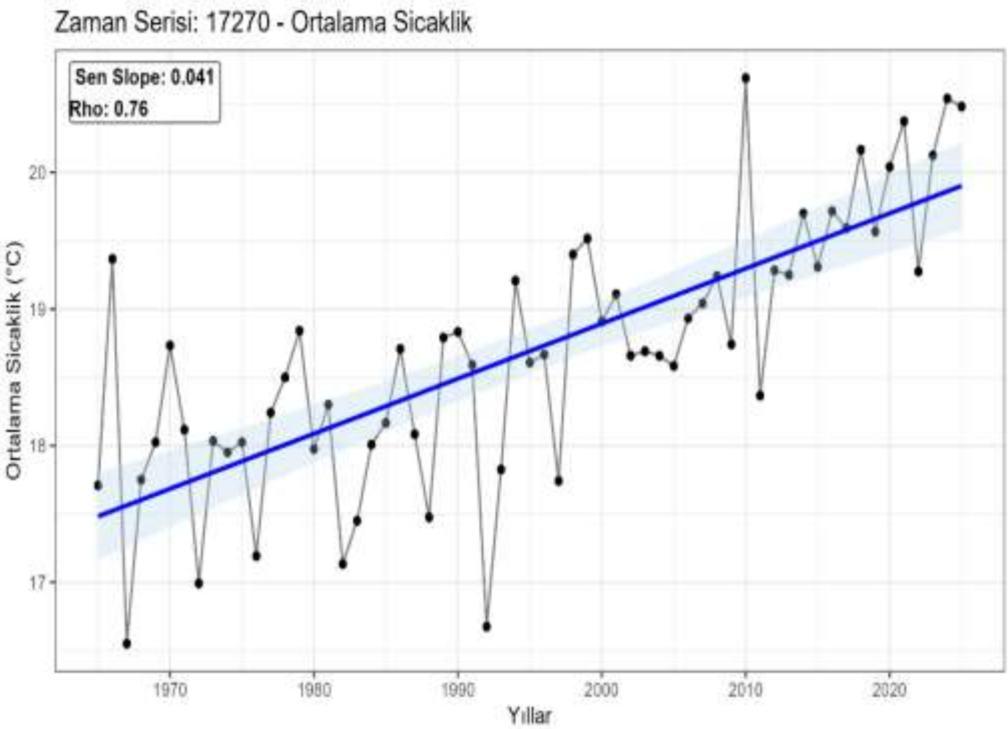

Figure 32. Time Series Analysis of Average Temperature at Şanlıurfa Haliliye Station

Statistical analyses applied to precipitation data from the Şanlıurfa Haliliye station show a significant drying trend in the hydrological character of the region. Figure 34 numerically supports a decrease of -0.157 mm on an annual basis, while Figure 33 confirms that this decrease is a systematic and stable process spread throughout the entire series.

These findings provide strong statistical evidence that meteorological parameters in the region exhibit a decreasing trend consistent with climate change.

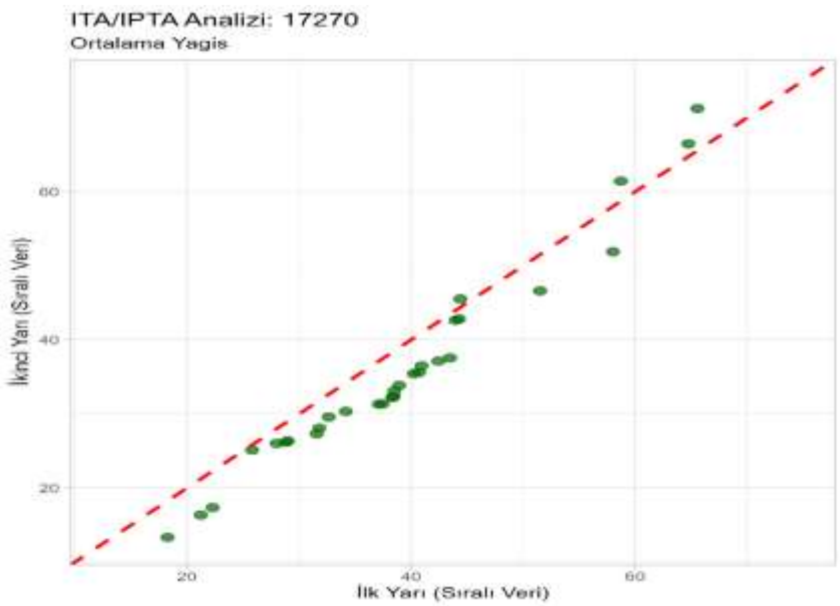

Figure 33. Average Precipitation ITA/IPTA Analysis for Şanlıurfa Haliliye Station.

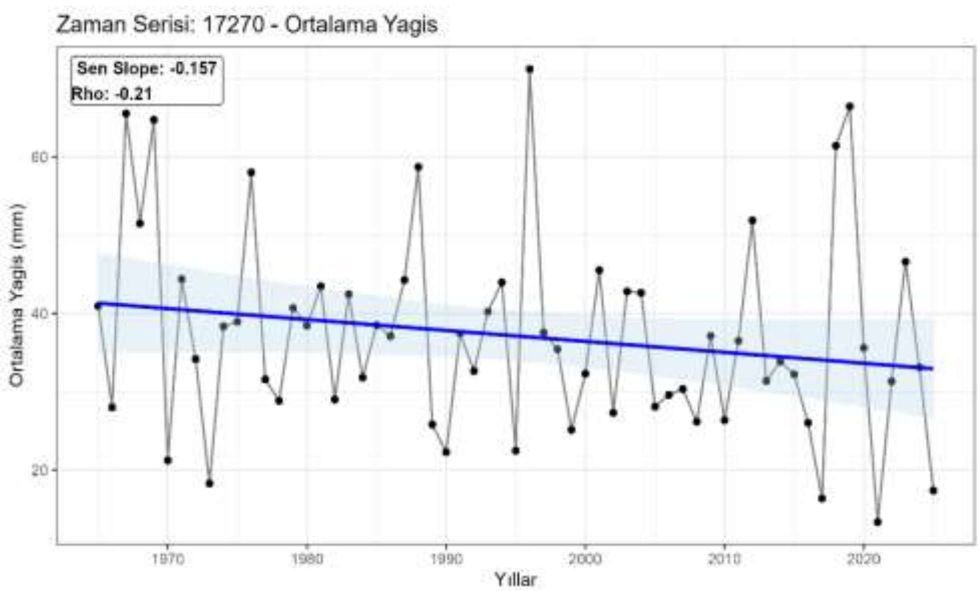

Figure 34. Average Precipitation Time Series Analysis of Şanlıurfa Haliliye Station

Analyses conducted at the Şanlıurfa Haliliye station reveal a warming trend consistent with all stations examined to date in terms of temperature regime, while exhibiting the most significant and systematic decreasing trend in precipitation regime within the scope of this study. The calculation of the Sen slope value as 0.041 in the average temperature data indicates a warming rate similar to that of Adıyaman (0.036), Elazığ Merkez (0.04), and Gaziantep (0.05) stations. The clustering of all data points on the 1:1 reference line in the ITA/IPTA graph confirms that this warming is occurring homogeneously and systematically across all temperature levels. These findings once again demonstrate the superiority of the ITA method developed by Şen (2012) in revealing trend differences at low and high values compared to the classical Mann-Kendall test. Furthermore, this regional consistency of temperature increase is in complete agreement with the warming trend highlighted by Türkeş (2012) in his assessments of climate change across Turkey, and particularly noticeable in the Southeastern Anatolia Region.

From the perspective of precipitation regime, the Şanlıurfa Haliliye station exhibits the highest negative trend value (-0.157) among all stations, presenting the most striking finding of the study. This value is higher than the -0.142 value at the Palu station and the -0.108 value at the Keban station, indicating a significant break in the region's precipitation regime. The systematic clustering of data below the 1:1 line in the ITA/IPTA graph proves that this decrease is not coincidental, and that precipitation amounts decreased significantly in the second half of the series compared to the first half. This finding is consistent with the increasing drought severity trend identified by Tonkaz and Çetin (2005) in their study using the SSI method in Şanlıurfa, and with the findings of Gümüş et al. This directly coincides with the increase in the frequency of drought periods determined at the same station by (2016). Furthermore, analyses conducted by Özfidaner and Topaloğlu (2020) across the Southeastern Anatolia Region emphasized that the area around Şanlıurfa is one of the driest parts of the region. Kılıç (2026), in his spatiotemporal analyses of the GAP Region, stated that Şanlıurfa is critically important for agricultural production and that the decreasing rainfall trend negatively affects soil moisture dynamics, increasing irrigation water demand. This significant decrease of -0.157 mm/year detected at the Şanlıurfa station, combined with increasing temperatures, will further increase evaporation losses and may push water demand to critical levels, especially in agricultural lands opened to irrigation within the scope of GAP. As emphasized in the review of drought concepts by Mishra and Singh (2010), the risk of meteorological drought (decreased rainfall) turning into agricultural and hydrological drought is quite high, especially in regions located in the semi-arid climate zone, such as Şanlıurfa.

Precipitation and Temperature Analysis of Şanlıurfa Siverek Station

Trend analysis applied to the data from the Şanlıurfa Siverek station shows that the annual average temperatures exhibit an increasing trend of 0.029 °C annually (Figure 36). The Spearman correlation coefficient, calculated as 0.61, proves that this increase is statistically strong and significant. In addition, findings obtained using the ITA/IPTA method show that all temperature values recorded in the second half of the series are systematically higher (Figure 35). These results demonstrate that a stable warming process is occurring in the region regarding temperature parameters, and this change can be considered an indicator of local climate change effects.

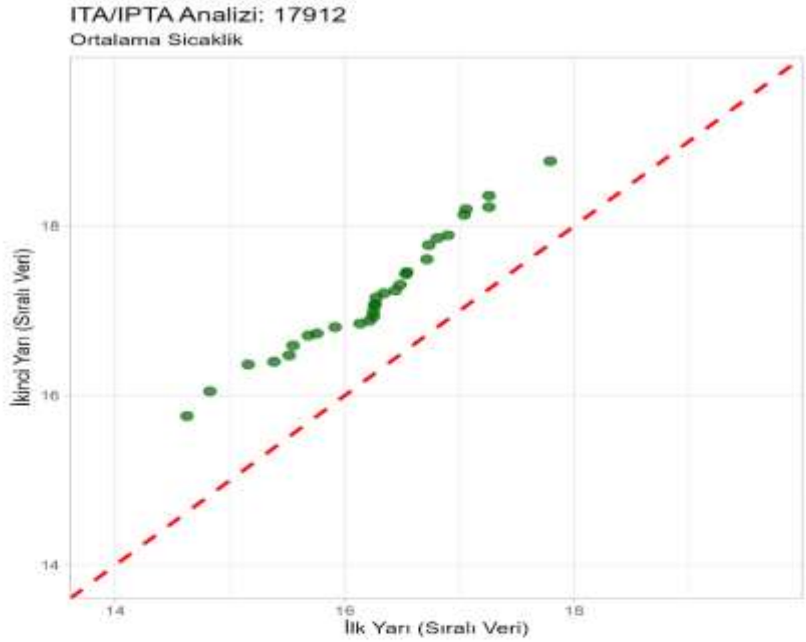

Figure 35. ITA/IPTA Analysis of Average Temperature at Şanlıurfa Siverek Station

The data in Figure 37 is based on the ITA method, which compares the first half of the data with the second half. Using a 1:1 line as a reference, it is observed that low and high precipitation values generally cluster below the 1:1 line. This indicates that in the second half of the precipitation series, especially at extreme values, a slight decrease is dominant compared to the first half. The distribution of the data around the 1:1 line supports the idea that the overall trend in the time series is close to stationary, but exhibits a decreasing trend with small deviations.

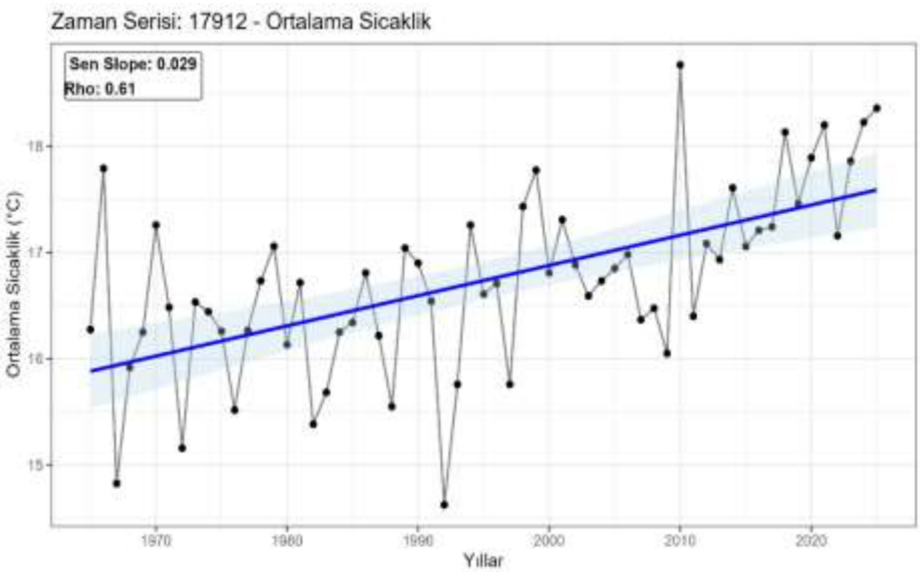

Figure 36. Time Series Analysis of Average Temperature at Şanlıurfa Siverek Station

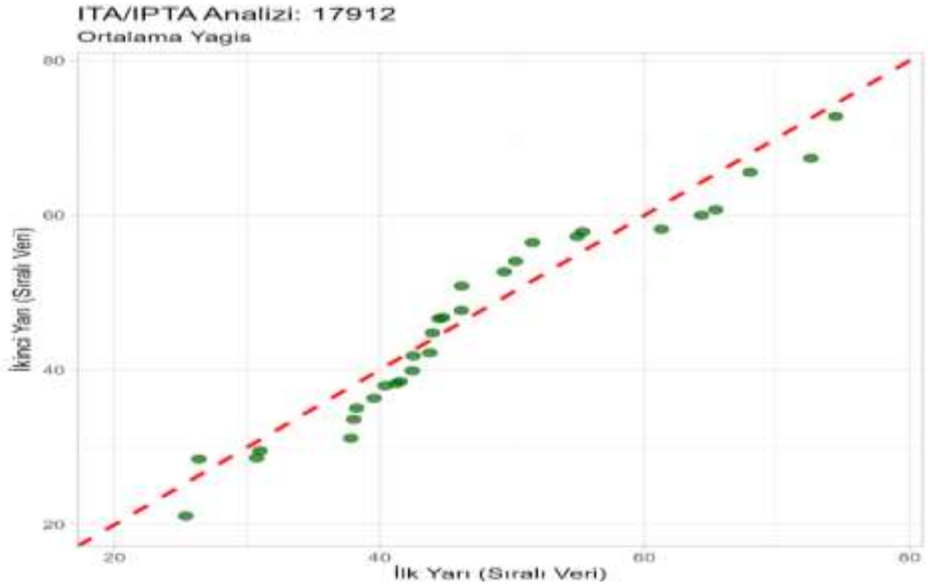

Figure 37. Average Precipitation ITA/IPTA Analysis for Şanlıurfa Siverek Station

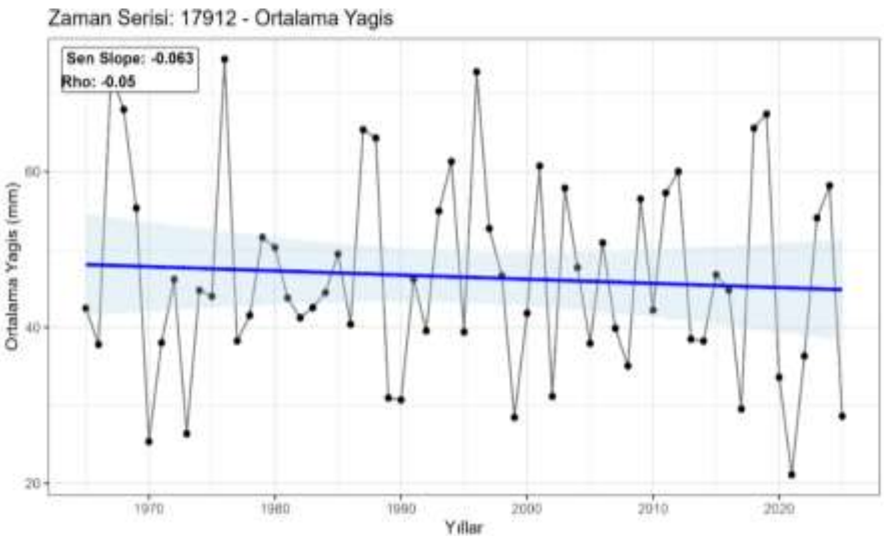

Figure 38. Time Series Analysis of Average Rainfall at Şanlıurfa Siverek Station

Figure 38 presents the year-on-year change in the data and the linear trend line. The calculated Sen slope coefficient from the analysis was determined to be -0.063. This negative value indicates a slight downward trend in the time series. Furthermore, the Spearman Rho value of -0.05 suggests that this downward trend has a statistically weak correlation. The blue trend line on the graph confirms that, in the long term, the data shows a near-stationary but slightly downward trend.

Precipitation and Temperature Analysis of Şanlıurfa Birecik Station

As a result of the analysis, the ITA/IPTA method shows that the temperature values in the second half of the time series of station 17966 are systematically higher than the first half. The fact that all data points lie above the 1:1 reference line confirms that the observed warming trend is statistically dominant and consistent. Especially the deviation in high temperature values may indicate that the warming trend is also effective on extreme values.

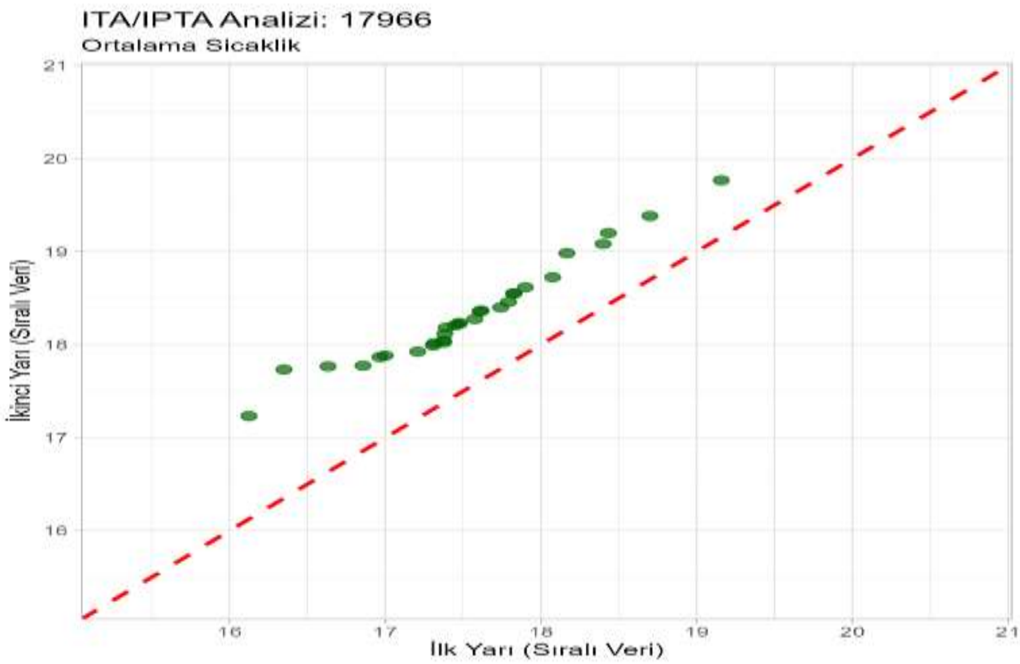

Figure 39. Average Temperature ITA/IPTA Analysis of Şanlıurfa Birecik Station

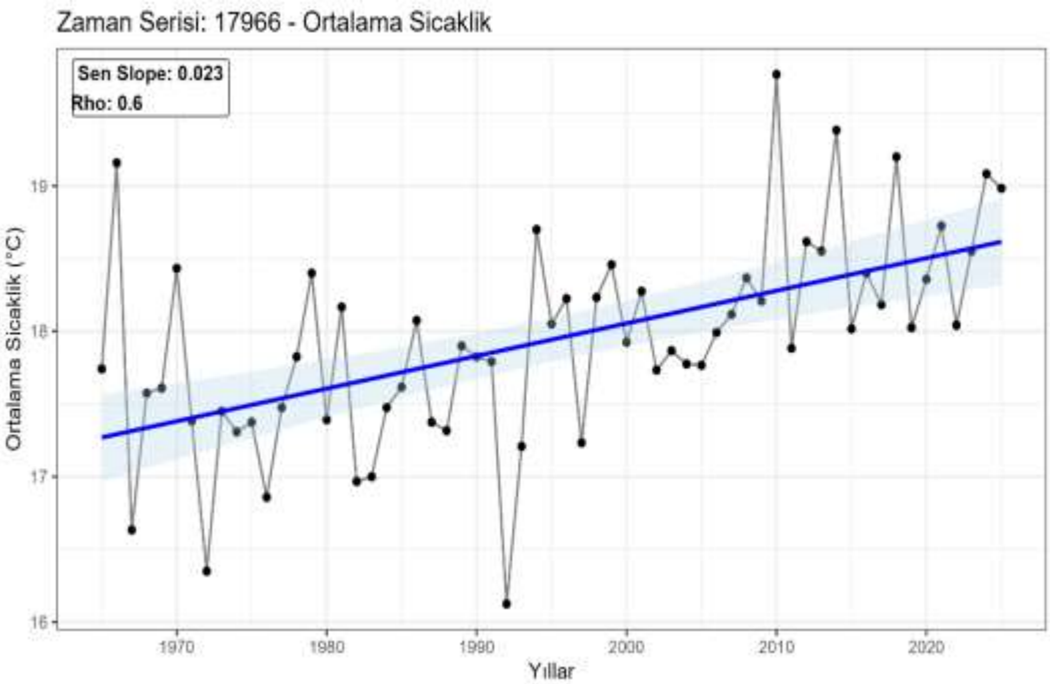

Figure 40. Time Series Analysis of Average Temperature of Şanlıurfa Birecik Station

Figure 40 shows the long-term temperature changes and trend line. The calculated Sen slope coefficient of

0.023 indicates a positively increasing temperature trend in the series. The Spearman Rho value of 0.6 demonstrates that this increase has a moderate-to-high statistical correlation and proves the presence of a significant warming trend in the time series. The blue trend line shown on the graph supports the finding of a steady increase in average temperatures over the years.

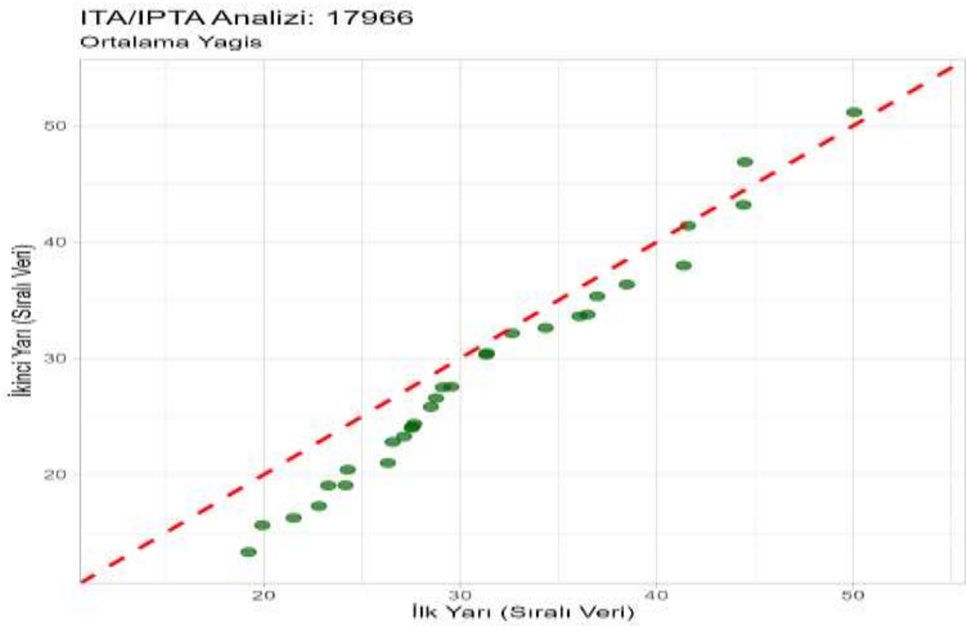

Figure 41. Average Precipitation ITA/IPTA Analysis of Şanlıurfa Birecik Station

The results of the ITA/IPTA analysis, conducted to examine the long-term trend behavior of the series in more detail, are presented in Figure 41. Using a 1:1 (45°) line as a reference, it is observed that the vast majority of data points are located below this line. This clearly shows that the precipitation values in the second half of the series are lower than their counterparts in the first half, and therefore there is a general decreasing trend in the series. The distribution in the visualization confirms the negative slope result obtained from the time series analysis (Figure 42).

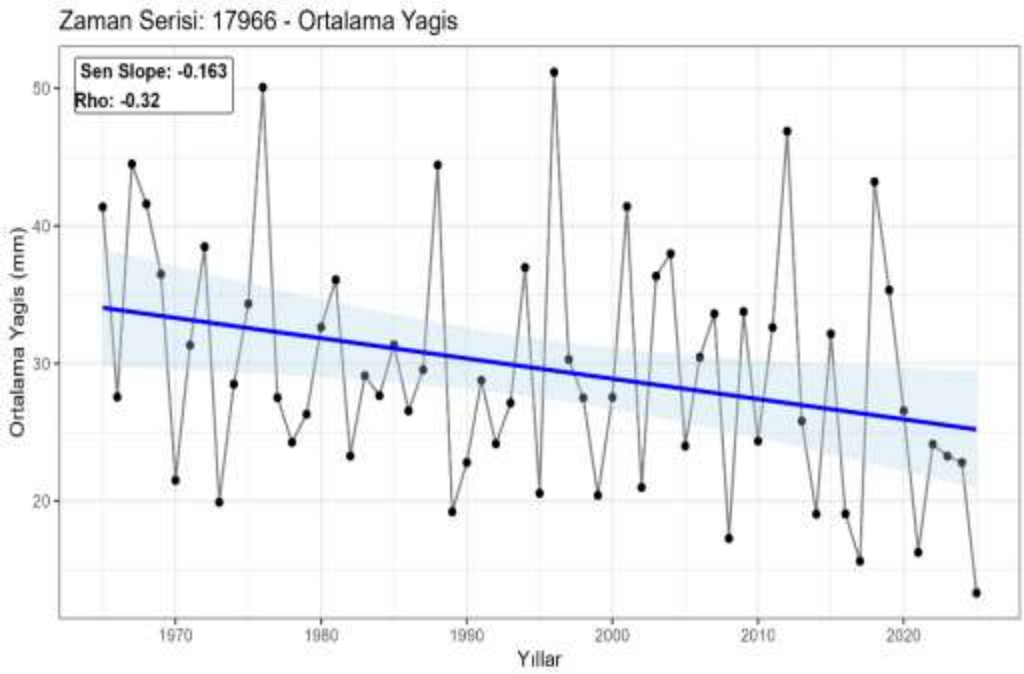

Figure 42. Time Series Analysis of Average Rainfall of Şanlıurfa Birecik Station

Average rainfall time series analysis shows a significant downward trend in rainfall amounts in recent years (Figure 42). The Sen slope value of -0.163 indicates that the average annual rainfall is decreasing by approximately 0.16 mm each year. This decrease is not simply a matter of variability, but a trend that could put pressure on the hydrological cycle in the region. The Spearman's Rho coefficient of -0.32 reveals a weak to moderate negative correlation, indicating a systematic nature of the decline. Analyses conducted at the Şanlıurfa Siverek and Birecik stations confirm a regional warming trend in the temperature regime, while revealing one of the highest negative trend values in the study, particularly at the Birecik station, in the rainfall regime.

The calculation of the Sen slope value as 0.029 and the Spearman's Rho coefficient as 0.61 at the Siverek station indicates a relatively lower warming rate compared to other stations, but still shows a statistically significant and strong increase. At Birecik station, the Sen slope value is 0.023, indicating the lowest warming rate within the scope of the study, and the Spearman's Rho value of 0.6 proves that this increase is moderately-highly reliable. In both stations, the clustering of data points above the 1:1 reference line in the ITA/IPTA graphs confirms that warming occurred homogeneously across all temperature levels. When these findings are considered together with the higher warming rate at Şanlıurfa Haliliye station (0.041), they show that even within the same provincial boundaries, the rate of temperature increase can vary depending on microclimatic and topographical factors. Türkeş (2012), in his assessment of climate change for Turkey as a whole, emphasized that temperature increases are particularly significant in the Southeastern Anatolia Region, and the findings obtained in this study confirm these regional projections on a station basis.

When evaluated in terms of precipitation regime, significant differences are observed between the two stations. The Sen slope value of -0.063 and the Spearman's Rho coefficient of -0.05 at the Siverek station indicate a very slight decrease in precipitation, although this decrease is statistically weak. The distribution of points around the 1:1 line in the ITA/IPTA graph shows that the precipitation regime in Siverek is close to a stationary structure, and that a significant drying trend, as seen in Haliliye (-0.157), has not yet formed. In contrast, the Sen slope value of -0.163 calculated at the Birecik station is almost at the same level as the Haliliye station (-0.157), representing one of the highest negative trend values within the scope of the study. More importantly, the calculation of the Spearman's Rho coefficient as -0.32 proves that this decreasing trend has a much stronger statistical correlation compared to other stations, and that the drying trend in Birecik has acquired a systematic character. The clustering of the vast majority of data points below the 1:1 line in the ITA/IPTA graph methodologically confirms this systematic decrease. These findings reveal that the precipitation regime is not homogeneous in the Şanlıurfa province; while Siverek, located in the northern part of the city, has a relatively preserved precipitation regime, Haliliye and Birecik in the southern and western parts are experiencing a significant drying trend. Birecik, in particular, has strategic importance due to its location on the banks of the Euphrates River and its proximity to the dam reservoir. The systematic decrease in precipitation in Birecik (Rho = -0.32), combined with increasing temperatures, could increase evaporation losses and put pressure on the water budget of the Birecik Dam.

Spatiotemporal analyses conducted by Kiliç (2026) in the GAP Region highlight that soil moisture deficits are more pronounced in the southern parts of Şanlıurfa, and the demand for agricultural irrigation water is steadily increasing. In the drought analysis conducted by Taşkolu (2023) for the Southeastern Anatolia Region, it was stated that the area around Şanlıurfa is one of the driest parts of the region and that the severity of drought is increasing. As emphasized by Mishra and Singh (2010), the risk of meteorological drought (reduced rainfall) turning into agricultural and hydrological drought is quite high, especially in regions with intensive agricultural production and dependence on dam reservoirs, such as Birecik. The strong correlation of Rho = -0.32 at the Birecik station suggests that the drying trend at this station is not just a seasonal fluctuation, but may be a harbinger of a long-term climatic transformation.

CONCLUSION

This study involved trend analyses of annual average temperature and annual average precipitation data from 10 meteorological stations located within the Lower Euphrates Basin; namely Adıyaman Center, Elazığ Center, Elazığ Keban, Elazığ Palu, Gaziantep Center, Malatya Doğanşehir, Malatya Yeşilyurt, Şanlıurfa Haliliye, Şanlıurfa Birecik, and Şanlıurfa Siverek, for the years 1965-2025. The findings obtained from the analyses, conducted using Mann-Kendall, Spearman's Rho, Innovative Trend Analysis (ITA), and Statistical Trend Analysis (IPTA) methods, and their comparative evaluation with the literature are summarized below.

Temperature Regime Findings

A statistically significant and positive warming trend was detected in the average temperature data at all stations. The highest warming rate was observed at the Gaziantep Central station (Sen slope: 0.05 °C/year; Rho: 0.82), while the lowest warming rate was recorded at the Şanlıurfa Birecik station (Sen slope: 0.023 °C/year; Rho: 0.60). Analyses performed using the ITA/IPTA method confirmed that warming occurred homogeneously and systematically at all stations across all temperature ranges: low, medium, and high. These findings are in complete agreement with the warming trend highlighted in the climate change assessments conducted by Türkeş (2012) for Turkey as a whole, and which is particularly noticeable in the Southeastern

Anatolia Region. Furthermore, the drying trend due to temperature increase identified by Çelik et al. (2018) in the Eastern Anatolia Region and the significant temperature increases determined by Dabanlı (2017) in the Akarçay Basin also support the findings of this study. The ITA method developed by Şen (2012) offers the advantage of visually revealing trend differences in the lower and upper quantiles of the series compared to the classical Mann-Kendall test, and, as emphasized by Deger et al. (2025) in hydrological drought studies conducted in different basins, it once again confirms the effectiveness of the method in trend determination.

Precipitation Regime Findings

Significant differences were detected between stations in the precipitation regime. The highest negative trend value was observed at the Malatya Doğanşehir station (Sen slope: -0.176 mm/year), followed by Şanlıurfa Birecik (-0.163 mm/year), Şanlıurfa Haliliye (-0.157 mm/year), Elazığ Palu (-0.142 mm/year) and Elazığ Keban (-0.108 mm/year) stations, respectively. In contrast, while almost complete stagnation (Sen slope: 0.03 mm/year; Rho: 0.05) prevailed at the Elazığ Central station, a very slight decrease (Sen slope: -0.063 mm/year; Rho: -0.05) was detected at the Şanlıurfa Siverek station. These findings show that even within the same basin, the precipitation regime does not exhibit a homogeneous structure, and that topographic factors and microclimatic conditions play a decisive role in the temporal distribution of precipitation. Similarly, the study conducted by Özfidaner and Topaloğlu (2020) in the Southeastern Anatolia Region also emphasized that the variability in the precipitation regime shows differences on a regional scale. Furthermore, the increase in the frequency of drought periods detected in the SPI analyses conducted in Şanlıurfa by Gümüş et al. (2016) and Tonkaz and Çetin (2005) directly coincides with the significant decrease in precipitation trend determined in the Şanlıurfa stations in this study.

General Assessment

While an increase in temperature was observed in all 10 stations included in the study, differences were detected in the precipitation regime at the station level. The most critical finding is that in stations where temperature increase and precipitation decrease occurred simultaneously (especially Malatya Doğanşehir, Şanlıurfa Birecik, Şanlıurfa Haliliye, Elazığ Palu and Elazığ Keban), an increased thermal pressure on the hydrological water budget and a risk of drought emerged. This situation shows that the risk of meteorological drought (decreased precipitation) turning into agricultural and hydrological drought is quite high, especially in these regions located in the semi-arid climate zone, as emphasized by Mishra and Singh (2010). Similarly, in spatiotemporal analyses conducted in the GAP Region by Kılıç (2026), it was stated that the decreasing precipitation trend negatively affects soil moisture dynamics and increases the demand for irrigation water. Esit and Yuce (2023) and Yuce et al. In drought studies conducted in different basins by (2025), it was emphasized that the pressure exerted by temperature increase on the water budget through evaporation and its resulting increased risk of hydrological drought were highlighted.

In light of the findings obtained in this study, and in consideration of the relevant literature, it is evident that some regions have experienced particularly significant declines in precipitation. These regions include Malatya Doğanşehir, Şanlıurfa Birecik, Şanlıurfa Haliliye, Elazığ Palu, and Elazığ Keban. Given the severity and statistical significance of these observed decreases, there is an urgent imperative to revise and update existing water resource management plans. Furthermore, it is critically necessary to implement comprehensive drought action plans without further delay in order to mitigate the potential adverse hydrological, agricultural, and socio-economic impacts in these vulnerable areas. In addition, it is imperative to recognize that minimizing the detrimental impacts of environmental pollution, climate change, and drought necessitates the timely adoption and sustained implementation of appropriate mitigation measures. Ensuring that these interventions are both proactively initiated and consistently maintained over the long term remains a critical priority for safeguarding ecological integrity and societal well-being.

Acknowledgements

*Thanks so much to Adıyaman University Scientific Research Projects Unit, to support this research with project number MÜFYL/2025-0001

*Thanks to the Adıyaman Regional Directorate of the General Directorate of Meteorology (MGM) for providing the data used in this study.

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