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ANALYSIS OF ANNUAL, SEASONAL AND MONTHLY TRENDS OF CLIMATIC DATA: A CASE STUDY of SAMSUN

ABSTRACT

Climate change impacts are perceived today as being very noticeable; determination of precipitation, wind, flow, evaporation and temperature trends has become essential for water resources and engineering projects in management and planning. Nowadays there is a lot of studies have been made in progress on global and regional climate changes in literature. In this study, monthly, annual and seasonal trends in average temperature, total precipitation, and average wind speed data calculated by Mann-Kendall, linear trend and Sen's trend tests. The gauge station is located in Samsun, which is the largest city of the Turkey's Black Sea region. The data sets are obtained for the period 1980 to 2015. According to the results, at the levels of significance of 5% and 10%, Mann-Kendall's statistical results were found to be generally similar to those of trend analysis methods.

Keywords: Trend Analysis, Mann-Kendall Test, Linear Trend Method, Sen's Trend Test, Samsun

1. INTRODUCTION

Climate change will cause immediate consequences to mitigate the adverse effects we will encounter, other than the natural effects expected of the planet's transformation process. Climate change is a global problem beyond an environmental problem and the world be going to impressed from this issue in a long-term. Nowadays, a scientifically authenticated fact is that the planet will face a temperature increase and changes in precipitation patterns over the next decades [1]. Hydro-meteorological processes constantly affect climate and human activities, and effects appear as trends or sudden jumps. Extreme meteorological events and major projects to improve water resources can affect hydrological processes and cause sudden changes on the climatological time series [2]. Trend analysis is an active area of interest in producing climate change scenarios and improving climate impact studies. If the evolution of the climate system and the human impacts are into account, the presupposition of fixed, unifying time-invariant properties of times series examined seems to be invalid [3]. With the analysis, deterministic trends in time series, progression or at least operational changes can be estimated. In practice, the trend information of a particular variable is used in designing future scenarios and future realizations. Climate change prediction is becoming increasingly important, thus trend designation and evaluation, hydrological modeling,

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and simulation studies have been conducted by different researchers on a global scale by many methodologies [4, 11, 17, 18 and 20]. The realization of the expected influence of climate change and the decreasing of trends of hydrological variables to the ecosystem, public life and infrastructure have been obligatory. Since it has been necessary to make a provision by decision-makers, discovering and identifying of these trends is the most important step in such an analysis. In the present study climate parameters; average temperature, total precipitation and, average wind data series have been subjected to various trends methods in monthly, annual and seasonal basis for Samsun province. Climate data for Samsun station is obtained from the Turkish General Directorate of Meteorology. However, this study will provide the necessary services for the decision makers in terms of forecasting, projecting and execution processes.

2. RESEARCH SIGNIFICANCE

Climate change has a great impact on climatic variables all around the world. The importance of water resources has increased because of growing population, unplanned urbanization, industrial development and rapid changes in global climate events throughout the world. Studies of climate change are not being considered separately of trend analysis thus provides a broad overview of the past and future in climatic variables. It is very important to survey that change for future water demand. In this study, monthly, annual and seasonal trends in average temperature, total precipitation, and average wind speed data calculated by Mann-Kendall, linear trend and Sen’s Trend tests. Data obtained for the period from 1980 to 2015 for Samsun station which located north of Turkey.

3. SUBJECT

3.1. Study Area and Data

In the middle part of the Black Sea Costal line, Samsun province, which is located between Kizilirmak and Yesilirmak rivers pouring into the Black Sea, has a surface area of 9083km² (Figure 1). Samsun province has three distinctive features in terms of the forms of the earth. The first is mountainous in the South, the second are plateaus between mountainous coastline and coastal strip and the third is the coastal plain between the springs and the Black Sea. The rivers in the region have occurred as a result of disintegrated the land between plateau to a large extent and spread it in places. The geographic location of the study area is between latitude 41°16’46” and longitude 36°20’98”. Samsun’s area is 9.352km² and elevation is about 4.00m. Samsun generally has a temperate weather. Climate has two distinct characteristics in the coastal strip and interior areas. The effects of the Black Sea climate are seen on the coastline. Summer is hot on the coast and the winter is warm and rainy, while inner areas are under the influence of Akdag Mountain, which is 2000 meters high and Canik Mountains, which is 1500 meters high. As a result of this influence of the mountains, the winter season is cold, rainy and snowy and summer season is cool. The mean annual precipitation totals are above the country average (707.21mm). On the other hand, the rate of precipitation at the end is different from that of the Western Black Sea region. The greatest rivers of the province are Kizilirmak and Yesilirmak. These two rivers reach the Black Sea after passing the provincial lands. There are a number of small streams on the eastern side as shown in Figure 1.

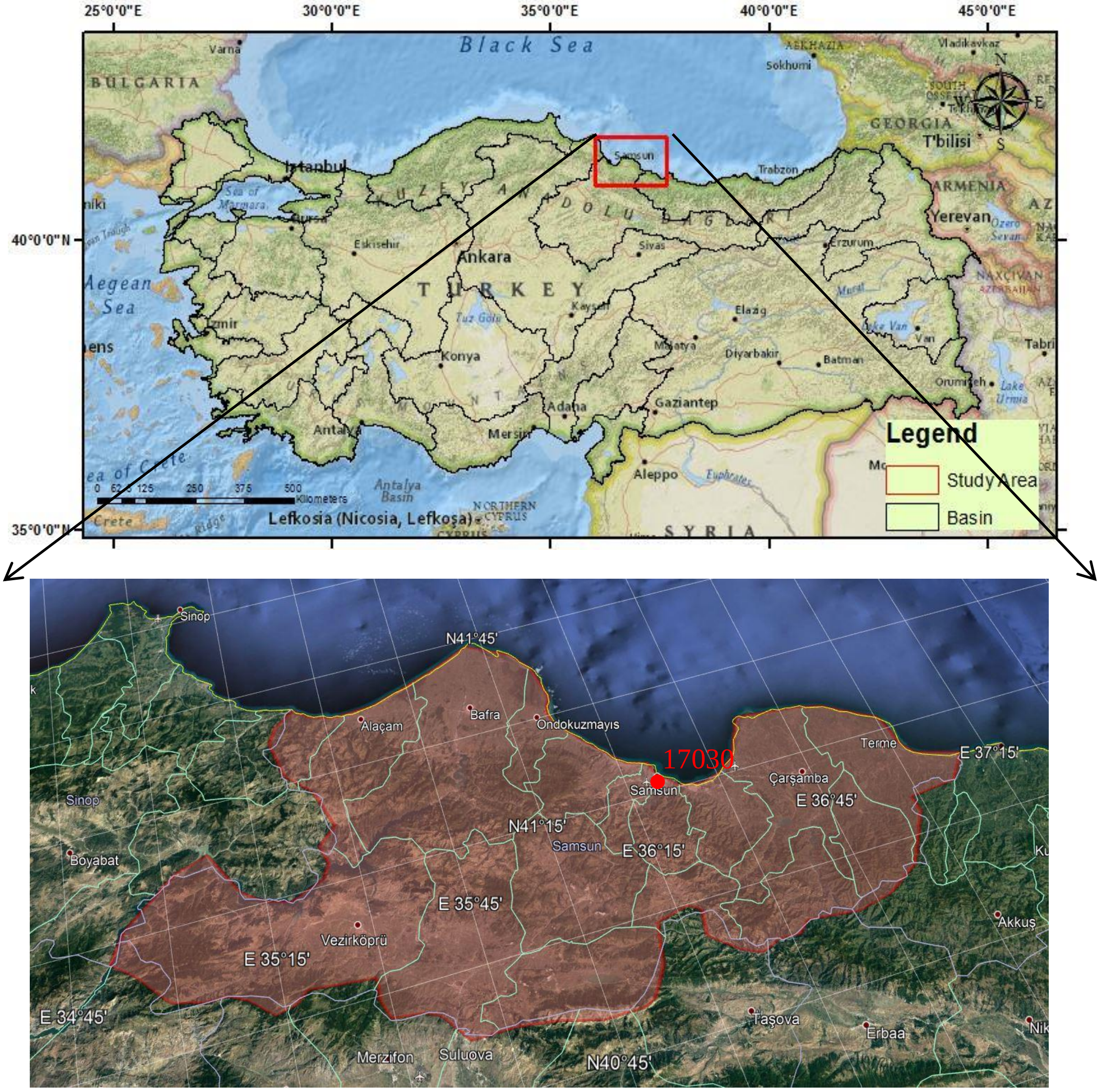

Figure 1. Location of station 17030

However, these streams are irregular. The location information of the Samsun station is in Table 1. Basic statistical information on monthly total precipitation data is provided in Table 2.

Table 1. Location information of Samsun station

Station No	Station	Latitude (°N)	Longitude (°W)	Altitude(m)
17030	Samsun	41.35	36.24	4

Monthly, seasonal and annual average temperature, total rainfall and average wind series were obtained from General Directorate of Meteorology. The 35-year period between 1980 and 2015 was chosen as the study period.

Table 2. Basic statistical information on monthly total precipitation

Months	Data range	Min.value (mm)	Max.value (mm)	Mean, µ (mm)	Standard deviation, σ (mm)	Cv*	Cs*
Jan	1980-2015	5.10	133.2	62.58	29.973	0.479	0.750
Feb	1980-2015	14.30	100.4	52.06	21.422	0.411	0.604
Mar	1980-2015	4.80	141.6	61.46	27.755	0.452	0.522
Apr	1980-2015	19.60	146.2	55.29	30.972	0.560	1.054
May	1980-2015	19.60	132.9	50.20	30.575	0.609	1.068
Jun	1980-2015	3.30	150.5	50.14	30.938	0.617	1.269
Jul	1980-2015	0.00	167.3	35.30	34.206	0.969	2.069
Aug	1980-2015	0.00	269.8	45.71	55.833	1.222	2.287
Sep	1980-2015	3.90	133.1	47.07	31.082	0.660	0.764
Oct	1980-2015	14.10	257.0	86.00	56.015	0.651	1.509
Nov	1980-2015	10.60	177.1	86.93	47.501	0.546	0.202
Dec	1980-2015	36.90	142.2	74.46	29.570	0.397	0.709
Annual	1980-2015	496.70	999.1	707.21	94.539	0.134	0.598
Winter	1980-2015	111.30	313.8	189.11	53.614	0.284	0.459
Spring	1980-2015	87.0	269.6	166.95	47.727	0.286	0.422
Summer	1980-2015	27.50	386.3	131.15	72.145	0.550	1.641
Autumn	1980-2015	96.10	400.0	220.01	74.133	0.337	0.533

*Cv'; Coefficient of variation, Cs'; coefficient of skewness

Table 2 shows that the total annual rainfall is 707.21mm. The Black Sea climate which dominates the region is a mild climate. The season with the highest total precipitation is autumn with 220.01mm and the lowest total precipitation is summer with 131.15mm. Basic statistical information on average monthly temperatures and average monthly winds are given in Table 3 and 4 respectively. According to Table 3, the highest temperatures are seen in summer with an average of 22.6°C and the lowest temperatures are seen in winter with an average of 8.7°C. Also, the annual average temperature of Samsun station is 15.1°C.

Table 3. Basic statistical information on average monthly temperatures

Months	Data Range	Min.value (°C)	Max.val ue (°C)	Mean, µ (°C)	Standard deviation, σ (°C)	Cv*	Cs*
Jan	1980-2015	4.6	27.7	8.3	4.361	0.527	3.898
Feb	1980-2015	3.0	27.7	7.8	4.548	0.586	3.709
Mar	1980-2015	4.7	28.1	8.6	4.305	0.499	4.104
Apr	1980-2015	9.0	28.4	11.9	3.739	0.313	3.788
May	1980-2015	9.0	28.6	16.0	2.962	0.185	3.385
Jun	1980-2015	18.8	29.3	20.6	2.220	0.108	2.802
Jul	1980-2015	20.4	29.5	23.5	1.793	0.076	1.622
Aug	1980-2015	20.8	29.7	23.8	1.919	0.081	1.523
Sep	1980-2015	17.6	29.2	20.6	2.308	0.112	2.272
Oct	1980-2015	14.2	29.1	16.8	3.028	0.180	3.037
Nov	1980-2015	8.0	28.5	13.0	3.855	0.296	2.788
Dec	1980-2015	6.4	27.9	10.2	4.200	0.413	3.338
Annual	1980-2015	13.3	28.6	15.1	3.000	0.199	4.148
Winter	1980-2015	6.1	27.8	8.7	4.167	0.477	4.288
Spring	1980-2015	9.2	28.4	12.2	3.539	0.290	4.256
Summer	1980-2015	20.7	29.5	22.6	1.882	0.083	2.339
Autumn	1980-2015	14.1	28.9	16.8	2.871	0.171	3.363

Table 4. Basic statistical information on average monthly winds

Months	Data Range	Min. Value (m/sec)	Max. Value (m/sec)	Mean, μ (m/sec)	Standard Deviation σ (m/sec)	Cv*	Cs*
Jan	1980-2015	1.00	2.70	1.59	0.404	0.254	0.578
Feb	1980-2015	0.80	2.40	1.42	0.364	0.256	0.530
Mar	1980-2015	0.70	1.80	1.22	0.277	0.227	-0.130
Apr	1980-2015	0.60	1.30	1.04	0.191	0.184	-0.743
May	1980-2015	0.60	1.30	0.92	0.201	0.217	0.046
Jun	1980-2015	0.60	1.40	1.06	0.206	0.194	-0.249
Jul	1980-2015	0.80	1.60	1.26	0.229	0.182	-0.434
Aug	1980-2015	0.80	1.60	1.22	0.206	0.169	-0.202
Sep	1980-2015	0.60	1.40	1.10	0.207	0.188	-0.608
Oct	1980-2015	0.50	1.40	1.03	0.223	0.216	-1.050
Nov	1980-2015	0.60	1.90	1.22	0.372	0.305	0.008
Dec	1980-2015	0.80	2.30	1.54	0.380	0.247	0.011
Annual	1980-2015	0.72	1.47	1.22	0.219	0.180	-1.049
Winter	1980-2015	0.93	2.20	1.52	0.331	0.218	-0.152
Spring	1980-2015	0.63	1.37	1.06	0.194	0.183	-0.858
Summer	1980-2015	0.73	1.53	1.18	0.199	0.169	-0.439
Autumn	1980-2015	0.57	1.43	1.12	0.241	0.216	-0.865

Table 4 shows that, the highest wind velocity is seen in winter with an average of 1.52m/sec and the lowest wind velocity is seen in spring with an average of 1.06m/sec. Annual average of wind velocity is 1.22m/sec in Samsun station.

4. METHODS

In this study, three trend methods that well known in the literature were used for estimations. Mann-Kendall trend test is used as a non-parametric method, the linear trend is used as a parametric method and Sen Trend test as an innovative trend test was used in analyses that successfully applicated in many recent studies [9, 10 and 11]. In consequence of anthropogenic and instrumental effects, a generally homogeneous data set could not be used in climatological studies. Analysis of the statistical homogeneity of the data was adopted at the 1% significance level for the Standard Normal test, Pettitt test, Von Neumann rate and Buishand range test [12, 13, 14, 15 and 16]. Consequently, the data Samsun Station found homogeneous, as reviewed by Dogan *et al.* [8]. As a result, after the homogeneity analysis, homogeneous data series of Samsun station were subjected to trend analysis.

4.1. Mann-Kendall Trend Test

The Mann-Kendall method is based on the investigation of trends of time series. Mann-Kendall is a non-parametric rank-based method that is resistant against the effects of extremes and suitable for application with distorted variables [17]. Test statistics are;

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

n; is the number of data points, x_i and x_j are the data values for time series i and j, in Equation 1 and sgn $(x_j - x_k)$ is the sign function in Equation 2 below;

$$sgn\left(x_k - x_j\right) = \begin{Bmatrix} 1; & If\ x_j > x_k \\ 0; & If\ x_j = x_k \\ -1 & If\ x_j < x_k \end{Bmatrix} \tag{2}$$

The variance computed below;

$$Var\ (S) = \frac{n(n-1)(2n+5) - \sum_{k=1}^{P} t_k(t_k-1)(2t_k+5)}{18} \quad (3)$$

In Equation 3, p indicates the number of tied groups, n means a set of data, and t_i is the total number of ties extent k. With the same value a tied group is a set of sample data. If the sample size is n>10, Z the standard normal test is calculated by Equation 4. In Equation 3, P indicates the number of tied groups, and sum sign (Σ) shows the total amount of all tied groups. t_k is the number of data values in P^{th} group. If there are no tied groups, the summary process is neglected. Computing variance of time series with Equation 3, then standard Z value is computed using the following equation.

$$Z = \begin{Bmatrix} \dfrac{S-1}{\sqrt{Var(S)}}; & If\ S > 0 \\ 0; & If\ S = 0 \\ \dfrac{S+1}{\sqrt{Var(S)}} & If\ S < 0 \end{Bmatrix} \quad (4)$$

The computed standard Z value is checked with standard normal distribution according to the two-tailed confidence levels (α=10 %, α=5%). If $|Z|>|Z_{1}- \alpha/2|$ value is less than, calculated Z, the null hypothesis (H_0) is rejected and the H_1 hypothesis is accepted. On the contrary the H_0 hypothesis is accepted and that means the trend is not significant statistically. α=10% and α=5% (two-tailed confidence levels) are into account in this study [18].

4.1.1. Linear Trend Test

Regression analysis is based on the solution of the graph obtained by writing two different variables on separate axes. It is necessary to select a line that best expresses the obtained graph and determine the curve of this line.

$$Y = \beta_0 + \beta_1 . X \quad (5)$$

In Equation 5, β_0 is a constant value and β_1 is the slope. If this equation used in the determination of trend analysis, β_1 is expressed the amount of decrease or increase on trend [19].

4.1.2. Sen's Trend Test

The Sen [11] method is independent of assumptions such as sample size and serial correlation, within the data can be distributed as normally and non-normally also. The time series are divided into two equal parts from the beginning to the end date and then sorted in ascending order. At this time in the Cartesian coordinate system, there is an X_i sub-series on the X axis and a sub-series X_j on the Y axis (Figure 2).

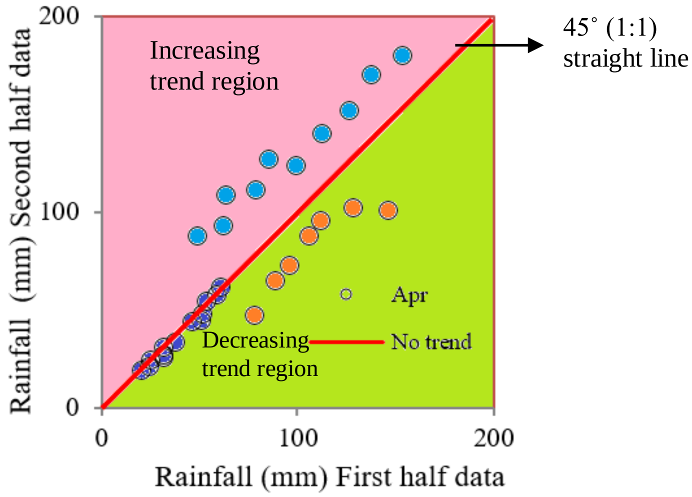

Figure 2. Increasing and decreasing trends versus trendless time series

There is a decreasing trend if the data corresponds to the triangular area below the 1: 1 line, if the data corresponding to the triangular area above the 1: 1 line, there is an increasing trend against [7, 11 and 20]. Sen [20] suggested a new statistical process. Steps of this method are given in Equation 6-11.

$$E(s) = \frac{2}{n}\left[E(\overline{y_2}) - E(\overline{y_1})\right] \tag{6}$$

$$\sigma_s{}^2 = \frac{4}{n^2}\left[E(\overline{y_2}^2) - 2E(\overline{y_2 y_1}) - E(\overline{y_1}^2)\right] \tag{7}$$

$$\rho_{\overline{y_2 y_1}} = \frac{E(\overline{y_2 y_1}) - E(\overline{y_2}) - E(\overline{y_1})}{\sigma_{\overline{y_2}}\sigma_{\overline{y_1}}} \tag{8}$$

$$\sigma_s^2 = \frac{8}{n^2}\frac{\sigma^2}{n}\left(1 - \rho_{\overline{y_2 y_1}}\right) \tag{9}$$

$$\sigma_s = \frac{2\sqrt{2}}{n\sqrt{n}}\sigma\sqrt{\left(1 - \rho_{\overline{y_2 y_1}}\right)} \tag{10}$$

$$CL_{(1-\alpha)} = 0 \mp s_{critical}\sigma_s \tag{11}$$

Where $\overline{y}_1$, mean of the first data; $\overline{y}_2$, mean of the second data; ρ, correlation between first and second data; s, slope value; n, number of data; σ, standard deviation of all data; σ_s, slope standard deviation; Z critical values in one-way hypothesis at 95% (for example) confidence level. Critical upper and lower values established for hypothesis test limits (Equation 11). It can be said that, if each station's slope value, s, is outside the lower and upper confidence limits, and also alternative hypotheses, H_1, are verified, there is a trend (Yes) in time series. The type of trend is stated depending on the slope value (s) sign. Slope (s) can be positive or negative. This means that there is an increasing (+) or a decreasing (-) trend in time series [20].

5. FINDINGS AND DISCUSSION

The aim of this study is to calculate the behavior of monthly, annual and seasonal trends with average temperature total precipitations and average wind data for Samsun gauge station. Mann-Kendall trend, linear trend and Sen's trend methods were used in the trend analysis.

5.1. Mann-Kendall Trend Analysis Results

The Mann-Kendall (MK) test is one of the non-parametric tests to analyze trend in a time series particularly for hydrological, climatological and meteorological data. The purpose of is to give the increasing or decreasing trend results of the Mann-Kendall test. Mann-Kendall test results for precipitation are shown in Table 5; here results are given for two-tailed confidence levels (α=10%, α=5%). There is an increase trend in precipitation on annual basis. Similarly, increasing trends are seen in the winter season in seasonal sense. Only for January month for Samsun station there is an increasing trend at α=10%, α=5% for monthly assessment. Mann-Kendall test results for average monthly temperatures are shown in Table 6; here results are given for two-tailed confidence levels (α=10%, α=5%). There is an increase trend in temperatures on annual basis. Similarly, increasing trends are seen in spring and summer seasons in seasonal sense. Also, for May, June, July, August and November months for Samsun station there is an increasing trend at α=10%, α=5% for monthly assessment.

Table 5. Mann-Kendall test results for precipitation

Station	Months	MKZ Values	Z, Critical Probability Values (α=10%)	MK test Tendency (α=10%)	H_0 Hypothesis	Z, Critical Probability Values (α=5%)	MK test Tendency (α=5%)	H_0 Hypothesis
Samsun 17030	**Jan**	**2.016**	**±1.645**	**(+)**	**Refuse**	**±1.96**	**(+)**	**Refuse**
	Feb	0.627	±1.645	No	Accept	±1.96	No	Accept
	Mar	1.512	±1.645	No	Accept	±1.96	No	Accept
	Apr	-0.095	±1.645	No	Accept	±1.96	No	Accept
	May	-0.136	±1.645	No	Accept	±1.96	No	Accept
	Jun	0.232	±1.645	No	Accept	±1.96	No	Accept
	Jul	1.158	±1.645	No	Accept	±1.96	No	Accept
	Aug	0.272	±1.645	No	Accept	±1.96	No	Accept
	Sep	0.885	±1.645	No	Accept	±1.96	No	Accept
	Oct	0.014	±1.645	No	Accept	±1.96	No	Accept
	Nov	-1.376	±1.645	No	Accept	±1.96	No	Accept
	Dec	1.485	±1.645	No	Accept	±1.96	No	Accept
	Annual	**2.220**	**±1.645**	**(+)**	**Refuse**	**±1.96**	**(+)**	**Refuse**
	Winter	**2.356**	**±1.645**	**(+)**	**Refuse**	**±1.96**	**(+)**	**Refuse**
	Spring	0.613	±1.645	No	Accept	±1.96	No	Accept
	Summer	1.607	±1.645	No	Accept	±1.96	No	Accept
	Autumn	-0.477	±1.645	No	Accept	±1.96	No	Accept

Table 6. Mann-Kendall test results for average monthly temperatures

Station	Months	MKZ Values	Z, Critical Probability Values (α=10%)	MK test Tendency (α=10%)	H_0 Hypothesis	Z, Critical Probability Values (α=5%)	MK test Tendency (α=5%)	H_0 Hypothesis
Samsun 17030	Jan	1.098	±1.645	No	Accept	±1.96	No	Accept
	Feb	1.541	±1.645	No	Accept	±1.96	No	Accept
	Mar	1.378	±1.645	No	Accept	±1.96	No	Accept
	Apr	1.378	±1.645	No	Accept	±1.96	No	Accept
	May	**3.340**	**±1.645**	**(+)**	**Refuse**	**±1.96**	**(+)**	**Refuse**
	Jun	**3.200**	**±1.645**	**(+)**	**Refuse**	**±1.96**	**(+)**	**Refuse**
	Jul	**3.597**	**±1.645**	**(+)**	**Refuse**	**±1.96**	**(+)**	**Refuse**
	Aug	**3.457**	**±1.645**	**(+)**	**Refuse**	**±1.96**	**(+)**	**Refuse**
	Sep	1.705	±1.645	(+)	Refuse	±1.96	No	Accept
	Oct	1.495	±1.645	No	Accept	±1.96	No	Accept
	Nov	**2.079**	**±1.645**	**(+)**	**Refuse**	**±1.96**	**(+)**	**Refuse**
	Dec	0.561	±1.645	No	Accept	±1.96	No	Accept
	Annual	**3.060**	**±1.645**	**(+)**	**Refuse**	**±1.96**	**(+)**	**Refuse**
	Winter	1.752	±1.645	(+)	Refuse	±1.96	No	Accept
	Spring	**2.989**	**±1.645**	**(+)**	**Refuse**	**±1.96**	**(+)**	**Refuse**
	Summer	**3.854**	**±1.645**	**(+)**	**Refuse**	**±1.96**	**(+)**	**Refuse**
	Autumn	1.892	±1.645	(+)	Refuse	±1.96	No	Accept

Results of Mann-Kendall test for average monthly winds are shown in Table 7. There is a decrease trend in winds on annual basis. Similarly, there is a decreasing trend at α=5% in seasonal sense. For winter, spring and, autumn seasons at α=10% there is a decreasing trend too. Besides for January, February, Mach, April, July, November and December months there is a decreasing at α=10%, in addition to that months there is a decreasing trend for June at α=5% too.

Table 7. Mann-Kendall test results for average monthly winds

Station	Months	MK Z Values	Z, Critical Probability Values (α=10%)	MK test Tendency (α=10%)	H_0 Hypothesis	Z, Critical Probability Values (α=5%)	MK test Tendency (α=5%)	H_0 Hypothesis
Samsun 17030	**Jan**	**-4.554**	**±1.645**	**(-)**	**Refuse**	**±1.96**	**(-)**	**Refuse**
	Feb	**-3.223**	**±1.645**	**(-)**	**Refuse**	**±1.96**	**(-)**	**Refuse**
	Mar	**-2.989**	**±1.645**	**(-)**	**Refuse**	**±1.96**	**(-)**	**Refuse**
	Apr	**-1.798**	**±1.645**	**(-)**	**Refuse**	**±1.96**	**No**	**Accept**
	May	-1.611	±1.645	No	Accept	±1.96	No	Accept
	Jun	**-1.658**	**±1.645**	**(-)**	**Refuse**	**±1.96**	**No**	**Accept**
	Jul	**-2.546**	**±1.645**	**(-)**	**Refuse**	**±1.96**	**(-)**	**Refuse**
	Aug	-1.238	±1.645	No	Accept	±1.96	No	Accept
	Sep	-1.541	±1.645	No	Accept	±1.96	No	Accept
	Oct	-0.794	±1.645	No	Accept	±1.96	No	Accept
	Nov	**-2.709**	**±1.645**	**(-)**	**Refuse**	**±1.96**	**(-)**	**Refuse**
	Dec	**-4.064**	**±1.645**	**(-)**	**Refuse**	**±1.96**	**(-)**	**Refuse**
	Annual	**-3.270**	**±1.645**	**(-)**	**Refuse**	**±1.96**	**(-)**	**Refuse**
	Winter	**-4.741**	**±1.645**	**(-)**	**Refuse**	**±1.96**	**(-)**	**Refuse**
	Spring	**-2.032**	**±1.645**	**(-)**	**Refuse**	**±1.96**	**(-)**	**Refuse**
	Summer	-1.822	±1.645	(-)	Refuse	±1.96	No	Accept
	Autumn	**-2.125**	**±1.645**	**(-)**	**Refuse**	**±1.96**	**(-)**	**Refuse**

5.2. Linear Trend Analysis Test Results

The linear trend analysis is one of the parametric tests to analyze trend in a time series particularly for a lot of study. Linear trend results for Samsun Station are shown in Table 8.

Table 8. Linear trend results for Samsun station

	Months	Linear Trend			Months	Linear Trend			Months	Linear Trend	
		Amount of change	Tendency			Amount of change	Tendency			Amount of change	Tendency
Total Precipitation	**Jan**	**0.917**	**(+)**	Average Monthly Temperatures	**Jan**	**0.059**	**(+)**	Average Monthly Winds	Jan	-0.044	(-)
	Feb	**0.474**	**(+)**		**Feb**	**0.102**	**(+)**		Feb	-0.031	(-)
	Mar	**0.777**	**(+)**		**Mar**	**0.061**	**(+)**		Mar	-0.024	(-)
	Apr	-0.159	(-)		**Apr**	**0.079**	**(+)**		Apr	-0.012	(-)
	May	-0.356	(-)		**May**	**0.134**	**(+)**		May	-0.009	(-)
	Jun	**0.225**	**(+)**		**Jun**	**0.126**	**(+)**		Jun	-0.009	(-)
	Jul	**0.749**	**(+)**		**Jul**	**0118**	**(+)**		Jul	-0.018	(-)
	Aug	**1.370**	**(+)**		**Aug**	**0.139**	**(+)**		Aug	-0.011	(-)
	Sep	**0.471**	**(+)**		**Sep**	**0.098**	**(+)**		Sep	-0.012	(-)
	Oct	-0,308	(-)		**Oct**	**0.076**	**(+)**		Oct	-0.015	(-)
	Nov	-1.117	(-)		**Nov**	**0.119**	**(+)**		Nov	-0.030	(-)
	Dec	**0.672**	**(+)**		**Dec**	**0.041**	**(+)**		Dec	-0.040	(-)
	Annual	**3.714**	**(+)**		**Annual**	**0.096**	**(+)**		Annual	-0.021	(-)
	Winter	**2.063**	**(+)**		**Winter**	**0.202**	**(+)**		Winter	-0.116	(-)
	Spring	**0.261**	**(+)**		**Spring**	**0.274**	**(+)**		Spring	-0.046	(-)
	Summer	**2.344**	**(+)**		**Summer**	**0.383**	**(+)**		Summer	-0.038	(-)
	Autumn	-0.954	(-)		**Autumn**	**0.293**	**(+)**		Autumn	-0.057	(-)

The average annual change in values and trend direction are included in this table. Table 8 shows that there is an increasing trend in total precipitation on annual basis. For winter, spring and summer seasons there is also an increasing trend too. In addition, monthly results of Samsun gauge station for precipitation shows that increasing trends for January, February, March, June, July, August, September and December. Annual, seasonal and the monthly results are shown in Figure 3, 4 and 5 more extensively. While temperatures tend to increase in all periods, there is a trend to decrease in the winds. The results of the linear trend analysis subjected to the annual, seasonal and monthly average temperatures for the Samsun station are shown in Figures 6, 7 and 8, respectively. The linear trend results for wind data are given for annual, seasonal and monthly basis in the following Figures 9, 10 and 11 respectively.

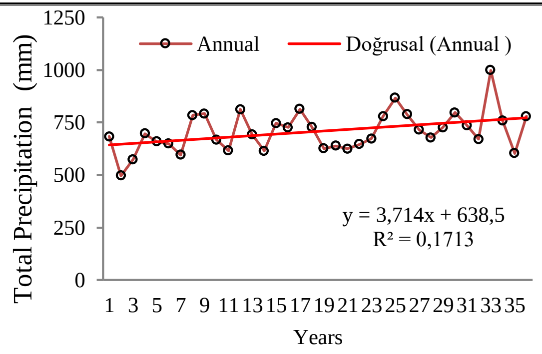

Figure 3. Annual total precipitation graph for linear trend analysis

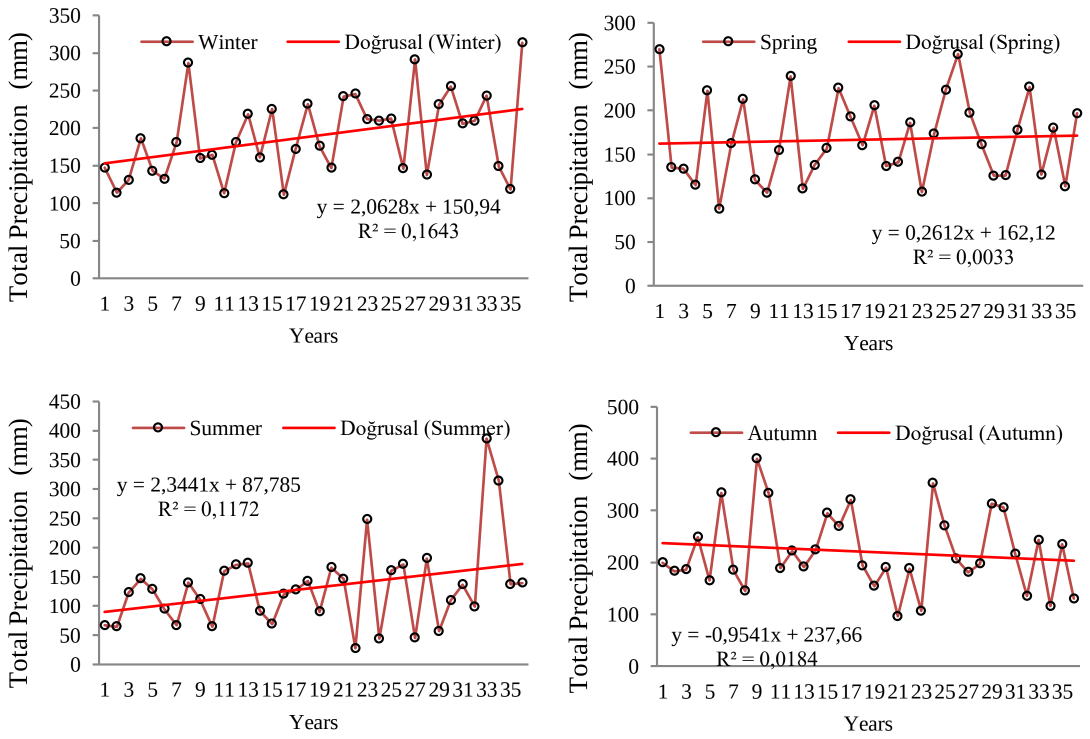

Figure 4. Seasonal total precipitation graphs for linear trend analysis

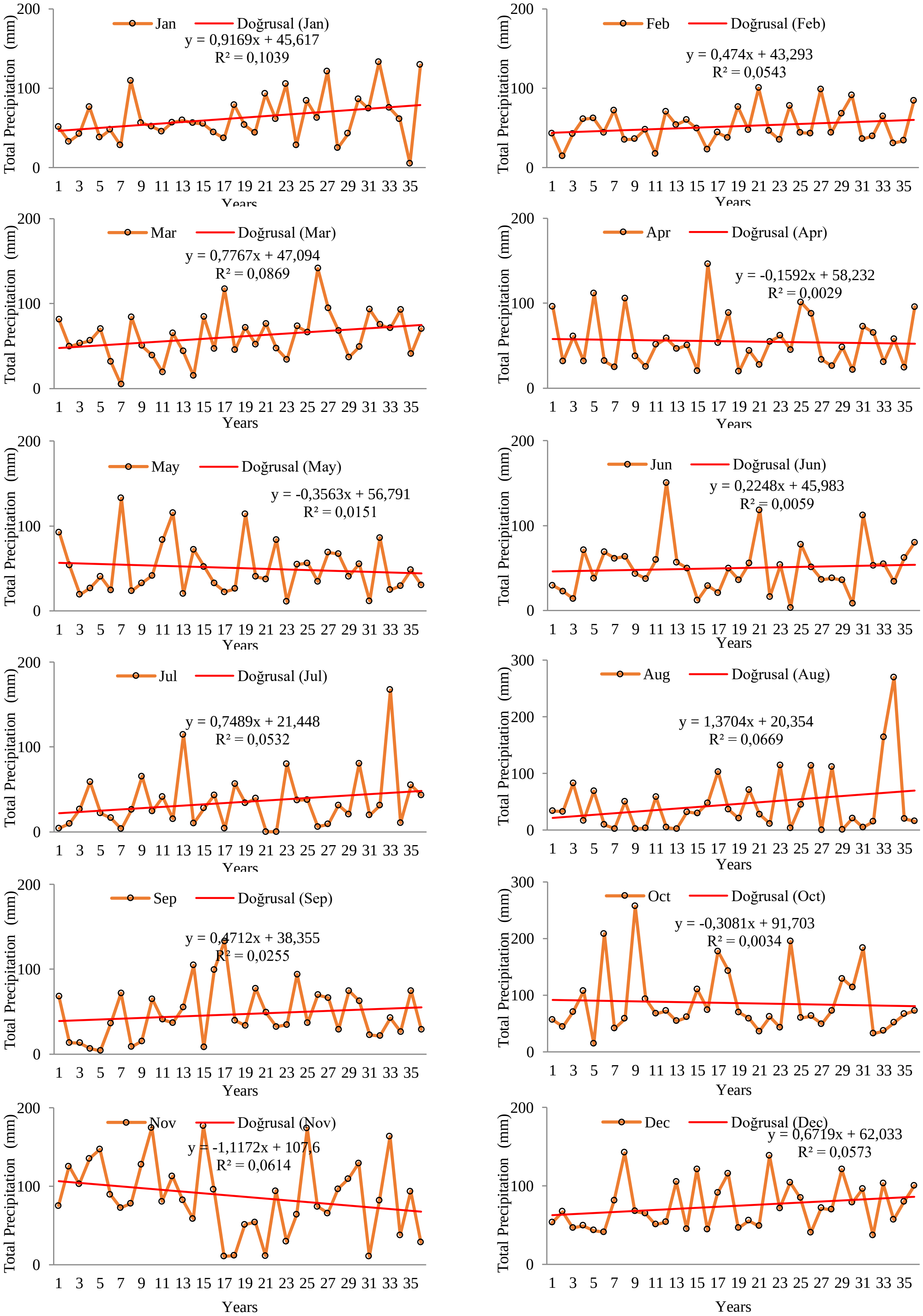

Figure 5. Monthly total precipitation graphs for linear trend analysis

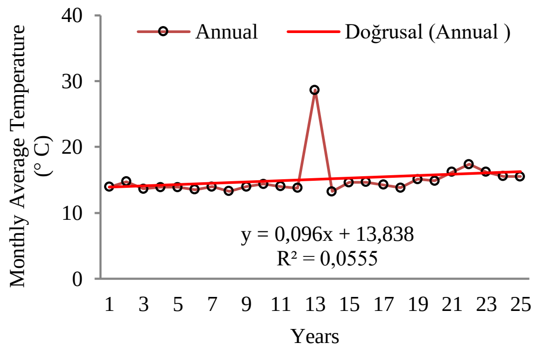

Figure 6. Annual average temperature graph for linear trend analysis

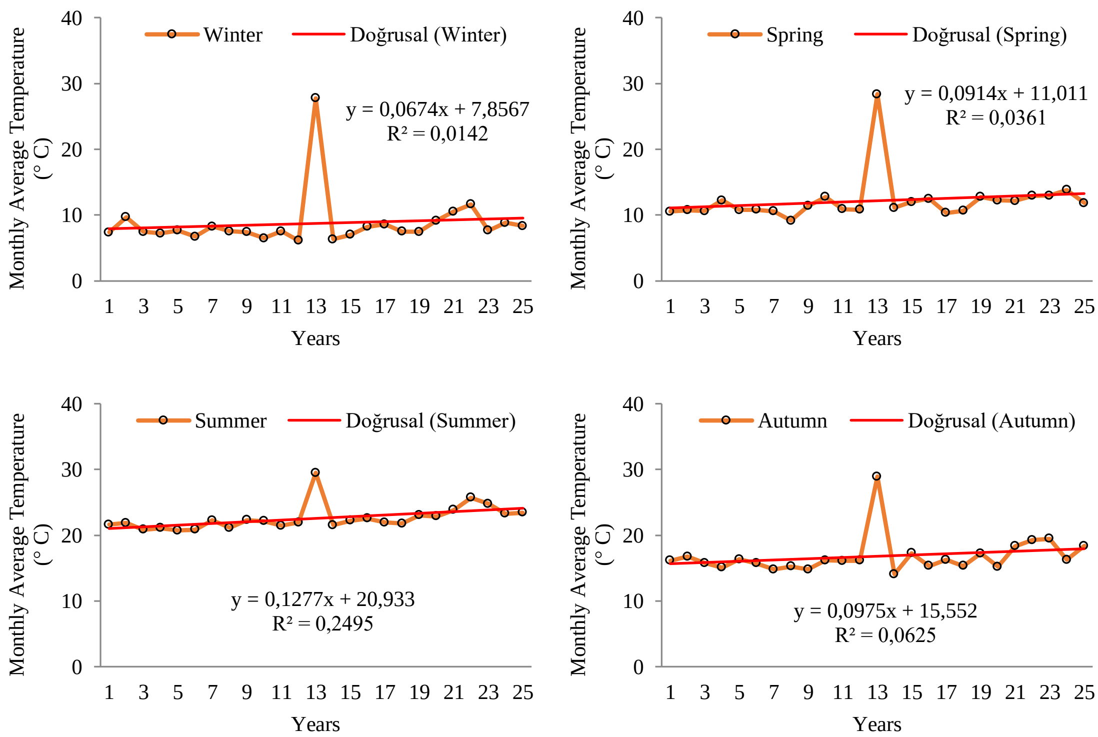

Figure 7. Seasonal average temperature graphs for linear trend analysis

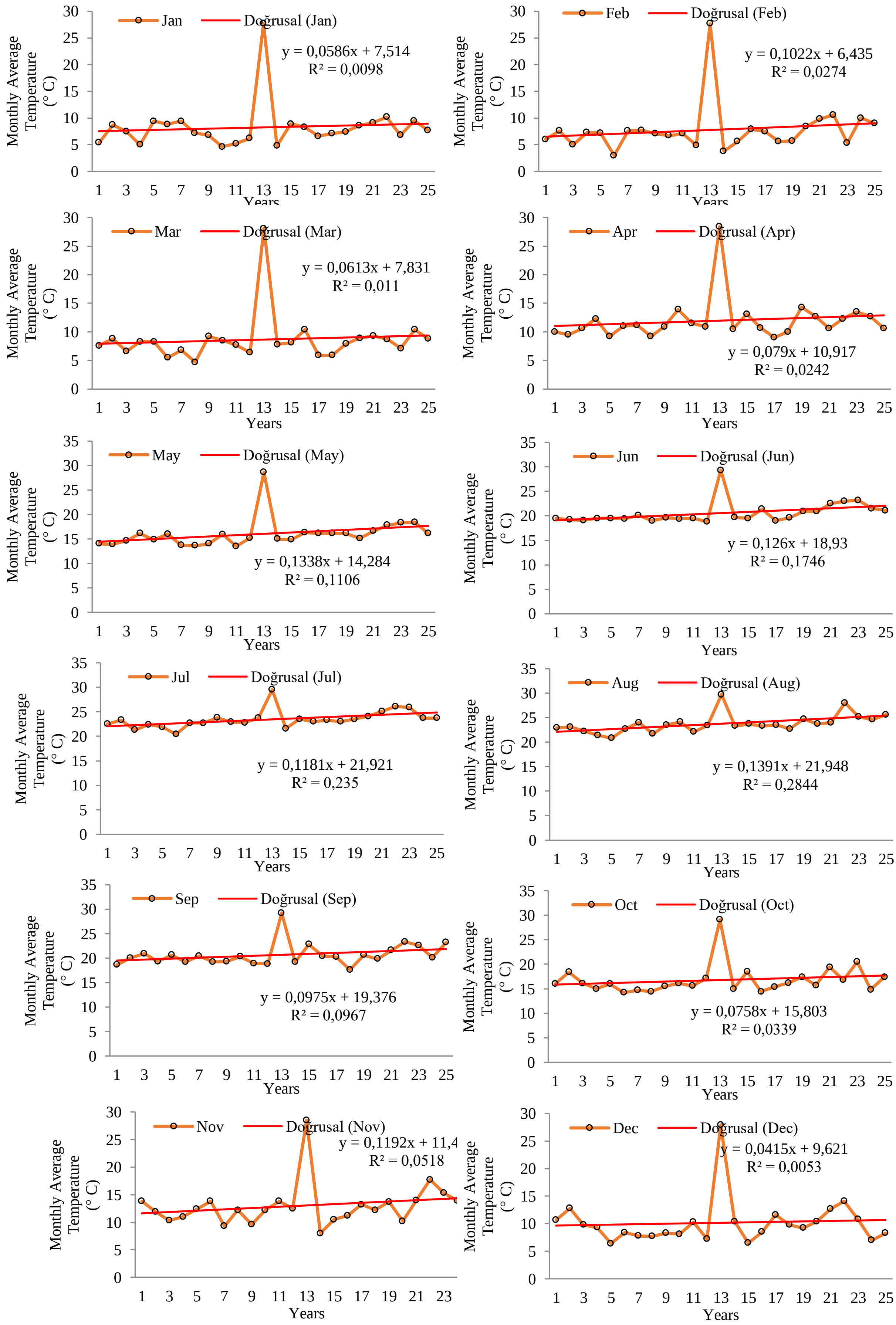

Figure 8. Monthly average temperature graphs for linear trend analysis

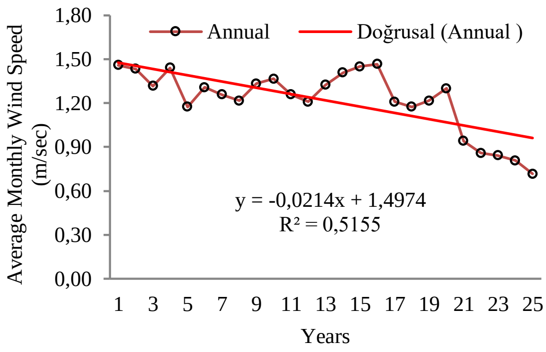

Figure 9. Annual average wind graph for linear trend analysis

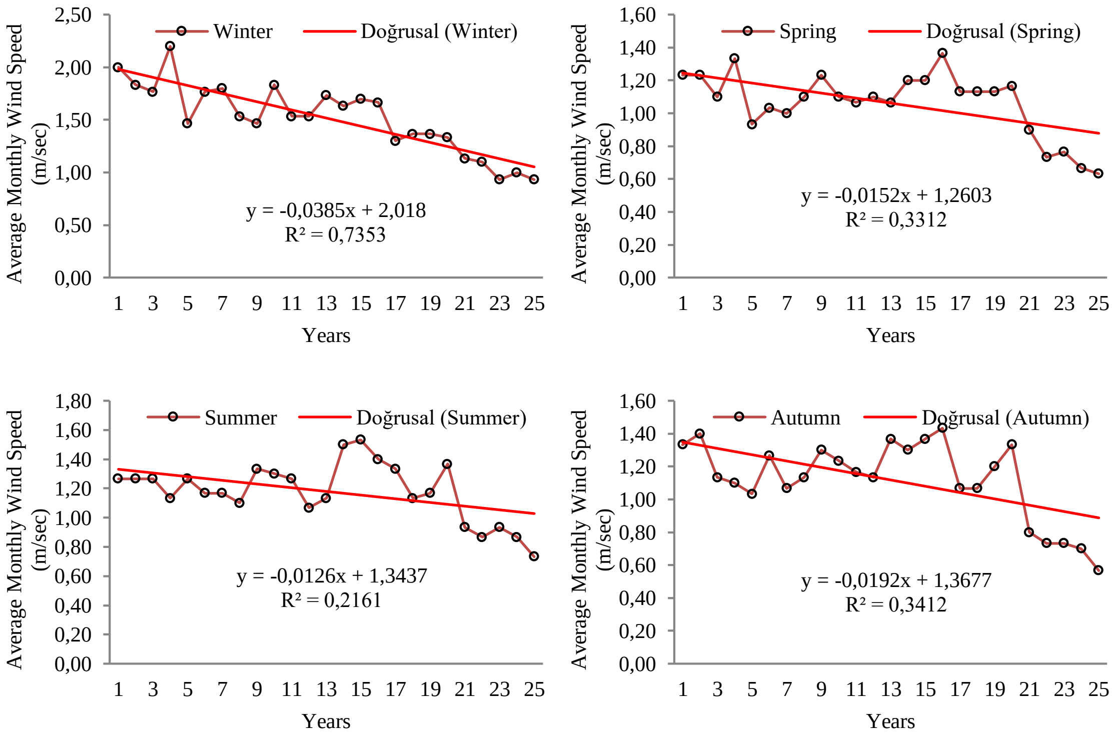

Figure 10. Seasonal average wind graphs for linear trend analysis

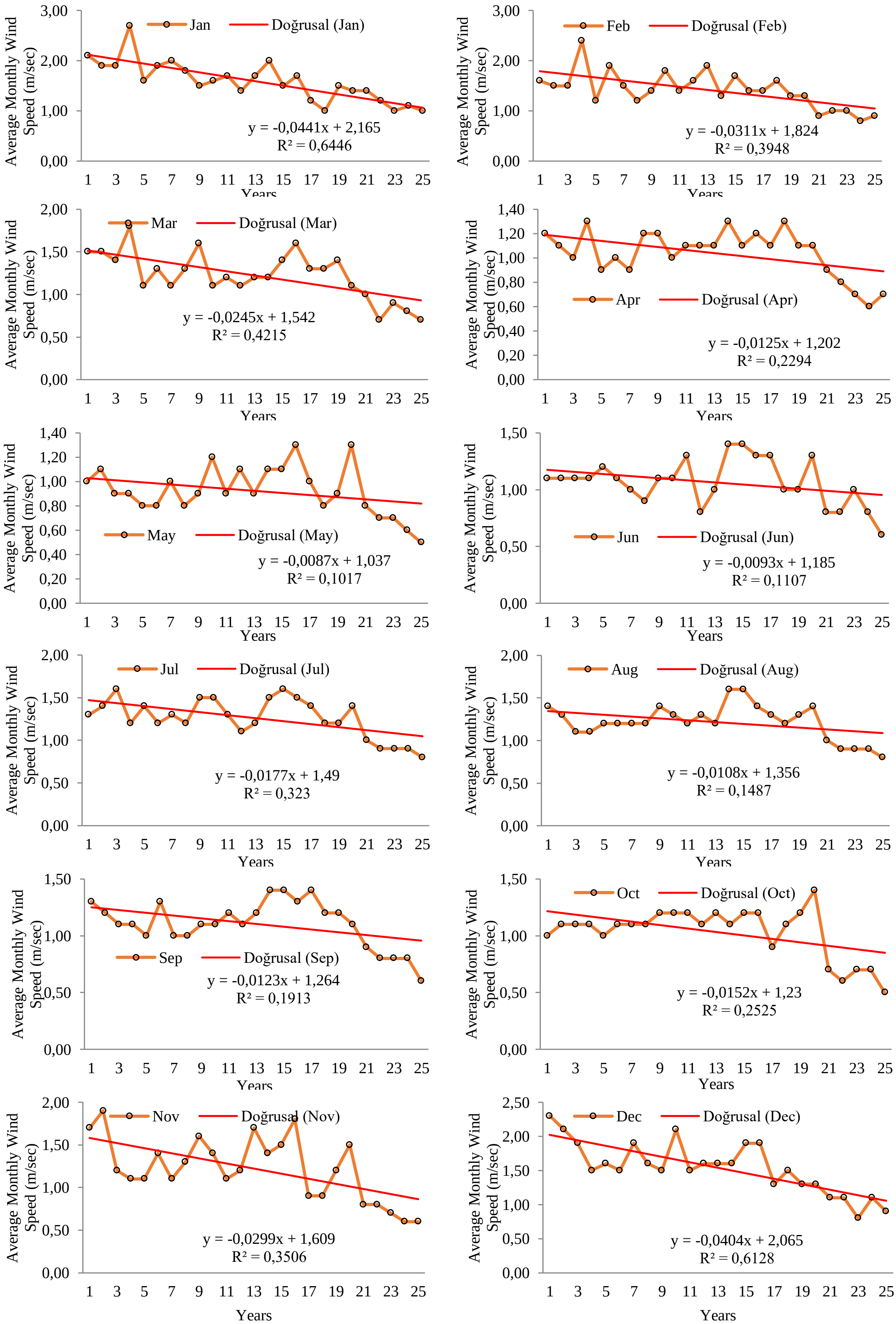

Figure 11. Monthly average wind graphs for linear trend analysis

4.3. Sen's Trend Method Results

The results obtained using Sen trend analysis for annual, seasonal and monthly precipitation series are given in Table 9, for 5% confidence interval and in Table 10, for 10% confidence interval. There are similar results for both Table 9 and Table 10. Tables show trendless times for May and June months. Besides except April, October, November and Autumn periods, there are increasing trends in total precipitation.

Table 9. Sen's trend method results for total precipitation (5%)

Station	District	Slope, s	Intercept, a	Standard deviation, σ	Correlation, ρy1y2	Slope standard deviation, σs	Significance level	Lower CL	Upper CL	Hypothesis	Decision	Type of trend
Samsun Station	Jan	0.981	45.617	29.972	0.919	0.111	0.05	-0.218	0.218	Ha	YES	Increase
	Feb	0.766	43.293	21.421	0.931	0.073	0.05	-0.143	0.143	Ha	YES	Increase
	Mar	0.916	47.94	27.754	0.972	0.060	0.05	-0.119	0.119	Ha	YES	Increase
	Apr	-0.480	58.231	30.972	0.973	0.065	0.05	-0.128	0.128	Ha	YES	Decrease
	May	-0.053	56.791	30.574	0.960	0.079	0.05	-0.156	0.156	Ho	No	No trend
	Jun	0.150	45.983	30.938	0.899	0.128	0.05	-0.251	0.251	Ho	No	No trend
	Jul	0.413	21.447	34.205	0.981	0.061	0.05	-0.120	0.120	Ha	YES	Increase
	Aug	1.277	20.353	55.832	0.942	0.175	0.05	-0.343	0.343	Ha	YES	Increase
	Sep	0.174	38.354	31.081	0.967	0.073	0.05	-0.143	0.143	Ha	YES	Increase
	Oct	-0.978	91.702	56.015	0.981	0.099	0.05	-0.194	0.194	Ha	YES	Decrease
	Nov	-1.198	107.601	47.500	0.967	0.112	0.05	-0.220	0.220	Ha	YES	Decrease
	Dec	0.368	62.033	29.569	0.955	0.081	0.05	-0.159	0.159	Ha	YES	Increase
	Annual	2.339	638.504	94.539	0.902	0.387	0.05	-0.758	0.758	Ha	YES	Increase
	Winter	2.116	150.943	53.613	0.955	0.148	0.05	-0.290	0.290	Ha	YES	Increase
	Spring	0.383	162.117	47.726	0.975	0.097	0.05	-0.191	0.191	Ha	YES	Increase
	Summer	1.841	87.784	72.144	0.921	0.265	0.05	-0.520	0.520	Ha	YES	Increase
	Autumn	-2.002	237.659	74.132	0.968	0.173	0.05	-0.340	0.340	Ha	YES	Decrease

Table 10. Sen's trend method results for total precipitation (10%)

Station	District	Slope, s	Intercept, a	Standard deviation, σ	Correlation, ρy1y2	Slope standard deviation, σs	Significance level	Lower CL	Upper CL	Hypothesis	Decision	Type of trend
Samsun Station	Jan	0.981	45.617	29.972	0.919	0.111	0.05	-0.184	0.184	Ha	YES	Increase
	Feb	0.766	43.293	21.421	0.931	0.073	0.05	-0.120	0.120	Ha	YES	Increase
	Mar	0.916	47.094	27.754	0.972	0.060	0.05	-0.100	0.100	Ha	YES	Increase
	Apr	-0.480	58.231	30.972	0.973	0.065	0.05	-0.108	0.108	Ha	YES	Decrease
	May	-0.053	56.791	30.574	0.960	0.079	0.05	-0.131	0.131	Ho	No	No trend
	Jun	0.150	45.983	30.938	0.899	0.128	0.05	-0.211	0.211	Ho	No	No trend
	Jul	0.413	21.447	34.205	0.981	0.061	0.05	-0.101	0.101	Ha	YES	Increase
	Aug	1.277	20.359	55.832	0.942	0.175	0.05	-0.288	0.288	Ha	YES	Increase
	Sep	0.174	38.354	31.081	0.967	0.073	0.05	-0.121	0.121	Ha	YES	Increase
	Oct	-0.970	91.702	56.015	0.981	0.099	0.05	-0.163	0.163	Ha	YES	Decrease
	Nov	-1.198	107.601	47.500	0.967	0.112	0.05	-0.185	0.185	Ha	YES	Decrease
	Dec	0.368	62.033	29.569	0.955	0.081	0.05	-0.134	0.134	Ha	YES	Increase
	Annual	2.339	638.504	94.539	0.902	0.387	0.05	-0.638	0.638	Ha	YES	Increase
	Winter	2.116	150.943	53.613	0.955	0.148	0.05	-0.244	0.244	Ha	YES	Increase
	Spring	0.383	162.117	47.726	0,975	0.097	0.05	-0.161	0.161	Ha	YES	Increase
	Summer	1.841	87.784	72.144	0.921	0.265	0.05	-0.438	0.438	Ha	YES	Increase
	Autumn	-2.002	237.659	74.132	0.968	0.173	0.05	-0.286	0.286	Ha	YES	Decrease

Sen Trend analysis for annual, seasonal and monthly temperature series are given in Table 11 for 5% and in Table 12 for the 10% confidence interval. They both show similar results. Both for 5% and 10% confidence interval and for all periods there is increasing trends in average temperatures.

Table 11. Sen's trend method results for average monthly temperatures (5%)

Station	District	Slope, s	Intercept, a	Standard deviation, σ	Correlation, ρy1y2	Slope standard deviation, σs	Significance level	Lower CL	Upper CL	Hypothesis	Decision	Type of trend
Samsun Station	Jan	0.21389	7.514	4.453	0.628	0.065	0.05	-0.127	0.127	Ha	YES	Increase
	Feb	0.21319	6.435	4.637	0.543	0.075	0.05	-0.147	0.147	Ha	YES	Increase
	Mar	0.20903	7.831	4.397	0.620	0.065	0.05	-0.127	0.127	Ha	YES	Increase
	Apr	0.19167	10.917	3.808	0.887	0.030	0.05	-0.060	0.060	Ha	YES	Increase
	May	0.23542	14.284	3.025	0.730	0.037	0.05	-0.074	0.074	Ha	YES	Increase
	Jun	0.19375	18.93	2.264	0.919	0.015	0.05	-0.030	0.030	Ha	YES	Increase
	Jul	0.15208	21.921	1.830	0.831	0.018	0.05	-0.035	0.035	Ha	YES	Increase
	Aug	0.17014	21.948	1.921	0.827	0.019	0.05	-0.037	0.037	Ha	YES	Increase
	Sep	0.15208	19.376	2.294	0.892	0.018	0.05	-0.035	0.035	Ha	YES	Increase
	Oct	0.16736	15.803	3.090	0.933	0.019	0.05	-0.037	0.037	Ha	YES	Increase
	Nov	0.17778	11.478	3.925	0.767	0.045	0.05	-0.089	0.089	Ha	YES	Increase
	Dec	0.22292	9.621	4.272	0.911	0.030	0.05	-0.059	0.059	Ha	YES	Increase
	Annual	0.19161	13.838	3.063	0.858	0.027	0.05	-0.054	0.054	Ha	YES	Increase
	Winter	0.65000	23.570	12.769	0.895	0.099	0.05	-0.194	0.194	Ha	YES	Increase
	Spring	0.63611	33.032	10.847	0.766	0.126	0.05	-0.247	0.247	Ha	YES	Increase
	Summer	0.51597	62.799	5.739	0.826	0.057	0.05	-0.112	0.112	Ha	YES	Increase
	Autumn	0.49722	46.657	8.742	0.789	0.096	0.05	-0.189	0.189	Ha	YES	Increase

Table 12. Sen's trend method results for average monthly temperatures (10%)

Station	District	Slope, s	Intercept, a	Standard deviation, σ	Correlation, ρy1y2	Slope standard deviation, σs	Significance level	Lower CL	Upper CL	Hypothesis	Decision	Type of trend
Samsun Station	Jan	0.213	7.514	4.453	0.628	0.065	0.05	-0.107	0.107	Ha	YES	Increase
	Feb	0.213	6.435	4.637	0.543	0.075	0.05	-0.124	0.124	Ha	YES	Increase
	Mar	0.209	7.831	4.397	0.620	0.065	0.05	-0.107	0.107	Ha	YES	Increase
	Apr	0.191	10.917	3.808	0.887	0.030	0.05	-0.050	0.050	Ha	YES	Increase
	May	0.235	14.284	3.025	0.730	0.037	0.05	-0.062	0.062	Ha	YES	Increase
	Jun	0.193	18.93	2.264	0.919	0.015	0.05	-0.025	0.025	Ha	YES	Increase
	Jul	0.152	21.921	1.830	0.831	0.018	0.05	-0.029	0.029	Ha	YES	Increase
	Aug	0.170	21.948	1.921	0.827	0.019	0.05	-0.031	0.031	Ha	YES	Increase
	Sep	0.152	19.376	2.294	0.892	0.018	0.05	-0.029	0.029	Ha	YES	Increase
	Oct	0.167	15.803	3.090	0.933	0.019	0.05	-0.031	0.031	Ha	YES	Increase
	Nov	0.177	11.478	3.925	0.767	0.045	0.05	-0.075	0.075	Ha	YES	Increase
	Dec	0.222	9.621	4.272	0.911	0.030	0.05	-0.050	0.050	Ha	YES	Increase
	Annual	0.191	13.838	3.063	0.858	0.027	0.05	-0.045	0.045	Ha	YES	Increase
	Winter	0.650	23.570	12.769	0.895	0.099	0.05	-0.163	0.163	Ha	YES	Increase
	Spring	0.636	33.032	10.847	0.766	0.126	0.05	-0.208	0.208	Ha	YES	Increase
	Summer	0.515	62.799	5.739	0.826	0.057	0.05	-0.094	0.094	Ha	YES	Increase
	Autumn	0.497	46.657	8.742	0.789	0.096	0.05	-0.159	0.159	Ha	YES	Increase

The wind results are given in Table 13 for 5% confidence interval and in Table 14 for 10% confidence interval. Similar results were obtained in Table 13 and Table 14. The tables showed that no trend in May, June, August and September, and decreasing trend all the other months.

Table 13. Sen's trend method results for average monthly winds (5%)

Station	District	Slope, s	Intercept, a	Standard deviation, σ	Correlation, ρy1y2	Slope standard deviation, σs	Significance level	Lower CL	Upper CL	Hypothesis	Decision	Type of trend
Samsun Station	Jan	-0.037	2.165	0.393	0.958	0.001	0.05	-0.003	0.003	Ha	YES	Decrease
	Feb	-0.023	1.824	0.354	0.943	0.002	0.05	-0.003	0.003	Ha	YES	Decrease
	Mar	-0.014	1.542	0.260	0.935	0.001	0.05	-0.003	0.003	Ha	YES	Decrease
	Apr	-0.004	1.202	0.181	0.904	0.001	0.05	-0.002	0.002	Ha	YES	Decrease
	May	-0.001	1.037	0.183	0.958	0.000	0.05	-0.001	0.001	Ho	No	No trend
	Jun	0.001	1.185	0.185	0.802	0.001	0.05	-0.003	0.003	Ho	No	No trend
	Jul	-0.009	1.49	0.212	0.971	0.000	0.05	-0.001	0.001	Ha	YES	Decrease
	Aug	-0.001	1.356	0.190	0.916	0.001	0.05	-0.002	0.002	Ho	No	No trend
	Sep	0.000	1.264	0.182	0.900	0.001	0.05	-0.002	0.002	Ho	No	No trend
	Oct	-0.009	1.23	0.197	0.766	0.002	0.05	-0.004	0.004	Ha	YES	Decrease
	Nov	-0.015	1.609	0.356	0.948	0.001	0.05	-0.003	0.003	Ha	YES	Decrease
	Dec	-0.031	2.065	0.363	0.929	0.002	0.05	-0.004	0.004	Ha	YES	Decrease
	Annual	-0.012	1.497	0.196	0.954	0.001	0.05	-0.001	0.001	Ha	YES	Decrease
	Winter	-0.093	6.054	0.941	0.911	0.006	0.05	-0.013	0.013	Ha	YES	Decrease
	Spring	-0.020	3.781	0.529	0.909	0.003	0.05	-0.007	0.007	Ha	YES	Decrease
	Summer	-0.009	4.031	0.540	0.917	0.003	0.05	-0.007	0.007	Ha	YES	Decrease
	Autumn	-0.025	4.103	0.650	0.914	0.004	0.05	-0.008	0.008	Ha	YES	Decrease

Table 14. Sen's trend method results for average monthly winds (10%)

Station	District	Slope, s	Intercept, a	Standard deviation, σ	Correlation, ρy1y2	Slope standard deviation, σs	Significance level	Lower CL	Upper CL	Hypothesis	Decision	Type of trend
Samsun Station	Jan	-0.037	2.165	0.393	0.958	0.001	0.05	-0.003	0.003	Ha	YES	Decrease
	Feb	-0.023	1.824	0.354	0.943	0.002	0.05	-0.003	0.003	Ha	YES	Decrease
	Mar	-0.014	1.542	0.260	0.935	0.001	0.05	-0.002	0.002	Ha	YES	Decrease
	Apr	-0.004	1.202	0.181	0.904	0.001	0.05	-0.002	0.002	Ha	YES	Decrease
	May	-0.001	1.037	0.183	0.958	0.000	0.05	-0.001	0.001	Ho	No	No trend
	Jun	0.0013	1.185	0.185	0.802	0.001	0.05	-0.003	0.003	Ho	No	No trend
	Jul	-0.009	1.490	0.212	0.971	0.000	0.05	-0.001	0.001	Ha	YES	Decrease
	Aug	-0.001	1.356	0.190	0.916	0.001	0.05	-0.002	0.002	Ho	No	No trend
	Sep	0.000	1.264	0.182	0.900	0.001	0.05	-0.002	0.002	Ho	No	No trend
	Oct	-0.009	1.230	0.197	0.766	0.002	0.05	-0.003	0.003	Ha	YES	Decrease
	Nov	-0.015	1.609	0.356	0.948	0.001	0.05	-0.003	0.003	Ha	YES	Decrease
	Dec	-0.031	2.065	0.363	0.929	0.002	0.05	-0.003	0.003	Ha	YES	Decrease
	Annual	-0.012	1.497	0.196	0.954	0.001	0.05	-0.001	0.001	Ha	YES	Decrease
	Winter	-0.093	6.054	0.941	0.911	0.006	0.05	-0.011	0.011	Ha	YES	Decrease
	Spring	-0.020	3.781	0.529	0.909	0.003	0.05	-0.006	0.006	Ha	YES	Decrease
	Summer	-0.0093	4.031	0.540	0.917	0.003	0.05	-0.006	0.006	Ha	YES	Decrease
	Autumn	-0.0250	4.103	0.650	0.914	0.004	0.05	-0.007	0.007	Ha	YES	Decrease

The results obtained using Sen Trend analysis for monthly, seasonal and annual precipitation series are given in Table 9, for 5% confidence interval and in Table 10, for 10% confidence interval. There are similar results for both Table 9 and Table 10. Tables show trendless times for May and June months. Besides except April, October, November and Autumn periods, there is increasing trends in total precipitation. Sen Trend analysis for annual, seasonal and monthly temperature series are shown in Table 11 for 5% confidence interval and in Table 12 for the 10% confidence interval. Similar results were obtained in Table 11 and Table 12. The tables showed that increasing trends in average temperatures for all periods. The wind results are given in Table 13 for 5% confidence interval and in Table 14 for 10% confidence interval. There are similar results for both Table 9 and Table 10. Both for 5% and 10% confidence interval and for all periods there is decreasing trends for wind data.

5. CONCLUSIONS

Temperature, precipitation, and wind data of Samsun station was
Temperature, precipitation, and wind data of Samsun station was analyzed

with the Mann-Kendall, linear trend and innovative Sen Trend analysis in this study. According to the results, at the levels of significance of 5% and 10%, Mann-Kendall's statistical results were found to be generally similar to the Sen’s trend method. Except January period for Samsun station there is an increasing and statistically significant trend seen at α=10%, α=5% two tailed confident levels for total precipitation. There is an increase trend in precipitation on an annual basis. Similarly, there is an increasing trend in the winter season in seasonal sense. For temperature data results there is an increase trend on a yearly basis. Similarly, there is an increasing trend in spring and summer seasons in seasonal sense. Also for June, July, August and November months for Samsun station there is an increasing, and statistically significant trend at α=10%, α=5% for monthly assessment for temperatures.

Mann-Kendall test results for average monthly winds; there is a decrease trend in winds on a yearly basis. Similarly, there is a decreasing trend in Winter, Spring and, Autumn seasons in seasonal sense. Besides for January, February, April, June, July, November and December months for Samsun station there is a decreasing, and statistically significant trend at α=10%, α=5% for monthly assessment.

The Samsun station show trendless time series (no trend) about precipitation in monthly, seasonal and annual periods according to the Mann-Kendall analysis. Also, the temperatures have significantly increasing trend in while winds have reduced in inspected periods. Generally, similar results are seen in the Sen’s method for 5% and 10% confidence interval. The total precipitation results show trendless times for May and June months. Besides; except April, October, November and autumn periods, there are increasing trends in total precipitation. Sen Trend analysis for average temperature series there is increasing trends for 5% and 10% confidence interval. Also, the wind result shows there is a decreasing trend for confidence interval 5% and 10% and for all periods. According to the Linear trend analysis in April, May, October, and autumn periods there have seen decreasing trends while in other periods have seen increasing trends. Also, the wind result shows there is a decreasing while the temperature result shows increasing trend for all periods. The reason is that the least-square technique used in the Linear trend method that is affected by the global ratio from high (peak) value data. The positive trends in the wind data have affect erosion and drought. Peak values can lead to differences in trends in linear trend analysis. The wind trend has been included in the study to examine the relationship of coastal floods and coastal winds.

Precipitation is very determinative in climate change studies, but temperature and wind are also very important in terms of influencing evaporation and transpiration which are the parameters of climate change. From this point the study will provide the necessary services for the decision makers in terms of forecasting, projecting and execution processes.

NOTE

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