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TREND ANALYSIS OF PRECIPITATION, TEMPERATURE AND WIND DATA IN SAMSUN (TURKEY)

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ABSTRACT: Climate change effects have been remarkably perceived today; the determination of trends in precipitation, stream flow, winds, evaporation, and temperatures has become considerable for the planning and management of water resources and engineering projects. Nowadays there is a lot of studies have been made in progress on global and regional climate changes in literature. The objective of this study is to analyze monthly, annual and seasonal trends in average temperature, total precipitation, and average wind data by Mann- Kendall, linear trend and Sen's Trend tests. The data sets are obtained for the period 1980 to 2015 for Samsun station. Samsun is the largest city placed in north of Turkey in the Central Blacksea region.

Key words: Trend analysis, Mann-Kendall Test, Sen's Trend Test, Linear trend, Samsun, Turkey

1. INTRODUCTION

Climate change will lead to outcomes other than anticipated natural impacts on the planet's transformation process indicate urgent measures for lightening the negative impacts we will be facing. Being an issue beyond an environmental problem at the global level, climate change will continue to affect the world in the long term. Today, it is a scientifically proven fact that the planet will face an increase in temperatures and changes in precipitation in the coming decades [R.T. Ministry of Environment and Urbanization, 2012]. Hydro-meteorological processes affect the climate and human activities in a continuous manner and their impacts appear in the forms of trends or sudden jumps. Some extreme climatic phenomena as well as all kinds of large-scale water resources development projects may alter hydrological processes and may lead to abrupt changes in the hydrological time series. [Xiong and Guo, 2004]. Trend detection is an active area of interest for both hydrology and climatology in order to investigate climate changes scenarios and enhance climate impact research. The assumption of stationary, connoting time-invariant characteristics of the time series under consideration, seems to be invalid as a result of anthropogenic influences and the natural variability of the climate system [Jain and Lall 2000; Xu et al. 2003]. The presence of deterministic trends in the analyzed time series may provide information about the future evolution of the process or at least on the modifications occurred. In practical applications, the knowledge of the trend for a given variable of interest may help to forecast future realizations and to design future scenarios. With the growing importance of climate change assessment, trend detection and evaluation have been investigated by many researchers and organizations by using different methodologies. [Cohn and Lins, 2005; Pujol et al., 2007; Kumar et al., 2010; Gocic and Trajkovic 2013; Simsek et al., 2013; IPCC, 2014; Sen, 2014; Dogan, 2015].

The aim of this study is to analyze monthly, annual and seasonal trends with average temperature, total precipitation and average wind data (between 1980 and 2015) for the Samsun station obtained from the General Directorate of Meteorology.

2. STUDY AREA AND DATA

Samsun is the largest city placed in the north of Turkey in the Central Blacksea region. the geographic location of the study area is between Latitude 41.690 and Longitude 36.333. Samsun's area 9,352 km^2 and elevation is about 4.00 m. Study area is shown in Figure 1. The location information of the Samsun station where the data are obtained is given in Table 1.

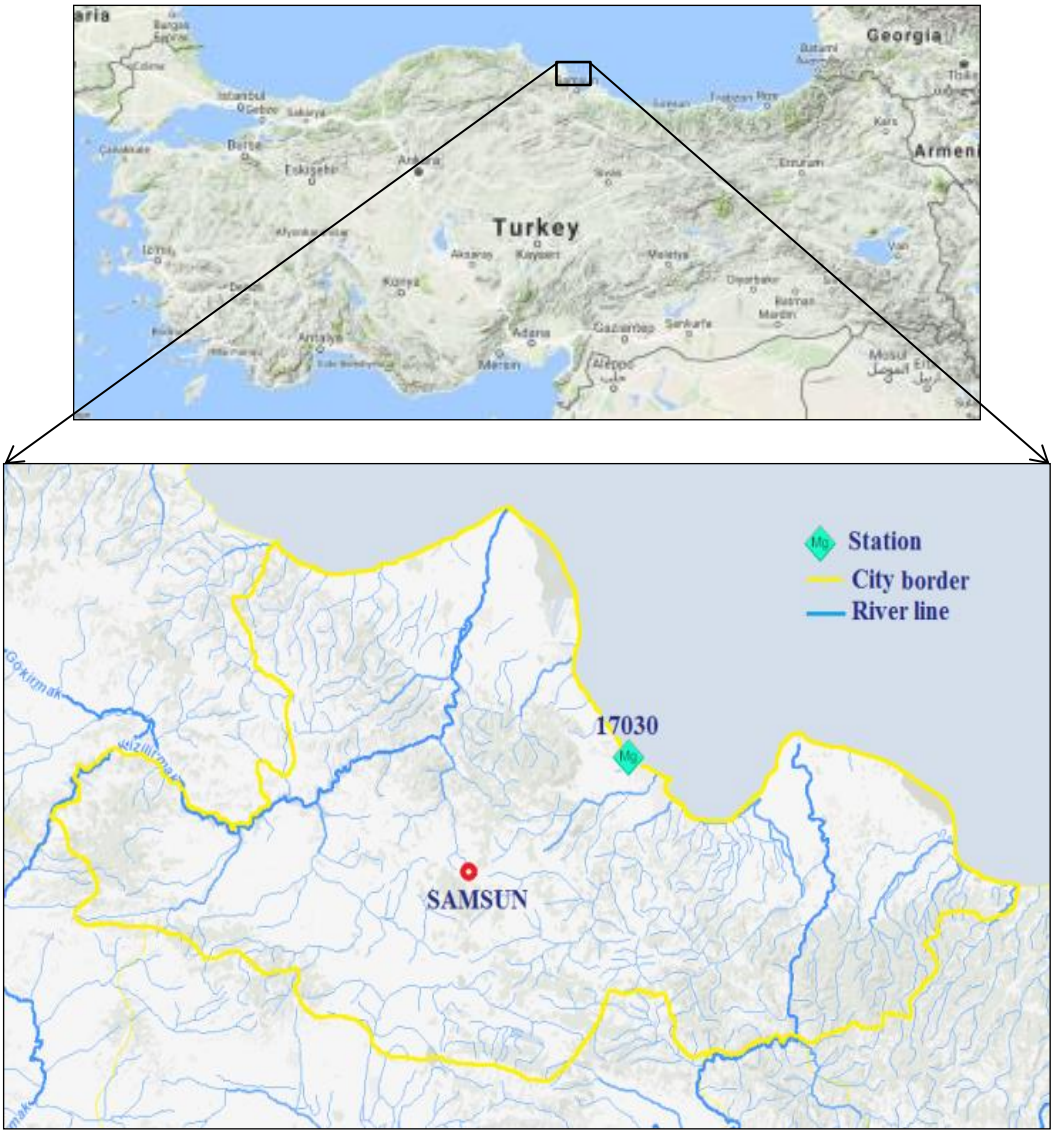

Figure 1: Location of station 17030

Station No	Station	Latitude (ºN)	Longitude (ºW)	Altitude(m)
17030	Samsun	41.35	36.24	4

Basic statistical information on monthly total precipitation data is provided in Table 2.

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***	**Sc***
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
Monsoon	1980-2015	111,30	313,8	189,11	53,614	0,284	0,459
Summer	1980-2015	87,70	269,6	166,95	47,727	0,286	0,422
Winter	1980-2015	27,50	386,3	131,15	72,145	0,550	1,641
Post Monsoon	1980-2015	96,10	400,0	220,01	74,133	0,337	0,533

*Cv; Coefficient of variation, Sc; coefficient of skewness

Basic statistical information on average monthly temperatures is given in Table 3.

Table 3. Basic statistical information on average monthly temperatures

Months	**Data range**	**Min.value (mm)**	**Max.value (mm)**	**Mean, μ (mm)**	**Standard deviation, σ (mm)**	**Cv***	**Sc***
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**
Mansoon	**1980-2015**	**6,1**	**27,8**	**8,7**	**4,167**	**0,477**	**4,288**
Summer	**1980-2015**	**9,2**	**28,4**	**12,2**	**3,539**	**0,290**	**4,256**
Winter	**1980-2015**	**20,7**	**29,5**	**22,6**	**1,882**	**0,083**	**2,339**
Post Monsoon	**1980-2015**	**14,1**	**28,9**	**16,8**	**2,871**	**0,171**	**3,363**

Basic statistical information on average monthly winds is given in Table 4.

Table 4. Basic statistical information on average monthly winds

Months	**Data range**	**Min.value (mm)**	**Max.value (mm)**	**Mean, μ (mm)**	**Standard deviation, σ (mm)**	**Cv***	**Sc***
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**
Mansoon	**1980-2015**	**0,93**	**2,20**	**1,52**	**0,331**	**0,218**	**-0,152**
Summer	**1980-2015**	**0,63**	**1,37**	**1,06**	**0,194**	**0,183**	**-0,858**
Winter	**1980-2015**	**0,73**	**1,53**	**1,18**	**0,199**	**0,169**	**-0,439**
Post Monsoon	**1980-2015**	**0,57**	**1,43**	**1,12**	**0,241**	**0,216**	**-0,865**

3. METHODS

In analyses; Mann-Kendall trend test [Mann 1945; Kendall 1975] is used as a non-parametric method, the linear trend is used as a parametric method and Sen trend test [Sen, 2012] as a innovative trend test was used that successfully applicated in many recent studies.

3.1. Mann – Kendall Method

This method tests if there is a trend in the time series data. It is a non-parametric rank-based procedure, robust to the influence of extremes and suitable for application with skewed variables [Hamed, 2008]. Test statistics are;

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

In Equation 1, n is the number of data points, xi and xj are the data values in time series i and j, respectively and in Equation 2, sgn ($x_j - x_k$) is the sign function as;

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

The variance is computed as;

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

In Equation 3, n refers to a number of data, p shows the number of tied groups, and t_i indicates the number of ties of extent k. A tied group is a set of sample data and has the same value. In cases of sample size n > 10, the standard normal test statistic Z is calculated using Equation 4; In Equation 3, P shows the number of tied groups (equal data in time series), and summary sign (Σ) indicates the summation over all tied groups. t_k is the number of data values in P^{th} group. If tied groups do not exist, this summary process is ignored for this equation. After computing variance of time series with Equation 3, standard Z value is computed using the following equation.

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

The computed standard Z value is compared with standard normal distribution according to the two-tailed confidence levels (α =10 %, α =5 %). If the computed Z value is greater than $|Z| > |Z_1 - \alpha/2|$, the null hypothesis (H_0) is rejected and thus H_1 hypothesis is accepted. Otherwise, the H_0 hypothesis is accepted and this means that the trend is not statistically significant. In this study, two-tailed confidence levels (α =10 % and α =5 %) are used for the Mann-Kendall trend test [Yue et al., 1993].

3.2. Linear Trend Method

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 [Davidson and MacKinnon, 2003].

3.3. Sen's Slope Method

The Sen's slope method uses a linear model to estimate the slope of the trend, and the variance of the residuals should be constant in time [Helsel and Hirsch, 2002]. Thus, it can be concluded that there are individually some negative aspects to applying these methods to the climatological, meteorological, and hydrological data. Besides, Sen (2012) method does not depend on such assumptions including serial correlation, and size of the sample. Moreover, data can be normally and non-normally distributed.

In this method, first, time series is divided into two equal halves from the first date to the end date. Each sub-series is sorted in ascending manner. Then, the first sub-series (X_i) is located on the X-axis, and the other sub-series (X_j) is located on the Y-axis (Figure 2) in Cartesian coordinate system. If data are in the triangular area below the 1:1 line, it is said that there is a decreasing trend. If data are in the upper triangular area of the 1:1 line, it is said that there is an increasing trend [Sen, 2012; 2014; 2015].

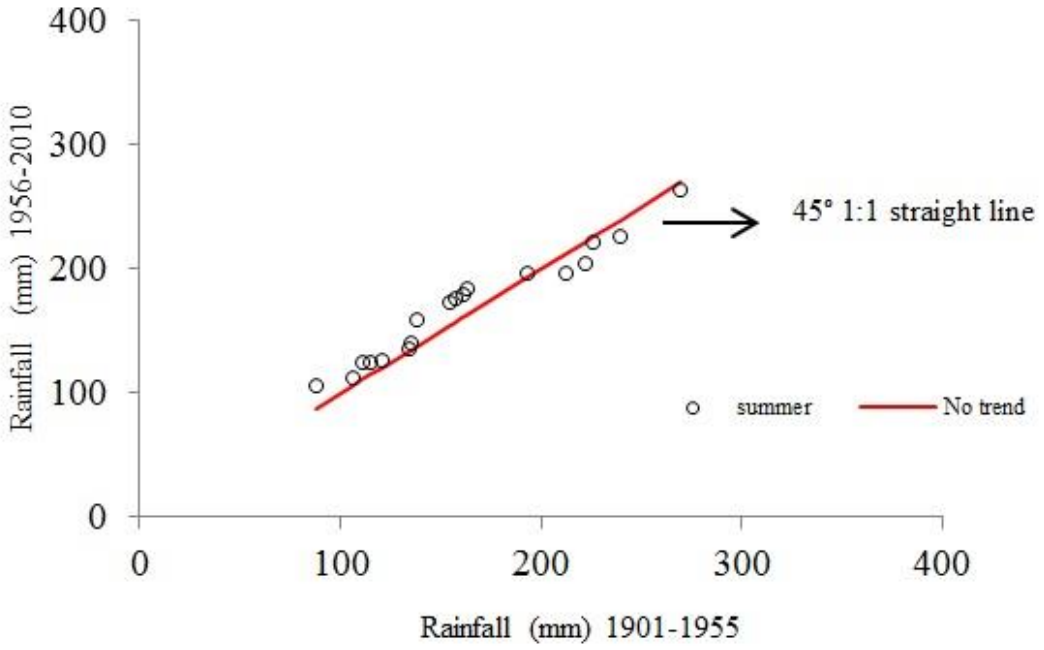

Figure 2: Decreasing and increasing trends versus trend-free time series

4. APPLICATION AND RESULTS

The aim of this study is to analyze the behavior of monthly, annual and seasonal trends with average temperature total precipitations and average wind data for Samsun gauge station. Observation data from Samsun gauge station were applied to the non-parametric Mann–Kendall (MK) test, as a parametric method linear trend test and the innovative trend analysis (Sen Trend) approach to investigate the temperature, wind and the rainfall trends.

4.1. Mann-Kendall Trend Analysis Results

Monthly results of Samsun gauge station for precipitation are shown in Figure 3, seasonal results are shown in Figure 4 and the annual result is shown in Figure 5. Mann-Kendal test results for rainfall are shown in Table 5. Monthly average temperature graphs are shown in Figure 6. Seasonal average temperature graphs are shown in Figure 7. Annual temperature graph is shown in Figure 8. Yearly Mann-Kendal test results for average monthly temperatures are shown in Table 6. Monthly average wind graphs are shown in Figure 9. Seasonal wind graphs are shown in Figure 10. Annual wind graph is shown in Figure 11. Yearly Mann-Kendal test results for average monthly winds are shown in Table 9.

Figure 3. Monthly precipitation graphs

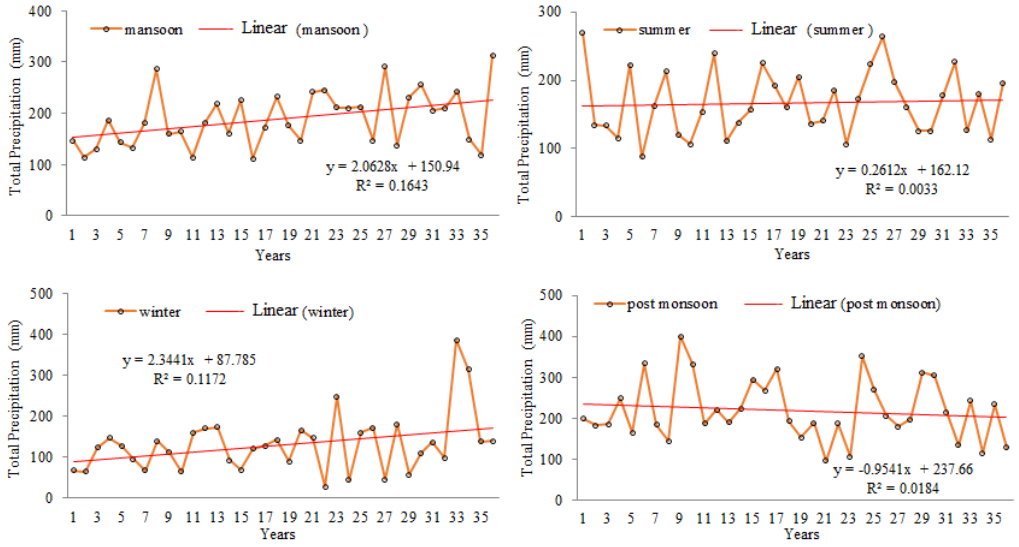

Figure 4. Seasonal precipitation graphs

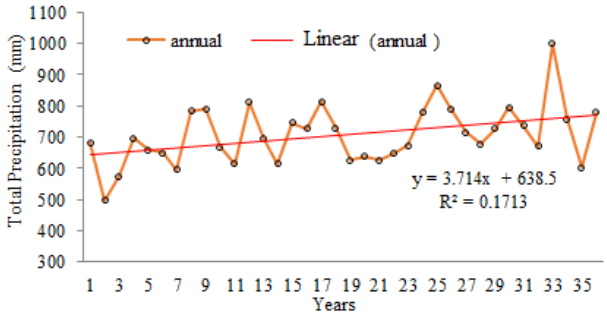

Figure 5. Annual precipitation graph

Table 5. Mann-Kendal test results for rainfall

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	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
	Monsoon	2,356	±1.645	(+)	Refuse	±1.96	(+)	Refuse
	Summer	0,613	±1.645	No	Accept	±1.96	No	Accept
	Winter	1,607	±1.645	No	Accept	±1.96	No	Accept
	Post Mons	-0,477	±1.645	No	Accept	±1.96	No	Accept

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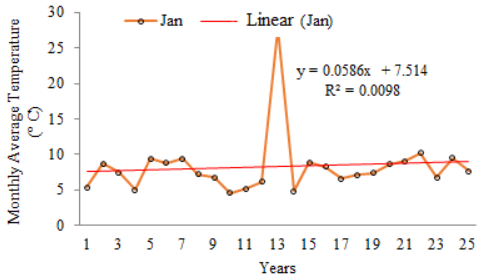
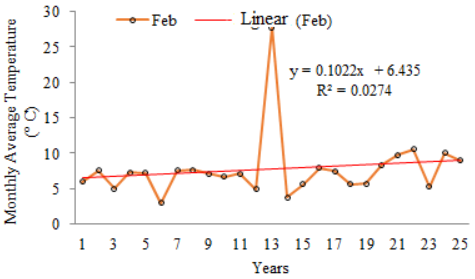
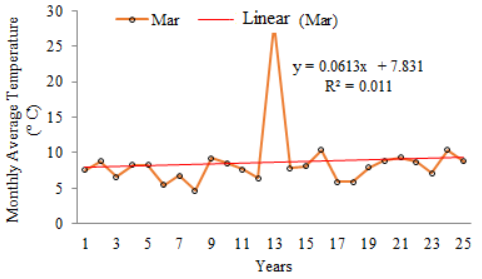
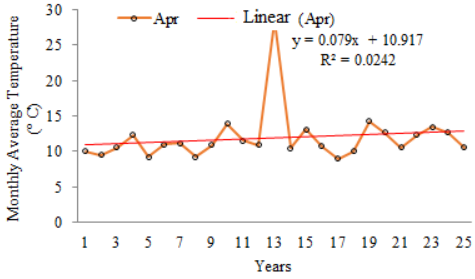
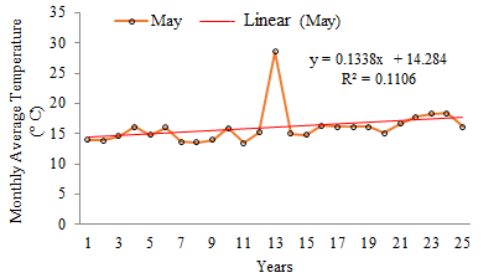
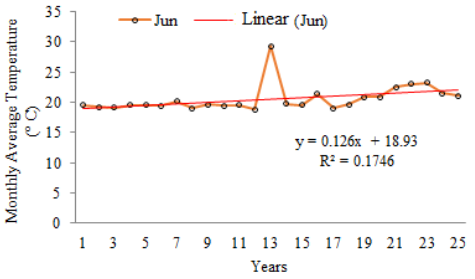

Jan
Linear (Jan)
y = 0.0586x + 7.514
R² = 0.0098
Monthly Average Temperature (° C)
Years

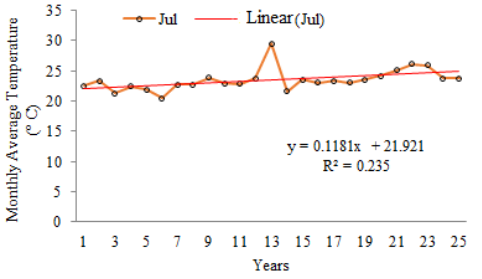

Feb
Linear (Feb)
y = 0.1022x + 6.435
R² = 0.0274
Monthly Average Temperature (° C)
Years

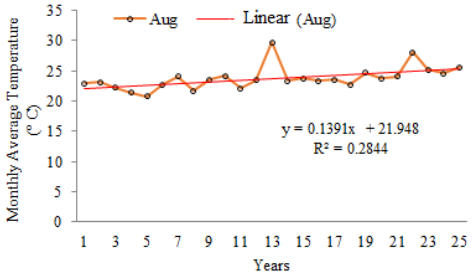

Mar
Linear (Mar)
y = 0.0613x + 7.831
R² = 0.011
Monthly Average Temperature (° C)
Years

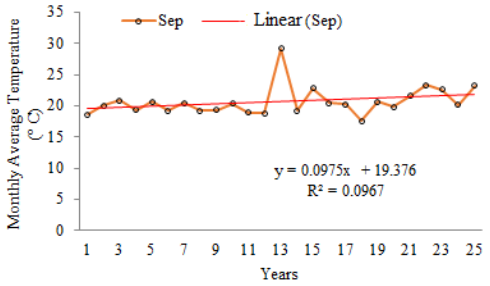

Apr
Linear (Apr)
y = 0.079x + 10.917
R² = 0.0242
Monthly Average Temperature (° C)
Years

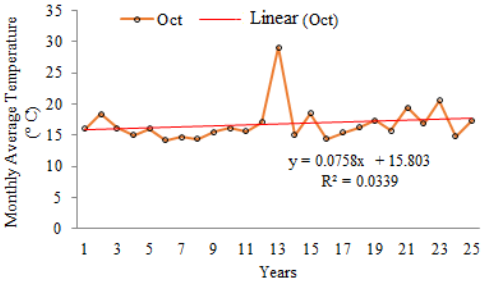

May
Linear (May)
y = 0.1338x + 14.284
R² = 0.1106
Monthly Average Temperature (° C)
Years

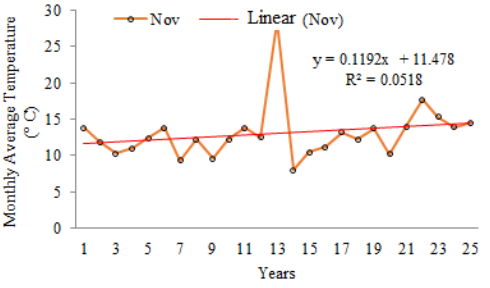

Jun
Linear (Jun)
y = 0.126x + 18.93
R² = 0.1746
Monthly Average Temperature (° C)
Years


Jul
Linear (Jul)
y = 0.1181x + 21.921
R² = 0.235
Monthly Average Temperature (° C)
Years


Aug
Linear (Aug)
y = 0.1391x + 21.948
R² = 0.2844
Monthly Average Temperature (° C)
Years


Sep
Linear (Sep)
y = 0.0975x + 19.376
R² = 0.0967
Monthly Average Temperature (° C)
Years


Oct
Linear (Oct)
y = 0.0758x + 15.803
R² = 0.0339
Monthly Average Temperature (° C)
Years


Nov
Linear (Nov)
y = 0.1192x + 11.478
R² = 0.0518
Monthly Average Temperature (° C)
Years

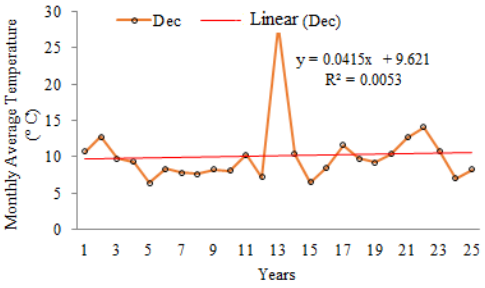

Dec
Linear (Dec)
y = 0.0415x + 9.621
R² = 0.0053
Monthly Average Temperature (° C)
Years

Figure 6. Monthly average temperature graphs

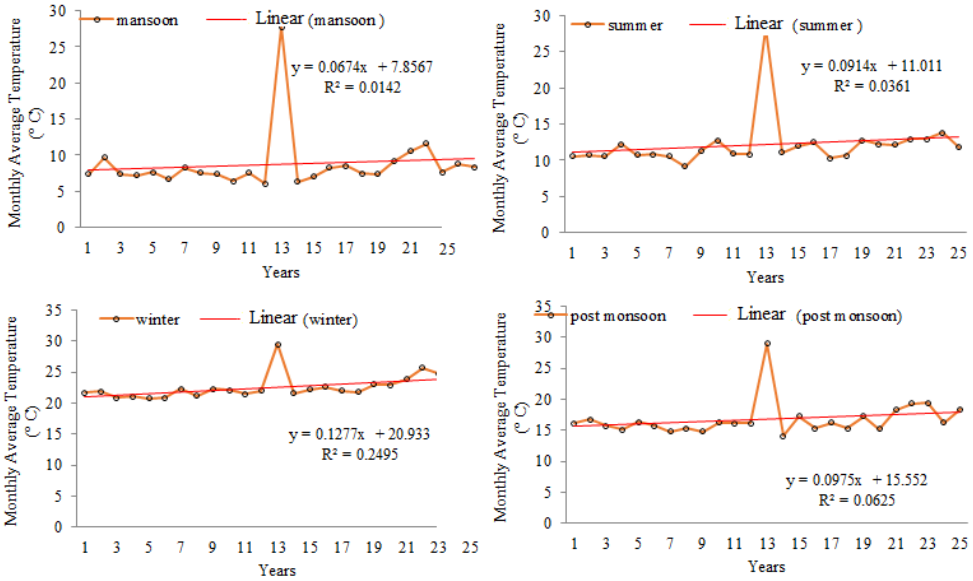


Figure 7. Seasonal temperature graphs

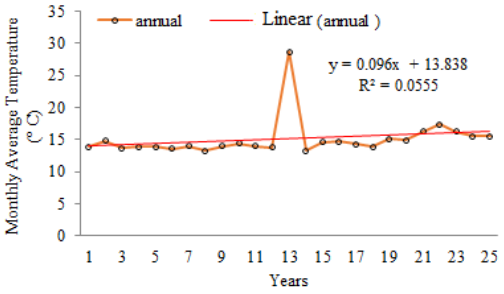
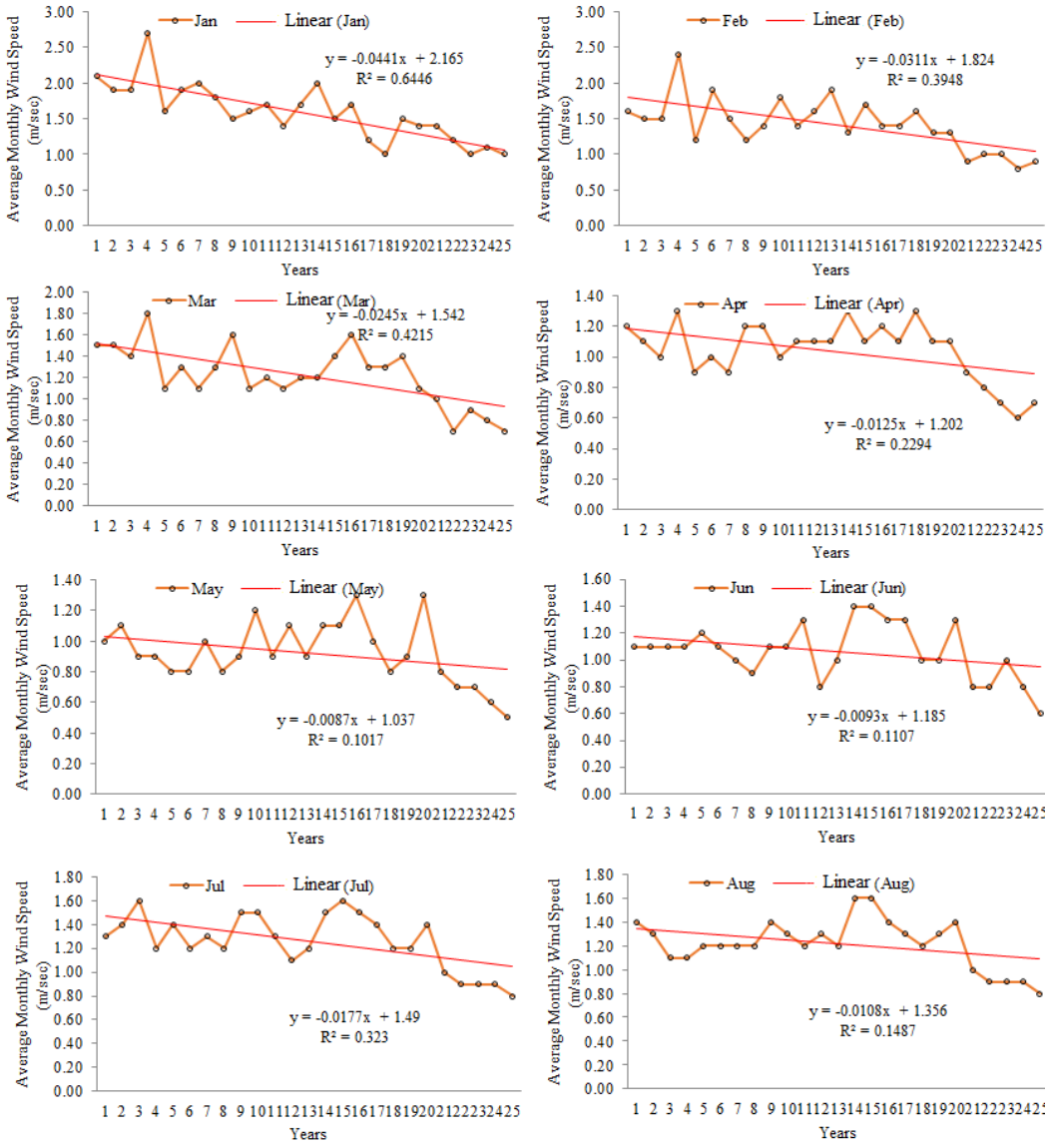


Figure 8. Annual temperature graphs

Table 6. Yearly Mann-Kendal test results for average monthly temperatures

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	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
	Monsoon	1,752	±1.645	(+)	Refuse	±1.96	No	Accept
	Summer	2,989	±1.645	(+)	Refuse	±1.96	(+)	Refuse
	Winter	3,854	±1.645	(+)	Refuse	±1.96	(+)	Refuse

	Post Monsoon	1,892	±1.645	(+)	Refuse	±1.96	No	Accept



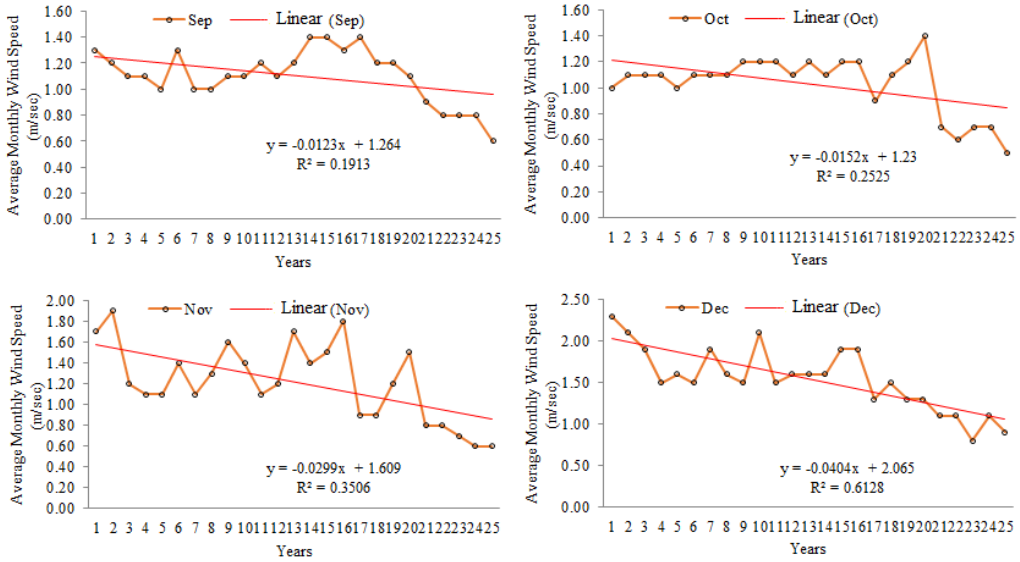


Figure 9. Monthly average wind graphs

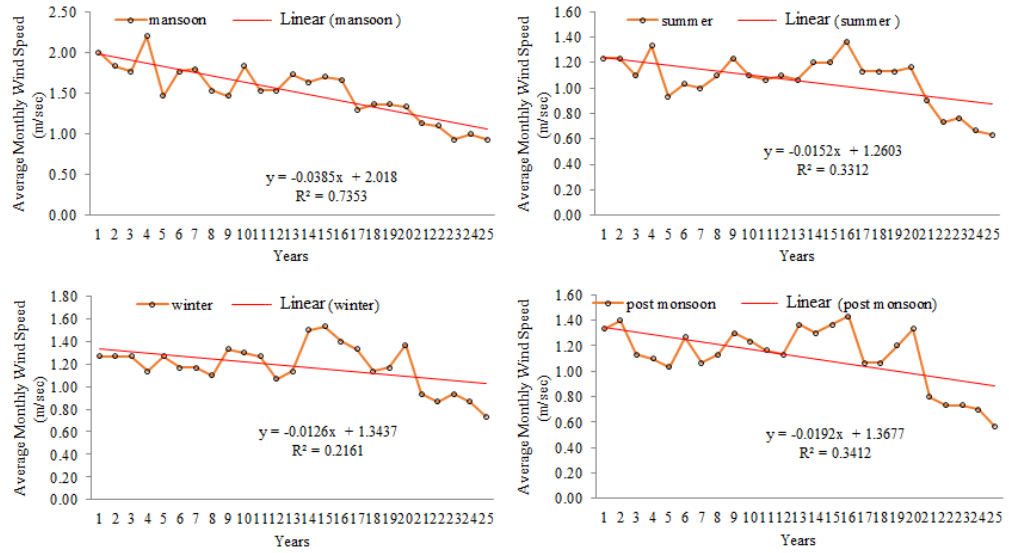


Figure 10. Seasonal wind graphs

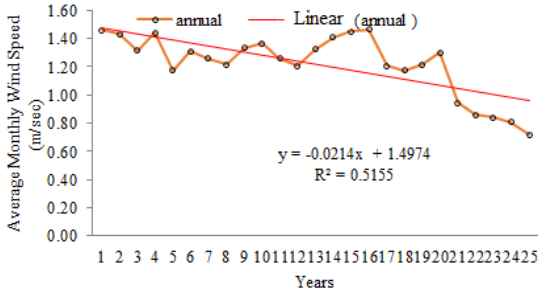


Figure 11. Annual wind graph

Table 7. Yearly Mann-Kendal test results for average monthly winds

Station	Months	MK Z Values	Z, Critical Probability Values (α=10%)	MK test Tendency (α=10%)	H0 Hypothesis	Z, Critical Probability Values (α=5%)	MK test Tendency (α=5%)	H0 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
	Monsoon	-4,741	±1.645	(-)	Refuse	±1.96	(-)	Refuse
	Summer	-2,032	±1.645	(-)	Refuse	±1.96	(-)	Refuse
	Winter	-1,822	±1.645	(-)	Refuse	±1.96	No	Accept
	Post Monsoon	-2,125	±1.645	(-)	Refuse	±1.96	(-)	Refuse

4.2. Linear Trend Analysis Test Results

Linear Trend results for Samsun Station are shown in Table 8.

Table 8. Linear Trend results for Samsun Station

Station	**Months**	**Linear Trend**	
		Amount of change	**Tendency**
Rainfall	Jan	0,917	(+)
	Feb	0,474	(+)
	Mar	0,777	(+)
	Apr	-0,159	(-)
	May	-0,356	(-)
	Jun	0,225	(+)
	Jul	0,749	(+)
	Aug	1,370	(+)
	Sep	0,471	(+)
	Oct	-0,308	(-)
	Nov	-1,117	(-)
	Dec	0,672	(+)
	Annual	3,714	(+)
	Monsoon	2,063	(+)
	Summer	0,261	(+)
	Winter	2,344	(+)
	Post Monsoon	-0,954	(-)
Average Monthly Temperatures	Jan	0.059	(+)
	Feb	0.102	(+)
	Mar	0.061	(+)
	Apr	0.079	(+)
	May	0.134	(+)
	Jun	0.126	(+)
	Jul	0.118	(+)
	Aug	0.139	(+)
	Sep	0.098	(+)
	Oct	0.076	(+)
	Nov	0.119	(+)
	Dec	0.041	(+)
	Annual	0.096	(+)
	Monsoon	0.202	(+)
	Summer	0.274	(+)

	Winter	0.383	(+)
	Post Monsoon	0.293	(+)
Average Monthly Winds	Jan	-0.044	(-)
	Feb	-0.031	(-)
	Mar	-0.024	(-)
	Apr	-0.012	(-)
	May	-0.009	(-)
	Jun	-0.009	(-)
	Jul	-0.018	(-)
	Aug	-0.011	(-)
	Sep	-0.012	(-)
	Oct	-0.015	(-)
	Nov	-0.030	(-)
	Dec	-0.040	(-)
	Annual	-0.021	(-)
	Monsoon	-0.116	(-)
	Summer	-0.046	(-)
	Winter	-0.038	(-)
	Post Monsoon	-0.057	(-)

4.3. Innovative Trend Analysis (Sen Trend) Test Results

Trends of the monthly precipitation with the Sen trend analysis are illustrated in Figure 12 for Samsun station. This figure shows increasing, decreasing or trendless time series of the data.

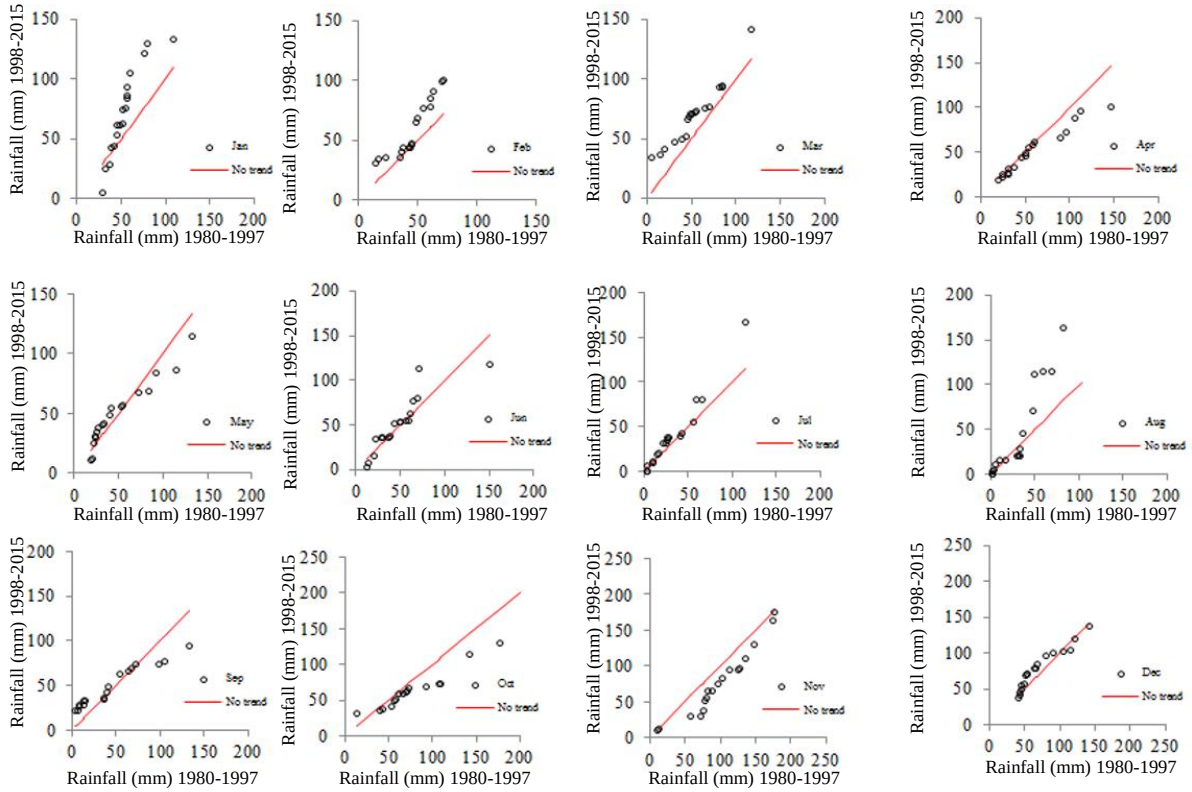


Figure 12. Monthly results of rainfall (%5 significance level)

ID_2973

Table 9. Innovative trend test results for rainfall (%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	0,98179	45,61746032	29,97267	0,9191	0,11165	0,05	-0,21883	0,21883	Ha	YES	Increasing
	Feb	0,76667	43,29301587	21,42190	0,9318	0,07324	0,05	-0,14356	0,14356	Ha	YES	Increasing
	Mar	0,91698	47,09412698	27,75459	0,9720	0,06087	0,05	-0,11930	0,11930	Ha	YES	Increasing
	Apr	-0,48056	58,2315873	30,97229	0,9738	0,06565	0,05	-0,12867	0,12867	Ha	YES	Decreasing
	May	-0,05309	56,79142857	30,57488	0,9601	0,07999	0,05	-0,15678	0,15678	Ho	No	No trend
	Jun	0,15093	45,98333333	30,93827	0,8995	0,12842	0,05	-0,25170	0,25170	Ho	No	No trend
	Jul	0,41327	21,44777778	34,20565	0,9813	0,06124	0,05	-0,12002	0,12002	Ha	YES	Increasing
	Aug	1,27716	20,35365079	55,83261	0,9427	0,17507	0,05	-0,34313	0,34313	Ha	YES	Increasing
	Sep	0,17469	38,35460317	31,08162	0,9675	0,07342	0,05	-0,14390	0,14390	Ha	YES	Increasing
	Oct	-0,97870	91,70253968	56,01545	0,9817	0,09926	0,05	-0,19455	0,19455	Ha	YES	Decreasing
	Nov	-1,19815	107,6019048	47,50086	0,9674	0,11233	0,05	-0,22017	0,22017	Ha	YES	Decreasing
	Dec	0,36821	62,0331746	29,56974	0,9556	0,08161	0,05	-0,15996	0,15996	Ha	YES	Increasing
	annual	2,33920	638,5046032	94,53920	0,9022	0,38724	0,05	-0,75899	0,75899	Ha	YES	Increasing
	monsoon	2,11667	150,9436508	53,61393	0,9554	0,14826	0,05	-0,29059	0,29059	Ha	YES	Increasing
	summer	0,38333	162,1171429	47,72680	0,9756	0,09758	0,05	-0,19126	0,19126	Ha	YES	Increasing
	winter	1,84136	87,7847619	72,14460	0,9210	0,26556	0,05	-0,52049	0,52049	Ha	YES	Increasing
	post monsoon	-2,00216	237,6590476	74,13259	0,9681	0,17349	0,05	-0,34005	0,34005	Ha	YES	Decreasing

The results obtained using Innovative Sen trend analysis for monthly, seasonal and annual rainfall series are given in Table 9, for 5% confidence interval and in Table 10 , for %10 confidence interval.

Table 10. Innovative trend test results for rainfall (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	**0,98179**	45,61746032	**29,97267**	0,9191	**0,11165**	0,05	**-0,18422**	**0,18422**	Ha	YES	Increasing
	Feb	**0,76667**	43,29301587	**21,42190**	0,9318	**0,07324**	0,05	**-0,12085**	**0,12085**	Ha	YES	Increasing
	Mar	**0,91698**	47,09412698	**27,75459**	0,9720	**0,06087**	0,05	**-0,10043**	**0,10043**	Ha	YES	Increasing
	Apr	**-0,48056**	58,2315873	**30,97229**	0,9738	**0,06565**	0,05	**-0,10832**	**0,10832**	Ha	YES	Decreasing
	May	**-0,05309**	56,79142857	**30,57488**	0,9601	**0,07999**	0,05	**-0,13198**	**0,13198**	Ho	No	No trend
	Jun	**0,15093**	45,98333333	**30,93827**	0,8995	**0,12842**	0,05	**-0,21189**	**0,21189**	Ho	No	No trend
	Jul	**0,41327**	21,44777778	**34,20565**	0,9813	**0,06124**	0,05	**-0,10104**	**0,10104**	Ha	YES	Increasing
	Aug	**1,27716**	20,35365079	**55,83261**	0,9427	**0,17507**	0,05	**-0,28886**	**0,28886**	Ha	YES	Increasing
	Sep	**0,17469**	38,35460317	**31,08162**	0,9675	**0,07342**	0,05	**-0,12114**	**0,12114**	Ha	YES	Increasing
	Oct	**-0,97870**	91,70253968	**56,01545**	0,9817	**0,09926**	0,05	**-0,16378**	**0,16378**	Ha	YES	Decreasing
	Nov	**-1,19815**	107,6019048	**47,50086**	0,9674	**0,11233**	0,05	**-0,18535**	**0,18535**	Ha	YES	Decreasing
	Dec	**0,36821**	62,0331746	**29,56974**	0,9556	**0,08161**	0,05	**-0,13466**	**0,13466**	Ha	YES	Increasing
	annual	**2,33920**	638,5046032	**94,53920**	0,9022	**0,38724**	0,05	**-0,63895**	**0,63895**	Ha	YES	Increasing
	monsoon	**2,11667**	150,9436508	**53,61393**	0,9554	**0,14826**	0,05	**-0,24463**	**0,24463**	Ha	YES	Increasing
	summer	**0,38333**	162,1171429	**47,72680**	0,9756	**0,09758**	0,05	**-0,16101**	**0,16101**	Ha	YES	Increasing
	winter	**1,84136**	87,7847619	**72,14460**	0,9210	**0,26556**	0,05	**-0,43817**	**0,43817**	Ha	YES	Increasing
	post monsoon	**-2,00216**	237,6590476	**74,13259**	0,9681	**0,17349**	0,05	**-0,28626**	**0,28626**	Ha	YES	Decreasing

The results obtained using Innovative Sen trend analysis for monthly, seasonal and annual temperature series are given in Table 11 for 5% confidence interval and in Table 12 for the 10% confidence interval

Table 11. Innovative trend test 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	4,45304	0,6288	0,06527	0,05	-0,12792	0,12792	Ha	YES	Increasing
	Feb	0,21319	6,435	4,63787	0,5435	0,07538	0,05	-0,14775	0,14775	Ha	YES	Increasing
	Mar	0,20903	7,831	4,39772	0,6204	0,06518	0,05	-0,12775	0,12775	Ha	YES	Increasing
	Apr	0,19167	10,917	3,80834	0,8873	0,03076	0,05	-0,06029	0,06029	Ha	YES	Increasing
	May	0,23542	14,284	3,02554	0,7308	0,03777	0,05	-0,07402	0,07402	Ha	YES	Increasing
	Jun	0,19375	18,93	2,26447	0,9195	0,01546	0,05	-0,03029	0,03029	Ha	YES	Increasing
	Jul	0,15208	21,921	1,83065	0,8318	0,01806	0,05	-0,03540	0,03540	Ha	YES	Increasing
	Aug	0,17014	21,948	1,92105	0,8274	0,01920	0,05	-0,03763	0,03763	Ha	YES	Increasing
	Sep	0,15208	19,376	2,29419	0,8923	0,01811	0,05	-0,03550	0,03550	Ha	YES	Increasing
	Oct	0,16736	15,803	3,09063	0,9339	0,01912	0,05	-0,03747	0,03747	Ha	YES	Increasing
	Nov	0,17778	11,478	3,92580	0,7674	0,04555	0,05	-0,08928	0,08928	Ha	YES	Increasing
	Dec	0,22292	9,621	4,27224	0,9117	0,03054	0,05	-0,05986	0,05986	Ha	YES	Increasing
	annual	0,19161	13,83816667	3,06307	0,8588	0,02769	0,05	-0,05427	0,05427	Ha	YES	Increasing
	monsoon	0,65000	23,57	12,76589	0,8957	0,09920	0,05	-0,19442	0,19442	Ha	YES	Increasing
	summer	0,63611	33,032	10,84347	0,7660	0,12617	0,05	-0,24730	0,24730	Ha	YES	Increasing
	winter	0,51597	62,799	5,73990	0,8262	0,05756	0,05	-0,11282	0,11282	Ha	YES	Increasing
	post monsoon	0,49722	46,657	8,74248	0,7896	0,09648	0,05	-0,18910	0,18910	Ha	YES	Increasing

Table 12. Innovative trend test 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	0,21389	7,514	4,45304	0,6288	0,06527	0,05	-0,10769	0,10769	Ha	YES	Increasing
	Feb	0,21319	6,435	4,63787	0,5435	0,07538	0,05	-0,12438	0,12438	Ha	YES	Increasing
	Mar	0,20903	7,831	4,39772	0,6204	0,06518	0,05	-0,10755	0,10755	Ha	YES	Increasing
	Apr	0,19167	10,917	3,80834	0,8873	0,03076	0,05	-0,05076	0,05076	Ha	YES	Increasing
	May	0,23542	14,284	3,02554	0,7308	0,03777	0,05	-0,06231	0,06231	Ha	YES	Increasing
	Jun	0,19375	18,93	2,26447	0,9195	0,01546	0,05	-0,02550	0,02550	Ha	YES	Increasing
	Jul	0,15208	21,921	1,83065	0,8318	0,01806	0,05	-0,02980	0,02980	Ha	YES	Increasing
	Aug	0,17014	21,948	1,92105	0,8274	0,01920	0,05	-0,03168	0,03168	Ha	YES	Increasing
	Sep	0,15208	19,376	2,29419	0,8923	0,01811	0,05	-0,02988	0,02988	Ha	YES	Increasing
	Oct	0,16736	15,803	3,09063	0,9339	0,01912	0,05	-0,03154	0,03154	Ha	YES	Increasing
	Nov	0,17778	11,478	3,92580	0,7674	0,04555	0,05	-0,07516	0,07516	Ha	YES	Increasing
	Dec	0,22292	9,621	4,27224	0,9117	0,03054	0,05	-0,05039	0,05039	Ha	YES	Increasing
	annual	0,19161	13,83816667	3,06307	0,8588	0,02769	0,05	-0,04569	0,04569	Ha	YES	Increasing
	monsoon	0,65000	23,57	12,76589	0,8957	0,09920	0,05	-0,16367	0,16367	Ha	YES	Increasing
	summer	0,63611	33,032	10,84347	0,7660	0,12617	0,05	-0,20818	0,20818	Ha	YES	Increasing
	winter	0,51597	62,799	5,73990	0,8262	0,05756	0,05	-0,09497	0,09497	Ha	YES	Increasing
	post monsoon	0,49722	46,657	8,74248	0,7896	0,09648	0,05	-0,15919	0,15919	Ha	YES	Increasing

The results obtained using Innovative Sen trend analysis for monthly, seasonal and annual wind series are given in Table 13 for 5 % confidence interval and in Table 14 for 10 % confidence interval.

Table 13. Innovative trend test 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	-0,03750	2,165	0,39306	0,9580	0,00194	0,05	-0,00380	0,00380	Ha	YES	Decreasing
	Feb	-0,02361	1,824	0,35499	0,9435	0,00203	0,05	-0,00398	0,00398	Ha	YES	Decreasing
	Mar	-0,01458	1,542	0,26040	0,9357	0,00159	0,05	-0,00311	0,00311	Ha	YES	Decreasing
	Apr	-0,00486	1,202	0,18173	0,9041	0,00135	0,05	-0,00265	0,00265	Ha	YES	Decreasing
	May	-0,00139	1,037	0,18396	0,9585	0,00090	0,05	-0,00177	0,00177	Ho	No	No trend
	Jun	0,00139	1,185	0,18572	0,8023	0,00199	0,05	-0,00389	0,00389	Ho	No	No trend
	Jul	-0,00903	1,49	0,21260	0,9712	0,00087	0,05	-0,00170	0,00170	Ha	YES	Decreasing
	Aug	-0,00139	1,356	0,19035	0,9169	0,00132	0,05	-0,00259	0,00259	Ho	No	No trend
	Sep	0,00000	1,264	0,18238	0,9000	0,00139	0,05	-0,00272	0,00272	Ho	No	No trend
	Oct	-0,00903	1,23	0,19777	0,7660	0,00230	0,05	-0,00451	0,00451	Ha	YES	Decreasing
	Nov	-0,01597	1,609	0,35628	0,9489	0,00194	0,05	-0,00380	0,00380	Ha	YES	Decreasing
	Dec	-0,03194	2,065	0,36316	0,9291	0,00233	0,05	-0,00456	0,00456	Ha	YES	Decreasing
	annual	-0,01233	1,497416667	0,19644	0,9549	0,00100	0,05	-0,00197	0,00197	Ha	YES	Decreasing
	monsoon	-0,09306	6,054	0,94190	0,9111	0,00676	0,05	-0,01324	0,01324	Ha	YES	Decreasing
	summer	-0,02083	3,781	0,52908	0,9092	0,00384	0,05	-0,00752	0,00752	Ha	YES	Decreasing
	winter	-0,00903	4,031	0,54011	0,9172	0,00374	0,05	-0,00733	0,00733	Ha	YES	Decreasing
	post monsoon	-0,02500	4,103	0,65025	0,9149	0,00456	0,05	-0,00895	0,00895	Ha	YES	Decreasing

Table 14. Innovative trend test 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	-0,03750	2,165	0,39306	0,9580	0,00194	0,05	-0,00320	0,00320	Ha	YES	Decreasing
	Feb	-0,02361	1,824	0,35499	0,9435	0,00203	0,05	-0,00335	0,00335	Ha	YES	Decreasing
	Mar	-0,01458	1,542	0,26040	0,9357	0,00159	0,05	-0,00262	0,00262	Ha	YES	Decreasing
	Apr	-0,00486	1,202	0,18173	0,9041	0,00135	0,05	-0,00223	0,00223	Ha	YES	Decreasing
	May	-0,00139	1,037	0,18396	0,9585	0,00090	0,05	-0,00149	0,00149	Ho	No	No trend
	Jun	0,00139	1,185	0,18572	0,8023	0,00199	0,05	-0,00328	0,00328	Ho	No	No trend
	Jul	-0,00903	1,49	0,21260	0,9712	0,00087	0,05	-0,00143	0,00143	Ha	YES	Decreasing
	Aug	-0,00139	1,356	0,19035	0,9169	0,00132	0,05	-0,00218	0,00218	Ho	No	No trend
	Sep	0,00000	1,264	0,18238	0,9000	0,00139	0,05	-0,00229	0,00229	Ho	No	No trend
	Oct	-0,00903	1,23	0,19777	0,7660	0,00230	0,05	-0,00380	0,00380	Ha	YES	Decreasing
	Nov	-0,01597	1,609	0,35628	0,9489	0,00194	0,05	-0,00320	0,00320	Ha	YES	Decreasing
	Dec	-0,03194	2,065	0,36316	0,9291	0,00233	0,05	-0,00384	0,00384	Ha	YES	Decreasing
	annual	-0,01233	1,497416667	0,19644	0,9549	0,00100	0,05	-0,00166	0,00166	Ha	YES	Decreasing
	monsoon	-0,09306	6,054	0,94190	0,9111	0,00676	0,05	-0,01115	0,01115	Ha	YES	Decreasing
	summer	-0,02083	3,781	0,52908	0,9092	0,00384	0,05	-0,00633	0,00633	Ha	YES	Decreasing
	winter	-0,00903	4,031	0,54011	0,9172	0,00374	0,05	-0,00617	0,00617	Ha	YES	Decreasing
	post monsoon	-0,02500	4,103	0,65025	0,9149	0,00456	0,05	-0,00753	0,00753	Ha	YES	Decreasing

5. CONCLUSION

The importance of water resources has increased cause of global changes, the increase in world population, unplanned urbanization, industrial development and rapid changes in global climate events throughout the world. Trend analysis is one of the most important issues in any global climate change problem. Moreover, it provides a view for meteorological, hydrological and climatological variables in past and future time's changes.

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In this study, temperature, precipitation, and wind data of Samsun station were analyzed with the Mann–Kendall, linear trend and innovative Sen trend analysis. The Mann-Kendall and Sen trend tests giving different trends for precipitation variable provide to us important aspects and complexity of trend phenomenon. According to the Mann-Kendall analysis, The Samsun gauge station showed trendless time series (no trend) about precipitation. The temperatures had significantly increasing trend in the period while winds have reduced. Generally, similar results are seen in the Sen's method. However, the range of statistical acceptance is very sensitive in Sen trend analysis to the Mann-Kendall method. Linear trend analysis showed that in April, May, October, and Monsoon periods there have seen (-) trends while in other periods reverse have seen (+) trends related to precipitation, temperature and wind analysis results. 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. 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.

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