International Journal of Technology and Emerging Sciences (IJTES)

www.mapscipub.com

Volume 02 || Issue 04 || October 2022 || pp. 34-39 E-ISSN: 2583-1925

Statistical and Trend Analysis of Long-Term Rainfall in Ayvalık

Meral KORKMAZ[1]

[1]*Munzur University, Engineering Faculty, 62000, Tunceli, TURKEY*

---***---

Abstract - *The issue of climate change that may occur in the short and long term is a significant problem in Turkey. The greatest impact of climate change is on precipitation; while this climate change causes drought in some regions, it causes floods in some regions. A general assessment has been made of the importance of trend analysis. This research paper presents trend analysis for different regions of the world by compiling examples of the most commonly used trend tests on hydro-meteorological variables. Trend analysis was performed on an annual, seasonal, and monthly basis using a specific data period for precipitation. Linear regression is a quick and easy test to determine if there is a trend. Mann - Kendall Test and Sen's slope test trend analysis methods are used to analyze monthly and annual rainfall. As a result, the Mann-Kendall test and Sen's slope estimation method have been widely used from the past to the present and have performed very well in determining the trend for hydro-meteorological variables.*

Key Words**:** Rainfall, Statistical Analysis, Trend Analysis, Estimator of Sen's slope.

1. INTRODUCTION

One of the most important causes of global warming and climate change is the decrease in drought and precipitation. The decrease in precipitation affects both groundwater and streams. For this reason, learning about the precipitation situation and the forecasts is essential. Trend analysis of precipitation data is essential to ensure water resources planning and proper use [1]. Various methods are used to define the hydro-meteorological time series [2]. Trend analysis of precipitation time series includes determining the increasing and decreasing trend and the size of the trend and has statistical significance [3]. Various parametric and non-parametric tests detect trends in hydro-meteorological time series. The non-parametric Mann -Kendall test is one of the most popular methods many researchers prefer for trend analysis because it has some advantages over parametric methods [4].

The trend indicates the general tendency of the data to increase or decrease during an extended period. A trend is a general, long-term, average tendency. It is generally observed in long-term examinations of climatic events. Changes in the direction of increase or decrease may sometimes increase and sometimes slow down. As a result, the trend does not stay the same. The trend can be linear or curvilinear. The major challenge today is formulating and implementing a rational methodology for managing the available water resources in the areas. Therefore, the determination and identification of trends of precipitation are critical. Trend analysis of precipitation and rainy days will help determine future water status and predict the future temporal and spatial variation of water [5].

Cannarozzo et al. have global climate change as a result of changes in precipitation regimes all over the world; They said that it affects water resources management, hydrology, agriculture, and the whole of nature. In their study, the Mann-Kendall rank correlation method was used to confirm the existence of the trend in annual, seasonal, and monthly precipitation and the distribution of precipitation throughout the year [6]. Patel et al. (2020) carried out precipitation trends analysis for the 1969–2016. They used several trend analysis methods to determine annual and seasonal precipitation trends from eleven rain gauge stations from the Bhogavo River [7].

Kruger and Nxumalo studied the daily precipitation of 60 different precipitation stations in South Africa between 1921 and 2015. In order to detect the trends in climate change, they applied the extreme precipitation indices defined by the World Meteorological Organization Climate Change Detection and Indices Expert Team. They have optimally demonstrated the analysis of historical precipitation trends with the help of their previous work, taking the longest possible time period in their work. Overall, the results show an increase in precipitation for most precipitation stations in the southern interior of South Africa and a decrease in precipitation in the far north and northeast [8]. Researchers generally reveal that trends in heavy rainfall lead to changes in total precipitation. Trends in Australian precipitation from 1970 to 2006 were studied using the daily precipitation dataset. Parts of Western Australia are seeing an increase in heavy rainfall events. The total and monthly precipitation concentrations, mean values, inter-annual variability, and spatial diversity of 97 rain measurement stations in the Western Mediterranean Basin (eastern Spain) Valencia region were investigated. It was analyzed using both parametric and non-parametric tests to identify trends. A statistical method based on the Crame´r–von Mises test has been proposed to detect homogeneous areas with similar precipitation formation [9, 10]

Kamruzzamana et al. (2016) found that it is essential to know the observation periods of heavy rains in the southern part of Australia, the variability of precipitation has increased. However, there is no change in annual rainfall [11].

This study has investigated how rainfall changes affect water resource management and planning. Water resources are at risk; such as floods due to excessive rainfall. For this, it is essential to examine the rainfall event today. While examining the rainfall events, trend analysis samples of the most widely used trend tests for different regions of the world were examined. A general evaluation of the importance and application of trend analysis in line with these examples was made.

1.1 Materials and methods

Ayvalık, a district of the Aegean Region, was chosen as the study area. Ayvalık is located on the coast of the Aegean Sea in Turkey (Figure 1). The Aegean Sea surrounds it in the west, Burhaniye in the north, Bergama in the east, and Dikili in the south. Judging by its natural borders, Bezirgan stream, Gömeç and Gümüşlü road in the north; east of Sarimsak stream, Hisar and Demirhan straits; south of Altinova; There are many coves with the Sarimsakli peninsula formed by the Kaplan Mountains in the southwest.

Figure-1: Location of the study area: region of Ayvalık [12].

Mediterranean climate prevails in the district. Since it is located in the Aegean region, the winters are warm and rainy, and the summers are hot and dry. Lodos and northerly winds are dominant, especially when all the surrounding areas are in the scorching heat of summer.

The district's economy mainly depends on tourism and agriculture, especially olive cultivation. The rainfall in the region is vital due to the intense agriculture and tourism. Long-term precipitation data are required to determine how precipitation will change over time.

1.1.1 Methodological Approach

Compliance with the data is essential in the analysis of precipitation data. For this, parametric or non-parametric methods are used in statistical operations. Parametric methods examine time series by linear regression. Since nonparametric methods also list the data, they are not affected by deficiencies. Precipitation data vary widely. Therefore, nonparametric methods are used.

1.1.2 Mann-Kendall Method

Mann Kendall is a nonparametric test that considers independent values and accepts abnormal data. This test is a preferred statistical method due to the use of nonparametric data in hydro-meteorological data analysis. It is preferred because it is less affected by the difference in time series values. The equation of the M-K test [13] is,

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(y_i - y_j) \tag{1}$$

Where:

n=length of time series.

y_i and y_j = the annual values in years. (i > j. y_i rank from i=1, 2…., n-1 and y_j rank from j=n+1, n+2…. n.)

The value of the $sgn(y_i - y_j)$ is calculated by equation 2,

$$sgn(y_i - y_j) = \begin{cases} +1 \text{ if } (y_i - y_j) > 1 \\ 0 \text{ if } (y_i - y_j) = 1 \\ -1 \text{ if } (y_i - y_j) < 1 \end{cases} \tag{2}$$

Here, yi and yj are the value of the data.

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{p-1}^{m} t_k (t_p - 1)(2t_p + 5)}{18}$$

In case of n >10, the standard normal test statistics are calculated by equation 3,

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} \text{ if } S > 1 \\ 0 \text{ if } S = 1 \\ \frac{S+1}{\sqrt{Var(S)}} \text{ if } S < 1 \end{cases} \tag{3}$$

After the test analysis results, if it is positive, it indicates an increasing trend. If it is negative, it is a decreasing trend.

1.1.3 Linear regression method

Regression analysis is often used to model the linear trend. Regression analysis tries to determine how other variables (independent) explain a variable (dependent). It is possible to use more than one independent variable in regression analysis. A connection between two variables is required to use a linear regression model.

Linear Regression is based on the minimum squares of the difference between the actual values and the values found from the trend equation. The following equation 4 is used to define the linear regression model [1].

$$y = ax + b \tag{4}$$

constant a gives the direction and amount of change. Precipitation is a dependent variable, and time is an independent variable, either in months or years.

a: line slope (mm/year),

b: intercept constant coefficient,

y, x: the dependent variable like precipitation.

If "a" is positive, it means an increasing change. If "a" is negative, it means a decreasing change. If "a" is close to zero, there is no change. The modal's coefficients (m and C) are determined using the Least Squares method. The slope sign determines the trend. If the sign is positive, it increases; if it is negative, it decreases.

1.1.4 *Spearman's Rho (SR) test*

This test, which is used to determine whether there is a correlation between the two series of observations, is a quick and simple test to investigate the presence of a linear trend [14]. R (xi) is determined by ordering observations from small to large or large to small, and Spearman's Rho Test value is calculated by equation 5.

$$r_s = 1 - 6\frac{[\sum_{i=1}^{n} R(x_i - i)^2]}{(n^3 - n)} \quad (5)$$

$R(x_i)$; the order number of the observation,

i; the order of the data,

n; the total number of observations

The *Z* value is calculated by equation 6.

$$Z = r_s\sqrt{n-1} \quad (6)$$

1.1.5 *Sen's slope method*

The Sen slope method is also used to estimate the size of the time series. This method can be applied to records that are not affected by data errors or extreme values and have missing values.

The slope is usually obtained using the least squares method using linear regression for linear trends. The linear trend method is only valid when there is no serial correlation and the method is susceptible to outliers. A stronger method in equation 7 was developed by Şen (1968) [15]:

$$Q = \frac{y_j - y_i}{j - 1} \quad (7)$$

Q; Slope estimate,

y_j, y_i; data values at time j and i ($j > i$),

N; Multiple estimates of the slope are made using the:

$$N = n(n-2)/2 \quad (8)$$

Where,

$i = 1 \text{ to } n - 1,$

$j = 2 \text{ to } n$

y_j and y_i are data values at time j and i ($j > i$), respectively.

1.1.6 *Innovative Trend Analysis Method*

Increasing global warming and climate change lead researchers to study hydrological events. In order to examine these changes, it is necessary to know the current and past data. With these data, researchers identify trends in the past and future hydrological and meteorological variables. Many methods are used for this. The innovative trend analysis method is one of the most widely used methods today. The ITA method requires long-term data. The long-term data used in the analysis will be divided into two halves starting from the median year. Then both series will be sorted separately from smallest to largest. In Figure 2, in the X-Y coordinate system, the first sorted data will be processed on the x-axis, and the second-ordered data will be processed on the y-axis. The line y=x is drawn in the Cartesian coordinate system. If the ranked data is above the y=x line, it shows no trend. If the data is in the lower triangle area of the y=x line, it indicates a decreasing trend. If the data is in the upper triangle area, it is said that there is an increasing trend [16,17].

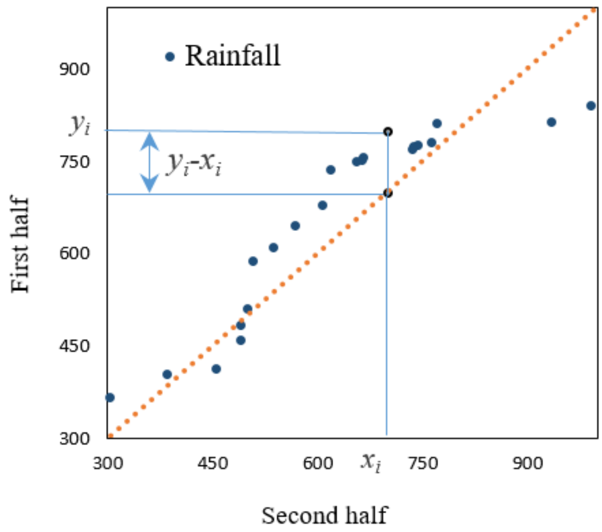

Figure-2: Annual total rainfall data by ITA Method [16,17].

Figure 2 shows that median values close to the y=x line indicate no trend, while low values describe a positive uptrend and high values a negative downtrend. Figure 2 shows the y and x values of a point on the y=x line. When we take the absolute value of this difference, we get the distance of that point from the non-trend line. The difference shows the magnitude of an uptrend or downtrend. Therefore, the mean difference expresses the general trend of a time series. The trend indicator is given by equation 8.

$$D = \frac{1}{n}\sum_{i=1}^{n}\frac{10(y_i - x_i)}{\bar{x}} \quad (9)$$

Here, a positive D value indicates an uptrend, and a negative D value indicates a downtrend. The indicator was multiplied by 10 for comparison with the MK test. n is the number of each subsequence, and x is the average of the first sequence [18].

2. Results and Discussion

Distribution of the monthly total rainfall

This study investigated monthly, seasonal, and annual precipitation changes using statistical methods for 41-year time series data (1980- 2021) [19]. Figure 3 shows the change in long-term rainfall of the region taken from DMI.

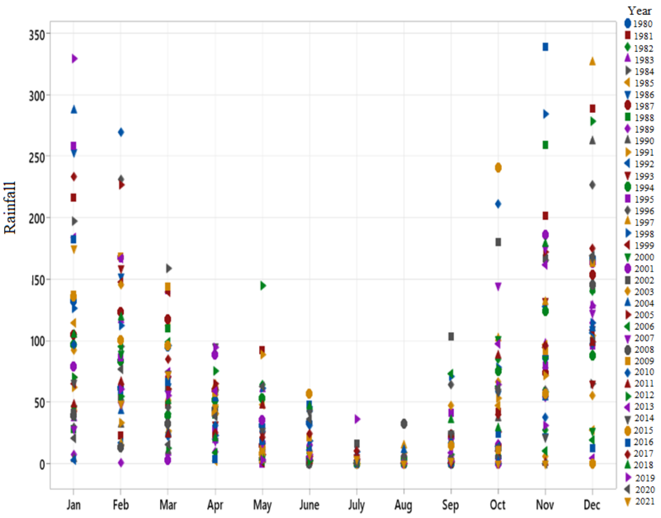

Figure-3: Rainfall in Ayvalık 1980-2021

Investigation of seasonal total rainfall

The precipitation was evaluated seasonally to determine the precipitation change, which is one of the meteorological parameters. Rainfall was analyzed as spring, summer, autumn, and winter. In addition, annual and monthly variation was evaluated with Mann Kendall and trend methods. Figure 4 shows how rainfall changes seasonally for many years. Rainfall is higher in the region in winter and autumn. In other seasons the amount of precipitation is relatively low.

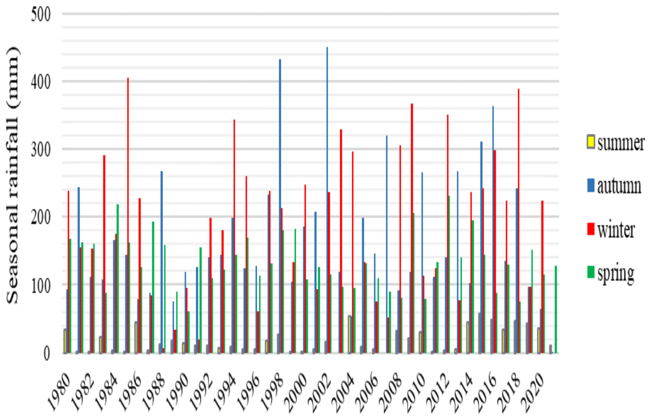

Figure-4: Seasonal total rainfall

Investigation of rainfall data with the Şen Method

When the annual precipitation series of Ayvalık are examined, it is seen that the average annual total precipitation is 638.95 mm. When the Şen Method is applied to the precipitation data of many years, it is seen that the precipitation is in a decreasing trend. When Figure 5 is examined, it is seen that it goes towards an increasing trend at extreme values, where it is a decreasing trend.

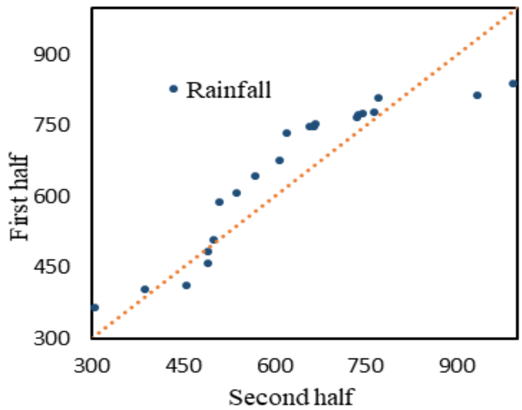

Figure-5: Long-term rainfall data for the period 1980-2021 (ITA Method)

Analysis of rainfall data by statistical methods

The Mann-Kendall trend and statistical significance of Sen's slope seasonally for precipitation from 1980 to 2021 are shown in Table 1. When annual precipitation is examined, it shows that it has decreased in the last two years. This shows that it is essential to examine the precipitation event. The Q statistics in Table 1 shows Şen's trend of annual rainfall trends. Positive values show the increasing trend according to the Slope of the Estimated Sen (Q). There is a negative trend only in the spring.

Mann Kendall shows an increasing trend with a positive value of Z= 2.11 in summer, Z= 1 in winter, and Z= -1.36, 0.95 in spring.

Table-1: Statistical Analysis of Rainfall data along

	Spearman's	Pearson'r	Kendall's tau	Z	Q
Spring	-0.192	-0.169	-0.145	-1,36	-0.937
Summer	0.357	0.401	0.221	2,11	0.463
Autumn	0.061	0.099	0.052	0,95	0.938
Winter	0.079	0.0822	0.057	1	1.821
Annual	0.016	0.061	0.078	-	-

In Table 1, non-parametric Pearson's, Kendall's tau, and Spearman's rho tests were also applied to determine the relationship between precipitation, which is one of the climate parameters, and time. Similar results were obtained as a result of these tests.

The precipitation data show an increasing (upward) trend for some months and decreasing trends for others. In Figure 6, the variation of precipitation data (trend) monthly was calculated separately for each month using the Mann-Kendall statistical method, and the magnitude of the slope was calculated with Sen's slope estimator. Figure 6 shows the data for April and May. April's Estimated Sen's Slope (Q) shows an increasing trend. On the other hand, in May, precipitation decreased considerably.

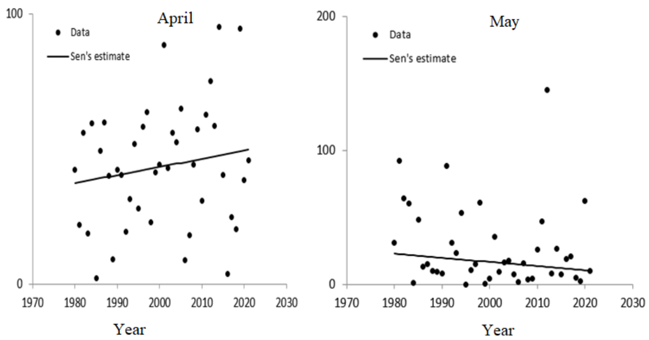

Figure-6: Estimated Sen's Slope

3. CONCLUSIONS

As a result of global warming and climate change, there is a significant change in precipitation. In recent years, irregular precipitation has manifested itself either by sudden precipitation or drought. Changes observed in the precipitation regime also directly affect our water resources. Irregular and sudden rains cannot pass into the groundwater and cause serious disasters such as floods. The decrease in precipitation and the increase in temperature cause the dry seasons to be drier and the precipitations more irregular and sudden. As a result, it has become necessary to examine regional precipitation events. In this study, trend analyzes were made with statistical software on the precipitation data of Ayvalık. As a result of the statistical analysis, it was seen that there was no decreasing trend in precipitation except for the spring months. However, it has been observed that there is a decreasing trend in May, which receives the most precipitation in drought and the change of seasons. It is seen that the reason for the negative precipitation in the spring months is the decreasing trend in May. Precipitation is significantly less in summer. In the Ayvalık region, precipitation is also significant in terms of agriculture. Therefore, the study will support precipitation forecasts in the future. Trend analysis needs to be learned and developed to make future applications.

REFERENCES

[1]. Aswad, F. K., Yousif, A. A., & IBRAHIM, S. A. (2020). Trend Analysis Using Mann-Kendall and Sen's Slope Estimator Test for Annual and Monthly Rainfall for Sinjar District, Iraq. Journal of Duhok University, 23(2), 501-508.

[2]. Duhan, D., & Pandey, A. (2013). Statistical analysis of long term spatial and temporal trends of precipitation during 1901–2002 at Madhya Pradesh, India. Atmospheric Research, 122, 136-149.

[3]. Jain, S. K., & Kumar, V. (2012). Trend analysis of rainfall and temperature data for India. Current Science, 37-49.

[4]. Karakus, C. B. (2017). Trend analysis methods for hydro-meteorological parameters. International Journal of Scientific and Technological Research, 3(2), 22-32.

[5]. Wale, V. D., Sthool, V. A., & Upadhye, S. K. (2020). Trend analysis of rainfall and rainy days using Mann Kendall method and sen's slope estimator in Tasgaon Tahsil of Sangli District of Maharashtra (India). Journal of Pharmacognosy and Phytochemistry, 9(4S), 99-102.

[6]. Cannarozzo, M., Noto, L. V., & Viola, F. (2006). Spatial distribution of rainfall trends in Sicily (1921–2000). Physics and Chemistry of the Earth, Parts a/b/c, 31(18), 1201-1211.

[7]. Patel, P. S., Rana, S. C., & Joshi, G. S. (2021). Temporal and spatial trend analysis of rainfall on Bhogavo River watersheds in Sabarmati lower basin of Gujarat, India. Acta Geophysica, 69(1), 353-364.

[8]. Kruger, A. C., & Nxumalo, M. P. (2017). Historical rainfall trends in South Africa: 1921–2015. Water SA, 43(2), 285-297.

[9]. Taschetto, A. S., & England, M. H. (2009). An analysis of late twentieth century trends in Australian rainfall. International Journal of Climatology: A Journal of the Royal Meteorological Society, 29(6), 791-807.

[10]. De Luis, M., Raventós, J., González-Hidalgo, J. C., Sánchez, J. R., & Cortina, J. (2000). Spatial analysis of rainfall trends in the region of Valencia (East Spain). International Journal of Climatology: A Journal of the Royal Meteorological Society, 20(12), 1451-1469.

[11]. Kamruzzaman, M., Beecham, S., & Metcalfe, A. V. (2016). Estimation of trends in rainfall extremes with mixed effects models. Atmospheric Research, 168, 24-32

[12]. Google earth, "Ayvalık location," 2022. https://earth.google.com/web/search/ayval%c4%b1k/@39.33360

8,26.70872046,21.11775884a,14392.27268033d,35y,359.999985 32h,0t,0r/data=CnMaSRJDCiUweDE0YmE3Njc3MTE5ZDM2OTE6MHgxMzZhNDc4NzM5NjZjNmFjGdcv2A3bqENAIfEsQUZAsTpAKghheXZhbMSxaxgCIAEiJgokCZJG4g6H8ElAEeFqD97fODNAGdaWj_F2DFFAIRY7htVoICXA

[13]. Ghosh, K. G. (2018). Analysis of rainfall trends and its spatial patterns during the last century over the Gangetic West Bengal, Eastern India. Journal of Geovisualization and Spatial Analysis, 2(2), 1-18.

[14]. Ahmad, I., Tang, D., Wang, T., Wang, M., & Wagan, B. (2015). Precipitation trends over time using Mann-Kendall and spearman's rho tests in swat river basin, Pakistan. Advances in Meteorology, 2015.

[15]. Sen, P. K. (1968). Estimates of the regression coefficient based on Kendall's tau. Journal of the American statistical association, 63(324), 1379-1389.

[16]. Korkmaz, M., (2021). Standart Yağış İndeksı (SPI) kullanarak kuraklık analizi, Serüven Publishing: Mühendislik Alanında Akademik Araştırma ve Değerlendirmeler.

[17]. Korkmaz, M. Yozgat İlinin Kuraklık Araştırması ve Trend Analizi. Engineering Sciences, 17(3), 21-34.

[18]. Wu, H., & Qian, H. (2017). Innovative trend analysis of annual and seasonal rainfall and extreme values in Shaanxi, China, since the 1950s. International Journal of Climatology, 37(5), 2582-2592.

[19]. General Directorate of Meteorology, "Ayvalık Total Rainfall." 2022.

https://mevbis.mgm.gov.tr/mevbis/ui/index.html#/Workspace