Comparison of Mann-Kendall and innovative trend method (Şen trend) for monthly total precipitation (Middle Black Sea Region, Turkey)

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ABSTRACT

The objective of this study is to determine possible trend in annual total precipitation based on Mann–Kendall (MK) and a novel method lately published by Şen. The novel method is used for trend analysis of annual total precipitation data recorded at Sinop, Samsun, Ordu, Corum, Amasya, and Tokat provinces in Turkey. This provinces are located in the central Black Sea region of Turkey. The novel Şen's trend method is applied to this data. According to the Şen's trend method, peak and low values of annual total precipitation of the six provinces demonstrate same trends (increasing, decreasing, or trendless time series) with the MK test. The study demonstrates that the Şen method can be used for identifying trend analysis of peak and low values of annual total precipitation data. According to the MK trend test, annual total precipitations demonstrate increasing trend for Sinop, Ordu and Tokat provinces while Şen's method indicates increasing trend in Sinop, Amasya and Tokat in Turkey. As a result, Şen's method provides an important advantage in terms of especially in all ranges graphically clarification of the data evaluation phase.

Keywords: Precipitation; Innovative Şen's trend method; Mann-Kendall, the Middle Black Sea Region

INTRODUCTION

Precipitation has a vital importance in climate and hydro-meteorology. Changes in precipitation may cause floods, droughts, agricultural productivity and biodiversity loss. Therefore, identifying the spatial and temporal trends of precipitation are very important for water resources planner and climate analyst [1].

During the 20th century, precipitation has shown considerable changes in different parts of the globe [2]. The studies related with climate change have indicated that the land-surface precipitation demonstrates an increase of 0.5–1% per decade in the vast majority of the Northern Hemisphere mid and high latitudes, and annual average of regional precipitation increased 7–12% for the areas in 30–85° N and by about 2% for the territories 0°–55° S over the 20th century [3-4].

Precipitation, one of the most important climatic parameter, can affect the drought and flood. Investigation of precipitation and drought data provides vital information which can be utilized to improve water management methodologies, protect the environment and plan agricultural production [5].

The detection and attribution of past trends, changes and variability in climatic variables is essential for the understanding of potential future changes resulting from anthropogenic activities. For this purpose various trend detection studies were employed for different parts of the worlds, mostly for determination of climate change. Some of these cases showed significant trends and increasing extreme events, especially during the last 40 year period [6].

Parametric and non-parametric procedures are utilized to detect to trends in climatic variables. The parametric test requires that the data be normally distributed. If the time series have non-normal distribution, missing values and serial correlation, non-parametric procedures are proposed. Consequently, non-parametric procedures have been commonly used because of require of not much acceptance [6].

Trend of precipitation have been investigated by many researchers using Mann-Kendall test (MK) [5-15]. In these days, innovative trend method (Şen trend) have been successfully implemented in water resources [16-21].

The objective of this study is to investigate the applicability of Şen trend method which is not dependent on any restrictive assumption as serial correlation, non-normality and sample number to annual total precipitation. For this aim, precipitation data from six different locations, Sinop, Samsun, Ordu, Tokat, Corum and Amasya in Turkey were used. This data were also analyzed by well-known Mann-Kendall trend test and results were compared.

STUDY AREA AND DATA

Annual precipitation data used in this study include the records of the precipitation stations of Sinop (long. 35º 9′ E, lat. 42º 1′ N, alt. 32 m), Samsun (long. 36º 14′ E, lat. 42º 21′ N, alt. 4 m), Ordu (long. 37º 53′ E, lat. 40º 58′ N, alt. 4 m), Corum (long. 34º 56′ E, lat. 40º 32′ N, alt. 776 m), Amasya (long. 35º 50′ E, lat. 40º 39′ N, alt. 412 m) and Tokat (long. 36º 33′ E, lat. 40º 18′ N, alt. 608 m) provinces from Turkey. This provinces are located in the central Black Sea region of Turkey, with an elevation range from -6 to 3094 meters above sea level.

Turkey is situated in northern hemisphere and is around 1,660 km long and 820 km wide, and it lies between latitudes 36° and 42° N and longitudes 26° and 45° E, and Turkey's area is about 770,60 km^2 (Figure 1). This figure also shows the locations of stations.

The precipitation records include observations spanning from 1960 to 2014 and cover 54 years (49 years for the station Ordu), which is considered to be long enough for a valid mean statistic [22]. The data were obtained from Turkish Meteorological Organization of Turkey (http://tumas.mgm.gov.tr/wps/portal/).

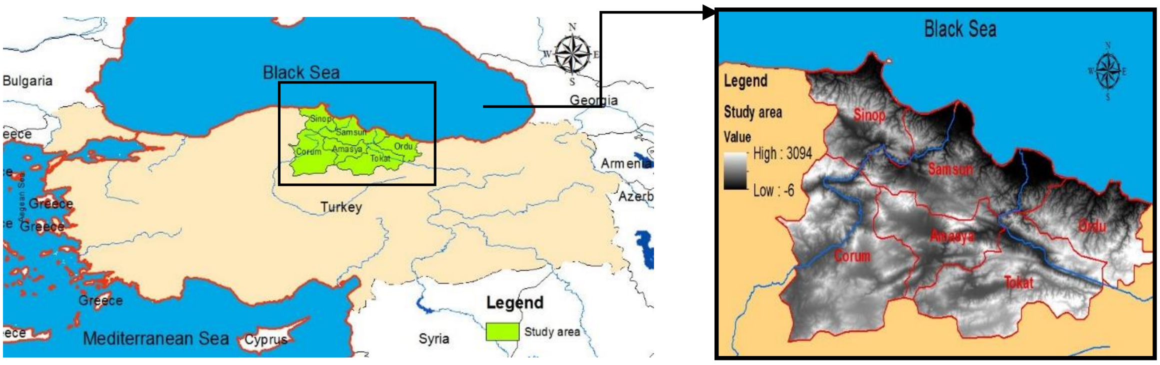

Figure 1 The locations of the stations in Sinop, Samsun, Ordu, Corum, Amasya and Tokat provinces, Turkey

Periods and basic statistical properties of the annual total precipitation data are provided in Table 1.

Table 1 Basic statistics of annual total precipitation of the six provinces in Turkey

Number	Station Number	Data range	Minimum value (mm)	Maximum value (mm)	Mean, μ (mm)	Standard deviation, σ (mm)	CV*	SC*
1	Sinop (17026)	1960-2014	84.9	1865.7	685.9	411.62	0.60	+0.91
2	Samsun (17030)	1960-2014	106.8	1933.7	706.9	417.75	0.59	+1.04
3	Ordu (17033)	1964-2013	218.3	2344.1	1036.1	506.08	0.66	+0.68
4	Corum (17084)	1960-2014	21.6	498.6	159.3	105.26	0.73	+1.17
5	Amasya (17085)	1961-2014	76.9	1234.8	459.1	271.9	0.59	+0.87
6	Tokat (17086)	1961-2012	57.8	1107.9	434.23	252.56	0.58	+0.85

*CV variation coefficient (σ/μ), SC skewness coefficient

METHOD

Innovative trend method (Şen, 2012)

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 (Xi) is located on the X-axis, and the other sub-series (Xj) is located on the Y-axis (Fig. 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 [16, 23, 24]. The innovative feature of Şen's trend analysis lies in the comments of all ranges of data [19].

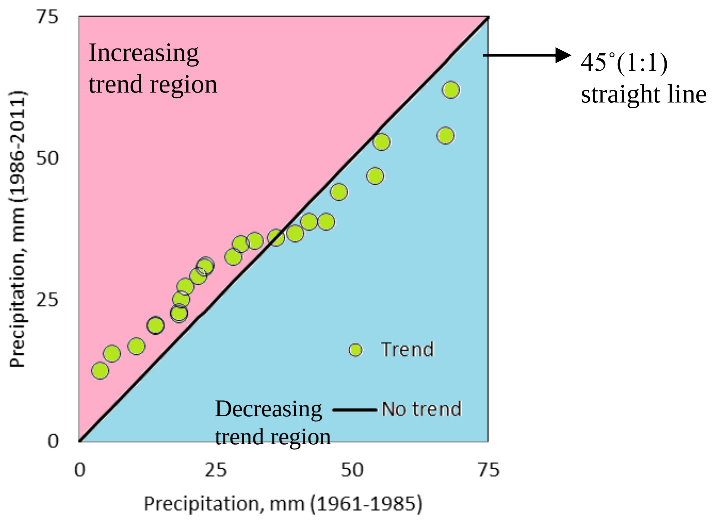

Figure 2 Drawing of increasing, decreasing and trendless regions

Mann Kendall method (Mann,1945; Kendall, 1975)

MK test is one of the non-parametric tests to catch trend in a time series especially in meteorological and hydrological time series [25–27]. The Mann–Kendall test statistic S is calculated by using [25, 26];

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

In Eq. (1), n is the number of data points, x_i and x_j are the data values in time series i and j, respectively and in Eq. (2), sgn (xj − xi) is the sign function as;

$$sgn(x_j - x_i) = \begin{cases} 1; & İf \ x_j > x_i \\ 0; & İf \ x_j = x_i \\ -1; & İf \ x_j < x_i \end{cases} \tag{2}$$

The variance is computed as;

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{P} t_i(t_i - 1)(2t_i + 5)}{18} \tag{3}$$

In Eq. 3, n refers to number of data, p shows the number of tied groups, and t_i indicates the number of ties of extent i. A tied group is a set of sample data and have the same value. In cases of sample size n > 10, the standard normal test statistic Z is calculated using Eq. (4);

In Eq. (3), P shows the number of tied groups (equal data in time series), and summary sign (∑) indicates the summation over all tied groups. ti 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 Eq. (3), standard Z value is computed using the following equation.

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{Var(S)}}; & İf \ S > 0 \\ 0; & İf \ S = 0 \\ \dfrac{S+1}{\sqrt{Var(S)}}; & İf \ S < 0 \end{cases} \tag{4}$$

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 $|Z| > |Z_{1-\alpha/2}|$, 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 MK trend test [19].

APPLICATION AND RESULTS

This paper analyzes the behavior of annual total precipitations in the north of Turkey. Observation data from 6 meteorological stations were applied to the non-parametric Mann–

Kendall test (MK) and the innovative trend analysis (Şen trend) approach to investigate the precipitation trends. Mann-Kendall test and innovative trend analysis were applied for significant trend detection, magnitude of trend and precipitation trends shift analysis, respectively.

Trends of the annual precipitation with the Şen analysis are illustrated in Fig. 3 for each station. This figure show increasing, decreasing or trendless time series of the data.

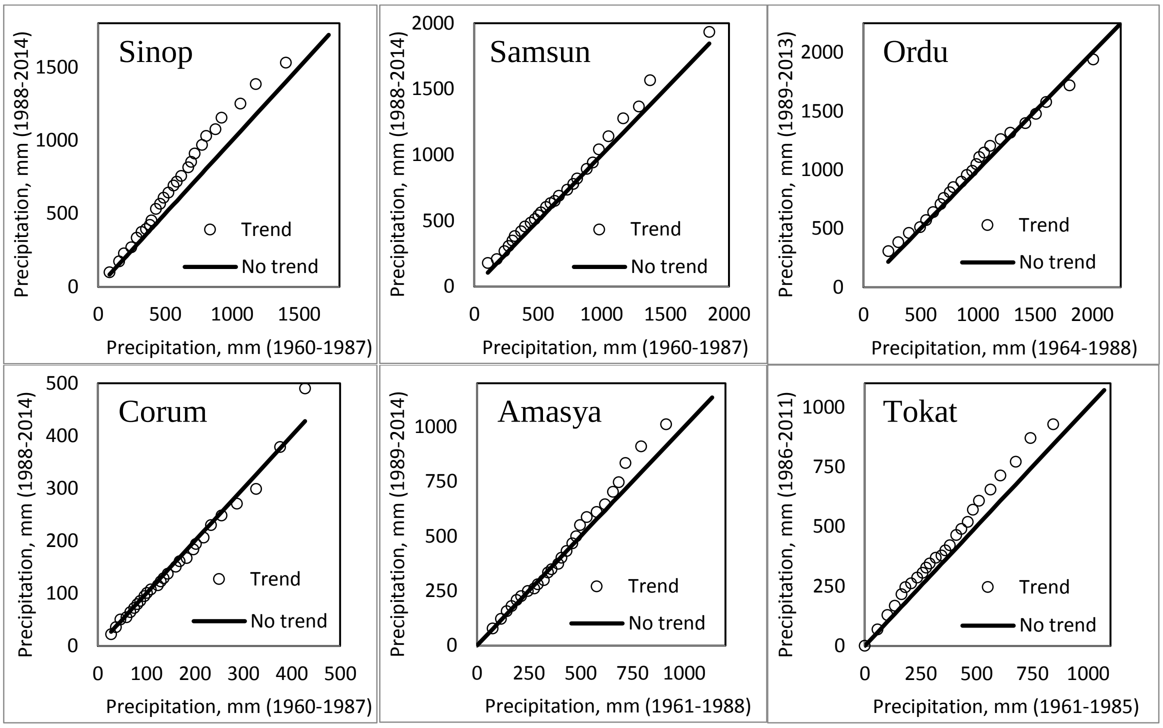

Figure 3 The result of Şen (2012) method for six provinces

The results obtained using MK-test and Innovative Şen trend analysis for annual precipitation series are given in Table 2. In general, this study showed that there is the great similarity between the statistical results from the Mann-Kendall and innovative trend analysis methods at the 5% and 10% significance levels. A similar conclusion has been confirmed by Şen (2012), Haktanir and Citakoglu (2014) and Kisi (2015).

Table 2 Results of the innovative trend analysis and Mann-Kendall test for annual total precipitation variable (for α=10 % and α=5 %, two-tailed confidence levels).

Station	**Şens's method**		**MK-test**	
	Peak	**Low**		
Sinop	Yes (+)	No	2.221[y]	Yes (+)
Samsun	No	No	1.161	No
Ordu	No	No	1.851 [x]	Yes (+)
Corum	No	No	0.387	No
Amasya	Yes (+)	No	1.313	No
Tokat	Yes (+)	No	3.330[y]	Yes (+)

The critical values for the 90 % and 95% confidence levels are ±1.645 and ±1.96, respectively
[x] Indicates trend significant at the 90 % confidence level
[y] Indicates trend significant at the 95 % confidence level

Table 2 shows the results of the MK trend test for the stations. The Z value of each station was calculated and compared with normal distribution critical Z values at the 90% and 95% for two-tailed confidence levels. It was seen that some parameters had an increasing trend while some parameters had a decreasing trend. Some parameters also had no trend (trendless time series). It is clear from the table that the Şen trend and MK give similar trend results for the Sinop, Samsun, Corum and Tokat stations. However, Şen trend gives some positive trends for the Amasya station.

The results of innovative method indicated that the Amasya station had some increasing trend for the peak precipitation values although there was no trend in this station according to the MK test.

CONCLUSIONS

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. In this context, trends of the annual precipitation in Turkey were investigated by using the Mann–Kendall and recently proposed innovative Şen trend analysis.

Data from Sinop, Samsun, Ordu, Corum, Amasya and Tokat stations in the central Black Sea region of Turkey were used in the analysis. According to the Mann–Kendall method, the Samsun, Corum and Amasya Stations showed trendless time series (no-trend) while the Sinop, Ordu and Tokat stations had significantly increasing trend in the period.

The results of innovative method, for the peak value, the Sinop, Amasya and Tokat stations showed increasing trends. Increasing or decreasing trend was not seen in the Samsun, Ordu and Corum station.

Mann–Kendall and innovative Şen trend methods provided same trend results for the Sinop, Samsun, Corum and Tokat stations.

The present study revealed that innovative trend analysis method has some advantages in relative to the MK method. One advantage is that it does not have any assumptions (e.g., serial correlation, non-normality, sample number etc.) as in the MK method. The other main advantage is that the trends of low, medium and high data can be easily identified by innovative method.

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