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Trend analysis of temperature and precipitation in Mediterranean region

Cavit Berkay Yılmaz*[1], Vahdettin Demir [1], Mehmet Faik Sevimli [1], Fikret Demir [2], Murat Yakar [3]

[1]KTO Karatay University, Engineering Faculty, Civil Engineering Department, Konya, Turkey
[2]Turkish State Meteorological Service, Ankara, Turkey
[3]Mersin University Engineering, Faculty, Surveying Engineering Department, Mersin, Turkey

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ABSTRACT

Hydrological parameters are heavily affected by climate changes and human activities. To confirm and take actions against such affects and changes caused by these affects trend analyzes must be performed. In this study, Linear Trend and Modified Mann-Kendall trend analyzes were performed using the annual average temperature data (̊C) and the annual total precipitation data (mm) between 1960-2020 of Burdur, Isparta, Kahramanmaraş, Muğla, Antalya, Mersin, Adana, Osmaniye, Antakya stations. The study concluded in increasing trends in temperature data (8 out of 9 stations) and no trend in precipitation data.

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1. Introduction

Climate change has a long-term impact on the ecosystem, resulting in considerable changes in hydrometeorological parameters. A shift in the ecological equilibrium can have long-term consequences for the entire ecosystem. The most important of these indicators are the increases in the global average air temperature, the melting of the glaciers in the poles and inland areas, the rise in sea levels, the increase in the frequency and intensity of floods, droughts and precipitation (Büyükyıldız, 2004). For this reason, analysis of such parameters is important for detecting extremes. İçel (2009) analyzed temperature, precipitation, and extreme instances throughout the eastern Mediterranean coast and found an increasing trend in 11 stations, with the increase being more noticeable after 1992. Bahadır (2011) used the Growth Curve and ARIMA model to investigate temperature and precipitation trend changes in the Mediterranean Region and found that all stations showed an increase in temperature and a decrease in precipitation. İlker et. al. (2019), examined the spatial distribution of precipitation in the Mediterranean Region and created precipitation distribution maps with the help of Geographic Information Systems. In the control of these maps, the coefficient of determination and the root mean square error values were used (Bacanlı & Akşan (2019), found that all stations in the Mediterranean Region are between mild drought and normal. It was determined that Adana had the lowest percentage values in both wet and dry conditions compared to other stations. Durmuş et. al. (2021), Between 1980-2019 examined the changes in temperature and precipitation extremes. With the RH test, the breaking dates in homogeneity were determined. 17 temperature and 6 precipitation indices from the climate indices determined by WMO and CLIVAR were applied to the temperature and precipitation data. They found that while the maximum temperature average values increased by 2.4 °C in general, the minimum temperature average increased by 4 °C in the coastal areas.

Linear Trend and Modified Mann-Kendall trend analysis methods were used in this study to detect statistically significant trends, with 95 percent confidence intervals.

*** Corresponding Author**

*(cavitberkayyilmaz@gmail.com) ORCID ID 0000-0002-2734-2073
(vahdettin.demir@karatay.edu.tr) ORCID ID 0000-0002-6590-5658
(mehmet.faik.sevimli@karatay.edu.tr) ORCID ID 0000-0002-4676-8782
(fidemir@mgm.gov.tr) ORCID ID 0000-0001-7675-9492
(myakar@mersin.edu.tr) ORCID ID 0000-0002-2664-6251

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2. Method

The Mediterranean Region includes three primary basins: the Eastern Mediterranean, Antalya, and Western Mediterranean basins. Agriculture and tourism are important industries in the region. The Mediterranean climate of the region has hot and dry summers and warm and heavy rains in the winter (Yılmaz et. al., 2021).

The spatial distribution of the stations used in the study is given in Figure 1. The numerical expressions in the figure show the global numbers of the stations. Statistical information of these stations and information about the recording period are given in Table 1.

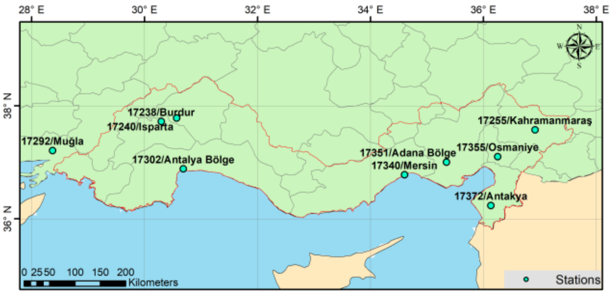

Figure 1. Spatial distribution of stations used in the study

Table 1. Statistical information about temperature and precipitation data

No	Data	Period	Std. Dev.	Skew.	Kurt.
17238	Temp.	1960-2020	0.73	0.25	-0.32
Burdur	Pre.	1960-2020	85.30	0.02	-0.59
17240	Temp.	1960-2020	0.81	0.14	0.04
Isparta	Pre.	1960-2020	142.06	0.42	0.26
17255	Temp.	1960-2020	0.91	-0.17	-0.21
Kahramanmaraş	Pre.	1960-2016	171.22	0.69	0.25
17292	Temp.	1960-2020	0.58	0.02	-0.47
Muğla	Pre.	1960-2020	280.05	0.18	0.00
17302	Temp.	2001-2020	0.55	0.72	0.39
Antalya	Pre.	2006-2020	451.59	-0.30	-1.49
17340	Temp.	1960-2020	1.03	0.20	-0.93
Mersin	Pre.	1960-2020	182.46	0.53	0.03
17351	Temp.	1960-2020	0.57	0.28	0.54
Adana	Pre.	1960-2020	202.51	0.72	0.38
17355	Temp.	1986-2020	0.64	-0.23	0.01
Osmaniye	Pre.	1986-2020	168.43	0.35	0.18
17372	Temp.	1960-2020	0.64	-0.20	0.03
Antakya	Pre.	1960-2020	185.29	0.28	-0.22

* Temp. = Average temperature data (C), Pre. = Total precipitation data (mm)

Table 1, which contains statistical data on temperature and precipitation data, shows that the temperature data of the stations are distributed symmetrically, with the exception of one (17302/Antalya) station. When the kurtosis coefficients are examined in the same way, it is clear that all 9 stations are flatter (Platykurtic) than the normal distribution curve. Except for three (17255/Kahramanmaraş, 17340/Mersin, and 17351/Adana) stations, the stations are spread symmetrically for precipitation data. When the kurtosis coefficients are examined in the same way, it is clear that all 9 stations are flatter (Platykurtic) than the normal distribution curve (Yılmaz et. al., 2021).

2.1. Linear trend test

The linear trend test is a parametric test that is used to determine the existence or absence of a trend in a time series. It is based on the assumption that the data is normally distributed (Karabulut & Cosun 2009). The main application of this method is to identify the trend curve using a graph and a line fitted to the graph. (Yağbasan et al. 2020). The linear regression expression obtained for the linear trend is included in equation 1.

$$y_i = ax_i + b \tag{1}$$

In Eq. 1. "a" represents slope and "b" represents the intersection point with the y axis (Demir, 2018). "a" and "b" values are calculated using Eq. 2. and 3.

$$a = \frac{\sum_{i=1}^{N} x_i y_i - N\bar{x}\bar{y}}{\sum_{i=1}^{N} x_i^2 - N\bar{x}^2} \tag{2}$$

$$b = \bar{y} - a\bar{x} \tag{3}$$

In Eq. 2. and 3. variables "N" represents the number of data in the series, "$\bar{x}$" represents the average of "x" variables, "$\bar{y}$" represents the average of "y" variables, "x_i" represents the "x" value in the "i-th" row, "y_i" represents the "y" value in the "i-th" row.

Trend existence is decided by applying "t" distribution and "t" test (Eq. 4.) (Student, 2018).

$$f(t) = \frac{\Gamma(\frac{v+1}{2})}{\sqrt{v\pi}\,\Gamma(\frac{v}{2})}\left(1 + \frac{t^2}{v}\right)^{-\frac{v+1}{2}} \tag{4}$$

The calculated "t" value is compared with the "$t_{critical}$" value corresponding to the 95% significance level (Demir, 2018).

2.2. Modified mann-kendall test

Although the process is considered to be independent in the original Mann-Kendall test, a correlation is shown in most hydrological events, and the presence of positive autocorrelation increases the likelihood of identifying a significant trend (Yağbasan et al. 2020). Eqs. 5 and 6 are used to determine the variance value in order to eliminate this situation (Hamed & Rao 1998).

$$\frac{n}{n_s^*} = 1 + \frac{2}{n(n-1)(n-2)} \sum_{i=1}^{n-1} (n-i)(n-i-2)\rho_s(i) \tag{5}$$

$$V(S) = Var(S)\frac{n}{n_s^*} = \frac{n(n-1)(2n+5)}{18}\frac{n}{n_s^*} \tag{6}$$

The remainder of the test is performed similarly to the original Mann-Kendall test After application calculated "Z" value compared with the "$Z_{critical}$" value to check statistically significant trend presence (Yılmaz et al., 2020).

3. Results

Linear and Modified Mann-Kendall trend analyses were used to investigate annual average temperature data (C) and annual total precipitation data (mm) for 9 stations in the Mediterranean Region from 1960 to 2020. Geographic Information System software is used to visualize the results (ArcGIS program-ArcMap sub package).

Results for temperature data are shown in Table 2.

Table 2. Trend test results for temperature data

No	Test	Critical Value	Result	Trend
17238 Burdur	LT	±1.67	3.77	Increasing
	MMK	±1.96	3.21	Increasing
17240 Isparta	LT	±1.67	3.23	Increasing
	MMK	±1.96	2.41	Increasing
17255 Kahramanmaraş	LT	±1.67	7.87	Increasing
	MMK	±1.96	6.11	Increasing
17292 Muğla	LT	±1.67	4.20	Increasing
	MMK	±1.96	3.06	Increasing
17302 Antalya	LT	-	-	-
	MMK	-	-	-
17340 Mersin	LT	±1.67	14.60	Increasing
	MMK	±1.96	8.00	Increasing
17351 Adana	LT	±1.67	3.92	Increasing
	MMK	±1.96	3.70	Increasing
17355 Osmaniye	LT	±1.69	2.97	Increasing
	MMK	±1.96	2.71	Increasing
17372 Antakya	LT	±1.67	3.55	Increasing
	MMK	±1.96	3.43	Increasing

-: Not enough data for trend analysis.
LT: Linear Trend Test
MMK: Modified Mann-Kendall Test

When the Table 2. examined, both test shows increasing trends in 8 stations which 2 of the stations shows extreme cases of increasing trends (17255/Kahramanmaraş, 17340/Mersin).

Maps of trend tests are shown in figures 2 and 3.

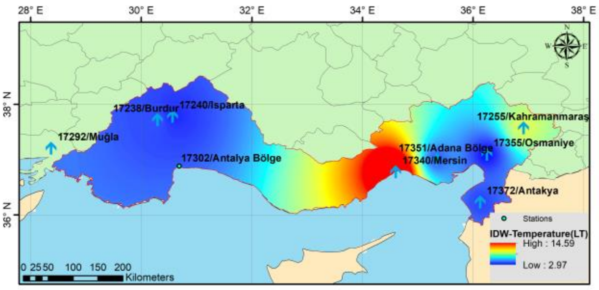

Figure 2. Linear Trend test results map for temperature data

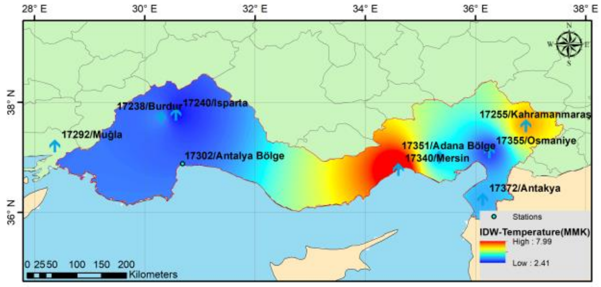

Figure 3. Modified Mann-Kendall trend test results map for temperature data

Results from trend tests for precipitation data are shown in Table 3.

Table 3. Trend test results for precipitation data

No	Test	Critical Value	Result	Trend
17238 Burdur	LT	±1.67	-0.04	No trend
	MMK	±1.96	0.13	No trend
17240 Isparta	LT	±1.67	-1.50	No trend
	MMK	±1.96	-0.78	No trend
17255 Kahramanmaraş	LT	±1.67	0.52	No trend
	MMK	±1.96	0.46	No trend
17292 Muğla	LT	±1.67	-1.13	No trend
	MMK	±1.96	-0.87	No trend
17302 Antalya	LT	-	-	-
	MMK	-	-	-
17340 Mersin	LT	±1.67	0.71	No trend
	MMK	±1.96	0.67	No trend
17351 Adana	LT	±1.67	-0.31	No trend
	MMK	±1.96	-0.21	No trend
17355 Osmaniye	LT	±1.69	-0.68	No trend
	MMK	±1.96	0.03	No trend
17372 Antakya	LT	±1.67	-0.76	No trend
	MMK	±1.96	-0.68	No trend

-: Not enough data for trend analysis.
LT: Linear Trend Test
MMK: Modified Mann-Kendall Test

When the Table 3. examined, no statistically significant trend detected.

As for the test results for individual stations:

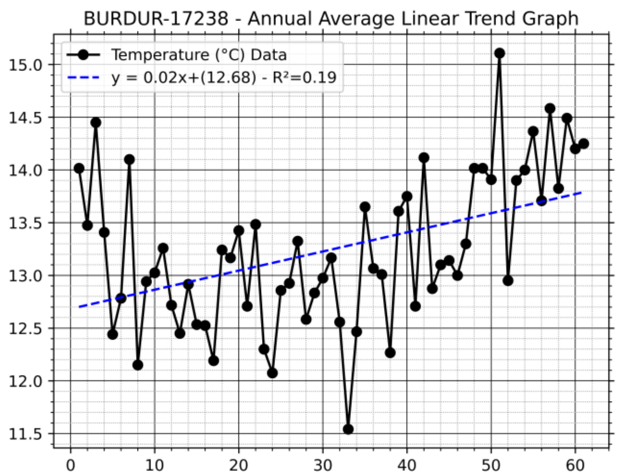

Figure 4. Linear Trend test graph for temperature data

As seen on Fig. 4 an increasing trend can be observed and observed trend is statistically significant for both Linear Trend test and Modified Mann-Kendall test (Table 2.).

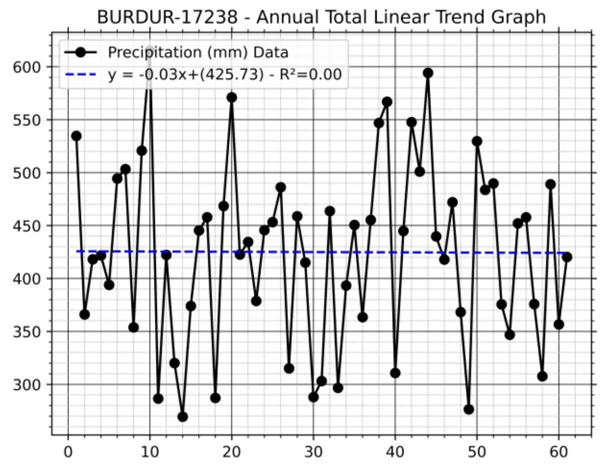

Figure 5. Linear Trend test graph for precipitation data

A decreasing trend can be observed (Fig. 5) in Burdur station but the observed trend is not statistically significant (Table 3.).

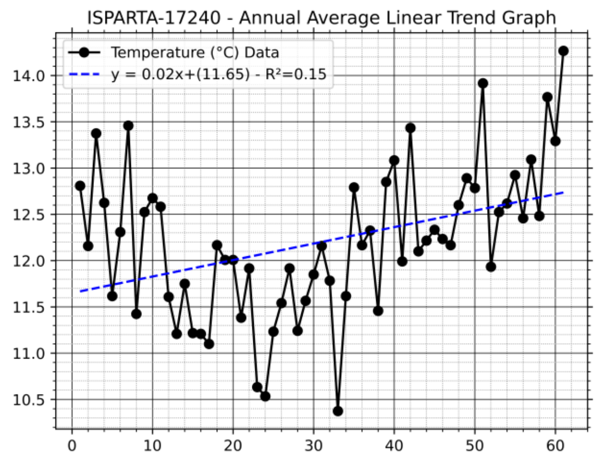

Figure 6. Linear Trend test graph for temperature data

Statistically significant increasing trend for both tests can be observed in Fig. 6 and Table 2.

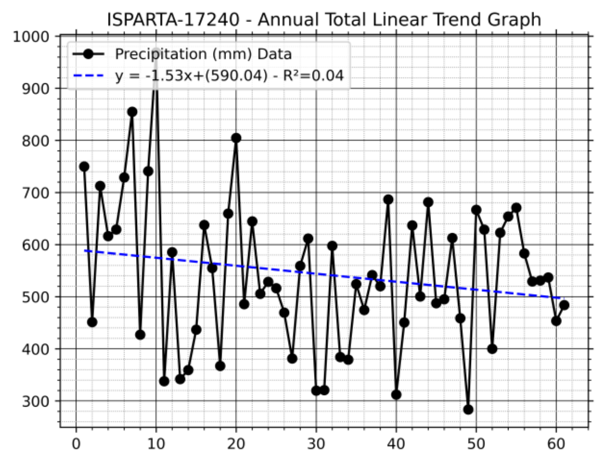

Figure 7. Linear Trend test graph for precipitation data

A decreasing trend can be observed for both tests (Fig 7 and Table 3.) but both results are below critical values.

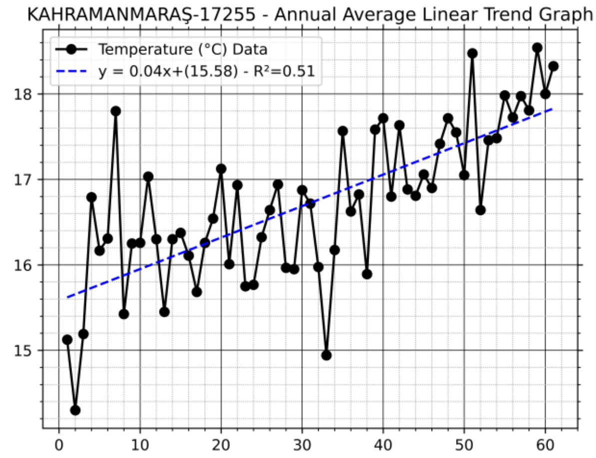

Figure 8. Linear Trend test graph for temperature data

In Kahramanmaraş station statistically significant increasing trend for both tests (Fig. 8 and Table 2.) has been observed.

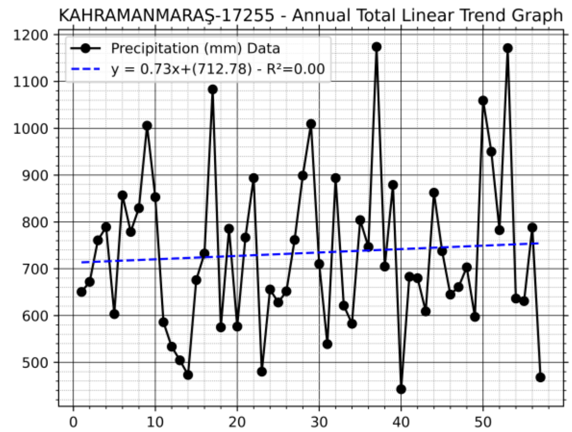

Figure 9. Linear Trend test graph for precipitation data

And a decreasing trend has been observed for precipitation data in Kahramanmaraş station but the observed trend is not statistically significant for both tests (Fig. 9 and Table 3.).

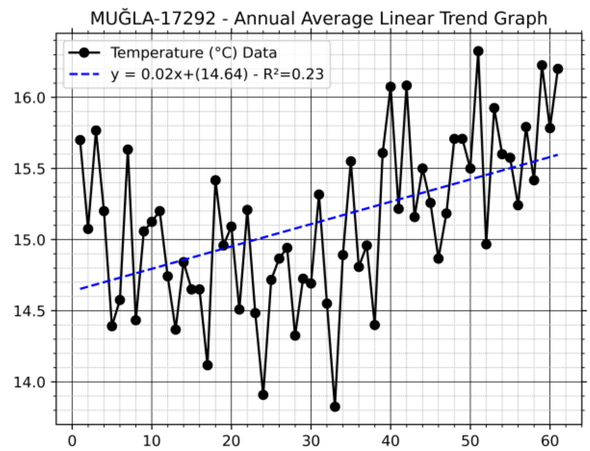

Figure 10. Linear Trend test graph for temperature data

Similarly, to the other stations an increasing trend for temperature data (Fig. 10, Table 2.) in Muğla station has been observed and the observed trend is statistically significant for both Linear Trend test and Modified Mann-Kendall test.

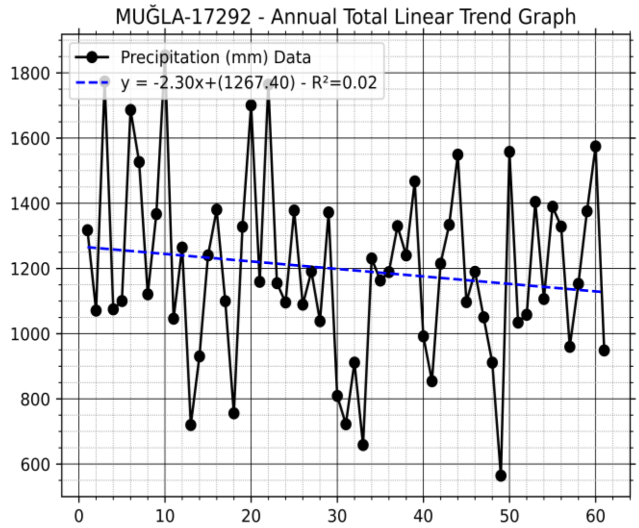

Figure 11. Linear Trend test graph for precipitation data

And a statistically unsignificant decreasing trend has been observed for the precipitation data (Fig. 11);

For Antalya station no trend test could have been applied due to insufficient data count for both temperature and precipitation data.

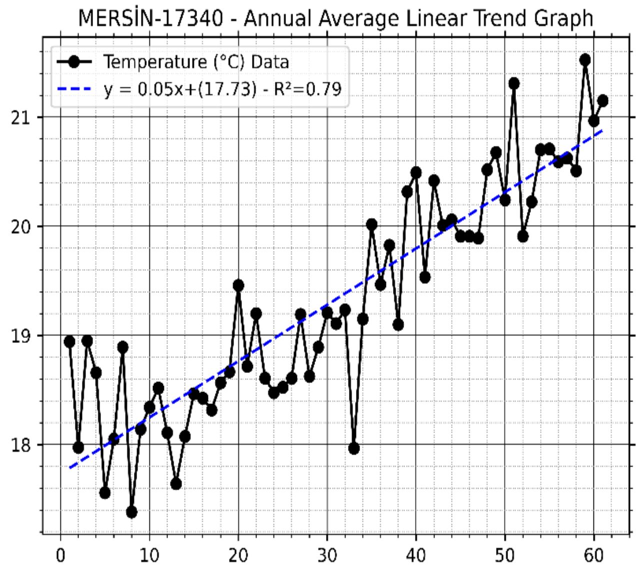

Figure 12. Linear Trend test graph for temperature data

As it is shown in Fig. 12 when the annual average temperature graph for Mersin station is examined a clear increase in temperature data over the years and statistically significant extreme case of increasing trend is observed for both tests (Table 2).

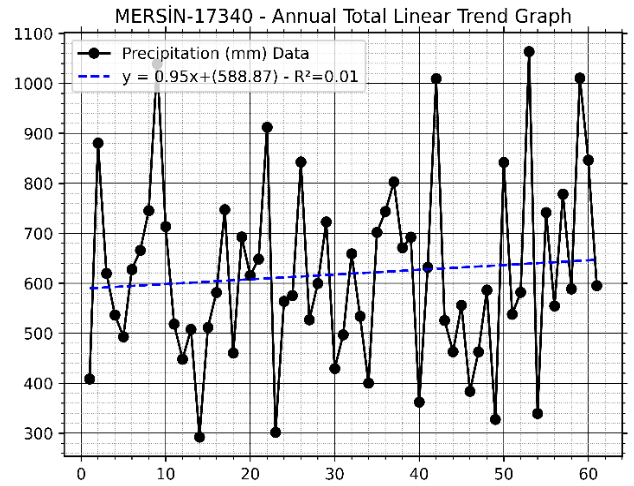

Figure 13. Linear Trend test graph for precipitation data

And an increasing trend can be observed for precipitation data (Fig. 13). But this observation is not statistically significant for both tests (Table 3).

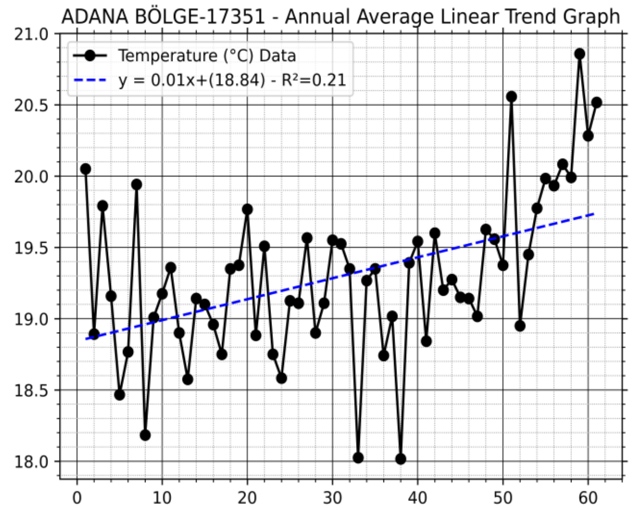

Figure 14. Linear Trend test graph for temperature data

A statistically significant trend has been observed for both Linear Trend test (Fig. 14) and Modified Mann-Kendall test (Table 2.) in Adana station for temperature data.

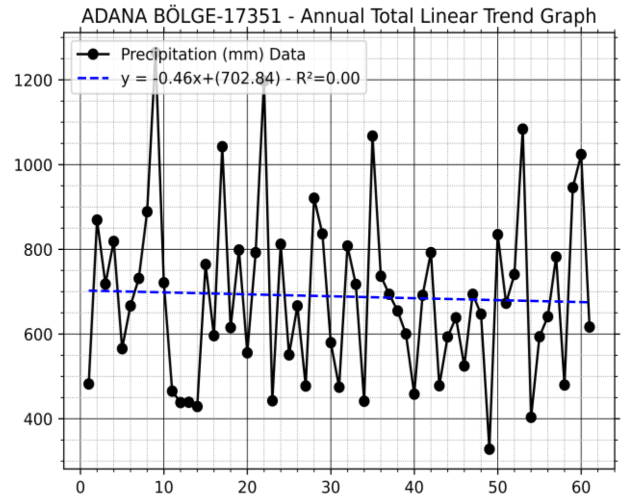

Figure 15. Linear Trend test graph for precipitation data

And a statistically unsignificant decreasing trend has been observed for the precipitation data in Adana station for both tests (Fig. 15, Table 3.).

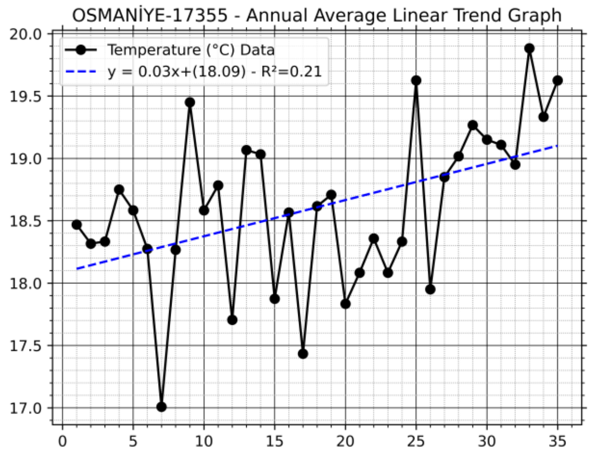

Figure 16. Linear Trend test graph for temperature data

A statistically significant trend for temperature data in Osmaniye station has been observed for both Linear Trend test (Fig. 16) and Modified Mann-Kendall test (Table 2.).

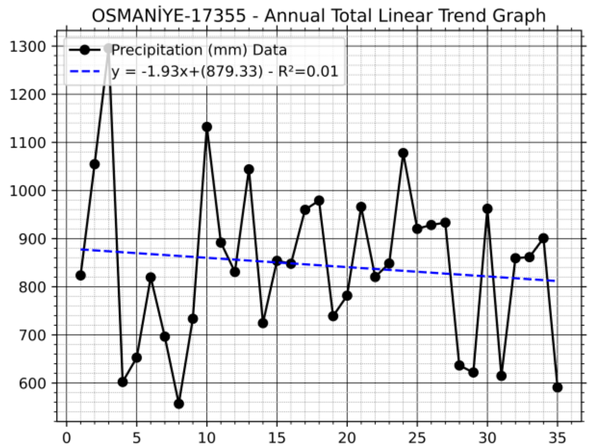

Figure 17. Linear Trend test graph for precipitation data

And a statistically unsignificant decreasing trend has been observed for both tests (Fig. 17, Table 3.) in Osmaniye station.

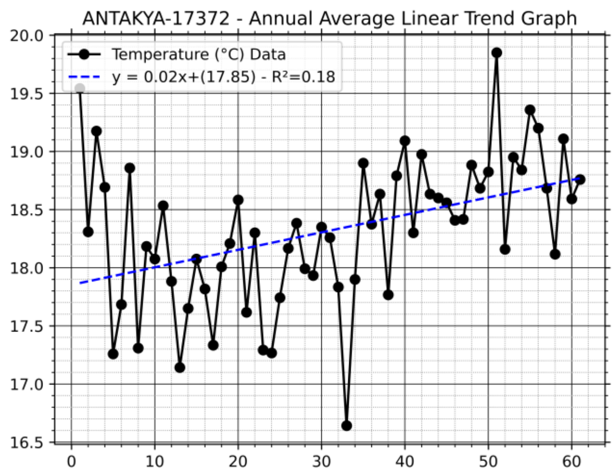

Figure 18. Linear Trend test graph for temperature data

In Antakya station statistically significant increasing trend has been observed for both tests (Fig. 18, Table 2.) for temperature data.

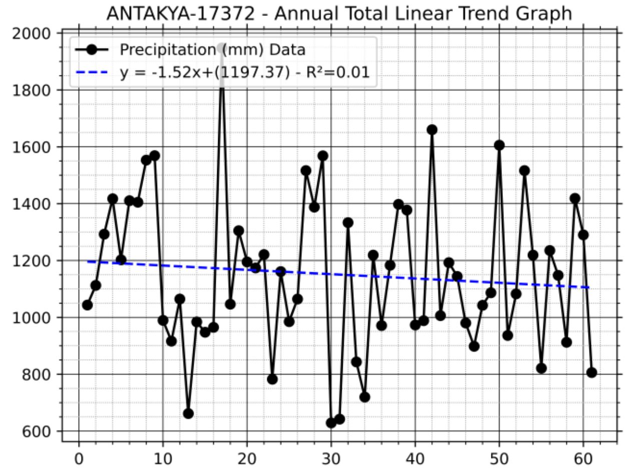

Figure 19. Linear Trend test graph for precipitation data

And statistically unsignificant decreasing trend has been observed for both tests (Fig. 19, Table 3.) in Antakya station for precipitation data.

4. Discussion

While temperature data usually gives a high coefficient of determination, the coefficient of determination values obtained from precipitation data are much lower. This conclusion indicates that the accuracy of linear trend analysis results decreases in data groups with high fluctuation. The increasing trends detected in the temperature data indicate that temperatures will increase in the near future.

5. Conclusion

When the temperature data from both tests is analyzed, both tests show an increasing trend in 8 stations, with two of these stations (17255/Kahramanmaraş, 17340/Mersin) having an extreme case of increasing trends. For both tests, no significant trend was detected in any of the stations when the same evaluation was applied to the precipitation results.

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Author Contributions

1st Author: Methodology, Software, Data, Writing-Original Draft Preparation, Visualization. 2nd, 3rd, and 5th Authors: Conceptualization, Reviewing and Editing.

4th Author: Providing data

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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