Trend analysis of Annual rainfall in Bastar plateau and Northern hill zones of Chhattisgarh, India

Abstract

This study was to find out the trend of annual rainfall for 11 districts of Bastar plateau and Northern hill zone of Chhattisgarh. Long-term rainfall data of (27 years) in respective districts were collected from the Department of Agro-meteorology. IGKV, Raipur (Chhattisgarh). The trend analysis of rainfall was computed with the help of Mann-Kendall method and linear trend graph method. Results revealed that the annual rainfall of two districts *i.e.* Sukma and Kondagaon of Bastar plateau zone recorded a significant increasing trend at 5 % level of significance whereas two districts *i.e.* Bastar and Bijapur were showing a significant increasing trend at 1 % level of significance. Jashpur district of Northern hill zone shows significant decreasing trend at 5 % level of significance whereas rest five districts *i.e.* Dantewada, Narayanpur, Surguja, Surajpur, and Koria districts reported non-significant. Two districts showed non-significant increasing trend *i.e.* Narayanpur and Balrampur district. The maximum number of districts reported more or less stable rainfall during the years. On annual basis Bijapur district recorded the maximum amount of rainfall *i.e.* 3144.5 mm in a year while the lowest rainfall was 511.4 mm in Dantewada district. The maximum average annual rainfall over the study period was 1624.7 mm in Sukma district and the lowest average annual rainfall was 1029.5 mm (in 17 years data set) in Balrampur district.

Keywords: - Trend analysis, Annual Rainfall, Bastar plateau, Northern hill zone, Mann-Kendall and Linear trend graph method.

Introduction

Water resource has become a prime concern for any development and planning including food production, flood control, and effective water resource management. Mondal *et al.*(2012). Indian agriculture primarily depends on monsoon (June-October) rainfall. Studies of large scale changes especially in occurrence and distribution of rainfall are foremost factors in the planning and management of irrigation projects, reservoir operation, changes in water requirement, and agricultural production. The variation of annual rainfall has great consequences in the planning of irrigation projects and therefore, such studies are important for agricultural planning in India. Trend analysis is one of the active areas of interest to investigate the rainfall variability over the years. (Chakraborty *et al.* 2013) associated with global warming, changing rainfall patterns and their impact on surface water resources are important climatic problems facing society presently. According to Goyal (2014) the earth's climate has changed over the past century in terms of variation of rainfall and temperature. The main impact of climate change is the changing precipitation patterns. Changes in rainfall due to global warming will influence the hydrological cycle and the pattern of stream flows and demands (particularly agricultural), requiring a review of hydrologic design and management practices. Urbanization is also leading to climate change with changing land use from the impact of agricultural and irrigation practices. Changes in run-off and its distribution will depend on likely future climate scenarios. Any changes in precipitation patterns will have an impact of stream flow as they are directly proportional. The rainfall received in an area is an important factor in determining the amount of water available to meet various demands, such as agricultural, industrial, domestic water supply, and for hydroelectric power generation. (Kumar *et al.* 2010) The Indian climate is dominated by the southwest monsoon. About 80% of the rainfall in India occurs during the four monsoon months (June–September) with large spatial and temporal variations over the country. Such a heavy concentration of rainfall results in a scarcity of water in many parts of the country during the non-monsoon period. Therefore, for India, where agriculture has a significant influence on both the economy and livelihood, the availability of adequate water for irrigation under changed climatic scenarios is very important. The agricultural output is primarily governed by timely availability of water. In the future, population growth along with a higher demand for water for irrigation and industries will put more pressure on water resources. (Ania and Brema 2018) In view of all above problems, the present study had done as an attempt to find out the trend of most important climatic variable, rainfall. In the present study, trend analysis of rainfall data for selected 27 years (1993-2019) is used. Mann-Kendall test and linear trend graph methods are used (Chaudhary *et al.* 2015). In Chhattisgarh climate is mainly of dry sub-humid type. The average annual rainfall of the state is approximately 1200 mm. Annual rainfall is highest over Bastar plateau (1396 mm) and lowest in Chhattisgarh plain (1103 mm) while it is intermediary over the Northern hilly zone (1270 mm). The area of Northern hill zone accounts for 20.86 % of the total geographical area of the State. Balrampur, Jashpur, Koria, Surajpur and Surguja are major districts situated in this zone. The mean annual rainfall of about 1200 mm which is received over 58 rainy days with variability 22 % though the annual variability in rainy day is low.

MATERIAL AND METHODS

Study area

Chhattisgarh is located in the east central part of the country, between 17 ^{o}46’ N to 24 ^{o} 06’ N latitude and 80 ^{o} 15’ to 84 ^{o} 24’E longitude. The present study was carried out in Bastar plateau and northern hills zone covering 11 districts of Chhattisgarh state. *viz*. Bastar, Sukma, Bijapur, Narayanpur, Dantewada, Kondagoan, Sarguja, Jashpur, Balrampur, Surajpur and Koria districts.

The Bastar Plateau Zone lies between the latitude ranging from 17^{0} 44’ to 20^{0} 30’ North and longitude from 82^{0} 15’ to 82^{0} 20’ East. It comprises of 6 districts (Bastar, Dantewada, Bijapur, Kondagaon, Sukma, Narayanpur) but the study was limited to old 2 districts *i.e*. Bastar and Dantewada. The geographical area is 25.90 % of the state (Soni, 2013).

Northern hills lie between the latitude from 22^{0} to 24^{0} 11’ North and longitude from 80^{0} to 84^{0} East. It includes 5 districts (Jashpur, Koria, Surajpur, Surguja, Balrampur) but the study was limited to old 3 districts i.e. Jashpur, Surguja and Koria with area of 23.52 lakh hectares which comprises 25.15% of the total geographical area of the state. The normal annual rainfall is 1270 mm. (Anonymous, 2020.)

Rainfall data

The daily rainfall data of 27 from (1993-2019) years were collected from the Department of Agrometeorology, IGKV, for different districts of Bastar plateau and Northern hill zone of Chhattisgarh.

Method description

Trend analysis

Trend analysis is a method of collecting information and attempting to find out a pattern or trend from that information. This method is based on the time series data where information (data) in sequence is plotted against time (significantly long period) to detect general pattern of a relationship between time and information (factor).

The Mann-Kendall test is a non-parametric test used to identify trends in time series data. The test was suggested by Mann (1945) and has been extensively used with environment time series by Hipel and McLeod (2005). The test compares the relative magnitude of sample data rather than the data value them. One benefit of this test is that the data need not confirm to any particular distribution . Let X_1, X_2 ………………X_n represent n data points where X_j represents the data point at time j. Then the Mann-Kendall statistics (S) is given by

$$S = \sum\sum Sign\ (X_j\text{-}X_k)$$

$$j = 2, 3....... n;$$

$$k = 1, 2...... j\text{-}1$$

Where:

$$Sign\ (X_j\text{-}X_k) = 1 \text{ if } X_j\text{-}X_k > 0$$

$$= 0 \text{ if } X_j\text{-}X_k = 0$$

$$= -1 \text{ if } X_j\text{-}X_k < 0$$

A very high positive value of S is an indicator of an increasing trend and a very low negative value indicates a negative trend. However, it is necessary to compute the probability associated with S and the sample size n, to quantify the significance of the trend. For a sample size > 10, normal approximations to the Mann-Kendall test may be used.

Then standardized statistical test is computed by:

$$Z = S\text{-}1/V(S) \text{ if } S>0$$

$$= 0 \text{ if } S = 0$$

$$= S\text{+}1/V(S) \text{ if } S<0$$

The presence of a significant trend is evaluated using Z value.

RESULT AND DISCUSSION

Trend analysis of annual rainfall for 11 districts of Chhattisgarh.

Trend analysis of Bastar plateau and Northern hill zone of Chhattisgarh has been done in the present study with 27 years of rainfall data from 1993 to 2019. Mann-Kendall and Linear trend graph method has been used for the determination.

1. **Bastar plateau zone**

Table-1 (a) represents the average annual rainfall for 27 years with maximum rainfall of 1624.7 mm and minimum rainfall was 1231.6 mm respectively. Bastar district recorded maximum rainfall of 2397.4 mm in 2019 year and minimum rainfall of 1097.0 mm in 1997 year along with average annual rainfall of 1470.1 mm. The significantly increasing trend of the average annual rainfall of Bastar district was recorded under both the methods applied. Average annual rainfall, maximum rainfall and minimum rainfall of Dantewada district were 1366.4 mm, 2287.7 mm in 2001 year and 511.4 mm in 2009 year respectively. Non-significant decreasing trend of rainfall was observed with both the methods. The average annual rainfall of Narayanpur district was 1419.6 mm with maximum and minimum value of rainfall was 2153.4 mm in 2019 year and 794.3 mm in 2000 year respectively. In both the methods non-significant increase of rainfall trend was reported. The average annual rainfall of Sukma district was 1624.7 mm with maximum value of 2544.7 mm and minimum value of 1024.8 mm during 2006 and 2008 year respectively. A significantly increasing trend in rainfall was reported with both methods of analysis. The average annual rainfall of Bijapur district was 1548.6 mm with maximum rainfall of 3144.5 mm in 2013 year and minimum rainfall of 994 mm in 1997 year. The trend of annual average rainfall was significantly increasing in both methods. The average annual rainfall of Kondagaon district was 1231.6 mm with maximum and minimum rainfall of 1703.6 mm in 2019 year and 749 mm in 2003 year respectively. A significantly increasing trend of rainfall was observed on annual basis when data was subjected to Mann-Kendall test method.

2. Northern hill zone

Table-1 (b) shows the average annual rainfall variation and it is shown that the maximum rainfall was 1327.8 mm and the minimum rainfall was 990.9 mm occurred in 2017 year. The year 2006 is referred as 'wet year' and 2012 'dry year' during the study period. Annual average rainfall of Jashpur district was 1327.8 mm, whereas maximum rainfall and minimum rainfall was 1892.6 mm in 1994 year and 931.9 mm in 2014 year respectively. Significantly decreasing trend of annual average rainfall was observed in Mann-Kendall test method, while in linear trend graph method it was increasing significantly. The average annual rainfall of Surguja district was 1238.4 mm with maximum rainfall of 1748.9 mm in 1994 year and minimum rainfall of 609 mm in 2010 year. Non-significantly decreasing trend of rainfall was reported in both the methods. The average annual rainfall of Balrampur district was 1029.5 mm with the maximum value of 1753.5 mm in 2003 year and minimum rainfall of 598 mm in 2010 year. There was non-significant trend of rainfall was observed under both the methods. Average annual rainfall of Surajpur district was 1225.6 mm, with the maximum value of 1884.2 mm in 2001 year and a minimum value of 540.3 mm in 2009 year. Results indicate that there was Non-significantly decreasing trend of rainfall in both the methods. The average annual rainfall of Koria district was 1232 mm, with maximum and minimum rainfall of 1894.6 mm in 2011 and 750.6 mm in 2007 year respectively.

Similarly, results were reported by Kumar *et al.* (2010) on precipitation trends with monthly, seasonal and annual trends of rainfall have been studied using monthly data series of 135 years (1871–2005) for 30 sub-divisions (sub-regions) in India. Half of the sub-divisions showed an increasing trend in annual rainfall. Mukharjee and Banerjee (2009) assessed the rainfall pattern from Twenty rain gauge stations covering three districts (namely Bankura, Birbhum and Purulia) where an increasing trend of yearly rainfall and shifting pattern of rainfall was observed in the said zone. Sridhar and Raviraj (2017) reported that a significant increasing trend of rainfall was observed during north-east monsoon season when compared to other seasons. Jana *et al*. (2016) reported that significant decreasing trends of annual monsoon and seasonal rainfall were observed while in the month of May it was in a significantly increasing trend. Bhutiyani *et al.* (2010) and Singh (2016) have found a significant decreasing trend in the monsoon precipitation over north-western Himalayan. Kundu and Mondal (2019) reported in the post change point period, the number of rainfall stations with decreasing trend has risen in northern and western part whereas it has lessened in southern part.

Table-1. (a) Annual Rainfall (mm) of six districts (Bastar, Dantewada, Narayanpur, Sukma, Bijapur and Kondagaon of Bastar plateau from 1993 to 2019.

District →	Bastar	Dantewada	Narayanpur	Sukma	Bijapur	Kondagaon
Year↓	RF(mm)	RF(mm)	RF(mm)	RF(mm)	RF(mm)	RF(mm)
1993	1290.2	1181.2	1179.3	1127.6	1290.2	NA
1994	1274.6	1554	1869.1	1686.1	1274.6	NA
1995	1371	1590.1	1537.8	1610.8	1371	NA
1996	1224.3	1225.7	1189.2	1606	1224.3	NA
1997	1094	1121.8	1442.8	1118.5	994	NA
1998	1168.2	1328.7	1119.9	1246.4	1168.2	NA
1999	1393.9	1501.4	1355.3	1548.1	1637.8	1377.5
2000	1251.5	1145.6	794.3	1325.7	1126	924.9
2001	1488.7	2287.7	1796.7	1166.1	1126.2	1590.8
2002	1032.2	1029	1918.1	1203.7	1157.4	967.2
2003	1652	1493.3	1559.3	1996.5	1314.4	749
2004	1621.3	2176.2	1454.9	1366.3	1193.7	949.4
2005	1472.7	1437.4	958.6	1487.5	1282.2	1316.2
2006	1483.1	1294.9	1688.4	2544.7	1153.3	1460.3
2007	1186.4	1759.3	1378.2	1747.7	1262.8	1187.4
2008	1364.7	1299.5	1276.7	1024.8	1551.1	1172.2
2009	1294.7	511.4	1117.2	1031.4	1207.5	1038.7
2010	1970.3	1705	1710.8	1691.1	2218.2	1129.6
2011	1175.2	1399.4	1144.9	1425.9	1200.5	1201.5
2012	1878.5	1371.3	1471.8	2042.2	2198.2	1201.7
2013	1430.6	1267.9	1538.7	1856.1	3144.5	1242.6
2014	1531.5	923	1510.6	1966.9	1851.5	1280.3
2015	1751	1043.2	1409.5	2293.4	2092.2	1225.7
2016	1867.2	1051.9	1280.4	1561.1	1702.7	1586.6
2017	1582.1	1315.1	1050.6	2297.8	1251.8	1285.2
2018	1446.7	1320.7	1422.3	2208.7	1994.6	1272.2
2019	2397.4	1558.2	2153.4	1686.3	2823.8	1703.6
Average	**1470.1**	**1366.4**	**1419.6**	**1624.7**	**1548.6**	**1231.6**

Table-1 (b) Annual Rainfall (mm) of five districts (Jashpur, Surguja, Balrampur, Surajpur and Koria of Northern hill zone from 1993 to 2019.

District →	Jashpur	Surguja	Balrampur	Surajpur	Koria
Year↓	RF(mm)	RF(mm)	RF(mm)	RF(mm)	RF(mm)
1993	1294.8	892.1	NA	1367	997
1994	1892.6	1977.4	NA	1770.2	1538
1995	1246.5	1352.4	NA	1039.5	1070
1996	1603.6	1193.6	NA	1019.2	1003.4
1997	1488	1501.9	NA	1143.5	1485.6
1998	1798.6	1748.9	NA	1032.4	1847.2
1999	1562.6	1342.6	NA	1827	1379.2
2000	1089.8	1543.9	NA	1376	923
2001	1611.1	751.8	NA	1884.2	1454.2
2002	1182.4	1511.1	NA	1646.4	952.2
2003	1351.8	1614.3	1753.5	1461.1	1584.1
2004	1127.3	1111.9	975.9	998.4	1464.5
2005	1285.4	907.2	945.8	1129.4	1157.4
2006	1276.4	1072.8	788.4	1236.2	1183
2007	1181.8	1167.1	1234	998.1	750.6
2008	1276.5	1129.9	975.9	689.8	1139.8
2009	1210.5	776.3	286.8	540.3	884.1
2010	1074.7	609	598.2	552.2	871
2011	1677.7	1286.9	1234	1303.9	1894.6
2012	1217.6	1250.8	995.4	1339.9	1545.5
2013	1018.2	1187	1083.1	820.9	1517.4
2014	931.9	1158	1065.4	998.5	1480.7
2015	1067	1217.2	993.4	934.6	761.1
2016	1427.7	1660.9	723.5	1684.8	1281
2017	1336	1321.9	1065.6	1395.7	873.4
2018	1100.1	1037.2	817.4	1363.6	1029.7
2019	1518.6	1112.7	1309.9	1539.3	1197.2
Average	**1327.8**	**1238.4**	**990.9**	**1225.6**	**1232.0**

Table-2 Trend analysis of Annual Rainfall for 11 district of Bastar plateau and Northern hill zone of Chhattisgarh based on Mann-Kendall and Linear trend graph method.

S.N.	District	Year	Mann-Kendall Trend Results	Linear trend graph Results
1	Bastar	1993-2019	S Inc*	Sig-Inc *
2	Dantewada	1993-2019	NS Dec	NS Dec
3	Narayanpur	1993-2019	NS Inc	NS Inc
4	Sukma	1993-2019	S Inc**	Sig-Ins *
5	Bijapur	1993-2019	S Inc*	Sig-Ins *
6	Kondagaon	1999-2019	S Inc**	NS Inc
7	Jashpur	1993-2019	S Dec**	Sig-Ins **
8	Surguja	1993-2019	NS Dec	NS Dec
9	Balrampur	2003-2019	NS Dec	NS Dec
10	Surajpur	1993-2019	NS Dec	NS Dec
11	Koria	1993-2019	NS Dec	NS Dec

[NS (non-significant), S (significant), Dec (decreasing), Inc. (increasing), * = 1 % significant level and ** = 5 % significant level for Mann-Kendal trend.]

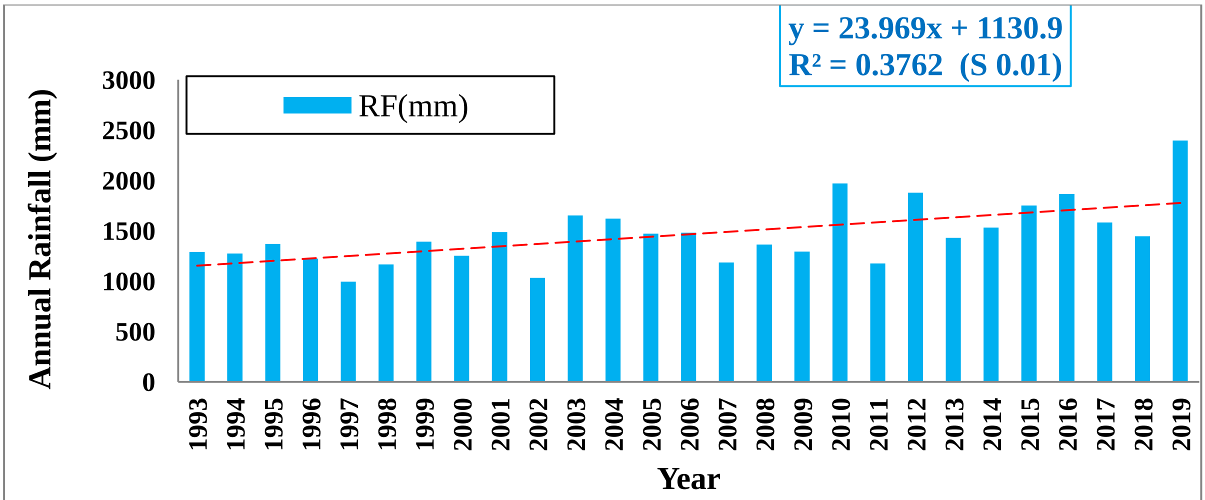

Fig. 1 Trend of Annual Rainfall for Bastar District

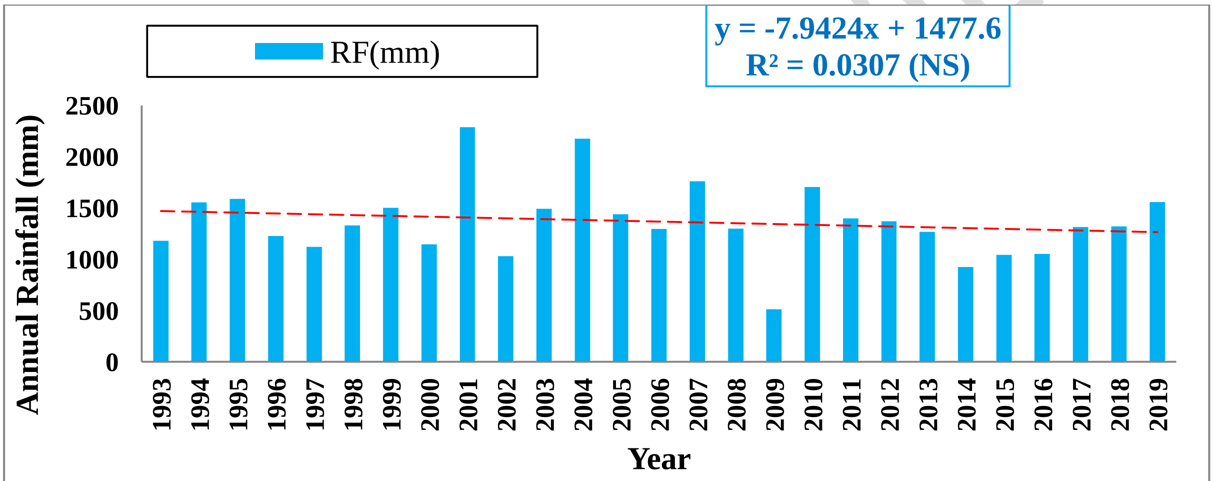

Fig. 2 Trend of Annual Rainfall for Dantewada District

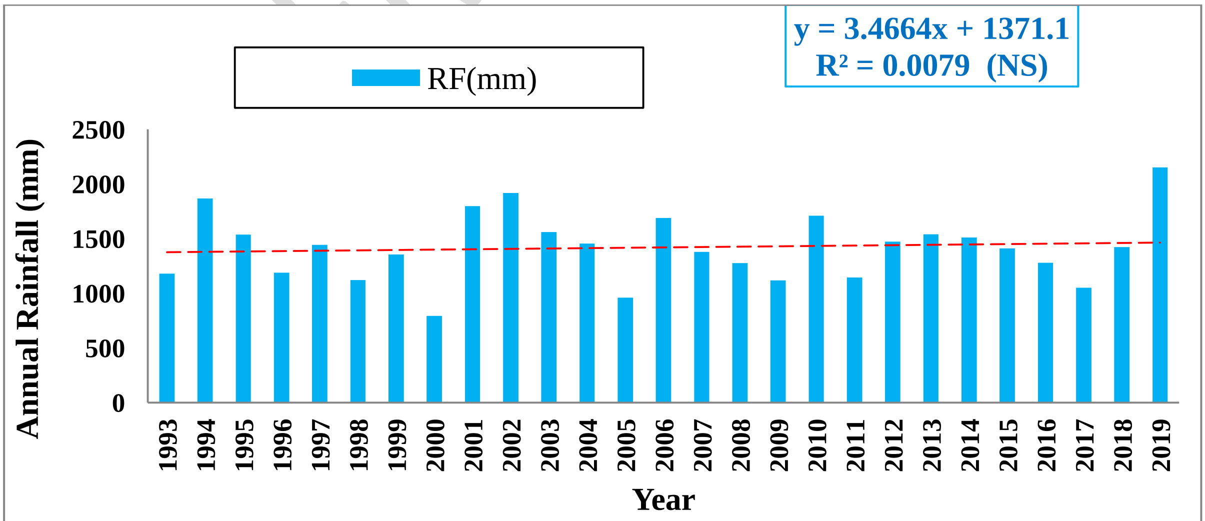

Fig. 3 Trend of Annual Rainfall for Narayanpur District

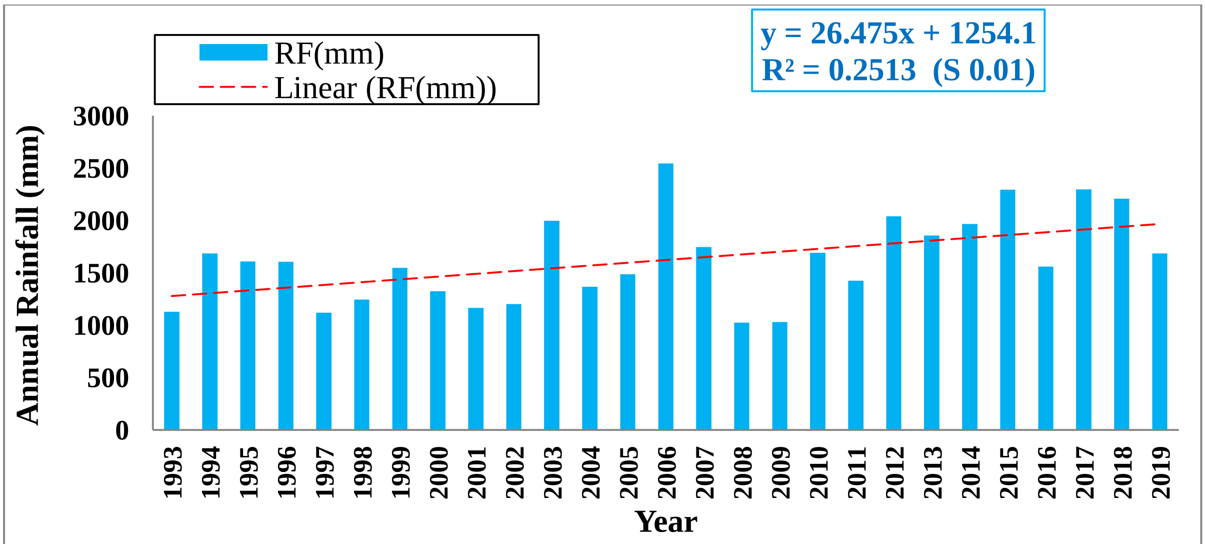

Fig. 4 Trend of Annual Rainfall for Sukma District

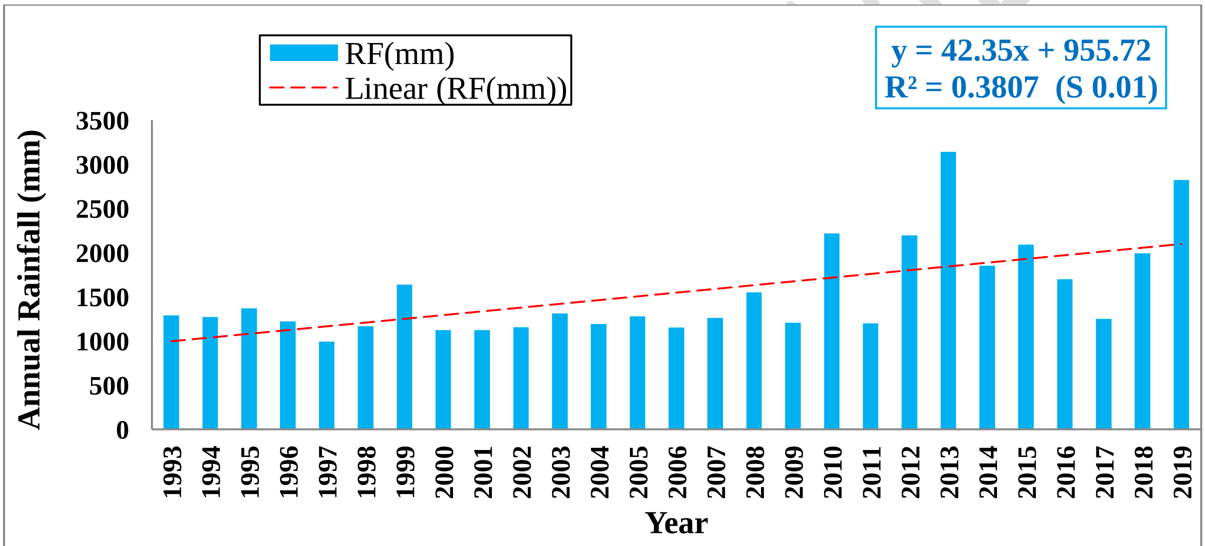

Fig. 5 Trend of Annual Rainfall for Bijapur District

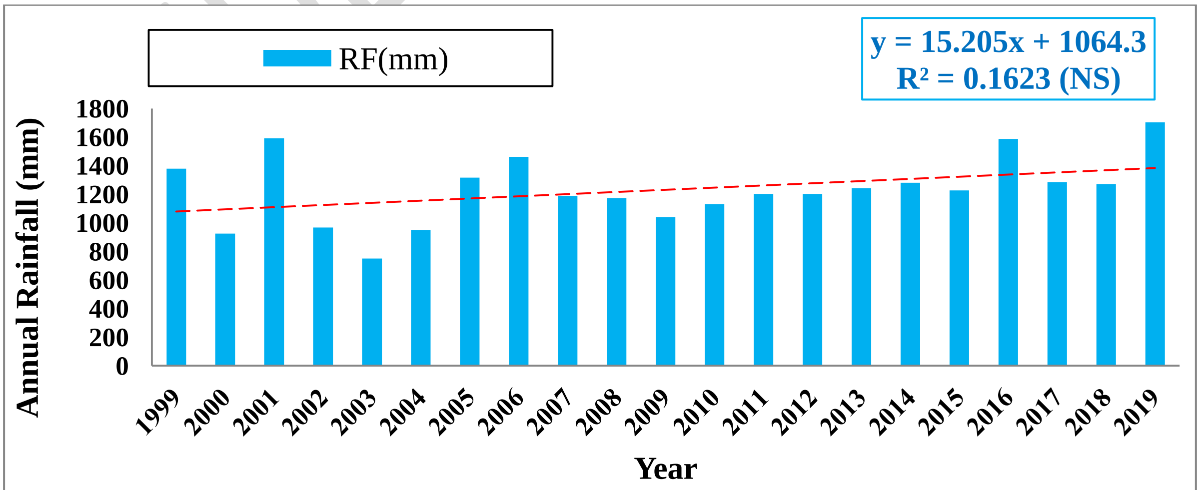

Fig. 6 Trend of Annual Rainfall for Kondagaon District

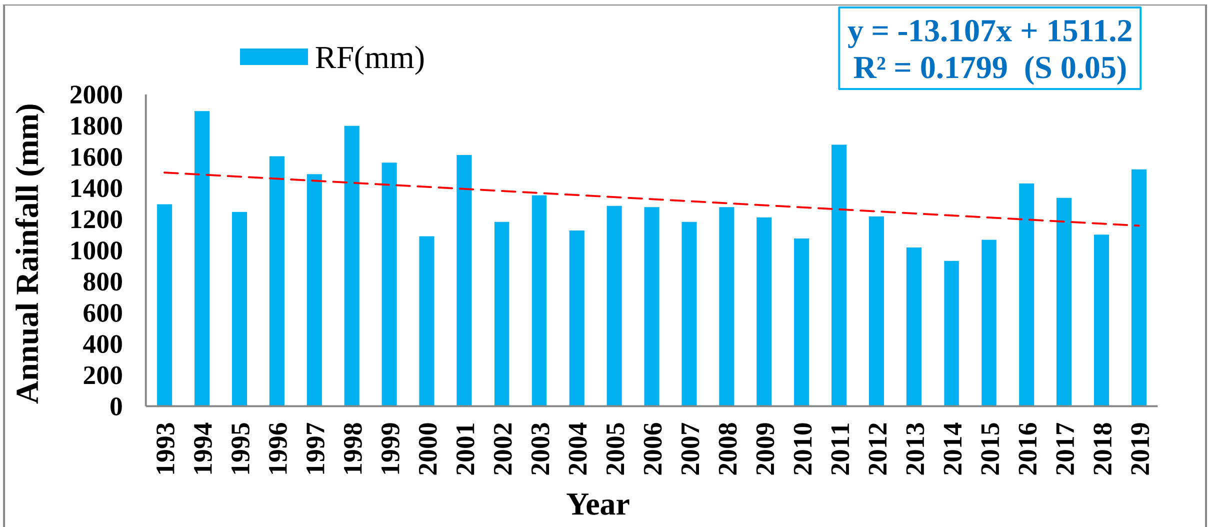

Fig. 7 Trend of Annual Rainfall for Jashpur District

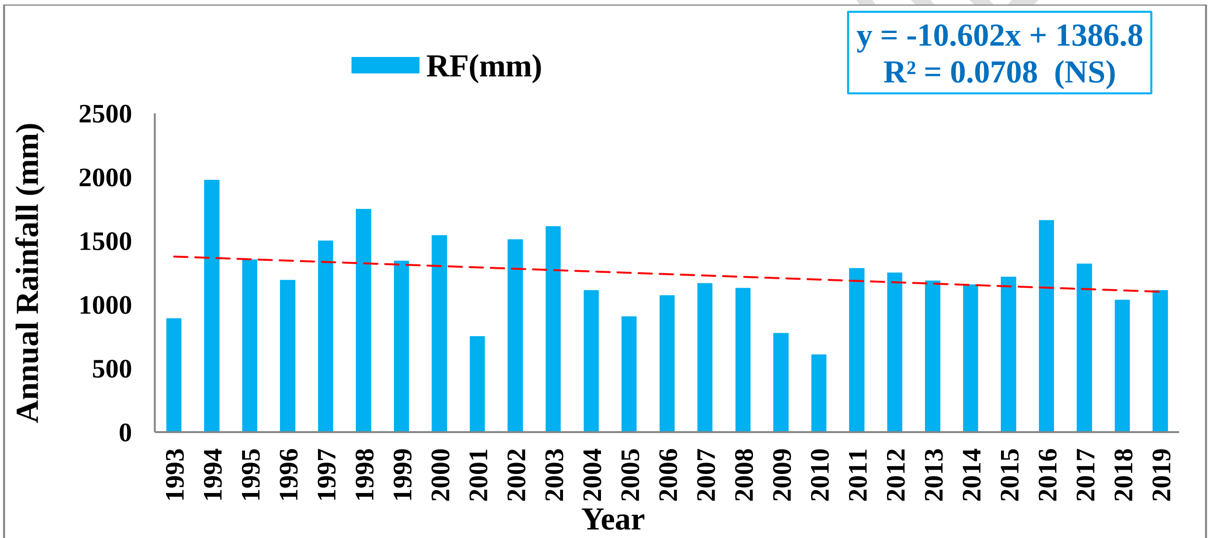

Fig. 8 Trend of Annual Rainfall for Surguja District

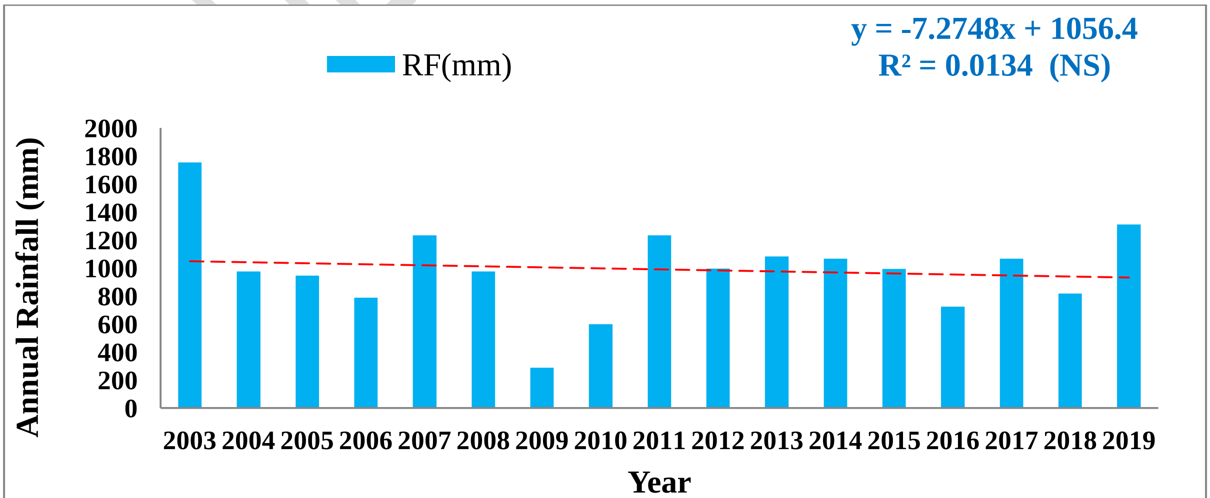

Fig. 9 Trend of Annual Rainfall for Balrampur District

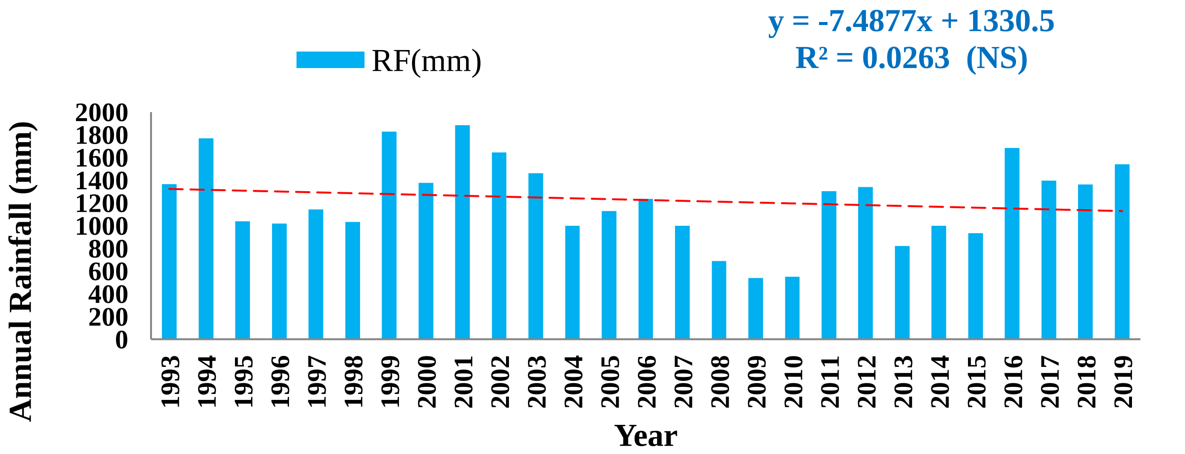

Fig. 10 Trend of Annual Rainfall for Surajpur District

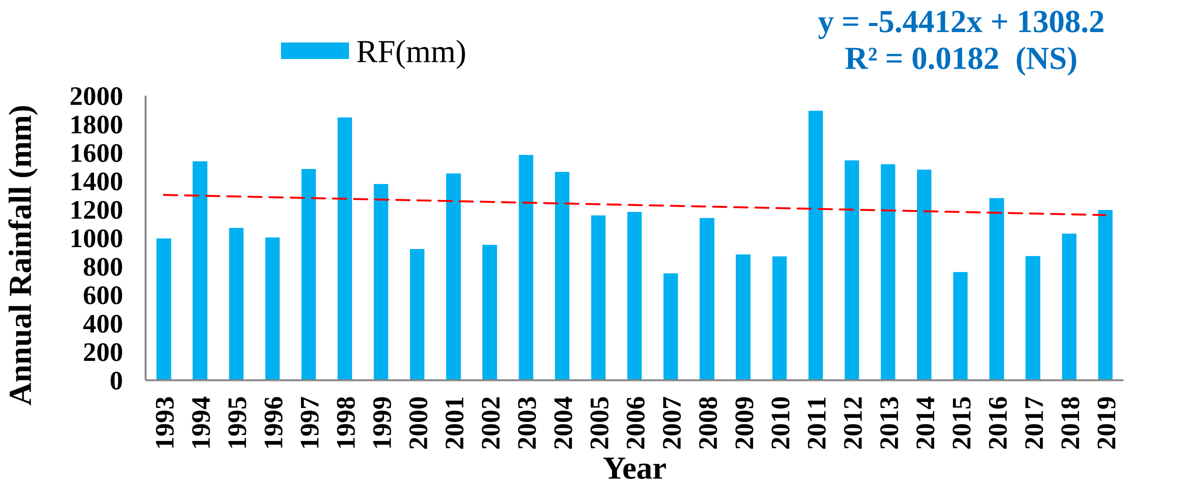

Fig. 11 Trend of Annual Rainfall for Koria District

Conclusion

On the basis of the study, we concluded that a significant decreasing trend in rainfall was observed in one district *i.e.* Jashpur while in rest four districts i.e. Bastar, Sukma, Bijapur, and Kondagaon annual rainfall were shows a significant increasing trend. Six districts were trend reported non-significant trend in rainfall i.e. Dantewada, Narayanpur, Surguja, Balrampur, Surajpur, and Koria district.

Reference

Anie, J.S. and Brema, J. 2018. Rainfall Trend Analysis by Mann-Kendall Test for Vamanapuram River Basin, Kerala, International Journal of Civil Engineering and Technology, 9(13): 1549-1556.

Anonymous. 2020. Ground Water Status Chhattisgarh, Water Resources Department.

Anonymous. Integrated watershed management programme, state level nodal agency (S.L.N.A.) panchayat & rural development govt.of Chhattisgarh vikas bhavan civil line Raipur.

Chakraborty, S., Pandey, R.P., Chaube, U.C. and Mishra, S.K. 2013. Trend and variability analysis of rainfall series at Seonath River Basin, Chhattisgarh (India), Journal of Applied Sciences and Engineering Research, 2(4): 22779442.

Chaudhary, J. L., Patil, S. K., Khavse, R., Chowdary, P. S., Manikandan, N., Rao, C. S., and Rao, V. U. M. 2015. Agroclimatic atlas of Chhattisgarh. Indira Gandhi Krishi Vishwa Vidyalaya, Raipur, 02: 36-37.

Goyal, M. K. 2014. Statistical analysis of long term trends of rainfall during 1901– 2002 at Assam, India. Water Resour Manage 28: 1501-1515.

Jana C., Sharma G.C., Alam N.M., Mishra P.K., Dubey S.K. and Kumar R. 2016. Trend analysis of rainfall and rainy days of Agra in Northern india, Int. J. Agricult. Stat. Sci. 12(1): 263-270.

Kumar, V., Jain, S.K. and Singh, Y. 2010. Analysis of long-term rainfall trends in India, Hydrology Science Journals, 55(4), 484–496.

Kundu S.K. and Mondal T.K. 2019. Analysis of long-term rainfall trends and change point in West Bengal, India. Theoretical and Applied Climatology, 138:1647–1666

Mondal, A., Kundu, S, and Mukhopadhyay, A. 2012. Rainfall trend analysis by Mann-Kendall test: a case study of north-eastern part of Cuttack district, Orissa, International Journal of Geology, Earth and Environmental Sciences, 2(1):70-78.

Mukherjee, A. and Banerjee, S. 2009. Rainfall and temperature trend analysis in the red and lateritic zone of West Bengal, Journal of agro-meteorology, 11(2): 196-200.

Singh, B. (2016). Variability and trend analysis of rainfall data of Jhalawar district of Rajasthan, India. Journal of Applied and Natural Science, 8(1): 116-121.

Soni, K.B.N. 2013. Ground water brochure of Bastar district Chhattisgarh. Government of India, Ministry of Water Resources, Central Ground Water Board, Raipur (C.G.).

Sridhar, S.I. and Raviraj, A. 2017. Statistical Trend Analysis of Rainfall in Amaravathi River Basin Using Mann-Kendall Test, Current World Environment, 12(1): 89-96.