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Trend Analysis with the Annual Temperature and Precipitation in the Izmir District of Turkey

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Abstract

The effects of climate change on the water resources of the Aegean Region in Turkey are investigated through trend analysis of yearly temperature (daily average) and total precipitation time series data gathered from 3 stations (Izmir, Seferihisar, Cesme) in the research region. The techniques of Sen, Mann-Kendall, and Spearman's rho test are employed to identify historical patterns in the area. Theil-Sen technique is used to identify the change point(s) in the time series, while the Pettitt test is used to determine the size of the slope in the time series. Results show statistically significant trends of an increasing character in the temperature and precipitation time series at the chosen station. The rate of rise in precipitation and temperature was determined using the Theil-Sen test to be 7.3 - 7.9 mm/year and 0.20 - 0.3 °C/decade, respectively. Additionally, it was found that 1998 was the year for all sites where the change points in the temperature trends identified by the Pettitt test occurred. By taking into account the findings, a framework to boost climate change resilience will be required since the scale of severe occurrences will alter in the future.

1 INTRODUCTION

Changes in the microclimate have an impact on the link between the frequency and size of climatic events and speed up the occurrence of catastrophic results. However, the majority of research on the effects of climate change focuses on changes in the trends of hydrological variables (e.g., temperature and precipitation). Numerous research has shown that evidence may be found in temperature data records and variations in precipitation patterns during the last year. The hydrometeorological patterns of Turkey's Aegean area are also the subject of several research. Ciflik (2012) used the t-test, non-parametrical Mann-Kendall, Mann-Kendall rank correlation, Spearman's Rho, and Sen's trend slope tests to examine the yearly rainfall pattern in the Aegean area. Additionally, Asikoglu et al. (2015) observed a declining trend in precipitation using data from 47 locations. In their 2017 study, Bacanli and Tanrikulu assessed the evaporation values obtained between 1960 and 2013 at 25 Aegean-area sites. They concluded that a 12%–24% decrease in evaporation rate occurred while there is a seasonal trend in the time series that must be carefully examined using the Mann–Kendall and Sen tests. According to Topuz et al. (2021), there has been an increase in precipitation, particularly in the fall seasons, utilizing the precipitation data from 29 meteorological stations between 1955 and 2013.

A quick review of the literature reveals that no thorough research has yet been done to track the hydro-meteorological trend connected to simultaneous changes in temperature and precipitation in Turkey's Aegean area. In order to evaluate past patterns and get a better understanding of potential outcomes, a variety of trend analysis methodologies are applied.

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2 STUDY AREA AND METHOD

The most populous city in Turkey's Aegean Region is Izmir (Fig.1 shows the study area). The Mediterranean Climate, with hot, dry summers and mild, rainy winters, is the predominant climate type in the area. However, the Mediterranean climate is more sensible at the coast. However, the Mediterranean Climate can also be found in the interior of the region due to the local topography and the maquis-covered land cover. Up to 400 meters above sea level, there are certain zones of woodlands and rainforest that are primarily covered with maquis. Rural villages are typically found on the banks of streams and in valleys, whereas urban areas are found on the margins of the fertile plains. In this study, temperature and precipitation data from three meteorological stations from 1973 to 2020 are used. The information is gathered in Cesme, Seferihisar, and Izmir.

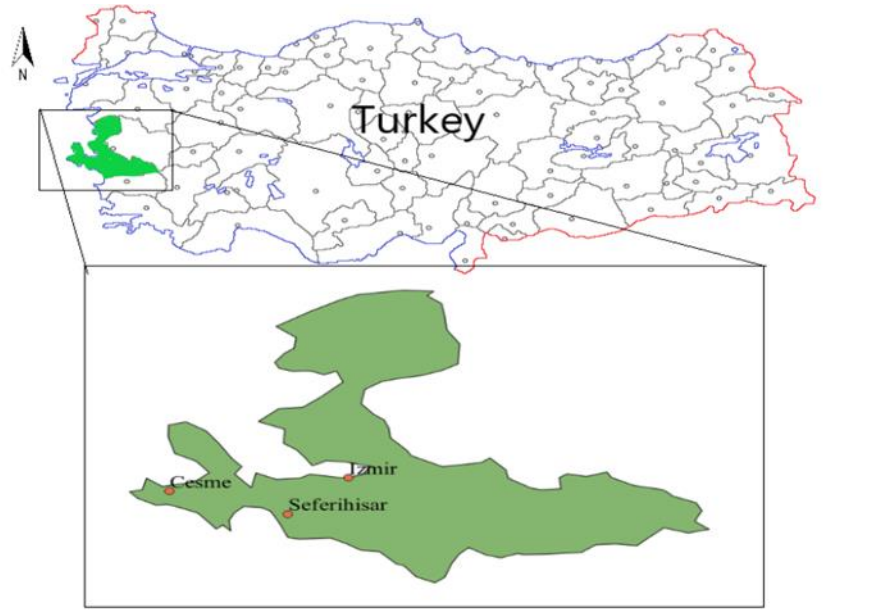


Figure 1. Study Area

One of the most significant markers of climate change is trend analysis. By employing historical meteorological records, trend analysis is primarily used in this study to generate projections for upcoming events. In this context, the trend in temperature and precipitation time series is determined using 47 years of meteorological records. While Pettitts' test (homogeneity analysis) is used to identify the turnpoint in the assigned time series, Mann Kendall, Spearman's rho, and Innovative Sen trend tests are used to identify trends in time series. The Thiel-sen method is also employed to calculate the slope of the temperature and precipitation trends.

2.1 Mann Kendall Test

The trend of a particular time series is ascertained using the Mann-Kendall test (Mann, 1945). The Mann-Kendall analysis is used in this study to statistically determine whether the interest variable has a monotonic temporal trend in an upward or downward direction. A continuous increase in the variable over time is referred to as a monotonic upward trend. A monotonic downward trend, on the other hand, shows that the variable is continually decreasing over time. As a result, the alternative hypothesis (H_a) of this test implies that slopes exist, as opposed to the null hypothesis (H_0), which indicates that slopes do not exist.
The Mann-Kendall test can be calculated as (Kisi and Ay, 2014)

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

where,

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

while x_i and x_j indicate the data values at the time i and j, respectively; and n is the length of the data set. As a result, if $S > 0$ it indicates a consistently increasing time series. But, if $S < 0$, it indicates a decreasing time series. If n is a positive number, it can be concluded that,

$$\sigma^2(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{p} t_i(t_i-1)(2t_i+5)}{18} \quad (3)$$

where t_i is the number of the data points at the p^{th} group and p is the number of groups. Then, the standard Z value can be determined as

$$Z = \begin{cases} \frac{S-1}{\sqrt{\sigma^2(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sqrt{\sigma^2(S)}} & if\ S < 0 \end{cases} \quad (4)$$

Afterward, the calculated Z value is compared with the standard normal distribution table using a two-sided confidence interval. Hence, if $|Z| > Z_{1-\alpha/2}$, H_o is rejected and H_a is accepted, and there exists a significant trend. But, if the $|Z| > Z_{1-\alpha/2}$ condition is not satisfied, H_0 is accepted and H_a is rejected, meaning that there is no statistical trend. It is noteworthy that in this study, a 5% significance level, as $Z_{1-\alpha/2} = 1.96$ is used in the analysis.

2.2 Spearman's Rho Test

The non-parametric statistical method based on rank The importance of monotonic patterns in hydrometeorological time series is assessed using the Spearman's Rho test. This test determines whether or not there are trends in data time series and determines if the trend is growing or shrinking. The alternative hypothesis H_a in this test indicates the presence of a trend, whereas the null hypothesis H_0 suggests that the presented data are independent and uniformly distributed over time. The Spearman's Rho test (Shadmani et al., 2012) statistic D, and the standardized test statistic Z_{SR}, can be obtained as

$$D = \frac{6\sum_{i=0}^{n}(R(x_i)-i)^2}{n(n-1)^2} \quad (5)$$

$$Z_{SR} = D\sqrt{\frac{n-2}{1-D^2}} \quad (6)$$

where $R(X_i)$ is the degree of observation X_i in the ith sample dimension. H_o is rejected in this test and H_a is accepted if $|Z_{SR}| > 2.08$ for a 5% significance level. Positive values of Z_{SR} indicate a downward trend, while the negative values indicate an upward trend.

2.3 Sen's Innovative Trend Detection Test

This technique, first presented by Sen in 2012, divides the time series into equal halves and ranks them in order of highest to lowest. The first (Xi) and second (Xj) sub-series are then projected on the X- and Y-axes, respectively, with both halves projected against one another. Data collected on a 1:1 (45) straight line indicates that there is no trend, data collected in the lower triangle area of the 1:1 straight line indicates a descending trend in the time series, and data collected in the upper triangle area of the 1:1 straight line indicates an increasing trend in the time series.

2.4 Thiel-Sen Approach

This method is used to calculate the magnitude of the slope associated with the trend. The Thiel-Sen approximation can be expressed (Shadmani et al., 2012) as

$$\beta = median\left(\frac{X_j X_i}{j-i}\right) \quad (7)$$

where, X_i and X_j show the ordinal data values of the time series in the ith and jth year. The β value is the estimated size of the trend slope in the time series.

2.5 **Pettitt's Test**

Pettitt's test is used to detect a single change-point in the hydro-meteorological time series with controversial data. For a time series of n realization $\{X_1, X_2, \ldots, X_n\}$, let the time of the change point be m. For instance consider $\{X_1, X_2, \ldots, X_m\}$ and $\{X_{m+1}, X_{m+2}, \ldots, X_n\}$, then the test statistic can be derived by dividing the time series into time m. The test statistic U_m (Chen et al., 2009) then can be expressed as

$$U_m = \sum_{i=1}^{n} \sum_{j=i+1}^{n} sgn(x_i - x_j) \quad (8)$$

$$sgn(x) = \begin{cases} 1 & if\ x > 0 \\ 0 & if\ x = 0 \\ -1 & if\ x < 0 \end{cases} \quad (9)$$

The most important change point at the time t is then accepted as $|U_t|$. Thus, the approximate probability of significant change $P(t)$ for the change point can be expressed as (Chen et al., 2009)

$$P(t) = 1 - e^{\left(\frac{-6U_t^2}{n^3+n^2}\right)} \quad (10)$$

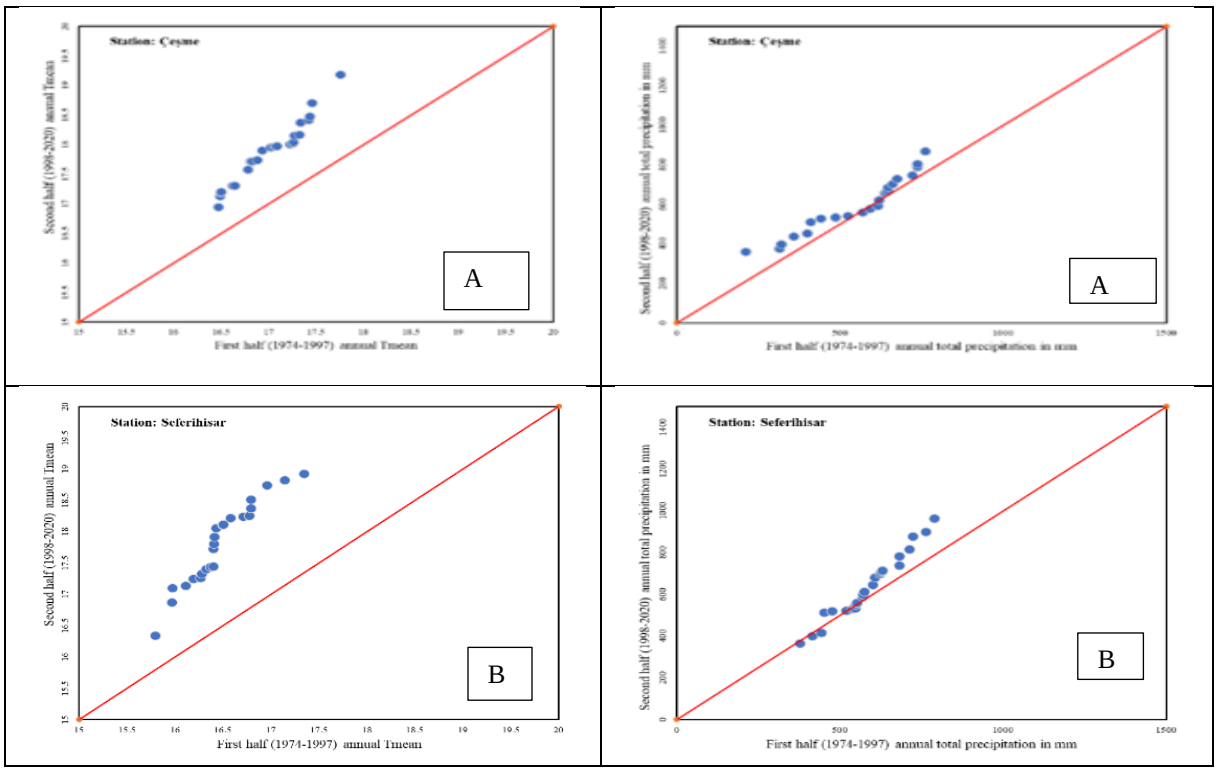
The change point is considered to be a statistically significant α level when the approximate probability exceeds the value (1-α).

3 RESULTS AND DISCUSSION

The MK, SR, ST, and PT tests are used to calculate average annual temperature trends. In temperature time series, patterns are discovered using the MK, ST, and SR. The change point in the time series is then identified using PT. Table 1 shows that there is a rising trend at 3 meteorological stations. The yearly average temperature is determined to be rising by 0.20 to 0.3 °C every decade once the TS technique is used to determine the slope.

Table 1. Test Results

Stations	Temperature					Precipitation				
	MK		SR	TS	PT	MK		SR	TS	PT
	Z	Sign?	Z_{SR}	β	year	Z	Sign?	Z_{SR}	β	year
Cesme	4,22	Yes	5,66	0,3	2007	2,663	Yes	3,79	7,9	1998
Seferihisar	4,99	Yes	5,72	0,2		2,31	Yes	3,43	7,5	
Izmir	4,8	Yes	5,79	0,3	2015	2,1	Yes	3,13	7,3	



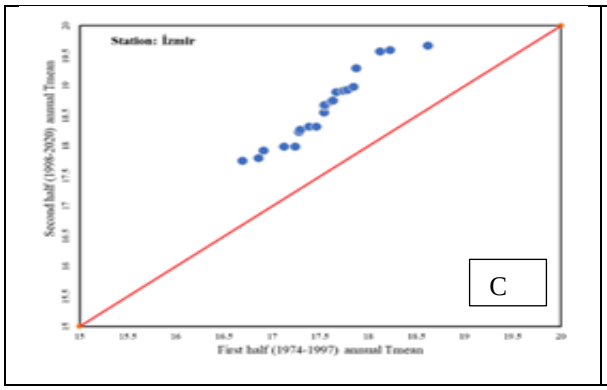


Figure 2. ST Analysis for Temperature

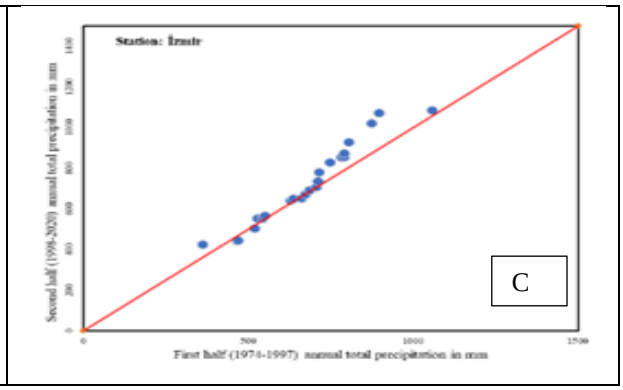


Figure 3. ST Analysis for Precipitation

4 CONCLUSION

In this section, the importance and effects of the study should be clearly stated. In the conclusion part, the results should not be repeated.

Acknowledgments

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