Vol. 44, No. 1, pp 44-49, 2016
Indian Journal of Soil Conservation
Online URL:http://indianjournals.com/ijor.aspx?target=ijor:ijsc&type=home

Trend analysis of rainfall of Sagar district, Madhya Pradesh

S. Singh[1] and S. Kumar

National Institute of Hydrology, Jal Vigyan Bhawan, Roorkee -247 667, Haridwar, Uttarakhand.

[1]*E-mail: surjeet@nih.ernet.in*

ARTICLE INFO

Article history :
Received : May, 2014
Revised : August, 2015
Accepted : September, 2015

Key words :
Mann-Kendall test,
Parametric,
Rainfall,
Regression,
Sen's slope

ABSTRACT

This paper aims to analyze the trends in historical rainfall of Sagar district using parametric and non-parametric approaches. The analysis is carried out using 45 years data (1960-2004) of four rain gauge stations located in different Tehsils namely Sagar, Khurai, Rehli and Banda. Mann-Kendall analysis, Sen's slope method and Linear regression method are used for the trend analysis. The analysis is segregated into four parts, *viz.* winter, monsoon, summer and annual rainfall. The results show that the Khurai station has significant rising trend in rainfall during the summer season while the Rehli station has significant falling trend during the summer season. The trend detected by Mann-Kendall analysis and Sen's method is also reflected in the linear regression approach. The magnitude of Sen's slope and regression analysis have also been presented and discussed.

1. INTRODUCTION

Rainfall is the main linking component of the hydrological cycle, which generally varies from place to place and month to month in a cyclic pattern. The lifestyle and socio-economic activities of people in the Bundelkhand region heavily rely on the rainfall. This region has felt severe water scarcity problem because of multiple reasons like erratic rainfall, undulating topography, underground bed-rocks, limiting soil depth, *etc.* In recent years, climate change has also posed a new threat to this region. Intergovernmental Panel on Climate Change (IPCC, 2007) has reported that future climatic change is likely to affect agriculture, increase of risk of hunger and water scarcity and may lead to rapid melting of glaciers. Rainfall is one of the main climatic factors that can indicate the climate change (Obot *et al.,* 2010). Kumar and Jain (2010) reported that a higher or lower or changes in rainfall distribution would influence the spatial and temporal distribution of runoff, soil moisture, groundwater reserves and would alter the frequency of droughts and floods. While the observed monsoon rainfall at the all-India level does not show any significant trend, regional monsoon variations have been recorded. A trend of increasing monsoon seasonal rainfall has been found along the west coast, northern Andhra Pradesh, and north-western India (+10% to +12% of the normal over the last 100 years) while a trend of decreasing monsoon seasonal rainfall has been observed over eastern Madhya Pradesh, north-eastern India, and some parts of Gujarat and Kerala (6 to 8% of the normal over the last 100 years) (Kumar and Singh, 2011). Mane *et al.* (2013) assessed the rainfall variability in the central Vidarbha agroclimatic region of Deccan plateau of India using non-parametric tests and found a shift in the temporal rainfall pattern over the central Vidarbha agro climatic region for the period included in the study. Patil *et al.* (2013) conducted rainfall trend analysis of the Pune district in western Maharashtra region. Jakhar *et al.* (2011) conducted a probability analysis of rainfall characteristics of Semiliguda in Koraput, Orissa and revealed that the onset of monsoon is on 11th June. The probability distribution of seasonal rainfall indicated that the occurrence of 75% probable rainfall in *kharif*, summer and *rabi* season are 1095.5, 91.4 and 83 mm, respectively, whereas 1274.5 mm is the annual rainfall.

Trends in rainfall in response to climate change have been studied by various researchers (Jayawardene *et al.,* 2005; Parta and Kahya, 2006; Kumar *et al.,* 2007, Obot *et al.,* 2010; Kumar and Jain, 2010; Olofintoye and Adeyemo, 2011; Manikandan and Tamilmani, 2012). These researchers have emphasized that the knowledge of rainfall variations is essential for the proper water management practices.

A comprehensive knowledge of the trend and persistence in rainfall of the area is of great importance because of economic implications of rain sensitive operations (Galkate *et al.,* 1999). With this in view, this paper presents a trend analysis of long-term historical rainfall of Sagar district using parametric and non-parametric approaches.

Study Area

Sagar city falls a few kms to the North of Tropic of Cancer at an altitude of 517 m amsl in the Bundelkhand region. The district occupies an area of 10252 sq km and extends between the latitude of 23°10' and 24° 27'N and longitude of 78° 04' and 79° 21'E. The district is bounded in the north by state of Uttar Pradesh, in the north east by Chhatarpur district, in south and west by Raisen, in the south east by Narsingpur district, in the northwest by Guna district and in the east by Damoh district. The rocky and hilly terrain of the district is having north-west drainage (Krishnan, 1967). Climatically, the area falls under semi-arid to sub-tropical region. Monsoon rains are received from June to October and the winter rains during December to February. The vegetation of the Sagar district can be included under Northern tropical dry deciduous forest (Krishnan, 1967). The normal annual rainfall of the district is 1234.8 mm. Air temperature varies between 5°C (minimum) in winter to 43°C (maximum) during peak summer. The location of rain gauge stations in different Tehsils of Sagar district is shown in Fig. 1. Rain gauge stations having good spatial coverage and long rainfall records are considered for the trend analysis. These rain gauge stations include Sagar, Khurai, Rehli and Banda and the altitude range varies from 404 to 540 m.

The major part of Sagar district is covered by black cotton soil. However, clay loam soils occurs in the northern parts of Banda blocks, north of Malthone, west of Sagar town, Kesli and Deori blocks. Sandy clay loam covers the areas falling in the southern parts Deori and Kesli blocks, east of Rehli and northern parts of Shahgarh block. Rehli block is by and large, covered by sandy loam soils. The southernmost tip of the district is drained by the Narmada river. However, the major part of the area falls in the Ganga basin. The drainage of the district is towards north and north east. The five rivers, from west to east are the Bina, the Dhasan, the Bewas, the Sonar and the Bamner (CGWB, 2009). Irrigation in the district is mainly from dug wells

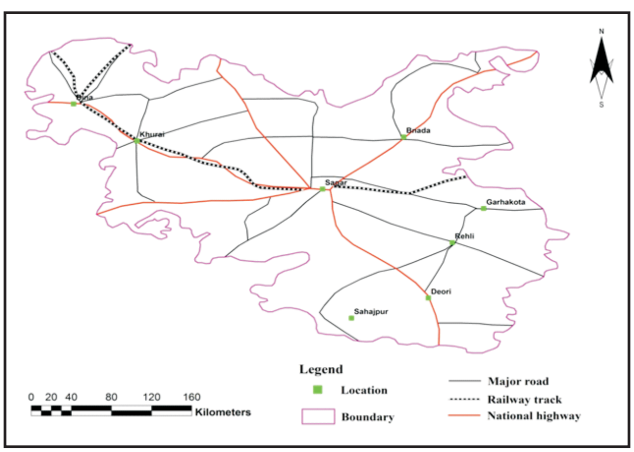

Fig. 1. Location of rain gauge stations in Sagar district, Madhya Pradesh

(1169 ha), tube wells (39852 ha), Canal (4825 ha), Ponds (2564 ha) and from other sources (72435 ha). There are 52190 dug wells, 6558 tube wells, 34 tanks/ponds and 43 canals. So, net irrigated area is 236635 ha (CGWB, 2009). Soyabean, wheat and gram are the main crops grown in the district.

2. MATERIALS AND METHODS

Data Availability

Monthly rainfall data of four rain gauge stations *viz.,* Sagar, Khurai, Rehli and Banda of the Sagar district was collected from the Land Records Office, Collectorate, Sagar district. The length of available data was 45 years (1960 to 2004) for the Sagar and Khurai stations and 38 years (1960 to 1997) for Rehli and Banda stations. The study area is located in the Sagar district where monsoon period falls between June to September and winter season starts in December and goes up to February. Summer months include March, April and May. Monthly rainfall data are converted to monsoon, summer and winter rainfall.

Trend Analysis

Mann-Kendall Test

The trend analysis and estimation of Sen's slope are done using Kendall (1975) and Sen (1968) method, respectively for the given data sets. Man-Kendall test is a non-parametric test for finding trends in time series. This test compares the relative magnitudes of data rather than data values themselves (Gilbert, 1987). The benefit of this test is that data need not to conform any particular distribution. In this test, each data value in the time series is compared with all subsequent values. Initially the Mann-Kendall statistics (*S*) is assumed to be zero, and if a data value in subsequent time periods is higher than a data value in previous time period, *S* is incremented by 1, and *vice-versa*. The net result of all such increments and decrements gives the final value of *S*. The Mann-Kendall statistics (*S*) is given as:

$$S = \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} sign(x_j - x_i) \quad ...(1)$$

Where, $sign(x_j - x_k) = 1$, if $(x_j - x_k) > 0$; 0, if $(x_j - x_k) = 0$; -1 if $(x_j - x_k) < 0$.

A positive value of *S* indicates an increasing trend, and a negative value indicates a decreasing trend. However, it is necessary to perform the statistical analysis for the significance of the trend. The test procedure using the normal-approximation test is described by Kendall (1975). This test assumes that there are not many tied values within the dataset. The variance (*S*) is calculated by the following equation:

$$Var\ (S) = \frac{1}{18}\left[n(n-1)\,(2n+5) - \sum_{p=1}^{g} t_p\,(t_p-1)\,(2t_p+5)\right]$$

Where, n is the number of data points, g is the number of tied groups and t_p is the number of data points in the p^{th} group.

The normal Z-statistics is computed as:

$$Z = \begin{cases} \frac{S - 1}{\sqrt{Var(S)}}, if\ S > 0 \\ 0 \quad , if\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, if\ S > 0 \end{cases}$$

The trend is said to be decreasing if Z is negative and the computed Z-statistics is greater than the z-value corresponding to the 5% level of significance. The trend is said to be increasing if the Z is positive and the computed Z-statistics is greater than the z-value corresponding to the 5% level of significance. If the computed Z-statistics is less than the z-value corresponding to the 5% level of significance, there is no trend.

Sen's Slope Estimator

Simple linear regression is one of the most widely used model to detect the linear trend. However, this method requires the assumption of normality of residuals (McBean and Motiee, 2008). Viessman *et al.* (1989) reported that many hydrological variables exhibit a marked right skewness partly due to the influence of natural phenomena and do not follow a normal distribution. Thus the Sen (1968) slope estimator is found to be a powerful tool to develop the linear relationships. Sen's slope has the advantage over the regression slope in the sense that it is not much affected by gross data errors and outliers. The Sen's slope is estimated as the median of all pair-wise slopes between each pair of points in the dataset (Thiel, 1950; Sen, 1968; Helsel and Hirsch, 2002). Each individual slope (m_{ij}) is estimated using the following equation:

$$m_{ij} = \frac{(Y_j - Y_i)}{(j-i)} \qquad ...(2)$$

Where, $i = 1$ to $n-1$, $j = 2$ to n, Y_j and Y_i are data values at time j and i ($j > i$), respectively. If there are n values of Y_j in the time series, there will be $N=n(n-1)/2$ slope estimates. The Sen's slope is the median slope of these N values of slopes. The Sen's slope is:

$$m = m_{\left[\frac{N+1}{2}\right]},\ if\ n\ is\ odd$$

$$m = \frac{1}{2}\left(m_{\left[\frac{N}{2}\right]} + m_{\left[\frac{N+2}{2}\right]}\right),\ if\ n\ is\ even$$

Positive Sen's slope indicates rising trend while negative Sen's slope indicates falling trend.

Linear Regression Analysis

Linear regression analysis is a parametric model and one of the most commonly used methods to detect a trend in a data series. This model develops a relationship between two variables (dependent and independent) by fitting a linear equation to the observed data. The data is first checked whether or not there is a relationship between the variables of interest. This can be done by using the scatter plot. If there appears no association between the two variables, linear regression model will not prove a useful model. A numerical measure of this association between the variables is the correlation coefficient, which range between -1 to +1. A correlation coefficient value of ±1 indicates a perfect fit. A value near zero means that there is a random, nonlinear relationship between the two variables. The linear regression model is generally described by the following equation:

$$Y = m.X + C \qquad ...(3)$$

Where, Y is the dependent variable, X is the independent variable, m is the slope of the line and C is the intercept constant. The coefficients (m and C) of the model are determined using the Least-Squares method, which is the most commonly used method. t-test is used to determine whether the linear trends are significantly different from zero at the 5% significance level.

3. RESULTS AND DISCUSSION

The time series of winter, summer, monsoon and annual rainfall are plotted in Fig. 2 to Fig. 5 for the four rain gauge stations located at Sagar, Khurai, Rehli and Banda during the period 1960 to 2004. It is seen from these Figures that all four stations receive very less rainfall during winter (up to 179 mm) and summer season (up to 165 mm). It is further observed that all the stations receive more than 90% rainfall during the monsoon season (June to September) which can be clearly seen that the monsoon series is almost close to the annual rainfall series and also follows the same pattern. It is

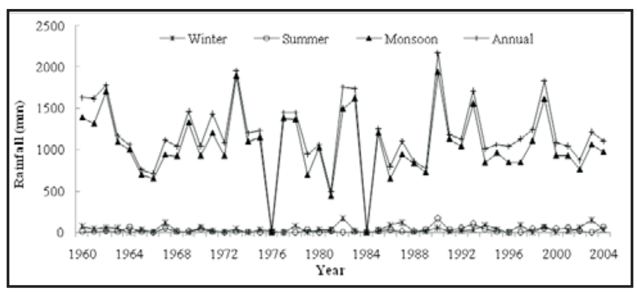

Fig. 2. Temporal variation of different rainfall series for Sagar

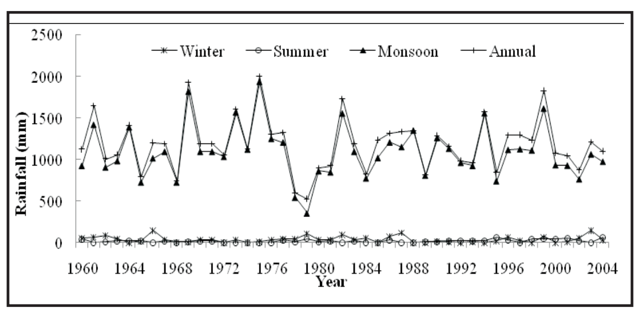

Fig. 3. Temporal variation of different rainfall series for Khurai

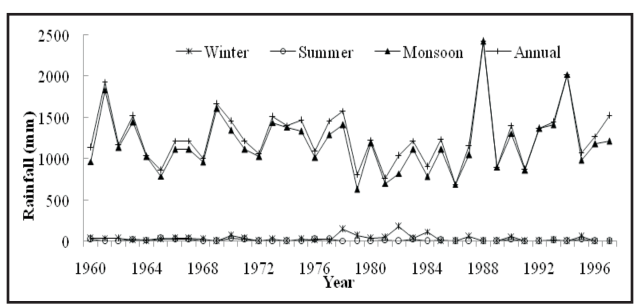

Fig. 4. Temporal variation of different rainfall series for Rehli

evident that all the stations receive maximum rainfall in monsoon season followed by summer season and minimum in winter season.

Fig. 6 shows the long-term average monthly rainfall. It is seen from the Figure that the monthly distribution of rainfall is almost same at all the four rain gauge stations. Further as mentioned above, most of the rainfall occurs during June to September with little winter rainfall during January and February. The average annual rainfall varies from 1087.9 (Banda) to 1273.9 mm (Rehli). It is also evident that maximum rainfall occurs in the month of August followed by July and then September and June at all the four rain gauge stations.

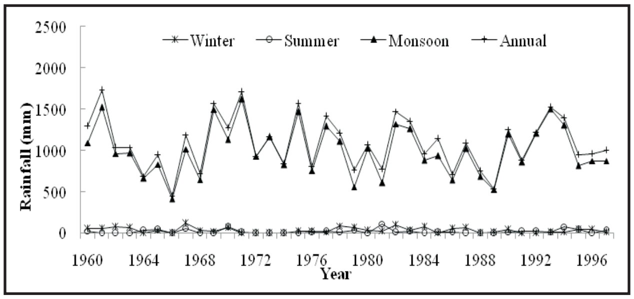

Fig. 5. Temporal variation of different rainfall series for Banda

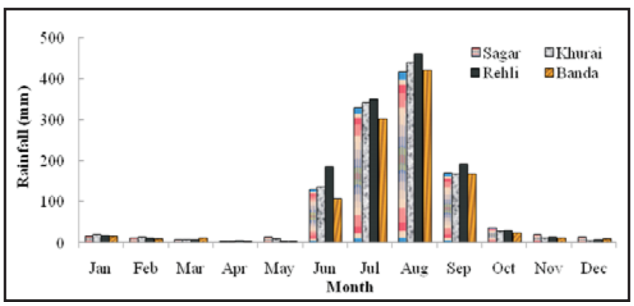

Fig. 6. Variation of average monthly rainfall at various rain gauge stations

The detailed statistics of rainfall at all the four stations is presented in Table 1. It can further be seen from this Table that most of the rainfall occurs during the monsoon season which is very close to the annual rainfall for all the stations. The monsoon rainfall varies from 1000 mm (Banda) to 1188 mm (Rehli). The coefficient of variation, which is the statistical measure of the distribution of data points in a data series around the mean, of annual rainfall varies from 0.27 (Khurai) to 0.37 (Sagar). This indicates that there is no variation in the annual amount of rainfall among all stations. However, the winter season rainfall shows a high coefficient of variation which ranges between 0.94 to 1.20. The skewness of all data series is found between -0.30 to 2.56. The winter and summer rainfall of all stations have positive skewness and shows that the data are right skewed. The monsoon and annual rainfall of Sagar and Banda have skewness close to zero which shows near normal distribution of rainfall. The kurtosis of all data series varies between -1.00 to 8.84. Positive kurtosis shows a peaked distribution while negative kurtosis shows a flat distribution.

A correlation analysis of rainfall is also carried out among all the rain gauge stations on the annual basis. All the four stations show positive correlation among themselves as shown in the correlation matrix (Table 2). The higher correlation coefficients are obtained in case of Banda station

Table: 2
Correlation matrix of annual rainfall of the rain gauge stations

Station Name	Sagar	Khurai	Rehli	Banda
Sagar	1.000	0.297	0.314	0.604
Khurai	0.297	1.000	0.447	0.478
Rehli	0.314	0.447	1.000	0.433
Banda	0.604	0.478	0.433	1.000

Table: 1
Statistical properties of rainfall at different rain gauge stations

Rainfall Series	Mean (mm)	Median (mm)	Minimum (mm)	Maximum (mm)	Standard Deviation	Coefficient of Variation	Skewness	Kurtosis
Sagar Station								
Winter	40.85	31.70	0.00	172.10	41.82	1.02	1.34	1.53
Summer	25.02	13.00	0.00	165.40	31.29	1.25	2.56	8.84
Monsoon	1048.03	1000.2	0.00	1935.50	402.80	0.38	-0.19	1.05
Annual	1170.28	1110.0	4.60	2167.10	434.43	0.37	-0.30	1.20
Khurai Station								
Winter	38.94	33.20	0.00	150.00	39.45	1.01	1.27	1.21
Summer	19.22	18.42	0.00	66.00	18.24	0.95	0.90	0.06
Monsoon	1088.98	1093.3	353.60	1930.60	313.41	0.29	0.52	0.79
Annual	1186.64	1188.2	524.30	2001.00	324.57	0.27	0.52	0.44
Rehli Station								
Winter	34.28	24.50	0.00	179.10	41.03	1.20	1.96	4.31
Summer	11.30	3.90	0.00	39.10	13.00	1.15	0.68	-1.00
Monsoon	1187.54	1113.2	632.00	2423.90	364.19	0.31	1.30	2.80
Annual	1273.95	1219.9	691.40	2423.90	356.33	0.28	1.04	1.95
Banda Station								
Winter	33.38	26.80	0.00	117.40	31.29	0.94	0.82	0.05
Summer	18.03	9.93	0.00	111.90	25.60	1.42	2.13	4.70
Monsoon	999.58	963.56	411.00	1618.60	306.71	0.31	0.20	-0.67
Annual	1087.89	1050.4	444.70	1732.49	320.33	0.29	0.18	-0.58

which shows the annual rainfall series of Banda is highly correlated with Sagar followed by Rehli and Khurai. The rainfall series of Khurai and Rehli also indicate a good correlation (0.447).

Trend Analysis

The summary of Mann-Kendall analysis of different rainfall series is presented in Table 3. The negative S-statistics indicates a falling trend and *vice-versa*. It can be seen from the table that in some cases the rainfall trend is falling while in some cases rainfall trend is rising. The computed z-statistics, as shown in Table 3, is less than the z-value corresponding to 5% significance level (1.96) in most of the cases, which indicates that no significant trend is detected in such cases. The trend of summer season at the Khurai station is showing a significant rising trend in rainfall while summer season at the Rehli station is showing a significant falling trend. There is no significant rising or falling trend at any other station.

Magnitude of above trends is calculated using Sen's slope estimator method. The estimated Sen's slope and their confidence limits are presented in Table 4. A positive slope gives rising trend and *vice-versa*. It can be seen from Table 4 that in some cases trend is falling and in some cases trend is rising as already detected using Mann-Kendall analysis. The annual rainfall series for the Rehli station does not show

Table: 3
Mann-Kendall trend analysis of rainfall at four rain gauge stations

S.No.	Rainfall Series	S-Statistics	z-statistics$_{comp}$	Trend	Trend at 5% Significance Level
Sagar Station					
1	Winter	-11	-0.098	Falling	No
2	Summer	169	1.649	Rising	No
3	Monsoon	-74	-0.714	Falling	No
4	Annual	-56	-0.538	Falling	No
Khurai Station					
1	Winter	-92	-0.895	Falling	No
2	Summer	211	2.062	Rising	Yes
3	Monsoon	-22	-0.206	Falling	No
4	Annual	-18	-0.166	Falling	No
Rehli Station					
1	Winter	-78	-0.974	Falling	No
2	Summer	-153	-1.992	Falling	Yes
3	Monsoon	-12	-0.138	Falling	No
4	Annual	5	0.050	No Trend	No
Banda Station					
1	Winter	-95	-1.188	Falling	No
2	Summer	78	0.985	Rising	No
3	Monsoon	-27	-0.327	Falling	No
4	Annual	-37	-0.453	Falling	No

Table: 4
Sen's slope estimator of rainfall at four rain gauge stations

S.No.	Rainfall Series	Sen's Slope	Trend	Confidence Limits for slope at 5% Significance Level	Regression Slope
Sagar Station					
1	Winter	-0.012	Falling	Lower Limit = -0.783; Upper Limit = 0.857	0.250
2	Summer	0.458	Rising	Lower Limit = -0.019; Upper Limit = 0.993	0.698
3	Monsoon	-3.244	Falling	Lower Limit = -11.410; Upper Limit = 4.843	-2.676
4	Annual	-1.794	Falling	Lower Limit = -12.034; Upper Limit = 4.700	-2.214
Khurai Station					
1	Winter	-0.247	Falling	Lower Limit = -1.076; Upper Limit = 0.481	-0.220
2	Summer	0.400	Rising	Lower Limit = 0.000; Upper Limit = 0.914	0.525
3	Monsoon	-0.762	Falling	Lower Limit = -7.701; Upper Limit = 5.540	-1.657
4	Annual	-0.652	Falling	Lower Limit = -8.447; Upper Limit = 6.063	-1.259
Rehli Station					
1	Winter	-0.233	Falling	Lower Limit = -1.131; Upper Limit = 0.298	-0.122
2	Summer	-0.071	Falling	Lower Limit = -0.571;Upper Limit = 0.000	-0.341
3	Monsoon	-0.650	Falling	Lower Limit = -10.619; Upper Limit = 9.286	1.372
4	Annual	0.000	No Trend	Lower Limit = -10.734; Upper Limit = 10.351	1.229
Banda Station					
1	Winter	-0.458	Falling	Lower Limit = -1.459; Upper Limit = 0.267	-0.633
2	Summer	0.081	Rising	Lower Limit = -0.056; Upper Limit = 0.667	0.183
3	Monsoon	-2.229	Falling	Lower Limit = -11.700; Upper Limit = 8.652	-1.286
4	Annual	-2.305	Falling	Lower Limit = -13.054; Upper Limit = 8.209	-2.265

any trend as the estimated slope in 0.00. The slope is also estimated for all the rainfall series using the simple linear regression approach which is given in Table 4. The trend obtained by regression analysis is same as given by Mann-Kendall analysis except (i) winter season for Sagar station, (ii) monsoon season for Rehli station and (iii) annual series for Rehli station. Test of significance at 5% significance level was also carried out on the regression slopes under various cases and significant rising trend in rainfall was found during the summer season at Khurai station only. At all other stations, no significant rising or falling trend was found.

4. CONCLUSIONS

The present study has been carried out to study the trend in the rainfall of Sagar district based on four rain gauge stations under different Tehsils. The trend analysis is carried out using the Mann-Kendall analysis, Sen's Slope estimator and simple regression approach. The analysis is carried out for the winter, summer, monsoon and annual rainfall time series. The Man-Kendall's analysis indicates that though there is some rising or falling trend under various instances but significant rising or falling trend is found only for two instances. The Khurai station has shown a significant rising trend in rainfall at 5% significance level during the summer season while the Rehli station has shown a significant falling trend during the summer season. The regression analysis, however, indicates significant rising trend in rainfall during the summer season only at the Khurai station. No significant trend is found in other seasons at any station.

REFERENCES

CGWB. 2009. Central Ground Water Board, District Ground Water Information Booklet, Sagar District, Madhya Pradesh, North Central Region, Bhopal.

Galkate, R.V. and Thomas, T. 1999. Statistical analysis of rainfall in Sagar Division, NIH Report No. CS(AR) 5/98-99.

Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. Van Nostrand Rienhold Company, Inc., New York.

Helsel, D.R. and Hirsch, R.M. 2002. Statistical methods in water resources: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. A3, 524 p. Available online at *http://water.usgs.gov/pubs/twri/twri4a3/*.

IPCC. 2007. Summary for policymakers In: Climate Change 2007: The Physical Sciences Basis (ed. By S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller). Cambridge University Press, UK.

Jakhar, P., Gowda, H.C.H., Naik, B.S. and Barman, D. 2011. Probability analysis of rainfall characteristics of Semiliguda in Koraput, Orissa. *Ind. J. Soil Cons.,* 39(1): 9-13.

Jayawardene, H.K.W.I., Sonnadar, D.U.J. and Jayewardene, D.R. 2005. Trends of rainfall in Sri Lanka over the last century. *Sri Lankan J. Phys.,* 6: 7-17.

Kendall, M.G. 1975. *Rank correlation methods,* 4th ed. Charles Griffin, London.

Krishnan, V.S. 1967. M.P. District Gazetteers: Sagar District. Government Press, Bhopal, M.P., India.

Kumar, Ambrish, Pal, R. and Sharma, H.C. 2007. Probability analysis of monsoon rainfall data of Saharanpur for Agricultural planning. *Ind. J. Soil Cons.,* 35(2): 122-124.

Kumar, C.P. and Singh, S. 2011. Impact of climate change on water resources and National Water Mission of India, National Seminar on Global Warming and Its Impact on Water Resources held on 14th January, 2011 at Kolkata.

Kumar, V. and Jain, S.K. 2010. Rainfall trends in Ganga-Brahmputra-Meghna river basins of India (1951-2004). *Hydrol. J.,* 33 (Special Issue): 59-66.

Mane, M.E., Parihar, S.S., Singh, M., Singh, D.K., Sarangi, A. and Chakravarthy, B. 2013. Assessment of rainfall variability in the central Vidarbha agroclimatic region of India. *J. Soil Water Conser,* 12(3): 198-206.

Manikandan, M. and Tamilmani, D. 2012. Statistical analysis of spatial pattern of rainfall trends in Parambikualam Aliyar sub-basin, Tamil Nadu. *IWRS,* 32(1-2): 40-49.

McBean, E and Motiee, H. 2008. Assessment of Impact of Climate Change on Water Resources: A Long Term Analysis of the Great Lakes of North America. *Hydrol. Earth Syst. Sci.,* 12: 239-255.

Obot, N.I., Chendo, M.A.C., Udo, S.O. and Ewona, I.O. 2010. Evaluation of rainfall trends in Nigeria for 30 years (1978-2007). *Int. J. Phys. Sci.,* 5(14): 2217-2222.

Olofintoye, O. and Adeyemo, J. 2011. The role of global warming in the reservoir storage drop at Kainji dam in Nigeria. *Int. J. Phy. Sci.,* 6(19): 4614-4620.

Parta, T. and Kahya, E. 2006. Trend analysis in Turkish precipitation data. *Hydrol. Process,* 20: 2011-2026.

Patil, J.P., Sarangi, A., Singh, D.K., Chakraborty, D., Rao, M.S. and Dahiya, S. 2013. Rainfall trend analysis: A case study of Pune District in Western Maharashtra Region. *J. Soil Water Conser.,* 12(1): 35-43.

Sen, P.K. 1968. Estimates of the regression coefficient based on Kendall's tau. *J. Am. Stat. Assoc.,* 63:1379-1389.

Thiel, H. 1950. A rank-invariant method of linear and polynomial regression analysis, Part 3. *Proceedings of Koninalijke Nederlandse Akademie van Weinenschatpen A.* 53:1397-1412.

Viessman, .W, Krapp, J.W and Harbough, T.E. 1989. Introduction to Hydrology, Third edition, Harper and Row Publishers Inc., New York.