

“Trend analysis of Annual rainfall in Bastar plateau and Northern hill zones of Chhattisgarh”

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-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 Korias districts reported non-significant. Two districts showed non-significant increasing trend *i.e.* Narayanpur and Balrampur district. ~~Maximum~~-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 an 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. ~~Main~~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, Korla, 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

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Study area

Chhattisgarh is located in the east central part of the country, between 17°46' N to 24° 06' N latitude and 80° 15' to 84° 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, Surguja, Jashpur, Balrampur, Surajpur and Korla districts.

The Bastar Plateau Zone lies between the latitude ranging from 17° 44' to 20° 30' North and longitude from 82° 15' to 82° 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 [lies](#) between the latitude from 22° to 24° 11' North and longitude from 80° to 84° East. It includes 5 districts (Jashpur, Korla, Surajpur, Surguja, Balrampur) but [the](#) study was limited [under-to](#) old 3 districts *i.e.* Jashpur, Surguja and Korla 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, \dots, X_n represent n

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data points where X_j represents the data point at time j . Then the Mann-Kendall statistics (S) is given by

$$S = \sum \sum \text{Sign} (X_j - X_k)$$
$$j = 2, 3, \dots, n;$$
$$k = 1, 2, \dots, j-1$$

Where:

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

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:

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

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 ~~was 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 ~~increasing-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. ~~Significantly-A significantly~~ increasing trend ~~of-in~~ rainfall was reported with both ~~the~~ 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. ~~Significantly-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' ~~among-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. ~~Average-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. ~~Average~~The average annual rainfall of Korias 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.

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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 |

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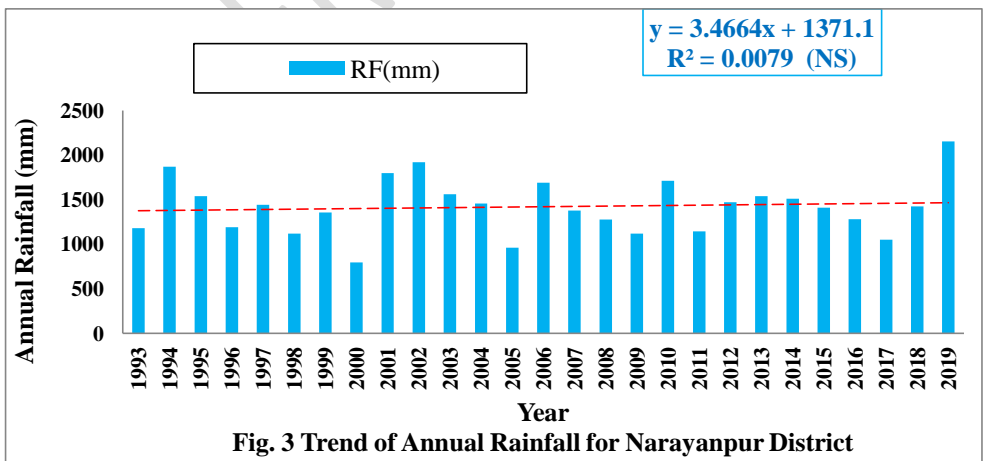
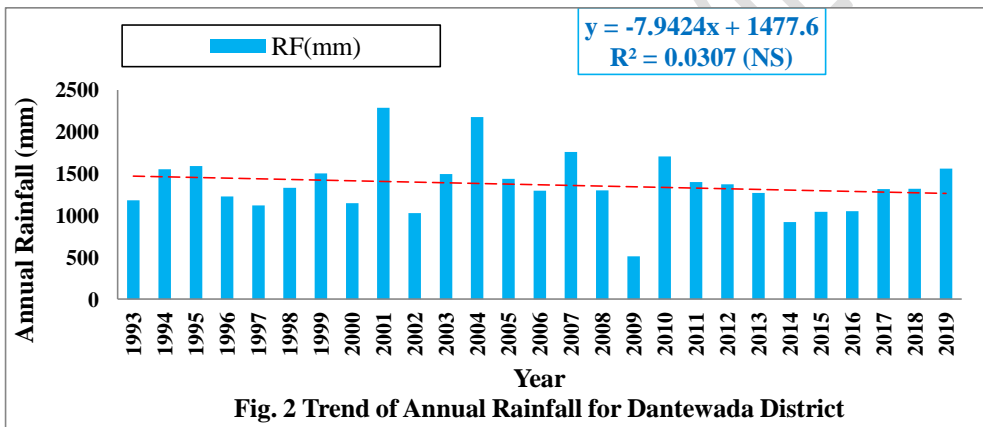
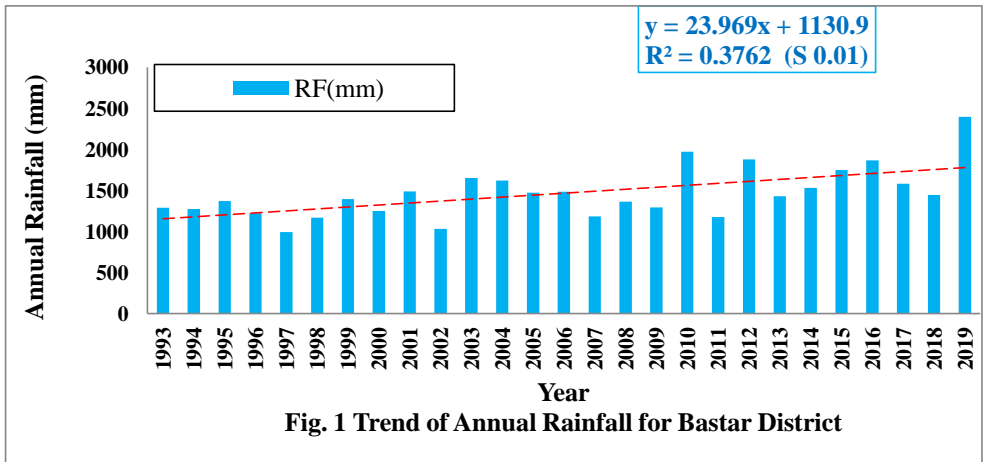
Table-1 (b) Annual Rainfall (mm) of five districts (Jashpur, Surguja, Balrampur, Surajpur and Korias of Northern hill zone from 1993 to 2019.

| 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 |

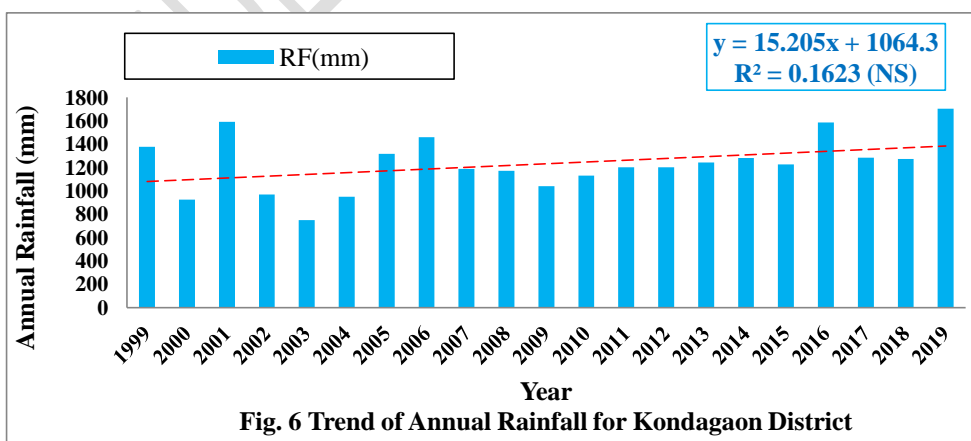
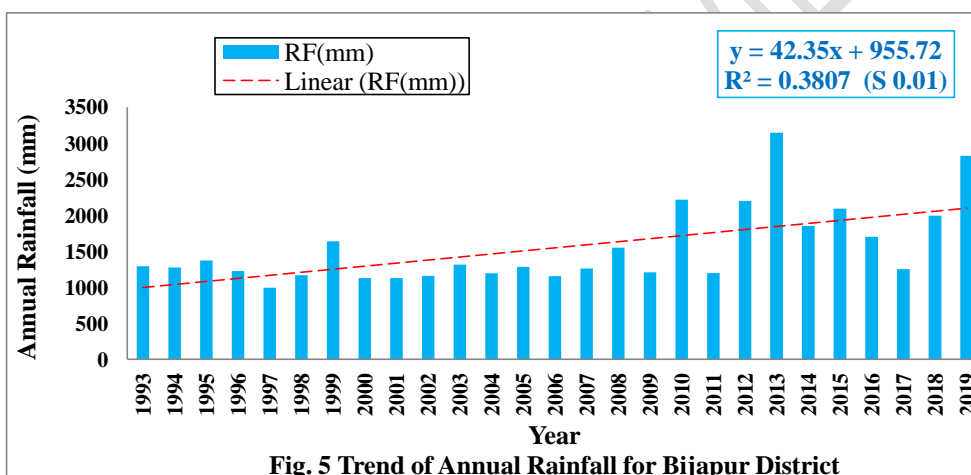
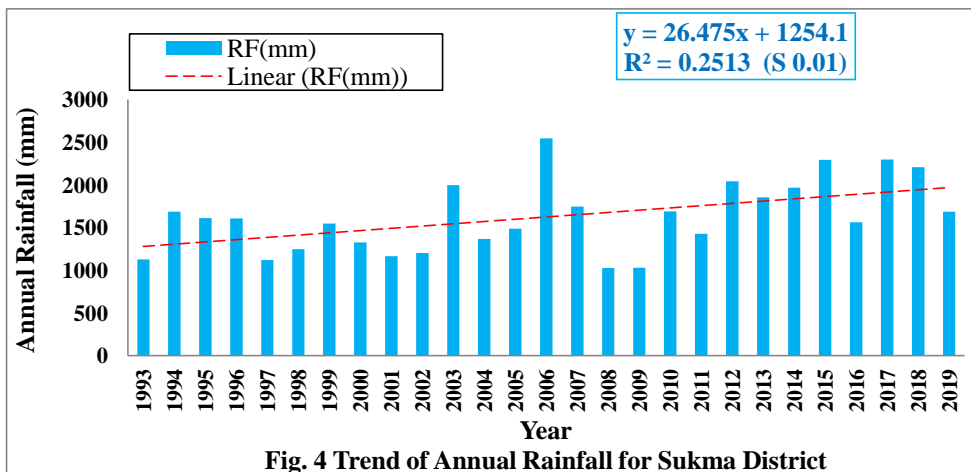
Table-2 Trend analysis of Annual Rainfall for 11 district of Bastar plateau and Northern hill zone of Chhattisgarh based on Mann-Kendall and Linear trend graph method.

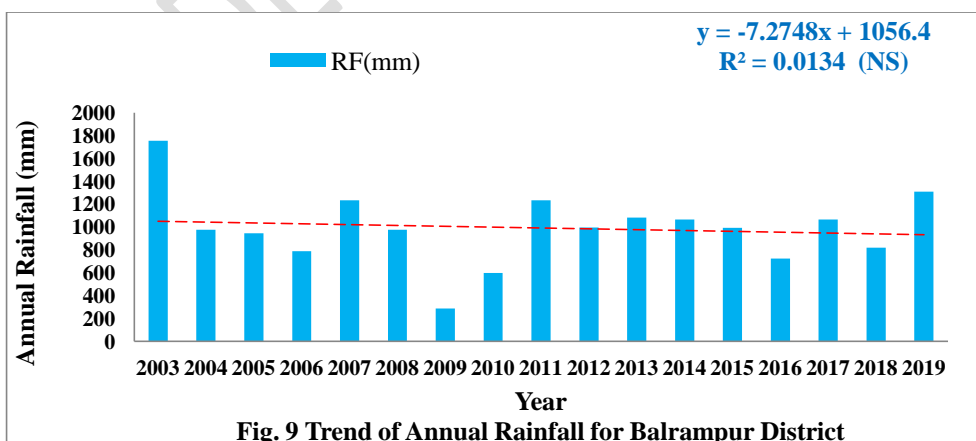
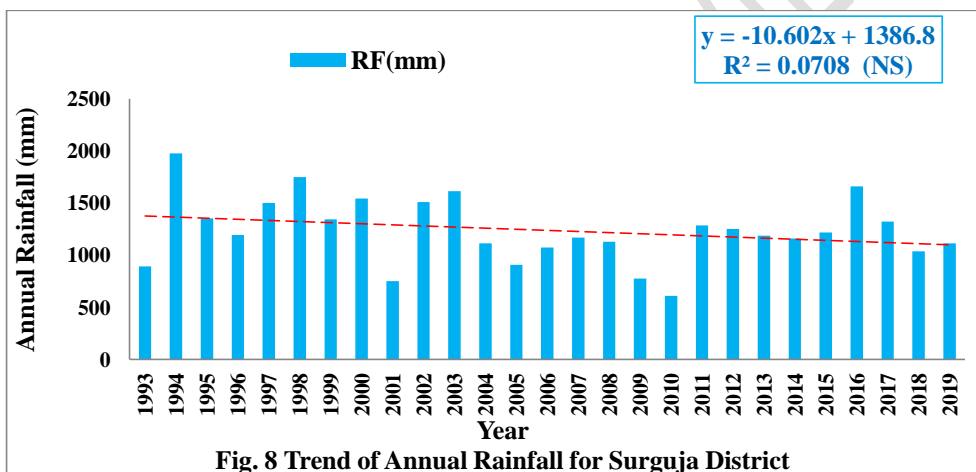
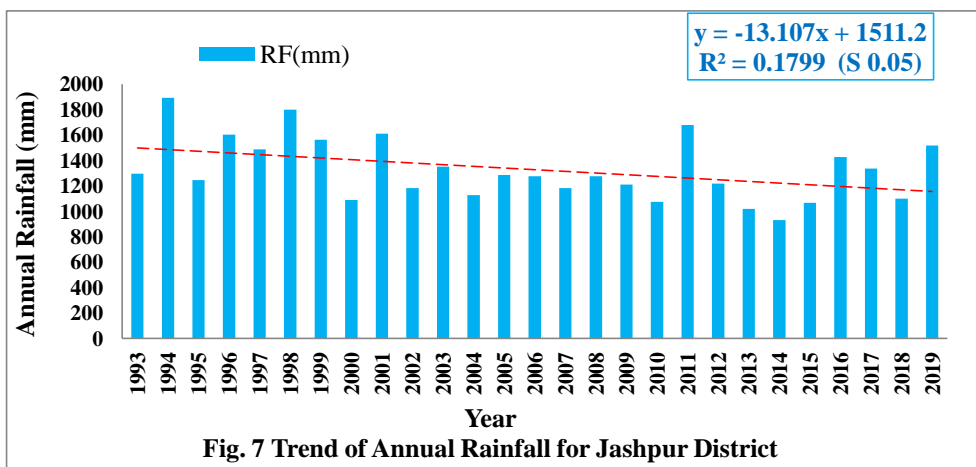
| S.N. | District | Year | Mann-Kendall Trend Results | Linear trend graph Results |
|------|------------|-----------|----------------------------|----------------------------|
| 1 | Bastar | 1993-2019 | S Inc* | Sig-Inc * |
| 2 | Dantewada | 1993-2019 | NS Dec | NS Dec |
| 3 | Narayanpur | 1993-2019 | 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 |

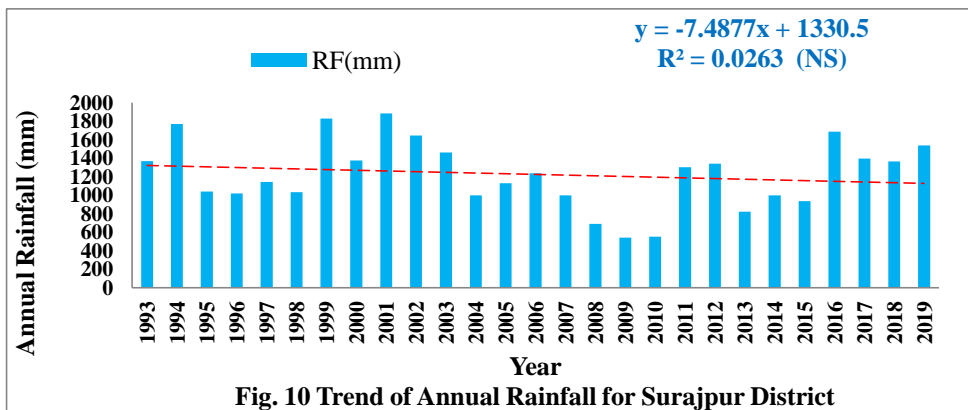
[NS (non-significant), S (significant), Dec (decreasing), Inc. (increasing), * = 1 % significant level and ** = 5 % significant level for Mann-Kendal trend.]



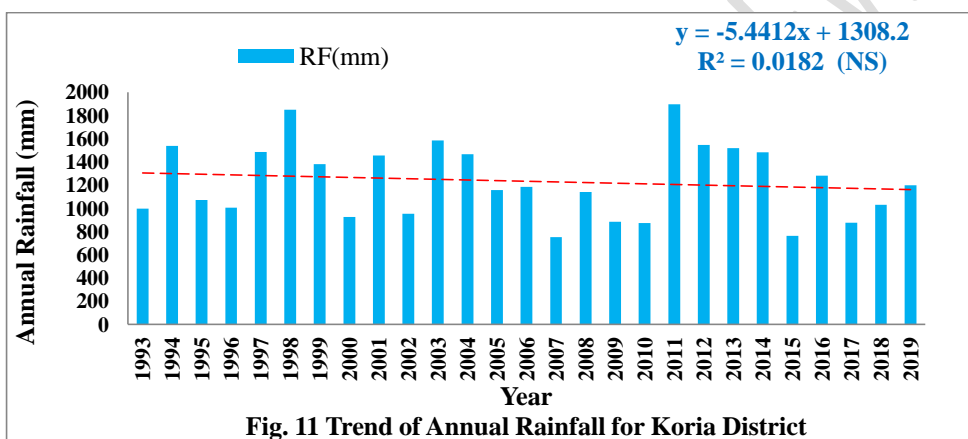
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Comment [TH5]: In tabulated data Balrampur district has no rainfall data from 1993-2002, where data come from in this figure.



Conclusion

On the basis of the study, we concluded that a significant decreasing trend of 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 Kororia district.

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