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Primary Article

Spatial And Temporal Analysis Of Rainfall Over Jharkhand, India (1901 - 2000)

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ABSTRACT

After the existence of Jharkhand state in 2000, there is no in-depth study for districts rainfall climatology, its variability and the changing pattern of rainfall using a long period of data is available for the state. About 75% of the agricultural production in Jharkhand is non-irrigated, showing the dependence of the state on monsoon rainfall. In the present study, based on monthly rainfall series of all the 24 districts of Jharkhand for the period 1901-2000 variability of rainfall during monsoon seasons and annual rainfall for Jharkhand state are presented. The study can form very useful information to the agriculture and water sectors of this state.

The analysis revealed that during 1901 to 1950 state has showed good rainfall activity than during 1951 to 2000. Variation in rainfall is mostly due to varied and undulating topography almost in all the districts. The maximum abnormality (>100%) in annual and seasonal rainfall was recorded during 1971-80, 1981-90 decades. Comparison of seasonality index for 1901-50, 1951-2000 and for the entire period 1901-2000 showed that SI has increased during 1951-2000. The long term mean annual rainfall based on 100 years data varied from 1136.8 mm over Koderma to 1542.5 mm over Pakur district.

Keywords:

Spatial and Temporal rainfall, Seasonal and Annual rainfall, Seasonality Index, Precipitation Ratio.

1. Introduction

Being a tropical country, India's agricultural planning and utilization of water mostly depends on monsoon rainfall. More than 75% of rainfall occurs during the monsoon season however, monsoon rainfall is uneven both in time and space, so it forms an important factor to evolve the rainfall analysis. Due to change in climate, the frequency of rain has become unpredictable causing floods in one part and drought in the other part of the country. As it is rightly said by Gadgil (1986), rainfall is a crucial agro-climatological factor in the seasonally arid parts and its analysis is an important perquisite for agricultural planning in India.

In view of the above, the present study deals with the study of rainfall characteristics of the Jharkhand State, which falls in the direct path of monsoon disturbances originating from the Bay of Bengal.However, Jharkhand receives only about 1200-1300 mm of rainfall every year and the rains are erratic in many areas (Sharan, 2005). Although Jharkhand has not been classified to be a severely drought prone area, drought still remains a recurrent phenomenon in Jharkhand. Twelve of the 24 districts of the state, covering 43% of the total land area, are covered under the Drought Prone Areas Programme (DPAP). Statistics of Drought Years for Jharkhand state during 1875 – 2010 (Based on monsoon rainfall) has shown increased frequency of Drought years in Jharkhand in last decade (A draft on Jharkhand State Disaster Management Plan, 2011).

Considering the above, after its existence in Nov. 2000, the Water Resources Department of Jharkhand State Government has undertaken survey of State Water Resources in 2011 for better water management practices. On 28 Feb.2011, a news was published in Down to Earth Journal wherein it was brought to the notice that

The state's groundwater directorate confirms what the study has observed:

Jharkhand's water table dropped by an average of 3 m between 2009 and 2010, from 17 m to 20 m. Till 8 years ago, the decline in water table levels before and after the monsoon was in centimetres. Now it is in metres, said S L S Jageshwar, Director of groundwater and minor irrigation. Many districts in Jharkhand are facing an acute water shortage. "Rapid urbanisation after Jharkhand became a separate state in 2000 is the main reason for the drastic fall in the water table," Jageshwar explained. According to his department's statistics, groundwater extraction (last recorded in 2004) is as high as 67% in Godda district where the water table declined by 5.15 m between 2009 and 2010. "This trend is dangerous as Jharkhand does not have deep aquifers found in the Gangetic plains, and the existing ones in the rocky terrain are porous; they will soon become dry due to overexploitation," he added.

However, so far there is no in-depth study for districts rainfall climatology, its variability and the changing pattern of rainfall using a long period of data is available for the Jharkhand state. In the present paper, monthly rainfall series of all the 24 districts of Jharkhand for the period 1901- 2000 has been studied with special reference to temporal and spatial distribution of rainfall and its variability through different seasons, years and decades for each of the 24 districts of Jharkhand. The study will be useful for better water management practices and form very useful information to the agriculture and water sectors of this state.

2. About Jharkhand State

Jharkhand is the 28th state of the Indian Union that was brought into existence by the Bihar reorganization Act on 15 November 2000. Geographically, the state is located in the eastern part of India covering 79714 sq.km of area. It is bordered by Bihar in the north, Odisha (Orissa) in the south, West Bengal to the east and Chattisgarh and part of Uttar Pradesh to the west. Tropic of Cancer passes through Kanke, few kilometers away from Ranchi, the capital of Jharkhand, making it the only state in India wherein Tropic of Cancer passes right through the centre (see Fig.1). Due to the climate variability and varied topographical features, the entire state has been divided into 24 districts and 38 small subdivisions.

2.1 Physiographic features of the state

Jharkhand is one of the richest state in the country in terms of natural resources The state having heterogeneous landscape, is located at an altitude up to 1142 m above msl and having humid to sub-humid tropical monsoon type of climate. The state has a number of agro-climatic/physiographic constraints viz. undulating terrain, shallow soil depth, low water retentive capacity and poor fertility of soils, fragmented holdings, high intensity (causing severe soil erosion) often erratically distributed (prolonged dry spells) rainfall and very meager irrigation potential (10-12%) etc.

The physiography of Jharkhand is largely defined by the Chhota Nagpur Plateau (CNP) region and other distinct geomorphic domains (see Fig.2). The CNP region extends from the western part of state to the West Bengal border in the east. This has been further divided into a number of divisions based on geomorphic parameters viz. variation in relief, drainage and geology into the following geomorphic domains:-

a) Ranchi Plateau: This is the largest part of the Chhota Nagpur Plateau having an average elevation of about 700 m above msl with many waterfalls at the edges.
b) Hazaribagh Plateau : This lies to the north of Ranchi Plateau and is separated by East-West running Damuda valley measuring about 64 km (east-west) by 24 km (north-south) with an average elevation of 610 m.
c) Koderma Plateau (or Hazaribagh Lower Plateau) : The northern face of this plateau, elevated 244 m (800 ft) above the plains of Bihar has the appearance of a range of hills but in reality it is the edge of a plateau. The southern boundary consists of the face of the higher plateau comprising Parasnath Hills.
d) The Pat Region : The Netarhat Planation Surface locally known as PATS has also been referred to as Western Ranchi Plateau. This is the highest plateau region of the Chhota Nagpur Plateau with an average height of 1000 m the highest point being 1164 m.
e) Simdega-Singhbhum Uplands : The Ranchi Plateau gradually slopes down towards south east into Singhbhum region. This region is characterized by highly dissected rugged hills (600-900m), steep hill sides, cliffs and narrow valleys from where Subarnrekha river flows.
f) Manbhum Area : The lowest step of the Chota Nagpur Plateau, the Manbhum area covers Dhanbad and part of Bokaro district. This area has a general elevation of 300 m and it consists of undulating land with scattered hills.
g) Palamau Plateau : It lies at a lower height than the surrounding areas of Chota Nagpur Plateau. This upland intrudes the Ranchi plateau on the east and merges with the Pat Region in the south. On the west are the Surguja highlands of Chhattishgarh and Sonbhadra district of Uttar Pradesh. On the north-western corner, the Son River forms the state boundary.
h) Rajmahal Plateau : It is located 150-200 m above msl in Shaebganj and Pakur districts of the eastern part of the state of Jharkhand.
i) Damodar Valley : The Damodar Valley is a trough between the Ranchi and Hazaribagh plateaus resulting from enormous fracture.

The above detailed physiographic features define the rainfall over the state and are responsible for erratic distribution of rainfall over the state.

2.2 Soil Type : Majority of Jharkhand state is covered by forest land. The state consists of the soil formed by the break down of rocks and stones. The composition of soil in the state is categorized under the following heads –

a)Red Soil - Found commonly in the Rajmahal area and the Damodar Valley.
b)Micacious soil - it is a type of soil that contains particles of Mica and is found commonly in the Koderma, Jhumeritilaiya, Barkagaon and areas surrounding the Mandar Hill.
c)Sandy soil - commonly found in Hazaribagh and Dhanbad.
d)Black soil - Seen in Rajmahal area.
e)Laterite soil - Generally found in the Western part of Ranchi, Palamu and parts of Santhal Parganas and Singhbhum.

2.3 River Systems As shown in Fig.2, rivers Damodar, Subarnarekha, Brahmani-Baitarni, Ajoy, Mayurakshi, North and South Koel, Son, Punpun, etc along with their tributaries form the major river systems of the state. The entire river system is highly associated with the physical features of the state.

3. Data Used and Methodology

Monthly Rainfall data for the period of 1901 to 2000 of all the 24 districts in Jharkhand state obtained from the National Data Centre (NDC), India Meteorology Department (IMD) forms the major data source.

On the basis of monthly rainfall data for the state, long term mean monthly, seasonal and annual and decadal rainfall was calculated for all the districts and the state as a whole for the period of 1901 to 2000 along with the standard deviation and coefficient of variability. Different statistical parameters viz. kurtosis, skewness (significant at 95% level) positive and negative deviations, monsoon precipitation index, seasonality index were also computed in order to know the trend of monsoon rainfall over the state.

4. Mean Rainfall Characteristics

The southwest monsoon normally advances over the state and adjoining areas by around 10 to 15 June and establishes firmly over the entire region by the end of June. It withdraws from the region by about second week of October comprising 100 to 200 days of rainy season (Wadood and Kumari, 2009) with the normal duration of 140 days. The state receives heavy to very heavy rainfalls when different low pressure systems like depressions, cyclonic storms, etc. originating in the Bay of Bengal, cross the Indian coast and move in a north to northeasterly direction.

4.1 Monthly Rainfall Variation

Table 1 gives the district wise monthly, seasonal and annual distribution of rainfall. It is seen from this table that all the districts have recorded 80% to 87% of their respective annual rainfall during Jun.-Sept. monsoon months. The variation of monthly rainfall over the 24 districts of Jharkhand showed that the intensity of rainfall gradually goes on increasing from May to July (see Fig.3) with the enhancement of southwest monsoon activity over the region. It decreases sharply by the month of October. July is the highest rainfall recording month in all the districts wherein Simdega district recorded highest average July rainfall followed by Khunti district. Districts in the northern part of the states viz. Godda, Deogarh, Koderma recorded comparatively less average July rainfall.

It is interesting to mention that Garhwa and Palamau the northwestern districts have recorded highest Jun.-Sept. percent rainfall than the other districts with less coefficient of variation. However, spatial distribution of actual average rainfall during monsoon months showed that Pakur, Simdega and Khunti districts experienced heavy rainfall (see Fig.4) and Godda, Deogarh, Koderma and Bokaro districts recorded less than 1000 mm of rainfall. The explanation for the heavy rainfall is that Pakur, Simdega and Khunti districts fall to the windward side of the Pakur Upland (see Fig.2) and Simdega and Ranchi Plateau respectively. Similarly, less rainfall received by Godda, Deogarh, Koderma and Bokaro districts can be explained. Godda district falls to the leeward side of Pakur Upland, Deogarh and Koderma districts to the Deogarh and Giridih Uplands and Bokaro to the lee side of Damodar Valley (see Fig.2). Lohardaga district which is surrounded from all sides by Ranchi, Hazaribagh Plateaus experienced less rainfall.

The spatial distribution of average annual rainfall is more or less same as that of Jun-Sept. rainfall with increase in magnitude of rainfall due to October month rainfall contribution. So far coefficient of variation of rainfall during Jun-Sept and annual is concerned; it is least for Ranchi district and high for Ramgarh district which is located in close vicinity of Ranchi district. This shows that rainfall is highly associated with the topography of the region.

4.2 Annual and Seasonal Rainfall Variation (1901-2000)

Table 2 gives the variation of rainfall for different seasons with coefficient of variation (CV) for all the districts. It is evident from the CV given in Table 2 that monsoon rainfall is reflected in annual rainfall. CV is more than 100% during non-monsoon periods of Jan to Apr and Oct to Dec. in all the districts than during the monsoon season. Similarly, skewness and kurtosis were less or negative (in high rainfall districts) during the monsoon season as it is the main rainfall season over the state.

4.2.1 Temporal Variation of Rainfall

The year to year variation in rainfall gives an idea about the changes in rainfall pattern over the regime. This helps for better water management and proper irrigation to cropping. In order to know the increasing or decreasing trend of rainfall during the 100 years period from 1901-2000, second degree polynomial distribution was fitted. It is seen that there was noteworthy decrease in rainfall activity during 1921 to 1980 periods in the following districts – Deoghar, Dhanbad, Godda, Khunti, Koderma, Pakur and Sahebganj. The Yearly and decadal variation of annual and seasonal rainfall showed the decreasing trend in 12 districts and increasing trend in 6 districts (see Table 3) and in 6 districts there was no noteworthy increase or decrease in rainfall.

It is also seen that average annual and seasonal rainfall was higher during 1901 to 1950 than during 1951 to 2000 period especially Koderma, Deogarh, Palamau, Garhwa districts have shown decrease in rainfall during the second 50-years period. Most of the districts have recorded <1000 mm of rainfall during Jun-Sept monsoon season. CV for annual rainfall ranged 4.4% (Dist. Singbhum West) to 37% (Dist. Bokaro) during 1901 to 1950 period and 8.6% (Dist. Ranchi) to 45.0% (Dist. Gumla) during 1951 to 2000. Similarly for seasonal rainfall, CV ranged 9.1% (Dist. Simdega) to 36.5% (Dist. Bokaro) during 1901 to 1950 period and 6.7% (Dist. Lohardaga) to 54.3% (Dist. Giridih) during 1951 to 2000. This shows that there is decrease in rainfall activity during 1951 to 2000 period although the last decade 1991-2000 has shown little increasing trend this is to be confirmed by the recent data for the period 2001 to 2012. It is to be mentioned here that results obtained for 1971-1980 decade may not be treated as final due to missing rainfall data for 3-4 years almost for all the districts.

In order to know the intensity of seasonal and annual rainfall under the undulating terrain conditions in different districts of Jharkhand, the trend of change in different levels (<200 mm, 200-400 mm, 400-600 mm and more than 600 mm) has been studied for different decades. It is observed that almost all the districts showed the highest frequency distribution of <200 mm ranging from 40 to 95 during the annual rainfall. On an average 15-20 events were recorded in the range of 200-400 mm and 2-10 events in the range of 400-600 mm. The frequency of recording frequency distribution >600 mm was only 1-2%. During the monsoon season all the districts showed higher frequency distribution in the range of 200-400 mm and there was reduction in the frequency <200 mm.

4.3 Annual and Seasonal Maximum Rainfall Variation

The above annual and seasonal rainfall statistics shows that there is great variation in rainfall in different districts of Jharkhand. As seen from Table 1, the average annual rainfall during the winter months viz. January to February are very less, and goes on increasing by the end of May. During the monsoon months of June to September, there is substantial increase in the annual and seasonal rainfall with highest in the month of July. With the advance of post-monsoon season, annual rainfall goes on decreasing.

As mentioned above, maximum annual rainfall values have occurred almost in all the months of the year. However, their magnitude and intensity is higher during the monsoon season. During the 100 year period (1901 to 2000), about 13-15 years with minimum and with maximum rainfall were observed as indicated in Tables 4. The low and high values of annual maximum rainfall during different months and seasons along with their year of occurrence and the district are given in Table 5. The time and duration of the seasons' high rainfall at a place or watershed is most important for the planning and design of agriculture or water managements. Figs.5 and 6 show the spatial distribution of seasonal and annual maximum rainfall for 24 districts in Jharkhand. It is seen from these figures that highest seasonal and annual maximum rainfall has been recorded by Giridih district. During Jun-Sept. monsoon season, Simdega and Pakur districts recorded second highest maximum rainfall. The lowest maximum (<1600mm) during this season was recorded by Deogarh, Garhwa and Palamau districts. Pakur district recorded second highest annual maximum rainfall (>2500 mm). The third highest maximum rainfall in case of annual rainfall was recorded by Jamtara, Simdega, Khunti and Lohardaga districts in the range of 2300-2500 mm). Garhwa district recorded lowest annual rainfall less than 1700 mm.

4.4 Precipitation Ratio (PR)

From the foregoing temporal and spatial distribution of rainfall over the Jharkhand, it is seen that rainfall is highly variable in space and time. The abnormalities of rainfall at any location may be brought by a simple ratio of precipitation. It is the difference between maximum and minimum rainfall of the annual rainfall series expressed in terms of mean.

$$P_R = \frac{(P_{Max} - P_{Min})}{P_{MAR}} \times 100 \qquad \text{.......... (1)}$$

Where,
P_R = Precipitation Ratio
P_{Max} = Maximum mean annual rainfall
P_{Min} = Minimum mean annual rainfall
P_{MAR} = Mean annual rainfall

This ratio may give the stability of rainfall with special relationship. Higher the ratio, higher is the abnormality in rainfall and vice versa (Rathod and Aruchamy, 2010). The minimum and maximum precipitation ratios for different decades were worked out for all the districts. It is seen that Precipitation ratio i.e. maximum abnormality for annual rainfall ranged from 8.5 (1971-80, Garhwa) to 167.8 (1951-60, Giridih) and for seasonal rainfall it ranged from 1.6 (1971-80, Garhwa) to 191.9 (1951-60, Giridih) (see Table 6).

This is mostly associated with the topographic features and drought seasons of 1972 and 1978. It is also seen that many districts have shown high precipitation ratio during annual and seasonal rainfall (>100) showing high abnormality. The low values of PR obtained for Garhwa district are due to non availability of rainfall during 1972-1974. Therefore, the second low PR values obtained for annual rainfall and seasonal rainfall were 15.4 (1921-30) for Palamau and 17.9 (1951-60) by Lohardaga district respectively.

4.5 Monsoon Precipitation Index (MPI)

Moetasim Ashfaq et al (2009) defined the precipitation index as the departure of rainfall from the climatological means (1961–1990), averaged over land points between 70 - 90E and 5–25N. Calculation of MPI is useful for both agricultural and hydrological applications. Since MPI is not adversely affected by the topography it gives us an idea about spatial variation of monsoon rainfall over different topographical regions. Higher the MPI, lesser is the rainfall variation at individual district. In the present study on the basis of available monthly rainfall data, monsoon precipitation index (MPI) has been calculated as,

$$\text{Monsoon Precipitation Index (MPI)} = \frac{\text{Annual Range}}{\text{Total Annual Rainfall}} \qquad \dots (2)$$

Where, Annual Range = (Monsoon rainfall – Non-monsoon rainfall)

MPI in case of 24 districts in Jharkhand varied from 0.1 (Dists: Godda, Ramgarh in 1929 and 1979) to 1.0. The lowest MPI of 0.1 to 0.3 was recorded mostly during drought years of 1903, 1906, 1917, 1929, 1979) when the state received very less rainfall during the monsoon months.

4.6 Seasonality Index (SI)

The changing pattern of rainfall is also investigated by computing Seasonality Index of rainfall. The relative seasonality of rainfall represents the degree of variability in monthly rainfall throughout the year (Walter, 1967; Walsh and Lawer 1981; Livada and Asimakopoulos, 2005; Adejuwon , 2012). Spatial distribution of precipitation seasonality in the United States was studied by Finkelstein and Truppi (1991). Markham (1970) has proposed a quantities technique for measuring precipitation seasonality based on vector analysis. The understanding of seasonality pattern of precipitation and also identifying changes in seasonality index helps in identifying the rainfall regimes based on the monthly distribution of rainfall and is also very useful for agricultural planning.

In order to define the seasonal contrasts, the seasonality index (SI) (Walsh and Lawer, 1981; Kanellopoulou, 2002), which is a function of mean monthly and annual rainfall, is computed using the following formula:

$$\overline{SI} = \frac{1}{\overline{R}} \sum_{n=1}^{n=12} \left| X_n - \frac{\overline{R}}{12} \right| \quad \text{..... (3)}$$

where *Xn* is the mean rainfall of month n and R is the mean annual rainfall.

Theoretically, the SI can vary from zero (if all the months have equal rainfall) to 1.83 (if all the rainfall occurs in one month). Table 7 shows the different class limits of SI and representative rainfall regimes (Kanellopoulou, 2002). Though the method uses the distribution of rainfall for all the 12 months, the index as table identifies the seasonal pattern when the value is more than 0.6. From Table 7, it is seen that the lower seasonality index value indicate better distribution of monthly rainfall among the months of the year.

To investigate the changes in rainfall pattern over the Jharkhand, the seasonality index was computed for all the 24 districts for two different periods, viz., a)1901–1950 and b)1951–2000 and for the entire period 1901-2000 of and compared the changes between these periods. Fig.15 shows the seasonality index during 1901–1950 and 1951–2000 periods.

The maximum SI value is over Garhwa, Palamau, Chatra and Simdega districts in both the periods 1901–1950 and 1951–2000 and entire 1901-2000 period. It is 1.04 to 1.07 during 1901-1950 and 1901-2000 and 1.04 to 1.11 during 1951-2000 period indicating most of the rain occurred in the northwestern and southwestern parts of Jharkhand in three months or less than that (see Fig.7). The three districts, Koderma, Latehar and Ranchi have SI value between 1.0 to 1.03 during 1901-1950 and 1951-2000. However during the entire period of 1901-2000 six districts, viz. Koderma, Giridih, Ramgarh, Bokaro, Latehar and Ranchi recorded SI values ranged 1.0 to 1.03. This indicates that only in these districts rainfall was markedly seasonal with rainfall evenly distributed in 3–4 months.

The spatial distribution of SI also showed that lower value of SI was in the range of 0.91 to 0.99 during 1901-1950, 0.94 to 0.99 during 1951-2000 and 1901-2000 indicating the type of rainfall regime with shorter dry season and high value indicating most of the rain occurs within few months (2–3 months). An increasing trend in seasonality index is thus an indicator of alarming situation for the agriculture.

5. Summary and Conclusion

Analysis of rainfall data of 100 years (1901-2000) over Jharkhand, a newly established state in eastern India, plays a significant role in the industrial and agricultural contribution and in the overall growth of the country. The analysis included variability of rainfall, trends in rainfall pattern and changes in spatial and temporal patterns of seasonality index. The impact of climate changes on temporal and spatial patterns over smaller spatial scales is clearly noticed in this analysis. The analysis revealed the following important results :-

1.Southwest monsoon season (June to September) is the main rainfall season for all the districts contributing more than 80% of the annual rainfall.
2.The long term mean annual rainfall based on 100 years data varied from 1136.8 mm over Koderma to 1542.5 mm over Pakur district whereas for seasonal rainfall the averaged varied from 934.4 mm over Godda to 1295.6 mm over Simdega district. In the year 2010, the state experienced very low and uneven rainfall which adversely affected the agriculture production.
3.Variation in annual rainfall of all the 24 districts showed that on an average, annual rainfall varies between 600 mm to 2000 mm. Six districts have recorded annual maximum rainfall greater than 2400 mm (see Fig.8). These are

a) Giridih (2805.7 mm, 1957) b) Pakur (2524.7 mm, 2000)
c) Khunti (2469.1 mm, (1917) d) Simdega (2464.6 mm, 1994)
e) Jamtara (2447.9 mm, 1959) f) Lohardaga (2441.0 mm, 1936)

Years which have recorded less than 600 mm of annual rainfall have sparse data.

The state as a whole received average annual rainfall of the order of 1315 mm during 1901 to 2000 period.

4.Comparison of CV with respect to their annual and seasonal rainfall during different decades showed that after 1950, there is increase in annual and seasonal CV for all the decades during 1951-2000 period ranging between 8.6% (Ranchi, 1981-90) to 44.8% (Giridih, 1951-60) for annual and 6.7% (Lohardaga, 1951-60) to 54.3% (Giridih, 1951-60) for season rainfall.

5.In order to have an idea about the distribution of spatial rainfall over different topographical region, monsoon precipitation index (MPI) was calculated for each of the district. It is seen that the average MPI varied from 0.1 to 1.0. The maximum abnormality (>100%) in annual and seasonal rainfall was recorded during 1971-80, 1981-90 decades.

6.Comparison of seasonality index for 1901-50, 1951-2000 and for the entire period 1901-2000 showed that SI has increased during 1951-2000. Districts which experienced heavy rainfall, recorded high SI where almost all the rain occurs in 1 or 2 months.

The present study was based on the rainfall data for 1901 to 2000. However, a considerable increase in average monthly maximum rainfall pattern with high variability, in recent decades has been noticed by Wadood and Kumari (2009) mentioning that it has enhanced the agricultural problems in Jharkhand. The quantitative increase in rainfall may be considered as a positive change in Jharkhand but it was associated with simultaneous increase in variability also (CV 13% in 1901-1910 to 24% in 1971-1980 and 1991-2000) which increased the level of uncertainty and possibility of intermittent prolonged dry spells. The increase in annual rainfall was mostly confined in the monsoon period. High intensity rainfall, often received in monsoon months, intensify the problem of soil erosion. Uncertainty on the dates of monsoon onset and its withdrawal also puts a great problem before the farmers. The most warning situation for the agriculture and water sectors is the increasing trends in the seasonality index in most of the districts. Spatial analysis of both the trends in monthly total rainfall and trends in seasonality index will help the planners of all sectors depending on rainfall in identifying the zones in Jharkhand for better management and planning.

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Table 1 : Mean monthly, seasonal and annual rainfall over different districts of Jharkhand

Months	Districts											
	Bokaro	Chatra	Deogarh	Dhanbad	Dumka	Garhwa	Giridih	Godda	Gumla	Hazaribagh	Jamtara	Khunti
January	14.9	20.3	15.7	14.0	13.9	22.6	16.4	12.9	25.6	20.1	14.5	22.8
February	20.8	23.8	18.3	23.6	18.5	27.5	20.9	14.5	34.6	24.8	21.7	31.3
March	18.2	15.9	14.6	20.5	18.2	16.0	14.7	12.1	23.6	18.2	21.5	25.0
April	17.2	9.2	19.5	20.8	26.0	7.8	16.1	19.5	20.2	15.7	20.7	18.5
May	45.7	23.3	55.6	51.9	76.9	15.4	42.7	63.7	41.7	41.2	60.4	45.6
June	180.5	170.7	188.8	204.5	223.2	140.4	184.0	186.6	197.2	186.1	223.3	228.7
July	326.9	335.3	312.6	336.0	349.9	336.1	325.4	277.4	370.1	329.5	336.9	387.8
August	297.3	329.5	281.2	321.8	321.4	343.5	287.7	258.0	365.6	321.7	324.9	395.6
September	235.6	226.1	219.0	243.2	263.8	216.3	224.6	212.4	231.1	228.2	234.8	246.9
October	83.7	62.7	87.2	91.2	111.8	50.4	83.5	79.9	81.2	83.4	99.7	83.4
November	11.4	10.4	10.9	10.5	13.4	11.4	9.8	8.1	16.2	12.3	12.0	18.6
December	4.3	5.3	3.8	4.4	3.9	5.0	3.7	3.9	6.8	5.4	3.0	7.2
Annual	1188.5	1232.5	1227.2	1342.4	1440.9	1192.4	1229.5	1149	1413.9	1286.6	1373.4	1511.4
Seasons												
Jan - Feb	34.5	44.1	34	37.6	32.4	50.1	37.3	27.4	60.2	44.9	36.2	54.1
Mar - May	76.4	48.4	89.7	93.2	121.1	39.2	73.5	95.3	85.5	75.1	102.6	89.1
Jun - Sept	982.3	1061.6	1001.6	1105.5	1158.3	1036.3	1021.7	934.4	1164	1065.5	1119.9	1259
Oct - Dec	95.3	78.4	101.9	106.1	129.1	66.8	97.0	91.9	104.2	101.1	114.7	109.2
Monsoon Season % w.r.t annual												
Jun - Sept	83	86	82	82	80	87	83	81	82	83	82	83

Table 1 contd....

Months	Districts											
	Koderma	Latehar	Lohardaga	Pakur	Palamau	Ramgarh	Ranchi	Sahebganj	Seraikela	Simdega	Singhbum (East)	Singhbum (West)
January	18.1	20.8	24.0	13.2	21.7	17.0	21.1	11.9	15.6	20.5	15.5	18.7
February	24.2	30.0	31.3	16.6	25.2	28.0	30.5	14.2	26.2	25.3	25.7	29.0
March	13.3	20.4	26.4	17.1	15.6	19.6	22.0	14.2	20.6	17.3	22.7	22.3
April	9.2	11.9	19.3	31.2	9.8	19.0	21.0	27.8	24.8	16.9	35.0	25.8
May	29.3	29.0	35.6	94.2	17.7	48.4	48.9	85.4	57.1	36.2	78.6	63.0
June	167.0	179.6	182.7	240.6	153.5	213.2	205.8	234.3	215.6	217.6	229.4	209.0
July	280.2	364.1	346.5	356.0	335.1	342.6	347.4	340.7	329.9	437.8	327.8	348.3
August	301.4	352.9	317.2	335.3	348.1	312.8	338.8	311.6	328.0	394.4	325.5	341.5
September	211.1	226.4	204.7	299.6	214.8	218.4	227.6	291.6	218.9	245.8	230.7	218.5
October	67.3	70.4	78.4	120.7	54.3	80.4	80.8	100.4	69.1	69.0	80.9	74.6
November	10.4	14.2	17.5	13.5	11.2	11.4	14.6	10.5	12.6	12.1	15.2	14.7
December	5.3	7.2	7.3	4.5	5.6	6.7	6.5	4.0	4.7	6.0	4.9	4.8
Annual	1136.8	1326.9	1290.9	1542.5	1212.6	1317.5	1365.0	1446.6	1323.1	1498.9	1391.9	1370.2
Seasons												
Jan - Feb	42.3	50.8	55.3	29.8	46.9	45.0	51.6	26.1	41.8	45.8	41.2	47.7
Mar - May	51.8	61.3	81.3	142.5	43.1	87.0	91.9	127.4	102.5	70.4	136.3	111.1
Jun - Sept	959.7	1123.0	1051.1	1231.5	1051.5	1087.0	1119.6	1178.2	1092.4	1295.6	1113.4	1117.3
Oct - Dec	83.0	91.8	103.2	138.7	71.1	98.5	101.9	114.9	86.4	87.1	101.0	94.1
Monsoon Season % w.r.t annual												
Jun - Sept	84	85	81	80	87	83	82	81	83	86	80	82

Table 2 : Descriptive statistical values of monthly, seasonal and annual rainfall of the districts in Jharkhand (1901-2000)

Parameters	Winter		Pre-Monsoon			Monsoon				Post-Monsoon			Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	
						BOKARO							
Mean(mm)	14.9	20.8	18.2	17.2	45.7	180.5	326.9	297.3	235.6	83.7	11.4	4.3	1188.5
S.D.	21.3	27.7	27.7	17.0	36.8	83.8	138.7	102.9	111.1	80.4	28.9	9.3	338.3
C.V.(%)	143.6	133.2	151.8	99.0	80.7	46.4	42.4	34.6	47.2	96.1	253.0	217.5	28.5
Skewness	2.2	2.0	3.1	1.1	1.4	1.1	1.3	0.4	0.6	1.4	4.6	2.6	-0.4
Kurtosis	5.2	3.7	13.5	0.5	2.7	2.4	3.3	0.1	0.2	1.5	25.2	6.6	1.4
						CHATRA							
Mean(mm)	20.3	23.8	15.9	9.2	23.3	170.7	335.3	329.5	226.1	62.7	10.4	5.3	1232.0
S.D.	24.9	25.9	20.7	14.2	27.0	119.8	129.1	118.4	113.1	63.2	21.7	11.8	277.8
C.V.(%)	122.7	108.9	130.4	154.5	116.1	70.2	38.5	35.9	50.1	100.7	209.8	223.6	22.5
Skewness	1.5	1.4	1.7	3.6	1.8	1.0	0.8	0.7	0.9	1.7	3.1	3.4	0.5
Kurtosis	1.5	1.3	2.6	20.1	4.0	0.9	0.9	0.5	1.2	3.9	11.5	13.6	0.0
						DEOGARH							
Mean(mm)	15.7	18.3	14.6	19.5	55.6	188.8	312.6	281.2	219.0	87.2	10.9	3.8	1218.2
S.D.	23.2	23.1	23.3	20.6	40.2	103.4	93.9	98.0	107.7	88.1	21.5	8.5	267.7
C.V.(%)	147.8	126.3	160.3	105.4	72.3	54.7	30.0	34.8	49.2	101.1	197.8	223.5	22.0
Skewness	2.3	2.6	2.5	1.4	1.2	1.5	0.1	1.0	1.8	1.9	3.2	3.2	0.0
Kurtosis	5.5	8.4	6.7	1.8	1.8	3.6	-0.3	1.2	8.0	4.6	12.8	12.5	-0.1
						DHANBAD							
Mean(mm)	14.0	23.6	20.5	20.8	51.9	204.5	336.0	321.8	243.2	91.2	10.5	4.4	1338.8
S.D.	17.1	27.9	25.7	20.4	33.2	100.7	102.1	96.2	106.3	78.6	20.9	8.7	238.4
C.V.(%)	122.0	118.3	125.2	98.0	63.9	49.2	30.4	29.9	43.7	86.2	198.8	200.5	17.8
Skewness	2.2	2.2	2.2	1.4	1.0	1.4	0.4	0.3	1.2	1.5	3.3	2.2	0.1
Kurtosis	7.1	5.5	5.8	2.1	2.0	2.8	0.1	-0.4	2.6	2.9	13.5	4.5	-0.5
						DUMKA							
Mean(mm)	13.9	18.5	18.2	26.0	76.9	223.2	349.9	321.4	263.8	111.8	13.4	3.9	1422.6
S.D.	20.8	22.3	24.3	27.4	52.8	121.2	117.0	103.5	117.2	103.9	24.7	9.9	325.8
C.V.(%)	149.1	120.6	133.7	105.5	68.7	54.3	33.5	32.2	44.4	93.0	183.9	253.9	22.9
Skewness	2.9	2.5	1.8	2.4	1.4	1.4	0.6	0.8	1.2	2.6	2.7	3.7	0.0
Kurtosis	11.9	8.5	2.7	8.7	2.2	2.6	0.1	1.1	3.0	10.5	8.0	14.1	0.8
						GARHWA							
Mean(mm)	22.6	27.5	16.0	7.8	15.4	140.4	336.1	343.5	216.3	50.4	11.4	5.0	1192.4
S.D.	27.3	32.6	21.8	10.3	18.2	92.4	115.5	110.5	94.2	47.6	24.7	11.6	226.9
C.V.(%)	120.9	118.8	135.9	131.2	117.9	65.8	34.4	32.2	43.5	94.3	216.4	231.0	19.0
Skewness	1.6	1.9	2.4	1.8	1.5	1.3	0.2	0.2	0.5	0.9	2.9	3.2	-0.2
Kurtosis	2.2	3.8	8.1	3.0	1.3	1.7	-0.1	-0.4	0.1	-0.2	8.2	10.9	0.3
						GIRIDIH							
Mean(mm)	16.4	20.9	14.7	16.1	42.7	184.0	325.4	287.7	224.6	83.5	9.8	3.7	1216.1
S.D.	23.5	25.8	22.7	17.7	33.3	113.5	143.8	96.7	97.9	83.6	20.6	7.9	312.8
C.V.(%)	143.7	123.5	154.3	110.1	78.0	61.7	44.2	33.6	43.6	100.1	211.3	211.7	25.7
Skewness	2.1	2.0	2.8	1.4	1.2	1.5	2.1	0.2	1.2	2.1	3.0	2.8	1.2
Kurtosis	5.1	4.2	9.5	1.8	1.6	2.7	9.7	-0.9	2.9	5.8	9.7	8.8	6.4
						GODDA							
Mean(mm)	12.9	14.5	12.1	19.5	63.7	186.6	277.4	258.0	212.4	79.9	8.1	3.9	1139.6
S.D.	19.3	18.1	16.7	20.7	47.7	106.2	91.6	98.6	103.9	80.2	17.7	9.5	254.7
C.V.(%)	150.3	124.6	137.3	105.9	74.9	56.9	33.0	38.2	48.9	100.4	218.1	247.1	22.3
Skewness	2.3	1.7	1.9	1.3	1.3	1.4	0.6	1.0	1.4	2.0	2.8	3.8	0.4
Kurtosis	6.1	3.2	4.7	1.4	1.7	1.9	0.0	2.1	3.8	6.0	7.7	17.3	2.1

Table 2 contd.....

Parameters	Winter		Pre-Monsoon			Monsoon				Post-Monsoon			Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	
					GUMLA								
Mean(mm)	25.6	34.6	23.6	20.2	41.7	197.2	370.1	365.6	231.1	81.2	16.2	6.8	1404.2
S.D.	31.1	39.1	26.1	19.2	34.3	96.9	114.8	120.3	96.6	66.3	30.6	14.1	308.7
C.V.(%)	121.7	113.1	110.8	95.1	82.3	49.2	31.0	32.9	41.8	81.6	188.5	207.7	22.0
Skewness	1.8	2.1	1.2	1.4	1.2	1.2	0.9	0.9	0.5	1.2	2.9	2.9	-0.6
Kurtosis	3.4	4.7	0.5	2.1	1.1	2.6	3.0	1.2	0.1	1.5	9.9	9.6	2.0
					HAZARIBAGH								
Mean(mm)	20.1	24.8	18.2	15.7	41.2	186.1	329.5	321.7	228.2	83.4	12.3	5.4	1286.6
S.D.	24.9	26.6	21.8	16.4	31.5	102.8	103.1	104.8	87.7	80.5	26.1	11.2	248.4
C.V.(%)	124.2	107.1	119.6	104.5	76.5	55.3	31.3	32.6	38.4	96.4	213.4	208.9	19.3
Skewness	1.8	1.6	1.6	1.8	1.0	1.0	0.5	0.6	0.5	1.7	3.3	3.3	0.4
Kurtosis	3.1	2.0	2.7	4.0	0.5	1.5	0.4	-0.1	0.3	3.0	11.9	13.2	0.2
					JAMTARA								
Mean(mm)	14.5	21.7	21.5	20.7	60.4	223.3	336.9	324.9	234.8	99.7	12.0	3.0	1334.6
S.D.	23.8	27.2	31.0	20.2	43.6	118.5	124.0	101.4	117.3	85.9	25.2	7.5	345.7
C.V.(%)	163.7	125.2	144.1	97.6	72.1	53.1	36.8	31.2	49.9	86.1	210.5	246.1	25.9
Skewness	3.2	1.9	2.4	1.6	0.8	1.4	0.6	0.6	1.3	1.1	3.1	3.2	0.2
Kurtosis	13.5	3.7	6.5	3.5	0.0	3.6	0.2	0.8	2.2	1.0	10.9	10.9	1.5
					KHUNTI								
Mean(mm)	22.8	31.3	25.0	18.5	45.6	228.7	387.8	395.6	246.9	83.4	18.6	7.2	1473.0
S.D.	29.1	35.3	34.9	18.0	33.9	115.2	140.1	141.8	99.2	75.7	32.1	14.3	358.9
C.V.(%)	127.6	112.5	140.0	97.5	74.5	50.4	36.1	35.8	40.2	90.7	172.5	199.6	24.4
Skewness	2.0	2.1	2.0	1.3	1.0	0.7	0.7	1.0	0.7	1.8	3.0	3.6	-0.2
Kurtosis	4.5	5.9	3.9	1.6	0.6	-0.1	0.2	1.5	0.3	4.8	10.9	16.0	1.8
					KODERMA								
Mean(mm)	18.1	24.2	13.3	9.2	29.3	167.0	280.2	301.4	211.1	67.3	10.4	5.3	1119.1
S.D.	24.5	32.7	19.8	13.8	28.5	103.5	109.0	109.6	88.1	76.9	22.3	13.6	255.7
C.V.(%)	135.0	135.2	148.4	150.4	97.6	62.0	38.9	36.4	41.7	114.2	214.4	259.1	22.9
Skewness	1.9	2.9	2.0	2.6	1.2	0.9	0.4	0.4	0.4	1.9	2.9	3.7	0.3
Kurtosis	4.1	11.7	4.0	8.1	1.5	0.8	0.3	0.3	-0.3	3.9	8.5	15.5	-0.3
					LATEHAR								
Mean(mm)	20.8	30.0	20.4	11.9	29.0	179.6	364.1	352.9	226.4	70.4	14.2	7.2	1322.6
S.D.	25.4	35.9	23.9	15.7	30.8	116.8	125.9	127.6	103.9	69.3	27.7	14.0	279.9
C.V.(%)	122.2	119.8	117.3	131.7	105.9	65.0	34.6	36.2	45.9	98.5	195.7	194.5	21.2
Skewness	1.7	2.0	1.4	2.2	1.6	1.0	1.0	0.8	1.2	1.7	2.6	2.9	0.4
Kurtosis	2.9	3.7	2.0	5.6	2.2	0.7	2.7	0.9	3.0	3.4	6.8	10.2	0.5
					LOHARDAGA								
Mean(mm)	24.0	31.3	26.4	19.3	35.6	182.7	346.5	317.2	204.7	78.4	17.5	7.3	1276.0
S.D.	31.4	39.1	34.4	22.4	30.3	105.2	133.5	111.8	99.7	80.0	32.6	14.7	298.2
C.V.(%)	130.7	124.9	130.3	116.0	85.2	57.6	38.5	35.2	48.7	102.1	186.8	202.3	23.4
Skewness	2.1	2.2	2.5	1.9	0.8	0.8	0.6	0.8	1.1	1.7	2.6	2.4	0.4
Kurtosis	4.9	4.9	9.5	4.1	-0.2	0.0	0.6	1.0	2.4	3.0	7.4	5.0	2.5
					PAKUR								
Mean(mm)	13.2	16.6	17.1	31.2	94.2	240.6	356.0	335.3	299.6	120.7	13.5	4.5	1528.7
S.D.	20.9	21.8	23.7	31.3	62.4	119.9	120.9	119.6	159.7	103.9	26.4	12.1	346.4
C.V.(%)	158.5	131.3	139.1	100.4	66.2	49.8	34.0	35.7	53.3	86.1	195.7	270.9	22.7
Skewness	2.7	2.4	2.0	1.5	1.0	1.5	0.4	0.6	3.0	1.5	2.7	3.4	0.2
Kurtosis	10.0	6.7	4.7	2.0	0.6	4.1	-0.4	0.3	16.0	2.2	7.3	11.3	0.4

Table 2 contd....

Parameters	Winter		Pre-Monsoon			Monsoon				Post-Monsoon			Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	
PALAMAU													
Mean(mm)	21.7	25.2	15.6	9.8	17.7	153.5	335.1	348.1	214.8	54.3	11.2	5.6	1212.6
S.D.	27.0	26.0	19.5	12.3	19.4	97.1	115.0	120.8	107.4	50.0	21.9	12.2	252.3
C.V.(%)	124.5	103.0	124.9	125.4	109.8	63.3	34.3	34.7	50.0	92.1	195.9	216.4	20.8
Skewness	1.9	1.4	1.8	2.0	1.7	0.8	0.4	0.3	1.7	1.2	3.1	3.8	0.2
Kurtosis	4.1	1.1	3.7	4.1	3.3	-0.1	0.9	-0.3	4.8	0.9	12.5	17.2	-0.4
RAMGARH													
Mean(mm)	17.0	28.0	19.6	19.0	48.4	213.2	342.6	312.8	218.4	80.4	11.4	6.7	1292.0
S.D.	22.9	34.3	29.2	20.1	53.2	125.7	131.8	112.3	101.5	90.9	27.1	14.7	344.3
C.V.(%)	134.8	122.5	148.5	106.1	110.0	58.9	38.5	35.9	46.5	113.0	237.8	218.6	26.7
Skewness	2.5	2.4	2.4	1.5	2.3	1.1	0.4	0.9	0.3	2.5	3.6	2.4	0.5
Kurtosis	9.2	7.7	7.0	2.6	7.8	1.7	-0.1	2.2	-0.7	9.0	14.7	5.2	-0.1
RANCHI													
Mean(mm)	21.1	30.5	22.0	21.0	48.9	205.8	347.4	338.8	227.6	80.8	14.6	6.5	1364.9
S.D.	24.9	34.4	26.3	18.1	33.2	94.3	101.6	97.9	89.1	69.5	28.0	13.2	222.8
C.V.(%)	118.3	112.9	119.8	86.3	67.9	45.8	29.2	28.9	39.1	86.1	192.5	202.3	16.3
Skewness	2.0	2.5	2.2	1.2	0.9	0.7	0.8	1.1	0.9	1.3	3.2	2.8	0.2
Kurtosis	5.6	7.4	5.7	1.6	0.8	0.4	1.1	3.0	1.3	1.4	11.8	8.0	-0.3
SAHEBGANJ													
Mean(mm)	11.9	14.2	14.2	27.8	85.4	234.3	340.7	311.6	291.6	100.4	10.5	4.0	1443.0
S.D.	20.9	18.9	19.4	36.2	67.1	128.2	113.0	121.1	157.6	102.1	23.9	11.1	302.2
C.V.(%)	176.1	133.7	136.7	129.9	78.6	54.7	33.2	38.9	54.0	101.6	227.6	274.2	20.9
Skewness	3.3	1.7	2.1	2.6	2.3	1.1	0.5	0.7	1.3	1.9	3.1	4.4	0.1
Kurtosis	14.0	2.1	6.3	9.9	8.5	0.8	0.3	0.9	2.0	4.2	9.9	24.2	-0.2
SERAIKELA													
Mean(mm)	15.6	26.2	20.6	24.8	57.1	215.6	329.9	328.0	218.9	69.1	12.6	4.7	1316.8
S.D.	21.3	34.4	28.9	27.9	40.9	105.3	127.8	117.3	95.0	59.4	23.6	10.9	259.0
C.V.(%)	136.5	131.2	140.2	112.4	71.7	48.8	38.7	35.7	43.4	86.0	186.9	234.6	19.7
Skewness	2.4	2.2	1.9	2.4	0.8	0.8	1.0	0.8	0.5	0.9	2.5	3.0	0.3
Kurtosis	7.6	6.3	3.8	8.8	0.2	0.2	0.9	0.8	-0.4	-0.1	6.5	9.0	0.0
SIMDEGA													
Mean(mm)	20.5	25.3	17.3	16.9	36.2	217.6	437.8	394.4	245.8	69.0	12.1	6.0	1478.3
S.D.	30.1	33.0	24.7	17.4	32.8	120.0	141.1	119.1	144.7	70.5	27.1	12.8	303.0
C.V.(%)	147.1	130.6	143.2	102.9	90.6	55.1	32.2	30.2	58.9	102.2	224.2	212.4	20.5
Skewness	2.7	1.9	2.3	1.5	1.2	1.0	0.9	0.0	4.6	1.9	4.2	2.7	0.1
Kurtosis	10.5	3.7	5.8	2.5	0.8	0.8	2.6	0.0	34.2	4.5	23.0	7.6	1.5
SINGBHUM EAST													
Mean(mm)	15.5	25.7	22.7	35.0	78.6	229.4	327.8	325.5	230.7	80.9	15.2	4.9	1384.5
S.D.	21.7	30.3	28.5	33.2	49.0	105.5	114.8	114.3	89.6	58.1	26.6	11.0	242.8
C.V.(%)	139.5	118.0	125.9	94.7	62.3	46.0	35.0	35.1	38.8	71.8	174.8	227.2	17.5
Skewness	2.5	1.9	1.9	1.6	0.8	0.7	1.0	0.8	0.6	1.1	2.3	3.3	0.2
Kurtosis	7.9	4.3	4.4	2.9	0.3	0.0	0.9	0.1	0.1	1.2	5.0	11.5	-0.2
SINGBHUM WEST													
Mean(mm)	18.7	29.0	22.3	25.8	63.0	209.0	348.3	341.5	218.5	74.6	14.7	4.8	1350.8
S.D.	27.3	37.1	27.2	28.9	39.3	102.2	147.6	114.5	86.2	63.7	25.2	11.3	255.2
C.V.(%)	146.1	127.9	121.9	111.7	62.3	48.9	42.4	33.5	39.5	85.3	171.3	234.3	18.9
Skewness	2.8	2.5	1.7	2.4	0.7	1.0	1.9	0.5	1.0	1.4	2.3	3.4	0.1
Kurtosis	10.3	8.7	2.9	7.5	0.1	1.3	5.2	0.0	1.3	2.7	5.5	13.6	-0.5

Table 3 : Trend analysis during decadal rainfall variation

Type of trend	Shown by districts
Increasing trend	Bokaro, Dhanbad, Giridih, Godda, Khunti, Sahebganj
Decreasing trend	Chatra, Dumka, Garhwa, Gumla, Hazaribagh, Koderma, Latehar, Lohardaga, Palamau, Ranchi, Singbhum East and West
No trend	Deogarh, Jamtara, Pakur, Ramgarh, Seraikela, Simdega

Table 4 : The statistical values of annual and seasonal rainfall with positive and negative deviation with range

No.	District	Annual / Seasonal	Mean Rainfall (mm)	Max. Rainfall		Min. Rainfall		Pos. Dev. (mm)	Pos. Dev. Ratio (%)	Neg. Dev. (mm)	Neg. Dev. Ratio (%)	Range
				(mm)	Year	(mm)	Year					
1	Bokaro	Annual	1188.5	2103.8	1994	143.1	1905	915.3	77.0	1045.4	88.0	1960.7
		Jun-Sep	992.4	1934.8	1994	196.3	1992	942.4	95.0	796.1	80.2	1738.5
2	Chatra	Annual	1232.0	2022.7	1917	15.6	1966	790.7	64.2	1216.4	98.7	2007.1
		Jun-Sep	1061.6	1724.2	1978	533.9	1966	662.6	62.4	527.7	49.7	1190.3
3	Deogarh	Annual	1218.2	1941.6	1971	595.3	1901	723.4	59.4	622.9	51.1	1346.3
		Jun-Sep	993.7	1540.0	1971	452.5	1901	546.3	55.0	541.2	54.5	1087.5
4	Dhanbad	Annual	1338.8	1842.8	1917	874.8	1966	504.0	37.6	464.0	34.7	968.0
		Jun-Sep	1103.5	1670.5	1984	719.0	1914	567.0	51.4	384.5	34.8	951.5
5	Dumka	Annual	1422.6	2281.9	1971	364.2	1988	859.3	60.4	1058.4	74.4	1917.7
		Jun-Sep	1143.4	1866.6	1971	174.5	1988	723.2	63.2	968.9	84.7	1692.1
6	Garwah	Annual	1192.4	1654.5	1948	517.8	1966	462.1	38.7	674.6	56.6	1136.7
		Jun-Sep	1036.3	1486.5	1994	503.9	1966	450.2	43.4	532.4	51.4	982.6
7	Giridih	Annual	1216.1	2805.7	1957	286.2	1910	1589.6	130.7	929.9	76.5	2519.5
		Jun-Sep	1011.1	2781.1	1957	200.6	1910	1770.0	175.1	810.5	80.2	2580.5
8	Godda	Annual	1139.6	2111.3	1999	276.3	2000	971.7	85.3	863.3	75.8	1835.0
		Jun-Sep	926.6	1635.9	1999	180.9	2000	709.3	76.5	745.7	80.5	1455.0
9	Gumla	Annual	1404.2	2287.0	1936	256.3	1974	882.8	62.9	1147.9	81.7	2030.7
		Jun-Sep	1155.8	1880.9	1936	256.3	1974	725.1	62.7	899.5	77.8	1624.6
10	Hazaribagh	Annual	1286.6	2068.7	1957	704.9	1966	782.1	60.8	581.7	45.2	1363.8
		Jun-Sep	1065.4	1833.8	1957	629.1	1966	768.4	72.1	436.3	41.0	1204.7
11	Jamtara	Annual	1334.6	2447.9	1959	267.4	1988	1113.3	83.4	1067.2	80.0	2180.5
		Jun-Sep	1087.3	1914.4	1984	193.4	1988	827.1	76.1	893.9	82.2	1721.0
12	Khunti	Annual	1473.0	2469.1	1917	140.7	1906	996.1	67.6	1332.3	90.4	2328.4
		Jun-Sep	1240.6	1952.0	1997	598.5	1908	711.4	57.3	642.1	51.8	1353.5

Table 4 contd....

No.	District	Annual / Seasonal	Mean Rainfall (mm)	Max. Rainfall		Min. Rainfall		Pos. Dev. (mm)	Pos. Dev. Ratio (%)	Neg. Dev. (mm)	Neg. Dev. Ratio (%)	Range
				(mm)	Year	(mm)	Year					
13	Koderma	Annual	1119.1	1834.8	1971	598.1	1962	715.7	64.0	521.0	46.6	1236.7
		Jun-Sep	947.0	1620.3	1971	542.1	1927	673.3	71.1	404.9	42.8	1078.2
14	Latehar	Annual	1322.6	2217.7	1978	7.7	1992	895.1	67.7	1314.9	99.4	2210.0
		Jun-Sep	1119.3	1884.9	1978	618.4	1992	765.6	68.4	500.9	44.7	1266.5
15	Lohardaga	Annual	1276.0	2441.0	1936	281.6	1909	1165.0	91.3	994.4	77.9	2159.4
		Jun-Sep	1038.5	1942.4	1936	107.3	1909	903.9	87.0	931.2	89.7	1835.1
16	Pakur	Annual	1528.7	2524.7	2000	650.9	1901	996.0	65.2	877.8	57.4	1873.8
		Jun-Sep	1218.8	2168.2	2000	521.9	1901	949.4	77.9	696.9	57.2	1646.3
17	Palamau	Annual	1212.6	1790.6	1971	810.4	1992	578.0	47.7	402.2	33.2	980.2
		Jun-Sep	1051.4	1538.2	1942	649.7	1992	486.8	46.3	401.7	38.2	888.5
18	Ramgarh	Annual	1292.0	2169.4	1917	581.0	1908	877.4	67.9	711.0	55.0	1588.4
		Jun-Sep	1069.3	1896.1	1953	428.4	1979	826.8	77.3	640.9	59.9	1467.7
19	Ranchi	Annual	1364.9	1904.4	1917	864.4	1979	539.5	39.5	500.5	36.7	1040.0
		Jun-Sep	1119.6	1677.3	1923	696.5	1979	557.7	49.8	423.1	37.8	980.8
20	Sahebganj	Annual	1443.0	2276.9	1999	753.8	1966	833.9	57.8	689.2	47.8	1523.1
		Jun-Sep	1175.8	1902.1	1999	668.9	1966	726.3	61.8	506.9	43.1	1233.2
21	Seraikela	Annual	1316.8	1987.7	1956	750.4	1979	670.9	51.0	566.4	43.0	1237.3
		Jun-Sep	1090.3	1737.8	1953	593.1	1998	647.5	59.4	497.2	45.6	1144.7
22	Simdega	Annual	1478.3	2464.6	1994	708.4	1965	986.3	66.7	769.9	52.1	1756.2
		Jun-Sep	1276.4	2295.5	1994	609.5	1979	1019.1	79.8	666.9	52.2	1686.0
23	Singbhum East	Annual	1384.5	1982.0	1913	767.9	1979	597.5	43.2	616.6	44.5	1214.1
		Jun-Sep	1107.9	1658.2	1904	608.3	1979	550.3	49.7	499.6	45.1	1049.9
24	Singbhum West	Annual	1350.8	1933.1	1929	820.6	1990	582.3	43.1	530.2	39.3	1112.5
		Jun-Sep	1100.7	1736.6	1920	400.0	1971	635.9	57.8	700.7	63.7	1336.6

Table 5 : Monthly/Seasonal annual maximum rainfall (mm) range

Season	Months	Annual Maximum Rainfall (mm)	
		Low	High
Winter	January	95.1 (1919, Dhanbad)	191.3 (1998, Simdega)
	February	78.7 (1937, Sahebganj)	226.8 (1906, Singbhum West)
Pre-monsoon	March	90.5 (1940, Chatra)	216.5 (1926, Lohardaga)
	April	46.0 (1909, Garhwa)	229.4 (1981, Sahebganj)
	May	66.2 (1963, Garhwa)	448.8 (1938, Sahebganj)
Monsoon	June	422.5 (1907, Palamau)	801.0 (1922, Pakur)
	July	507.9 (1997, Godda)	1137.7 (1957, Giridih)
	August	484.8 (1935, Giridih)	841.6 (1923, Khunti)
	September	439.5 (1907, Koderma)	1342.5 (1959, Simdega)
Post-monsoon	October	169.7 (1911, Garhwa)	702.5 (1959, Dumka)
	November	80.7 (1912, Godda)	206.1 (1930, Bokaro)
	December	43.1 (1991, Jamtara)	87.4 (1929, Khunti)

Table 6: Range of Precipitation ratio during different decades for annual and seasonal rainfall

District	Annual				Season			
	Min	Decade	Max	Decade	Min	Decade	Max	Decade
Bokaro	55.7	1981-1990	137.2	1991-2000	50.2	1961-1970	159.7	1991-2000
Chatra	40.5	1951-1960	100.7	1961-1970	57.2	1951-1960	100.0	1971-1980
Deogarh	38.4	1941-1950	93.1	1961-1970	47.6	1911-1920	100.5	1961-1970
Dhanbad	29.4	1941-1950	67.6	1971-1980	31.2	1931-1940	77.3	1981-1990
Dumka	41.6	1941-1950	125.3	1981-1990	32.3	1961-1970	166.8	1981-1990
Garhwa #	8.5	1971-1980	109.6	1971-1980	1.6	1974-1980	92.8	1961-1970
Giridih	34.2	1941-1950	167.8	1951-1960	52.1	1941-1950	191.9	1951-1960
Godda	36.2	1971-1980	148.9	1991-2000	39.3	1951-1960	141.7	1991-2000
Gumla	35.0	1901-1910	120.3	1971-1980	36.5	1941-1950	124.3	1971-1980
Hazaribagh	28.7	1941-1950	85.8	1961-1970	39.3	1921-1930	94.5	1951-1960
Jamtara	31.3	1941-1950	156.0	1981-1990	43.5	1941-1950	181.1	1981-1990
Khunti	38.7	1921-1930	141.0	1901-1910	35.5	1951-1960, 1961-1970	164.5	1901-1910
Koderma	27.6	1941-1950	109.7	1971-1980	42.6	1951-1960	110.4	1971-1980
Latehar	34.8	1921-1930	92.3	1971-1980	38.0	1941-1950	96.7	1971-1980
Lohardaga	33.4	1951-1960	128.8	1901-1910	17.9	1951-1960	155.8	1901-1910
Pakur	31.7	1941-1950	93.2	1991-2000	32.9	1941-1950	109.0	1921-1930
Palamau	15.4	1921-1930	83.9	1961-1970	32.8	1921-1930	79.6	1961-1970
Ramgarh	38.5	1921-1930	108.0	1951-1960	46.7	1921-1930	128.4	1951-1960
Ranchi	28.1	1941-1950	70.2	1991-2000	36.9	1931-1940, 1941-1950	71.6	1971-1980
Sahebganj	36.4	1941-1950	76.2	1921-1930	50.7	1911-1920	106.1	1921-1930
Seraikela	34.0	1961-1970	83.7	1991-2000	44.9	1961-1970	93.6	1991-2000
Simdega	19.0	1921-1930	107.2	1991-2000	29.1	1921-1930	108.5	1991-2000
Singbhum (E)	34.7	1961-1970	82.1	1971-1980	40.0	1931-1940	78.5	1971-1980
Singbhum (W)	28.2	1901-1910	80.1	1971-1980	34.4	1931-1940	109.5	1971-1980

Note : # For Dist. Garhwa very less and sparse rainfall data was available during 1971-80 decade

Table 7 : Seasonality index (SI) classes and the associated rainfall regimes

Rainfall regime	Seasonality index (SI)
Very equable	=0.19
Equable but with a definite wetter season	0.20–0.39
Rather seasonal with a short drier season	0.40–0.59
Seasonal	0.60–0.79
Markedly seasonal with a long drier season	0.80–0.99
Most rain in 3 months or less	1.00–1.19
Extreme, almost all rain in 1–2 months	=1.20

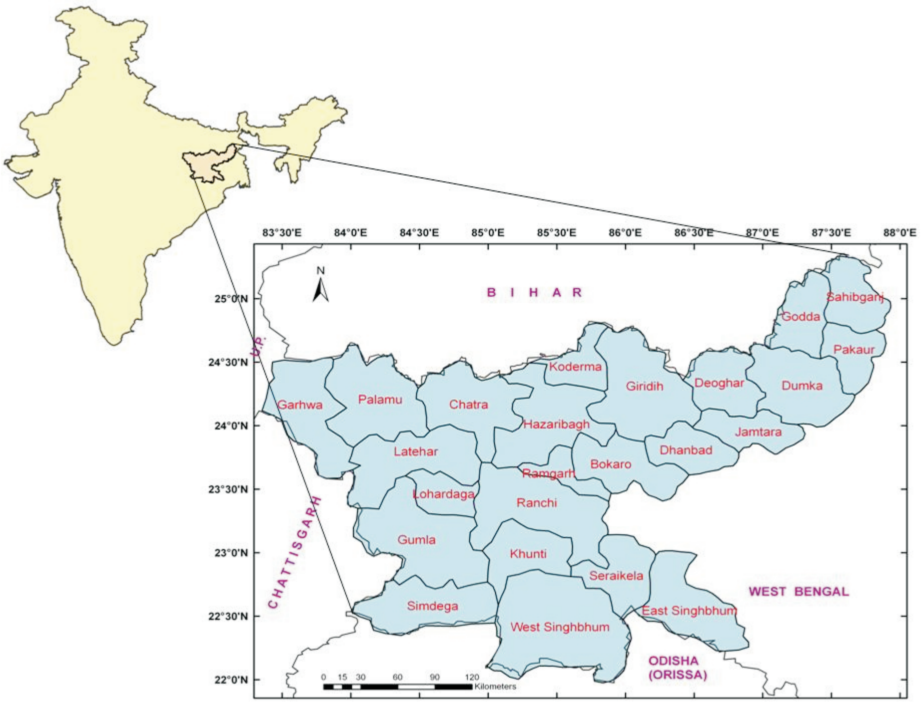
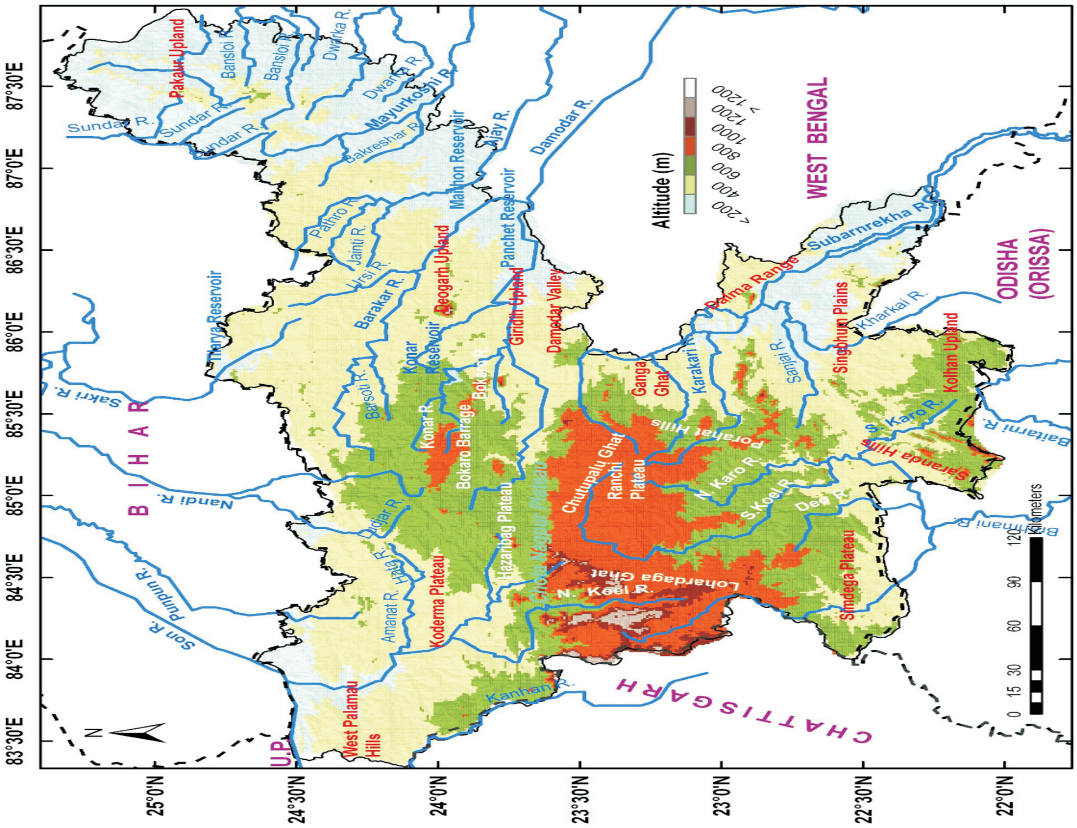


Fig. 1 : Location map of Jharkhand state



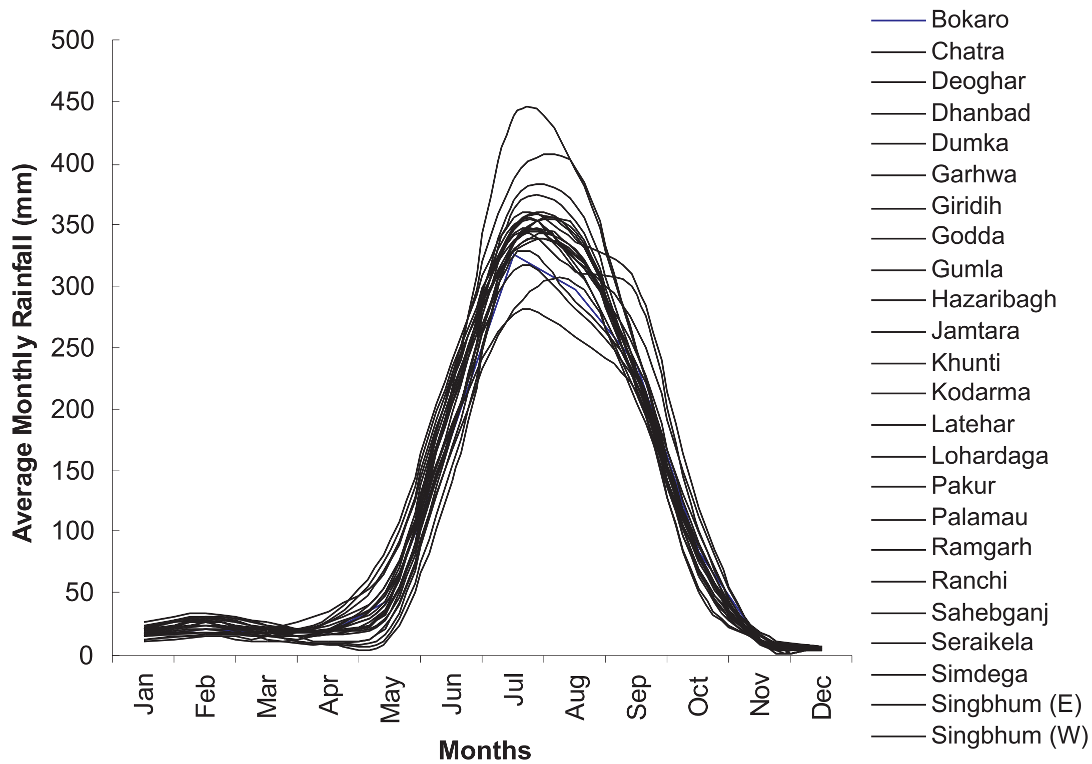


Fig.3 : Average monthly rainfall (mm) frequency curves for 24 districts of Jharkhand

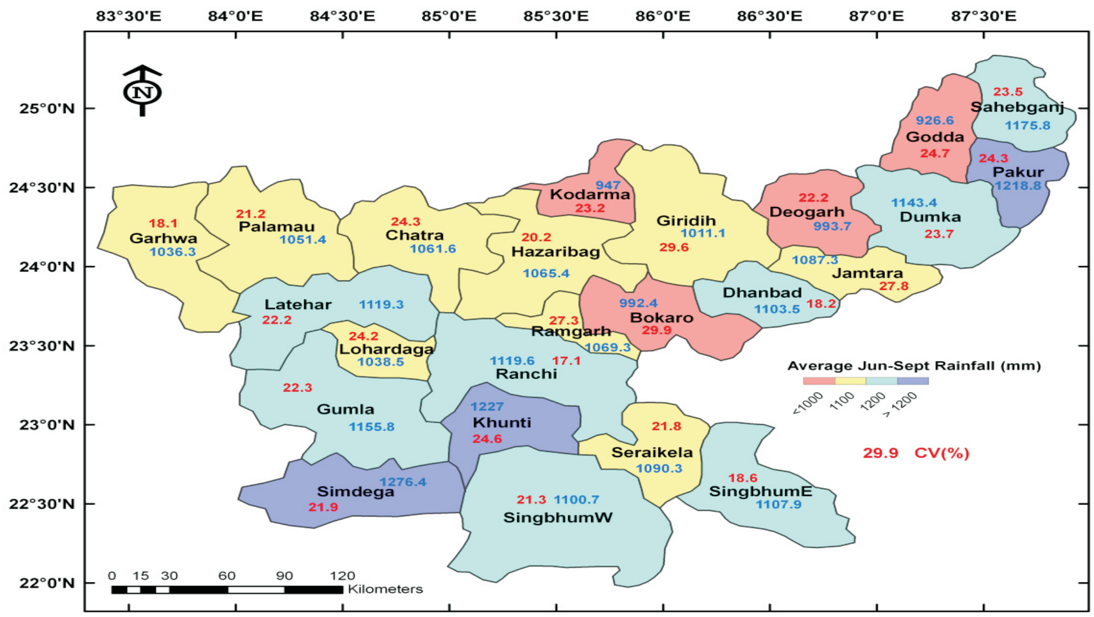


Fig.4 : Spatial distribution of average Jun-Sept. rainfall over the Jharkhand districts

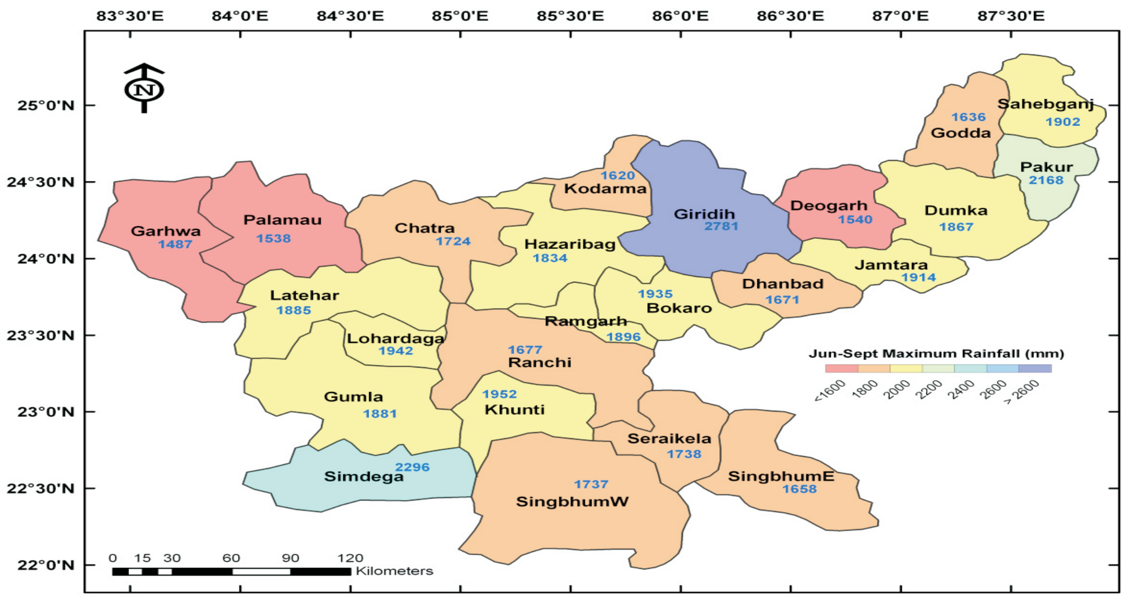


Fig.5 : Spatial distribution of Jun-Sept. maximum rainfall over Jharkhand

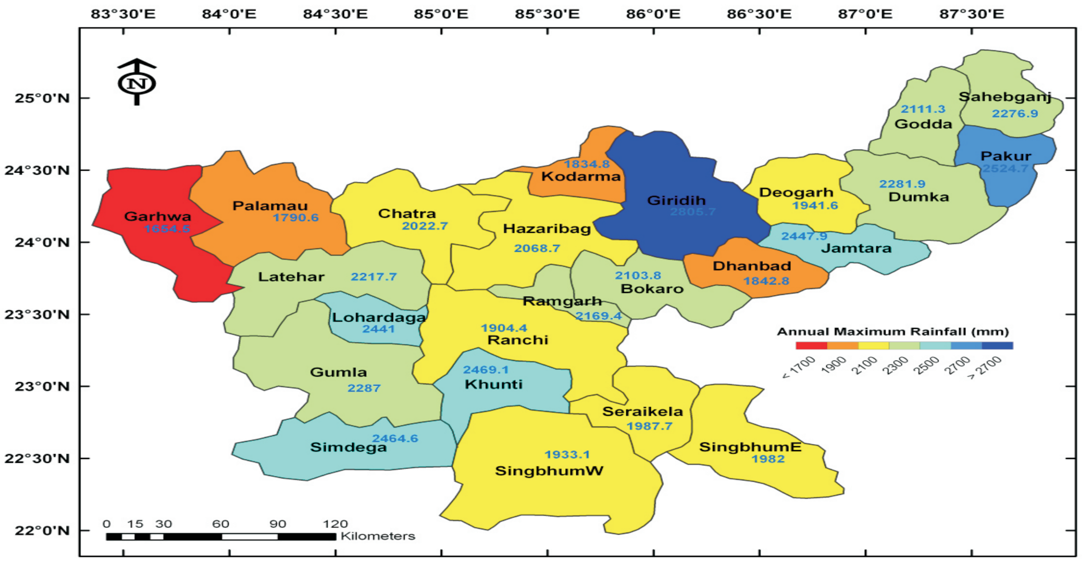


Fig.6 : Spatial distribution of Annual maximum rainfall over Jharkhand

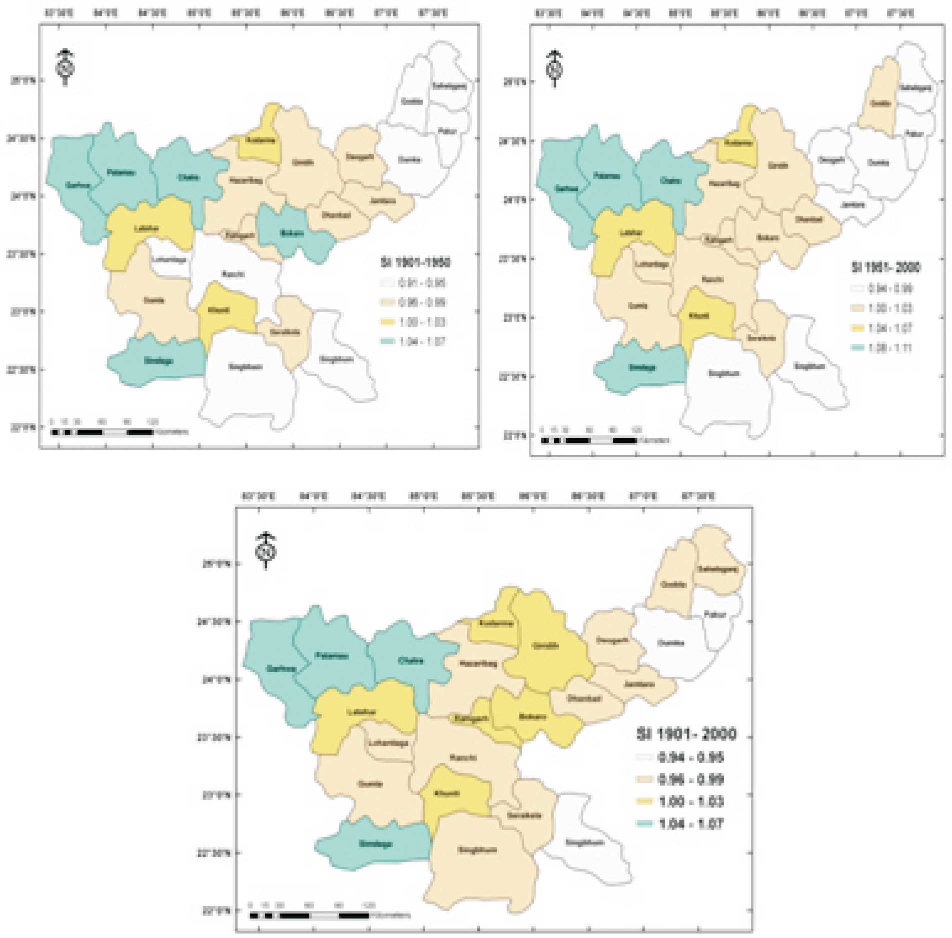


Fig.7 : Seasonality Index during different periods0

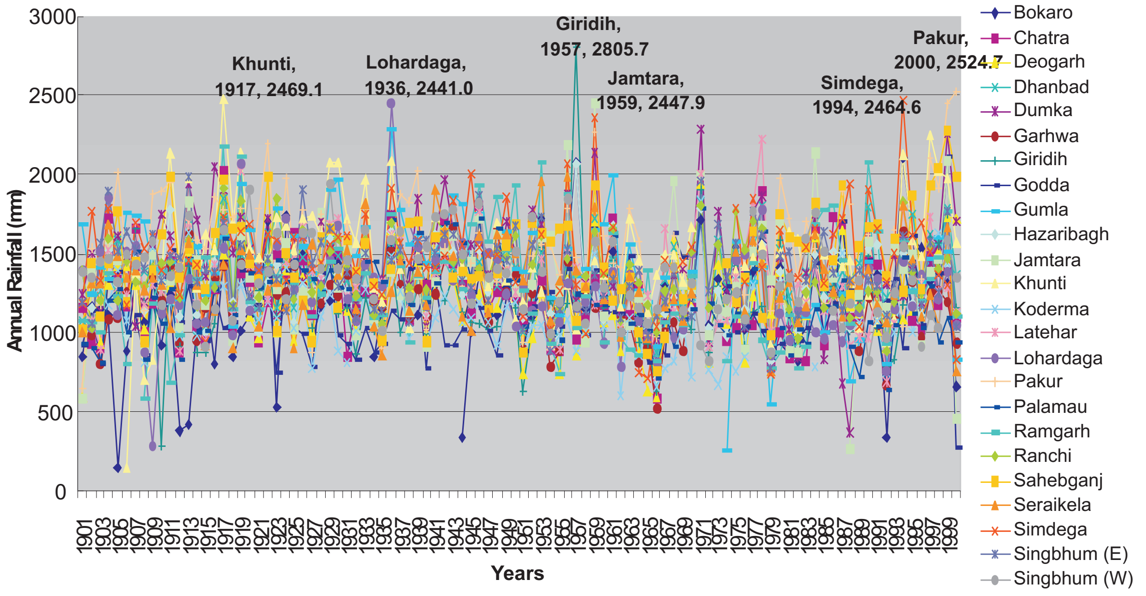


Fig.8 : Annual rainfall variation in 24 districts of Jharkhand during 1901-2000