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Determination of precipitation trend by time series: A case study Erbaa plain

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ABSTRACT

Changes in precipitation occur due to global or local climate changes. Studying this change is very important for human life. Rainfall is very important in meeting essential needs such as agricultural activities and clean water resources. Therefore, trend analysis in precipitation data is important. In this study, in order to examine whether there is a trend in the precipitation data of Erbaa Plain (Turkey), first homogeneity test was performed and then the standard precipitation index was calculated. The calculated data were analyzed using the Mann-Kendall test and Sen's Slope test. Monthly precipitation data for 40 years covering the years 1981-2020 were used in the study. Precipitation data were analyzed according to 90% confidence interval. Trends were detected in January and September in monthly precipitation series

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1. Introduction

Meteorological events on earth have unfixed feature. Therefore, the size and consequences of meteorological changes cannot be easily predicted (Coskun, 2019). The meteorological data changes are a complex natural hazard that causes drought and affects ecosystems and society in many ways. In order to minimization the drought effects, the drought risk should be assessed and the water resources management strategies should be developed (Beden et al., 2020).

Meteorology; is the science of the atmosphere. Pressure, temperature, humidity, wind, cloudiness, precipitation, insolation, evaporation are meteorological parameters. These combine at different rates to determine the climate of a region and are affected by factors such as latitude, land and seas, altitude, and vegetation (Mercan, 2016).

The most important common subject in hydrology, meteorology and hydrometeorology branches is precipitation. In general, the stages before and after the formation of precipitation in the atmosphere are of interest to meteorology, the situation after it reaches the earth's surface, hydrology, and the necessary evaluations and calculations for the preparation of water projects are also of interest to hydrometeorology (Gençer et al., 2005).

Changes in precipitation in a residential area can lead to important problems affecting human life. Change has significant effects on clean water resources and agricultural activities. Efficient use and control of water is provided by the correct evaluation and analysis of the meteorological data. In order to meet the needs, the management of water resources that change depending on time and quantity parameters is very important. Thus, the precipitation data should be examined on the presence of any trend (Yuce et al., 2017). While, the continuous decrease in precipitation values, disasters can be observed such as drought and desertification, the continuous increase precipitation values, disasters such as landslides and floods are seen. Therefore, trend analysis and disaster risk maps in rainfall data have great importance (Beden et al., 2020; Basara et al., 2021).

Various analysis methods such as time series, regression analysis and machine learning are used in the analysis of meteorological data. In this study, one of the analysis methods, time series methods were used.

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The sequences formed by ordering the observations for any event according to time are called time series. The process of generating new data from observed values is called time series analysis.

Time series have served different purposes with different models in many studies. Some of those: In his application, Sfetsos compared different forecasting methods based on time series analysis and hourly average wind speed observations (Sfetsos, 2000), In his application, Sarıyer estimated the demand in emergency services using ARIMA models with time series analysis (Sarıyer, 2018), Yavuz, in his application, investigated the effect of exports on economic growth in Turkey by using time series and Granger causality test (Yavuz, 2012).

The precipitation, known as most important meteorological data, was selected as study topic.

In this study, precipitation analysis of the Erbaa Plain, which has a high importance in terms of agricultural activities in Tokat province, located in the Middle Black Sea Region, was performed using Mann Kendall and Sen slope test.

This study is an extended version of the paper presented at the 2nd IGD symposium (Gunes et al., 2021).

2. Material and Method

2.1. Material

Wide flat areas that are not divided by valleys and are low compared to their surroundings are called plains. There are tectonic plains, delta plains and karst plains in Turkey. Especially tectonic plains are common. In the Black Sea region, there are tectonic and delta plains. Erbaa plain is one of the tectonic plains in the Black Sea region. It is a very fertile plain with an altitude of 250m and soils rich in humus. The application area given in Figure 1.

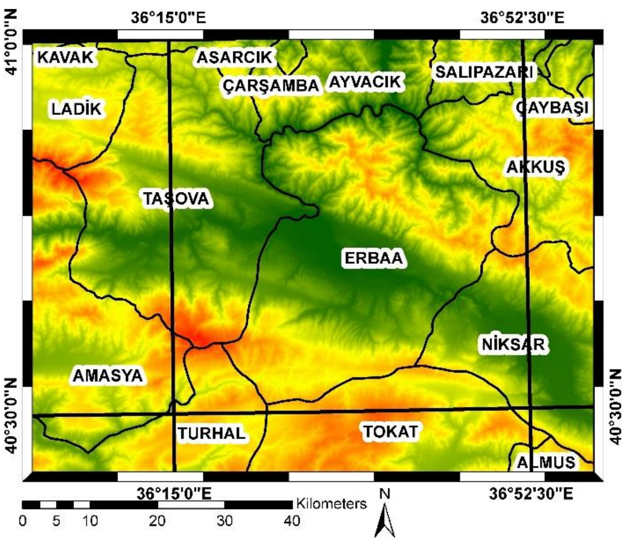

Figure 1. The Application Area

The precipitation data were taken from the NASA Langley Research Center (LaRC) POWER project. Monthly precipitation data for the 40-year period covering the years 1981-2020 were obtained from the website of the project. POWER Release 901 not only builds upon the data portal established with Release 8, but adds more recent data releases from NASA's GEWEX SRB Release 4, CERES SYN 1-deg, and FLASHFlux Version 4A. The data/parameters in POWER Release 901 are provided on a global grid with spatial resolutions equal to the input data. That resolution is 1.0° latitude by 1.0° longitude for the radiation data sets and ½° latitude by ⅝° longitude for the meteorological data sets. The POWER solar data is based upon satellite observations from which surface insolation values are inferred. The meteorological parameters are based upon the MERRA-2 assimilation model. The data of application area given in Figure 1 was created using geographic information systems.

2.1.2. Standard normal homogeneity test (SNHT)

The Standard Normal Homogeneity test (SNHT) method is used in the tests of many climatic and hydrological sizes (Alexandersson, 1986). A point "c" from the analyzed series is divided into two by reference and Equation 1 is calculated with the help of Equation 2 If the change occurs at a 'h' point, T (c) reaches its maximum value at the point c = h. The test statistic is as in Equation 3. If the test value exceeds the table value, it is rejected. In this case, it is decided that the data are not homogeneous.

$$T(c) = c.\bar{z_1}^2 + (n-c).c.\bar{z_2}^2 \quad c = 1, \ldots, n \quad (1)$$

$$\bar{z_1} = (\sum_{i=1}^{c} \frac{y_i - \bar{y}}{\sigma})/c \text{ ve } \bar{z_2} = (\sum_{i=1+c}^{n} \frac{y_i - \bar{y}}{\sigma})/(n-c) \quad (2)$$

The test statistic is as in Equation 3. If the test value exceeds the table value, it is rejected. In this case, it is decided that the data are not homogeneous.

$$T_0 = max_{1 \le c \le n} T(c) \quad (3)$$

2.1.2. Standard precipitation index (SPI)

The Standard Precipitation Index (SPI) was proposed in 1993 and is used to identify and monitor drought in regions with varying climate (Mckee et al., 1993). If the data is in a normal distribution, the difference of precipitation from the mean can be divided by the standard deviation to determine the abnormalities in the regions. SPI account are calculated using Equation 4. The Standard Precipitation Index (SPI) values are classified according to Table 1.

$$SPI = \frac{(x_i - x_i^{ort})}{\sigma} \quad (4)$$

Table 1. SPI Classification

SPI Value	Drought Category
≥ 2	Extremely Humid
1.5 to 1.99	Very Humid
1.0 to 1.49	Moderately Humid
0.50 to 0.99	Lightly Humid
-0.49 to 0.49	Normal
-0.99 to -0.50	Lightly Drought
-1.0 to -1.49	Moderate Drought
-1.5 to -1.99	Very Drought
≤ -2	Extreme Drought

2.2. Methods

Time series analysis is the process of generating new data with various data and models. It serves many different areas. Tests for the detection of increasing or decreasing trends in meteorological time series can be classified as parametric and non-parametric tests. Parametric methods are methods based on assumptions such as normal distribution of data, homogeneity of variances and linearity. Non-parametric methods, on the other hand, are the methods used in cases where the data do not show normal distribution and there are missing data. Meteorological data do not always show a normal distribution due to missing data and significant seasonality. For this reason, the use of non-parametric methods in the analysis of climatological data is more appropriate than parametric methods. Considering all these, Mann Kendall test was applied to determine the magnitude and direction of the trend, and Sen's Slope test was applied to determine the trend of the trend (Özdel, 2020).

2.2.1. Mann Kendall test

The Mann-Kendall method is a non-parametric method that is processed according to the presence or absence of change in parameters in a time series (Mann, 1945; Kendall, 1975). It is determined whether there is a trend in the data using Mann Kendall test (Besel & Tanir Kayıkçı, 2019). In this method, the order of the data is compared (Gilbert, 1987). One of the advantages of the test is that the data does not need to any distribution.

Mann-Kendall test is calculated using Equation 5 and Equation 6.

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \tag{5}$$

$$sgn(x_j - x_k) = \begin{cases} 1 \ (x_j - x_k) > 0 \\ 0 \ (x_j - x_k) = 0 \\ -1 \ (x_j - x_k) < 0 \end{cases} \tag{6}$$

The variance calculation of the test statistic with a normal distribution is calculated using Equation 7.

$$Var(S) = \frac{n(n-1)(2n+5)}{18} \tag{7}$$

In order to determine the significance of the test and probability function are calculated using Equation 8-9.

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & S > 0 \\ 0 & S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & S < 0 \end{cases} \tag{8}$$

$$F(Z) = \frac{1}{2\pi} e^{\frac{-z^2}{2}} \tag{9}$$

2.2.2. Sen's slope test

The direction and size of the trend in the data are determined using the Sen's Slope test (Sen, 1968). If there is a linear trend in the time series, the actual slope (change in unit time) can be determined using a nonparametric method. This method can be applied to records that are not affected by data errors or extreme values and where there are missing values (Yu et al., 1993).

The median is calculated using Equation 10 in Sen's Slope test.

$$Q_i = \frac{(x_j - x_k)}{(j-k)} \tag{10}$$

If the number of data (N), is an odd or even, Equation 11 and 12 are applied, respectively.

$$Q = Q_{(N+1)/2} \tag{11}$$

$$Q = \frac{1}{2}\left[Q_{N/2} + Q_{(N+2)/2}\right] \tag{12}$$

3. Results

In the first stage of the study, the Standard Homogeneity Test (SNHT) was applied to determine the suitability of the values in the data set for analysis. Then SPI values were calculated for drought classification. The Mann-Kendall test was applied to determine the direction of trends and statistical significance levels in the data series. In the last stage, Sen's Slope test was applied to determine the trend directions. This process was made for monthly and annual total precipitation series. The work flow chart of the study is given in Figure 2.

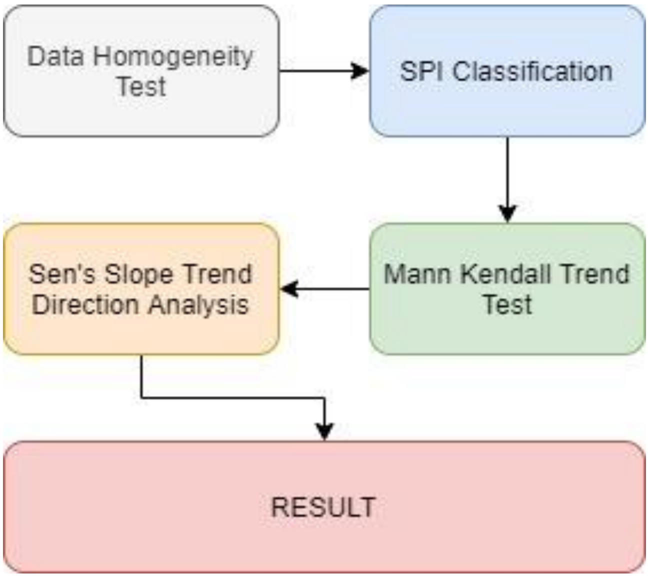

Figure 2. Flow Chart

Homogeneity testing was done using the R-Studio program. Results are given in Table 2. It was found that the data were homogeneous and suitable for analysis.

Table 2. Homogeneity Analysis Result

P-value	alpha	SNHT
0.466	0.05	Homogeneous

According to Table 2, it was decided that the data were homogeneous since P-value selected significance value (0.05). The calculation and classification of SPI values of application data are calculated using Equation 4 and Table 1. The results are given in Table 3.

Table 3. Annual SPI Classes

Year	SPI Class	Year	SPI Class
1981	Lightly Drought	2001	Normal
1982	Lightly Humid	2002	Normal
1983	Normal	2003	Normal
1984	Moderate Drought	2004	Moderately Humid
1985	Moderate Drought	2005	Lightly Humid
1986	Very Drought	2006	Moderate Drought
1987	Normal	2007	Normal
1988	Lightly Humid	2008	Normal
1989	Moderate Drought	2009	Extremely Humid
1990	Moderate Drought	2010	Lightly Humid
1991	Lightly Humid	2011	Moderately Humid
1992	Normal	2012	Very Humid
1993	Moderate Drought	2013	Very Drought
1994	Normal	2014	Normal
1995	Normal	2015	Lightly Drought
1996	Lightly Humid	2016	Moderately Humid
1997	Normal	2017	Lightly Drought
1998	Lightly Humid	2018	Normal
1999	Moderately Humid	2019	Lightly Drought
2000	Lightly Humid	2020	Very Drought

From the Table 3, Extremely, Very, Moderately and Lightly Humid in %35, Normal in %32.5, Lightly, Moderate, Very Drought in %32.5was observed. There was no SPI Class in the Extreme Drought class.

Mann-Kendall Test results of the monthly total precipitation data set are given in Table 4.

Table 4. Monthly Mann Kendall Trend Analysis Results

Months	MK-z Tau	MK-P Value	MK Hypo-thesis
January	0.297	0.007	Refuse
February	-0.108	0.328	Accept
March	0.162	0.142	Accept
Aprıl	-0.136	0.217	Accept
May	0.151	0.169	Accept
June	0.181	0.100	Accept
July	0.001	0.991	Accept
August	0.003	0.981	Accept
September	0.196	0.075	Refuse
October	-0.090	0.415	Accept
November	-0.110	0.316	Accept
December	0.074	0.499	Accept

Sen's Slope Test results for the monthly total precipitation data set are given in Table 5.

Table 5. Monthly Sen's Slope Trend Analysis Results

Months	Sen's Slope	Sen's Type of Trend
January	0.033	Increase
February	-0.007	No Trend
March	0.018	Increase
Aprıl	-0.016	Decrease
May	0.013	Increase
June	0.017	Increase
July	0.000	No Trend
August	0.000	No Trend
September	0.018	Increase
October	-0.010	Decrease
November	-0.018	Decrease
December	0.007	No Trend

Trend charts obtained as a result of the analysis are given in Figure 3-14.

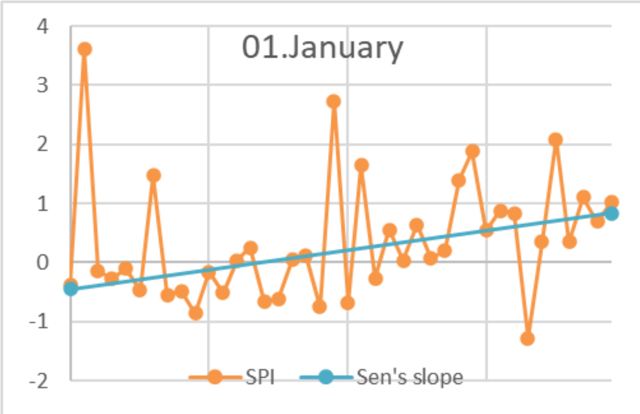

Figure 3. January Trend Graph

MK-z Tau value was calculated as 0.297 in January data. Since the calculated P value of 0.007 was lower than 10% significance level, the alternative hypothesis was accepted. Sen's Slope value was calculated as 0.033.

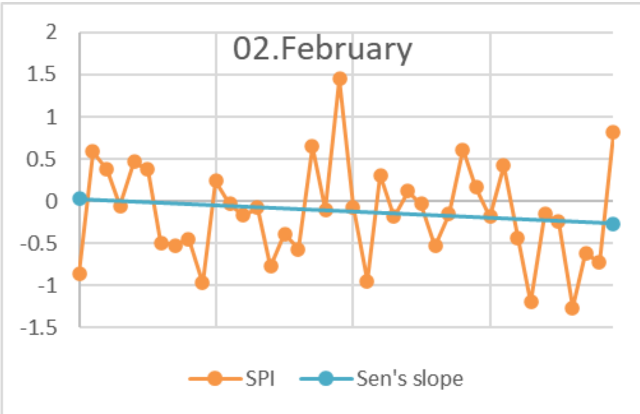

Figure 4. February Trend Graph

MK-z Tau value was calculated as -0.108 in February data. Since the calculated P value of 0.328 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as -0.007.

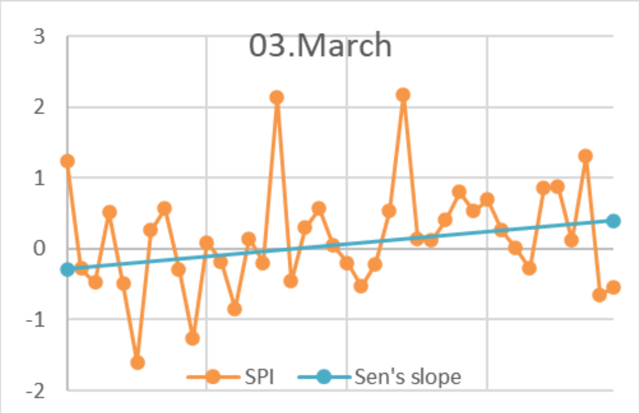

Figure 5. March Trend Graph

MK-z Tau value was calculated as 0.162 in March data. Since the calculated P value of 0.142 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as 0.018.

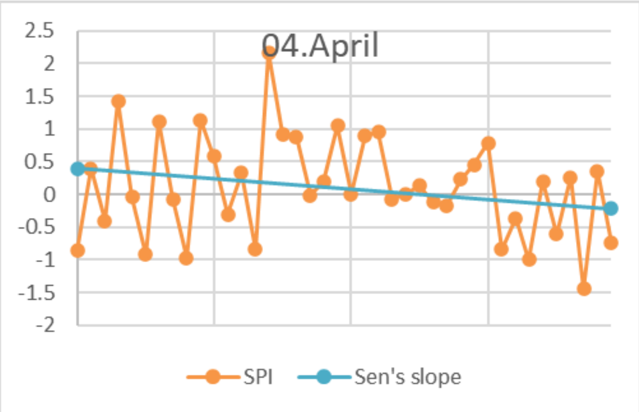

Figure 6. April Trend Graph

MK-z Tau value was calculated as -0.136 in April data. Since the calculated P value of 0.217 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as -0.016.

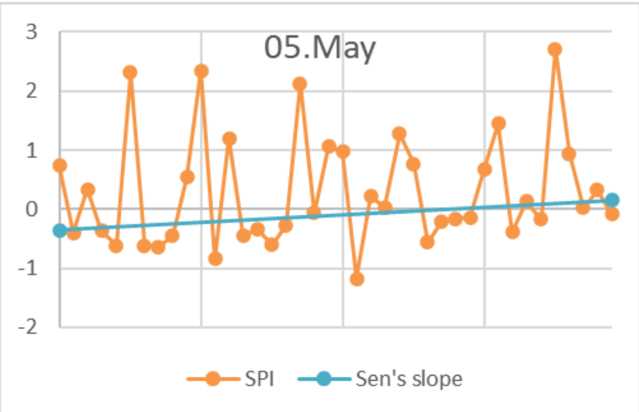

Figure 7. May Trend Graph

MK-z Tau value was calculated as 0.151 in May data. Since the calculated P value of 0.169 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as 0.013.

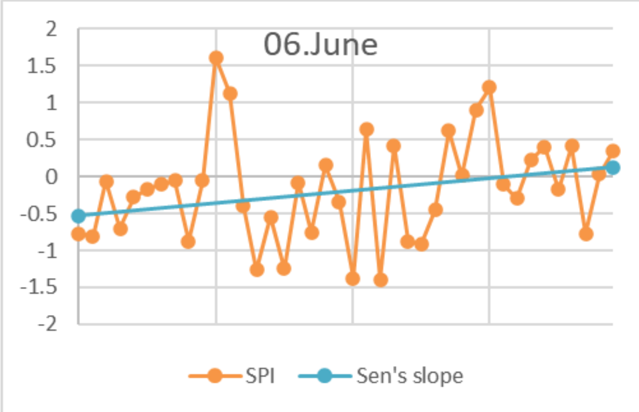

Figure 8. June Trend Graph

MK-z Tau value was calculated as 0.181 in June data. Since the calculated P value of 0.100 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as 0.017.

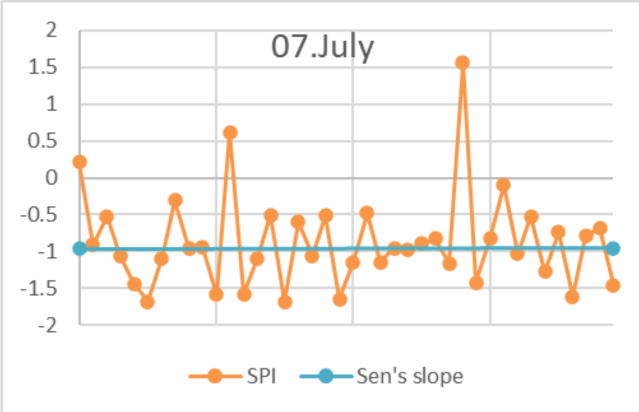

Figure 9. July Trend Graph

MK-z Tau value was calculated as 0.001 in July data. Since the calculated P value of 0.991 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as 0.000.

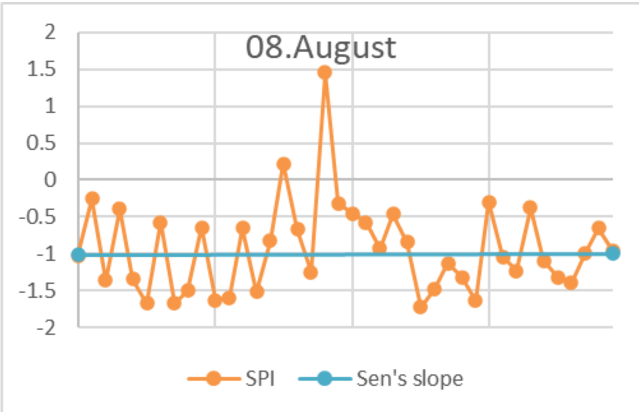

Figure 10. August Trend Graph

MK-z Tau value was calculated as 0.003 in August data. Since the calculated P value of 0.981 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as 0.000.

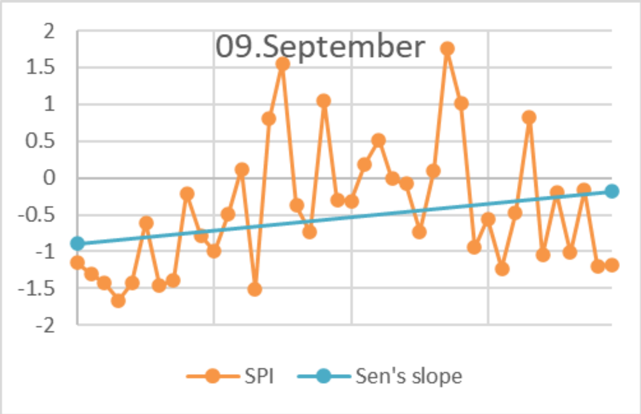

Figure 11. September Trend Graph

MK-z Tau value was calculated as 0.197 in September data. Since the calculated P value of 0.075 was lower than 10% significance level, the alternative hypothesis was accepted. Sen's Slope value was calculated as 0.018.

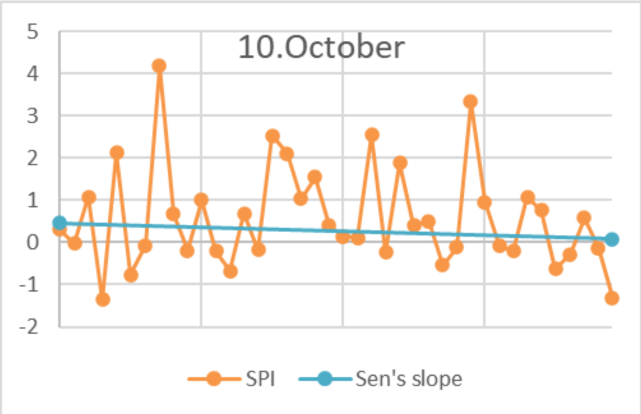

Figure 12. October Trend Graph

MK-z Tau value was calculated as -0.090 in October data. Since the calculated P value of 0.415 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as -0.010.

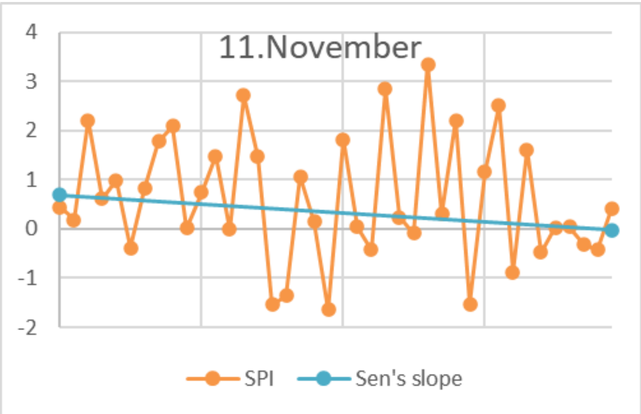

Figure 13. November Trend Graph

MK-z Tau value was calculated as -0.110 in November data. Since the calculated P value of 0.316 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as -0.018.

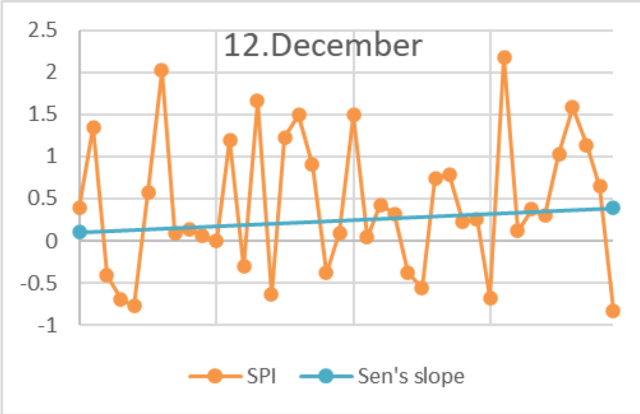

Figure 14. December Trend Graph

MK-z Tau value was calculated as 0.074 in December data. Since the calculated P value of 0.499 was higher than the 10% significance level, the null hypothesis was accepted. Sen's Slope value was calculated as 0.007.

4. Discussion and Conclusion

In this study, monthly precipitation data of Erbaa Plain in mm were used. SNHT was applied to monthly precipitation data and H_0 hypothesis was accepted since P = 0.466 value was higher than significance level 0.05 value. It was seen that the data were suitable for analysis.

The SPI values were analyzed with Mann-Kendall trend test, which is one of the non-parametric tests, as monthly. The analysis was made according to 10% significance level. According to the trend analysis, an increasing trend was determined in January and September. Although not statistically significant, an increasing trend was observed in March, May and June. A downward trend was observed in February, April, October and November.

The SPI values were analyzed with the Sen's Slope trend test, which is one of the non-parametric tests, for monthly with 10% significance level. According to the analysis results, Mann Kendall z values and Sen's Slope values show parallelism.

While there is generally increasing precipitation in the Erbaa Plain, droughts have been observed in recent years (2016-2020). It has been observed that the decreasing tends was in the autumn months, when the region receives the most precipitation. Also, an increasing trend was observed in the summer months, when the lowest drought was observed throughout the year. The plans should be made in order to reduce the damages that may occur due to the negative effects of climate change. Similar studies done for other regions of Turkey and hydrological and climatological elements. In this way, the formation and effects of climate changes can be observed on a wider scale and contribute to the planning to be made.

Author Contributions

1st Author: Conceptualization, Methodology, Software, Data Curation, Writing-Original Draft Preparation, Validation, Visualization
2nd Author: Visualization, Data Curation
3rd Author: Investigation, Reviewing and Editing

Statement of Conflicts of Interest

The authors declare no conflicts of interest.

Statement of Research and Publication Ethics

The authors declare that this study complies with Research and Publication Ethics.

References

Alexandersson, H. (1986). A Homogeneity test applied to precipitation data. *Journal of Climatology*, 6(6), 661-675.

Basara, A. C., Tabar, M. E., & Sisman, Y. (2021). Landslide susceptibility mapping of Samsun (Turkey) province using frequency ratio and AHP methods. *Turkish Journal of Geographic Information Systems*, 3(1), 24-30.

Beden, N., Demir, V., & Keskin, A. Ü. (2020). Trend Analysis of SPI and PNI drought indices in Samsun City. *Dokuz Eylul University Faculty of Engineering Journal of Science and Engineering (DEUFMD),* 22(64), 107-116.

Besel, C., Tanir Kayıkçı, E. (2019). The effect of serial correlation on nonparametric trend determination at zenith total delay time series. *Gümüşhane University Journal of Science and Technology Institute,* 9 (1), 180-188.

Coskun, M. (2019). E*arth Science.* Pegem Academy.

Gençer, M., Uğurlu, A., Kaçar, M., Özcan, H., Kesim, A., & Aydın, B (2005). *Hydrometeorology.* MGM.

Gilbert, R. O. (1987). *Statistical methods for environmental pollution monitoring.* Van Nostrand Reinhold Company.

Gunes, O. E., Basara. A. C., & Sisman, Y. (2021). Trend analysis of precipitation data using mann kendall and sen's slope test. *2nd Intercontinental Geoinformation Days (IGD),* Mersin, Turkey, 202-205.

Kendall, M. G. (1975). *rank correlation methods.* Charles Griffin.

Mann, H. B. (1945). Non-parametric test against trend. *Econometrika,* 13, 245-259.

Mckee, T. B., Doesken, N. J., & Kleist, J. (1993). The relationship of drought frequency and duration to time scales. *Eighth Conference on Applied Climatology,* Anaheim, California, 179–184.

Mercan, Y. (2016). *The relationship between the meteorological parameters and air pollution, and the deaths and emergency department admissions because of cardiovascular diseases and respiratory diseases in Kirklareli in 2010-2014* (Publication No. 448886) [Doctoral Thesis, Istanbul University]. YÖK National Thesis Center.

Özdel , M. M. (2020). *Trend analysis of temperature and precipitation parameters in Diyarbakir basin* (Publication No. 645267) [Master's Thesis, Nevşehir Hacı Bektaş Veli University]. YÖK National Thesis Center.

Sarıyer, G. (2018). Time series modelling for forecasting demand in the emergency. *International Journal of Engineering Research and Development*, 10(1), 66-77.

Sen, P. K. (1968). Estimates of the regression coefficient based on Kendall's Tau. J*ournal of the American Statistical Association*, 63, 1379–1389.

Sfetsos, A. (2000). A comparison of various forecasting techniques applied to mean hourly wind speed time series. *Renewable Energy*, 21(1), 23-35.

Yavuz, M. (2012). The effect of exports on economic growth in Turkey: A time series analysis. *Ege University 15th Economics Students Congress*, Izmır, Turkey.

Yu, Y. S., Zou, S., & Whittemore, D. (1993). Non-parametric trend analysis of water quality data of rivers in Kansas. *Journal of Hydrology*, 150: 61-80.