SPATIAL AND TEMPORAL VARIATION OF SUMMER MONSOON RAINFALL OVER CHHATTISGARH DURING THE PERIOD 1901-2000

1.   The Chhattisgarh state located in India got separated from Madhya Pradesh and became a new state of India on 1st November 2000. Chhattisgarh region is major producer of rice and is known as bowl of rice. The economy of this agricultural oriented state is very much dependent on summer monsoon rainfall as irrigation facilities are limited to a small part of the region. In the summer monsoon season of India, most of the weather systems that develop in the Bay of Bengal and pass through Chhattisgarh give good amount of rainfall over the region.

TABLE 1

Mean station rainfall, deviation, lowest and highest rainfall in monsoon season of Chhattisgarh during the 100 years period 1901 to 2000

S. No.	Station	Mean rainfall	Standard deviation	Lowest Rainfall		Highest Rainfall	
				Amount	Year	Amount	Year
1.	Raipur	1158.3	283.5	683.0	1902	2051.3	1947
2.	Pendra Road	1139.6	244.1	683.8	1905	1761.4	1961
3.	Ambikapur	1356.5	275.6	815.4	1966	2067.5	1994
4.	Raigarh	1424.5	295.4	693.9	2000	2779.8	1961
5.	Jagdalpur	1218.4	254.2	671.1	1997	2061.0	1929
6.	Durg	1042.7	252.6	503.0	1988	1625.1	1937
7.	Jashpurnagar	1427.9	266.9	893.4	1979	2276.6	1946
8.	Sukma	1232.2	235.1	687.7	1997	1810.8	1925
9.	Rajnandgaon	1175.0	350.9	574.6	1966	2604.8	1961
10.	Bilaspur	1146.5	243.7	682.4	1965	2172.6	1961
11.	Chhattisgarh	1232.2	171.9	873.8	1987	1821.0	1961

*All rainfall figures shown in table are in mm

Chhattisgarh with 59772.4 sq km of forest area in year 2000 (Tripathy and Tripathy, 2003), which is 12.26% of total forest area in India, is rich in forest wealth. But, there is continuous decrease in forest cover during the last few decades and 50% of forest in Chattisgarh has become degraded forest.

In 1950, the people of Chhattisgarh were totally dependent on agricultural and forest products. Industrialization started in Chhattisgarh during Second Five Year Plan *i.e.*, 1955 onwards. Big industries like Bhilai Steel Plant, BALCO, NTPC Korba etc. were started after 1955. The industrial growth has taken place in Chhattisgarh in the second half of century only although it is very rich in minerals.

To understand the influence of deforestation and industrialization in Chhattisgarh during last few decades on rainfall of Chhattisgarh, a detailed study of century long (*i.e.*, from 1901 to 2000) summer monsoon rainfall series of Chhattisgarh state/sub-division based on data of important raingauge stations spread over the region has been made and the results have been presented in this note.

2.   The validity of any statistical analysis depends on the quality of the data used. The monthly rainfall data of 10 important raingauge stations spread over the Chhattisgarh state has been used for this study. Considering the total area of Chhattisgarh state which is 135194 sq km, some more stations could have been included in this study but, rainfall network in Chhattisgarh was found to be not very dense due to vast forest area and less development in the area. The year with missing data in some stations were very high and so such stations could not be included. However the data of stations used in this study are very reliable. The monthly rainfall data of Raipur, Pendra road, Ambikapur, Raigarh, Jagdalpur, Durg, Jashpurnagar, Sukma, Rajnandgaon and Bilaspur stations from the period 1901 to 2000 have been used to calculate the average summer monsoon rainfall of Chhattisgarh. The rainfall data for period 1901 to 1950 has been collected from the publication of India Meteorological Department (IMD) and for the period 1951 to 2000 data has been collected from Regional Meteorological Centre, Nagpur.

3.1. *Station rainfall characteristics of Chhattisgarh* - The characteristics of seasonal rainfall of various stations in Chhattisgarh are studied and are presented in Table 1. It is seen from Table 1 that, in Chhattisgarh the highest mean seasonal rainfall of 1427.9 mm was recorded at Jashpurnagar and the lowest mean seasonal rainfall of 1042.7 mm was recorded at Durg during the last century.

3.2. *Statistical properties of Chhattisgarh rainfall* - The mean summer monsoon rainfall of Chhattisgarh is 1232.2 mm which is 85.9 % of annual rainfall in the region. The standard deviation of monsoon rainfall series is 171.9 mm. The coefficient of variation is 13.95 %. The median value of monsoon rainfall is 1221.7 mm. The auto correlation coefficient of first lag for the series is –0.0246
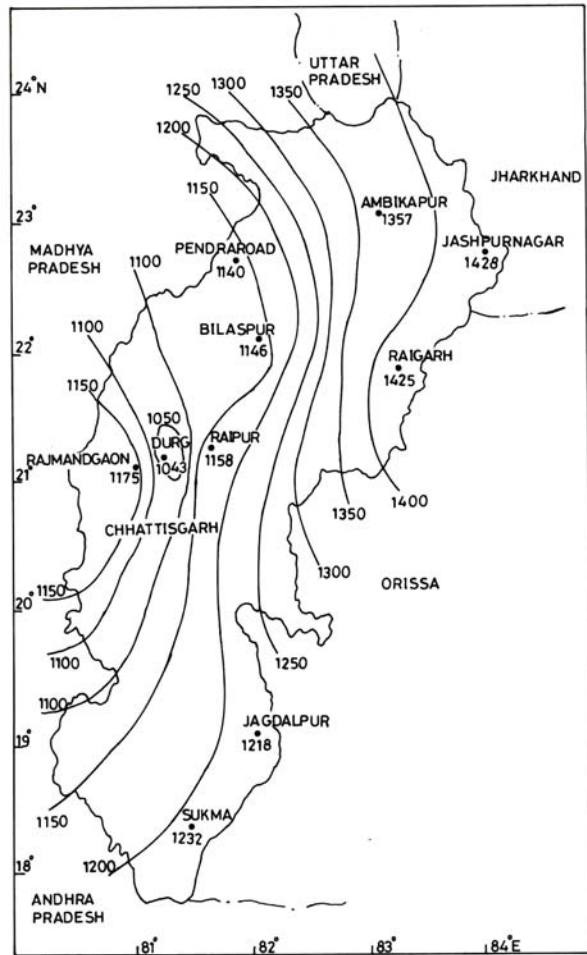
Fig. 1. Isohyets of 100 year mean monsoon rainfall of Chattisgarh

TABLE 2

Statistics of flood years of Chhattisgarh

S. No.	Year	Actual rainfall (mm)	Percentage departure from normal
1	1925	1618.2	31.3
2	1936	1602.8	30.0
3	1946	1488.6	20.8
4	1956	1490.6	21.0
5	1961	1821.0	47.8
6	1980	1569.4	27.4
7	1994	1527.6	24.0

TABLE 3

Statistics of drought years of Chhattisgarh

S. No.	Year	Actual rainfall (mm)	Percentage departure from normal
1	1941	976.1	-28.9
2	1966	930.8	-24.5
3	1974	902.5	-26.8
4	1979	975.1	-20.9
5	1987	873.8	-29.1
6	1998	992.2	-20.0
7	2000	960.1	-22.1

which is too low to suggest any persistence in the rainfall series. The frequency distribution of the time series was tested for normality by using Chi-square test and Chhattisgarh monsoon rainfall series was found to be Gaussian.

3.3. *Rainfall pattern in Chhattisgarh* - The 100 year mean seasonal rainfall of stations are plotted on a map of Chhattisgarh and isohyets are drawn in Fig. 1 to depict the spatial distribution of rainfall. It is observed that Jashpurnagar and Raigarh receive the highest rainfall whereas Durg station receives the lowest mean seasonal rainfall in Chhattisgarh. Thus, NE Chhattisgarh receives highest rainfall and it decreases towards west Chhattisgarh.

3.4. *Floods and droughts in Chhattisgarh* - As per IMD criteria, we identify flood (excess) if percentage departure is 20% or more from normal and drought (deficient) if percentage departure is -20% or -59%. Mooley and Parthasarthy (1983,1984) have defined standard deviate [$t_i = (R_i - R_m) / \sigma$] to identify flood and drought years. The flood and drought years with their statistical details as per IMD criteria are shown in Table 2 and Table 3.

It is seen from the tables that during the century there were 7 flood (excess) years and 7 drought (deficient) years in Chhattisgarh as per IMD criteria. The year 1961 was the severest flood year with percentage departure of 47.8%. The year 1987 was the severest drought year with percentage departure of −29.1 %.

3.5. *Sub period trend by Student's t-test* - In the present study Chhattisgarh monsoonal rainfall series of the period 1901 to 2000 has been broken into four equal periods, 1901-25, 1926-50, 1951-75 and 1976-2000. The significance of the difference of mean between two
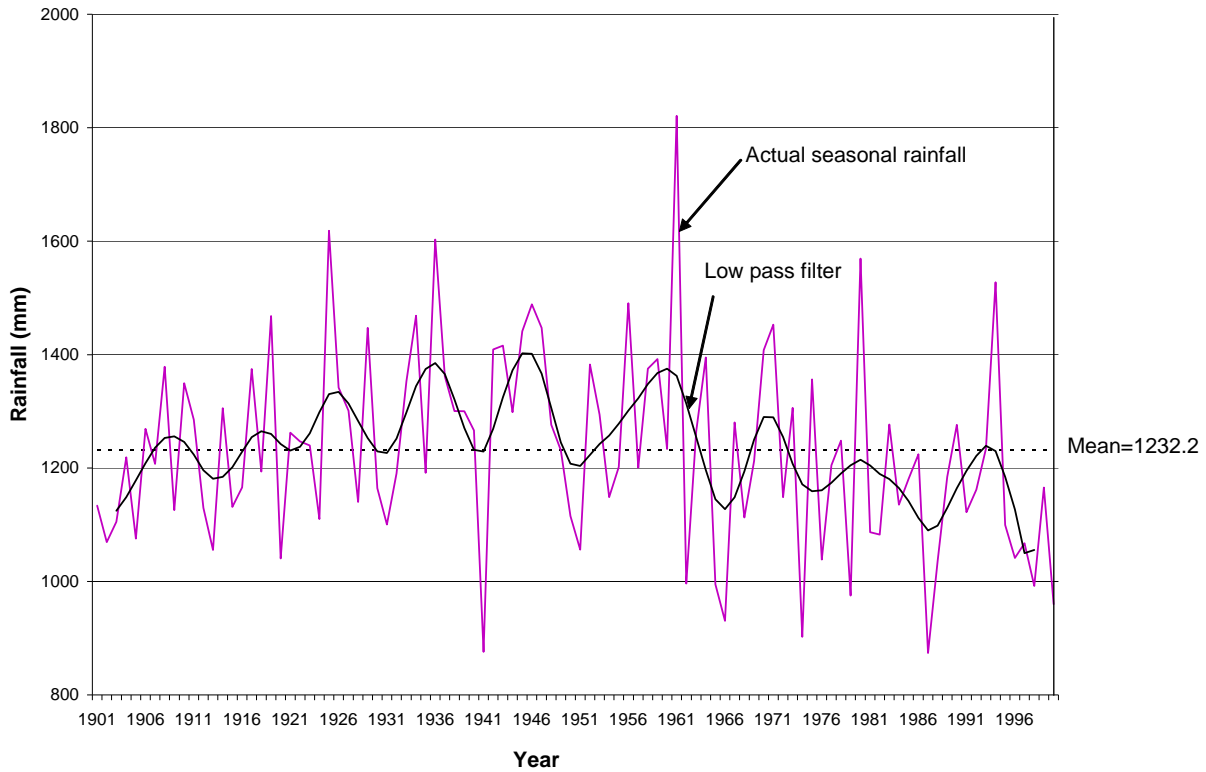
Fig. 2. Actual rainfall and Binomial Low pass filtered rainfall of Chhattisgarh

TABLE 4

Student's *t*-value for sub-period change in monsoon rainfall of Chhattisgarh

S. No.	First period		Second period		Difference of mean	% of change	Student's *t*-value
	Years	Mean	Years	Mean			
1.	1901-1925	1222.5	1926-1950	1301.2	+78.7	+6.44	-1.88
2.	1926-1950	1301.2	1951-1975	1254.3	-46.7	-3.59	+0.92
3.	1951-1975	1254.3	1976-2000	1150.7	-103.7	-8.27	+2.02

periods was tested by Student's *t*-test. Table 4 gives the statistics of the mean of two consecutive periods, their difference, percentage of change and Student's *t*-value which were tested at 95% significance level. It indicates that the increasing rainfall trend noticed during the period 1926 to 1950 is not statistically significant. However decreasing trend noticed during the period 1976 to 2000 is significant at 95% level.

3.6. *Rainfall trend in Chhattisgarh by Binomial Low - pass filter* - To understand the nature of the fluctuation or trend if any, the Chhattisgarh monsoon rainfall series has been subjected to the nine term Binomial low-pass filter (WMO, 1966). The filtered low-pass curve and actual rainfall curve of Chhattisgarh are shown in Fig. 2. It is observed from the figure that the low-pass filter has rising trend till 1950 and decreasing trend is noticed from

year 1960 to 2000. Thus, the occurrence of droughts is more in later half of the century *i.e.*, from 1950 to 2000, whereas floods are equally distributed in both half of the century.

3.7. *Periodicities in seasonal rainfall of Chhattisgarh* - The time series of Chhattisgarh monsoon rainfall has been subjected to power spectrum analysis to identify the periodicities in seasonal rainfall by following the method of Tuckey given in WMO Technical Note 79 (1966). For 100 year data serial correlation coefficients for 30 lags have been calculated. Then spectral density calculated and smoothed by appropriate weights. A cycle of 2.73 years has been detected from the spectrum analysis.

4.   The detailed statistical analysis of the Chhattisgarh summer monsoon rainfall during the period 1901-2000 enables us to highlight the following observational aspects:

(*i*)   The highest station rainfall of 2779.8 mm was recorded at Raigarh in 1961 and the lowest station rainfall of 503.0 mm at Durg in 1988 in Chhattisgarh during the last century.

(*ii*)   Isohyets drawn for 100 year mean rainfall shows that the NE part of Chhattisgarh receives the highest rainfall above 1400 mm which decreases slowly towards west where Durg receives less than 1050 mm seasonal rainfall. Thus, NE Chhattisgarh having more forest and hills receives the highest rainfall. The industrialized and urbanized area of west Chhattisgarh receives lowest rainfall in the region/state.

(*iii*) The average summer monsoon rainfall of Chhattisgarh is 1232.2 mm which is 85.9% of the annual rainfall. The coefficient of variation of monsoon rainfall is 13.95%. This indicates that variation in seasonal rainfall of Chhattisgarh is very less which is good from agricultural point of view. The monsoon rainfall of 1821.0 mm (*i.e.*, 147.8% of the normal) recorded in 1961 was highest and the monsoon rainfall 873.8 mm (*i.e.*, 70.9% of the normal) recorded in 1987 was the lowest rainfall in Chhattisgarh.

(*iv*) There are 7 deficient (droughts) and 7 excess (floods) rainfall years in 100 years period. The frequency of occurrence of droughts has increased during the recent time *i.e.*, 1970 to 2000. But, the frequency of occurrence of floods is almost same in both the halves of the century.

(*v*)   Student's *t*-test shows significant decreasing trend in rainfall of Chhattisgarh during the period 1951-75 to 1976-2000.

(*vi*) The trend analysis by Binomial low pass filter for summer monsoon rainfall of Chhattisgarh shows that increasing rainfall trend is observed during the period 1901 to 1950 and the decreasing rainfall trend from 1960 onwards.

(*vii*) The spectrum analysis shows 2.73 year cycle *i.e.*, Quasi-Biennial Oscillation in Chhattisgarh monsoon rainfall.

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