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Annual and seasonal variability of rainfall in central state of India

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Abstract
The uncertainty in occurrence of rainfall is a serious concern nowadays. There is an urgent need in studying the variability associated with rainfall in the context of changing climatic conditions. Proper understanding of variability of rainfall in spatial and temporal scale is crucial for crop and water resource planning and preparation of contingency plans. Chhattisgarh is an agrarian state where dependency of agriculture on rainfall is having great importance. In this context the spatio temporal variability of rainfall has been analyzed in this study in block level. Monthly gridded rainfall data of the 149 blocks of Chhattisgarh State was collected for a period of 1901 to 2020 (119 years) from the India Meteorological Department (IMD). Initially, long term statistics have been quantified in terms of mean, minimum, maximum, standard deviation, coefficient of variation, skewness, and kurtosis for annual, pre monsoon, south west monsoon, post monsoon and winter season. The spatial maps have been created using Inverse Distance Weighted (IDW) technique of interpolation in ArcGIS 10.6. The study was done at block level which offeres better understanding of rainfall variability over the state. The average annual rainfall over the state from 1901 to 2020 was 1366 mm which ranged from 1094 mm (Chhuikhadan block of Chhattisgarh Plains) to 1620 mm (Jagdalpur blockck of Bastar Plateau). The co efficient of variation of annual rainfall over Chhattisgarh was 24%. Among the four seasons, the maximum rainfall was noticed during monsoon season (1140 mm) with the smallest value of coefficient of variation (24%). The minimum amount of rainfall was seen during winter season (40 mm) while maximum amount of co efficient of variation was seen during pre monsoon season (123%). Among the three agro climatic zones, maximum value of average rainfall was noticed in Bastar Plateau (1482 mm) followed by northern hills zone and Chhattisgarh Plains. The study showed how the annual and seasonal rainfall showed variation over different blocks of Chhattisgarh. The findings of the study gives useful information for effective planning of water resources and crops in various regions of the state.

Keywords: Annual, seasonal variability, rainfall

Introduction
One of the most interesting element of weather is rainfall and its erratic distribution. The distribution of rainfall in both spatial and temporal scale is very important in deciding the distribution of crop over a particular area. Rainfall is the major source of river flow in India and the large variability in rainfall may cause hydrological extreme events such as drought and flood (Kalra and Ahmad 2012; Prabhakar *et al*., 2019) [2, 7]. Now a days, water demands are increasing due to population, industrialization, and urbanization. Major water demands are in agriculture, industry, irrigation, environmental flow, hydroelectric power generation and other anthropogenic activities. Allocation of demands as per availability is tedious task in terms of measurement and its management. Water resource management is getting complicated due to erratic rainfall and put the population under socio economic stress. India is blessed with vast water and other natural resources. The normal value of Indian annual rainfall from 1971 to 2020 period is 1160.1mm. The normal rainfall value for pre monsoon, monsoon, post monsoon and winter seasons were 130.6 mm, 868.6mm, 121 mm and 39.8 mm respectively. In India more than 60% of the Indian population is based on agriculture which generate 19.9% of GDP. More than 60% of the agriculture in our country is rainfed, hence the variability of rainfall over India has a significant impact on Indian agriculture and economy. By considering the vital role of rainfall in for designing crop planning, the accurate evaluation of rainfall variability is a major concern for scientific community and policy makers. The increased frequency of high intensity rainfall generates a large amount of water in least time interval, causes runoff and floods.

Various studies were conducted all around the world to evaluate the spatio temporal variability of rainfall. The 135 years of monthly rainfall time series for 30 sub-regions over the India were analyzed by Kumar *et al*., (2010) [4] and summarized the long term rainfall variability in terms of trend analysis over India. Prabhakar *et al*., (2019) [7] found out a declining trend of rainfall over the state of Odisha after 1945. The rainfall variability may have hazardous impact on agricultural crops. Ahmed *et al*. (2019) [1], assessed the variability of rainfall on ground nut yield in Bundelkhand region of India. From a period of 1951 to 2015, 6% decrease was noticed in summer monsoon rainfall over Indo Gangetic plains whereas the frequency of localized high rainfall events increased. The frequency of daily precipitation extremes with rainfall intensities exceeding 150 mm per day increased by about 75% over central India during 1950–2015 (Krishnan *et al*., 2021) [3]. Similar studies on rainfall variability assessment has been done over Chhattisgarh state. Nema *et al*., (2019) [5], has noticed strong inter annual rainfall variability and declining trend of rainfall over Chhattisgarh. District wise changes in rainfall variability and trend was noticed in Chhattisgarh (Praveen *et al*., 2020) [9].

In the context of the importance in assessment of rainfall variability, the present study was done to investigate the pattern of changes in rainfall in each block of Chhattisgarh during a period from 1901 to 2020. Annual and seasonal trend analysis of rainfall along with the spatial variation were presented in this study.

Study area

Chhattisgarh belongs to central India, extends over 135,192 km^2 has a forest cover of 44% of it's the total geographical area and contribute approximately 12% of the forest to the Indian subcontinent. The geographical location of the state is between 17.78–24.12° N latitude and 80.24– 84.39° E longitude. Location map of study area is shown in the fig. 1. The climate in Chhattisgarh is tropical, with significant regional variation. The temperature experience in the state in general varies from 28 °C to 46 °C, with a value of 46 °C may reach during summer. The state is divided into 27 districts (Balod, Balodabazar, Balrampur, Bastar, Bemetra, Bijapur, Bilaspur, Durg, Janjgir-Champa, Jashpur, Kanker, Kondagaon, Mungeli, Narayanpur, Raigarh, Rajnandgaon, Sukma, Surajpur, Raipur, Mahasamund, Koriya, Dantewada, Dhamtari, Gariabandh, Kawardha, Korba and Surguja) and 149 blocks. There are three agroclimatic zones named Chhattisgarh Plains, northern hills zone and Bastar Plateau. Nearly 60% of the area of Chhattisgarh plains is cultivated and sandy loam soil covers about 55% of the land area with fully bunded (100% bunding) agricultural fields. The Bastar plateau has undulating terrains largely covered with forests. Northern Hills include areas under high elevations of 900–1000 m. The principle river flow through the state include Rihand, Arpa, Hasdeo (a tributary of the Mahanadi), Indravati, Jonk, and Seonath.

The primary crop cultivating in Chhattisgarh state is Rice, which covers 77% of net sown area. Among the total rice cultivated areas, 80% of area is under rainfed (Nema *et al*., 2018) [5]. Rainfed cultivation is widely practices all around the state, except for some few light upland soils. Hence a good understanding of spatio temporal variability of the rainfall over the state is vital for supporting the crop and water resource planning

Data used

Monthly rainfall data of the 149 blocks of Chhattisgarh state for a period from 1901 to 2020 (119 years) were downloaded from the India Meteorological Department (IMD) site, India Water Portal (http://www.imdpune.gov.in/Clim_Pred_LRF_New/Grided_Data_Download.html) and were employed to examine the spatial and temporal variability of rainfall data series. Locations of meteorological stations are shown in Fig. 1. According to the India Meteorological Department, four prominent seasons are in India, namely (1) winter (December–February), (2) pre monsoon (March–May), (3) monsoon (June–September), and (4) post-Monsoon (October–November) (Gajbhiye *et al*. 2015a) [12].

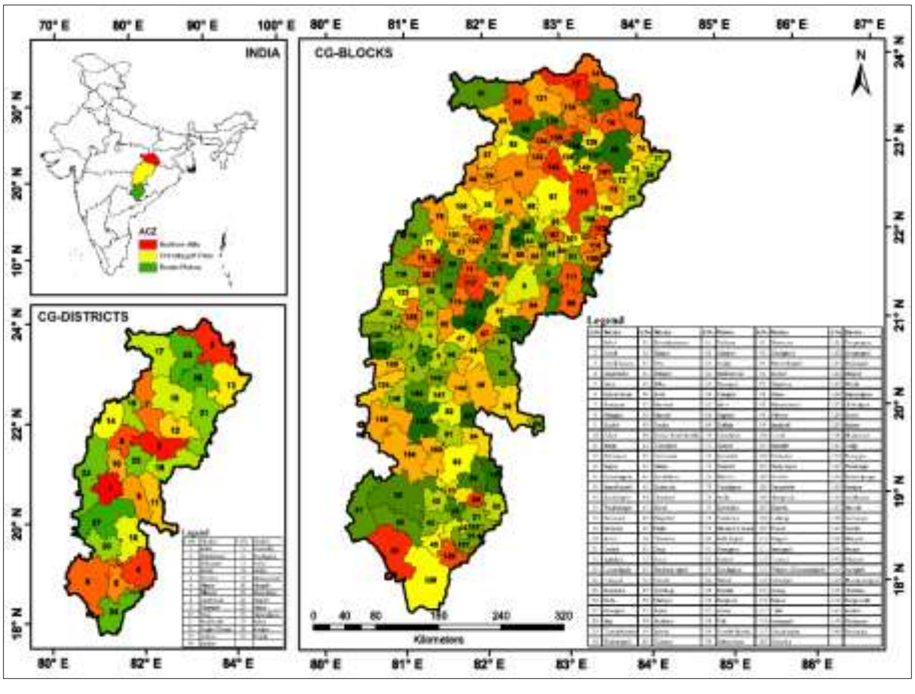

Fig 1: Location map of the study area (Administrative boundary of Chhattisgarh State)

Methodology

In this study, the annual and monthly rainfall of 149 blocks in Chhattisgarh State were used from 1901 to 2020. The methodology adopted for rainfall variability analysis has been illustrated in the form of flow chart Fig.2.

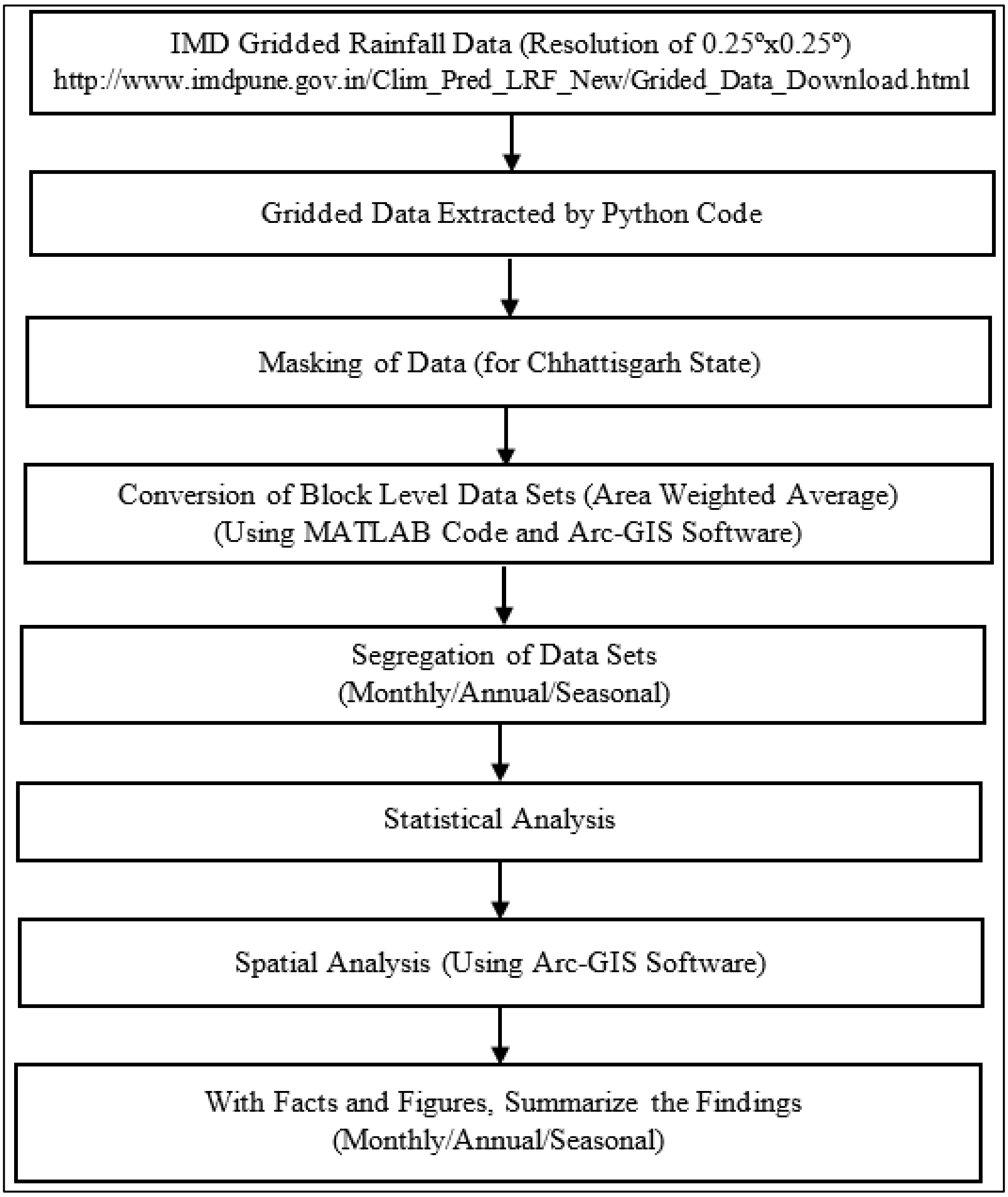

Fig 2: Methodology adopted for rainfall variability analysis

Conversion of gridded data into block level data sets

IMD gridded data sets which have a resolution of (0.25deg × 0.25deg) of rainfall is to be converted into area-weighted average rainfall by Thiessen polygon method of ArcGIS (ver. 10.6) for all the blocks. Daily rainfall data has been converted into monthly time series. Thereafter, monthly time series were segregated into different annual and seasonal i.e., pre-monsoon, monsoon, post-monsoon and wintertime series for each station. GIS administrative boundary shape files for the entire blocks are downloaded from the DIVA-GIS website.

General Statistics of Rainfall (1901-2020)

Long term statistics have been quantified in terms of mean, minimum, maximum, standard deviation, coefficient of variation, skewness, and kurtosis for 5 time series (annual, pre monsoon, monsoon, post monsoon and winter) for all the blocks of Chhattisgarh state. The block level study can be considered as micro level study which represent the best distribution of rainfall variability over the state. The statistical analysis were carried out using in MS Excel software

Mean

The Statistical mean refers to the mean or average which is used to derive the central tendency of the data. It is determined by adding all data points in a population and then dividing the total by the number of points. The resulting number is known as the mean or the average.

$$\text{Mean} = \frac{\text{Sum of rainfall corresponding to particular duration}}{\text{Number of year}}$$

Maximum
It is the maximum value in the given time series.

Minimum
It is the minimum value in the given time series.

Standard Deviation
In statistics, the standard deviation is a measure of the amount of variation or dispersion of a set of values. A low standard deviation means the values are close to the mean of the sample, while a higher value of standard deviation indicates that the values are spread out over a wider range. The standard deviation is denoted by σ.

$$\sigma = \sqrt{\frac{\sum(x_i - \mu)^2}{N}} \quad (2)$$

σ = population standard deviation
N = the size of the population
x_i = each value from the population
μ = the population mean

Coefficient of variation (%)
Variance is a statistical measure that describes how different data points differ from the mean value. The coefficient of variation (CV) is a normalized measure of deviation from the mean that is calculated as follows:

$$CV(\%) = \frac{\sigma}{\mu} \times 100 \quad (3)$$

Where, σ denotes the standard deviations and μ denotes the mean of the time series

Skewness
Skewness characterizes the degree of asymmetry of a distribution around its mean. Positive skewness indicates a distribution with an asymmetric tail extending toward more positive values. Negative skewness indicates a distribution with an asymmetric tail extending toward more negative values.

$$\tilde{\mu}_3 = \frac{\sum_i^N (x_i - \bar{x})^3}{(N-1)\cdot\sigma^3} \quad (4)$$

$\tilde{\mu}_3$ = skewness
N =number of variables in distribution
x_i = random variable
$\bar{x}$ = mean of the distribution
σ = standard deviation

Kurtosis
Kurtosis characterizes the relative peakedness or flatness of a distribution compared with the normal distribution. Positive kurtosis indicates a relatively peaked distribution. Negative kurtosis indicates a relatively flat distribution.

$$Kurt = \frac{\mu_4}{\sigma^4} \quad (5)$$

Kur = Kurtosis
μ_4 = Fourth central moment
σ^4 = Standard deviation

Preparation of spatial maps
Spatial maps have been prepared for average rainfall of the annual and seasonal time series, using the Inverse Distance Weighted (IDW) technique of interpolation in ArcGIS 10.6. (Singh and Chowdhury, 1986; Lebel *et al.*, 1987) [10, 8]. In the IDW methodology, the weight of any known point is set to be inversely proportional to its distance from the estimated point (Chen and Liu, 2012) [6]. It is calculated as follows:

$$\hat{x} = \frac{\sum_{i=1}^{n} \frac{1}{d_i} x_i}{\sum_{i=1}^{n} \frac{1}{d_i}} \quad (6)$$

$\hat{x}$ = value to be estimated
x_i = known value
d_i = distance between two consecutive points

Results
Statistical characteristics of annual and seasonal rainfall
Block wise general statistics of the long term rainfall time series are presented in Table 1. From the period of 1901 to 2020, average annual rainfall of the Chhattisgarh state is about 1366 mm and about 80 percent of annual rainfall occurred in the monsoon period. The annual average rainfall varies from 1094 mm to 1620 mm. The lowest annual average rainfall noticed in Chhuikhadan block and the highest annual average rainfall occurred in Jagdalpur blocks during 1901-2020. The standard deviation values vary between 215 mm to 422 mm with an average value of 319 mm. The average value of the coefficient of variance, skewness and kurtosis are 23.6%, 2.85 and 24.65 were estimated. The average rainfall for the state during monsoon period varies from 946 mm (Chhuikhadan) to 1333 mm (Pakhanjur) with an average value of 1139 mm. The standard deviation values noticed, as 176 mm to 383 mm with an average value of 280 mm. The average value of the coefficient of variance, skewness and kurtosis values are found to be 23.65%, 2.95 and 26.1 respectively. The average rainfall during pre-monsoon period varies from 34 mm (Palari) to 137 mm (Tokapal) with an average value of 85 mm. The standard deviation values noticed are 31 mm to 103 mm with an average value of 67 mm. The average value of the coefficient of variance, skewness and kurtosis values were found to be 123.35%, 4.5 and 42.4 respectively. The average rainfall for the post-monsoon period varies from 48 mm (Bhatapara) to 142 mm (Konta) with an average value of 95 mm. The standard deviation values noticed was ranged from 46 mm to 90 mm with an average value of 68 mm. The average value of the coefficient of variance, skewness and kurtosis values are found to be 83.08%, 1.55 and 3.8 respectively. The average

rainfall for winter period varies from 18 mm (Konta) to 61 mm (Manora) with an average value of 39 mm. The standard deviation values noticed was 23 mm to 54 mm with an average value of 38 mm. The average value of the coefficient of variance, skewness and kurtosis are found to be 113.7%, 2.05 and 7.9 respectively. It is found that when the average rainfall calculated from 1901 to 2020 was considered, around 83.94% of rainfall occurred in the monsoon season, 6.26% occurred in the pre-monsoon season, 7.00% rainfall occurred in the post-monsoon season and 2.87% rainfall occurred in the winter season.

Table 1: General statistics of annual and seasonal rainfall over different blocks of Chhattisgarh state during 1901-2020

Satation	Annual					Pre-Monsoon					Monsoon					Post-Monsoon					Winter				
	Mean	SD	CV	Skw	Kur	Mean	SD	CV	Skw	Kur	Mean	SD	CV	Skw	Kur	Mean	SD	CV	Skw	Kur	Mean	SD	CV	Skw	Kur
Balod	1281	297	23	0.4	0.2	48	49	101	1.9	4.9	1133	247	22	0.3	-0.1	71	67	94	1.3	1.4	28	35	124	2.4	8.4
Dondi	1324	284	22	0.4	0.2	49	45	91	1.9	5.6	1172	246	21	0.4	0.0	74	66	90	1.3	1.7	29	34	116	2.1	6.3
Dondi Luhara	1263	276	22	0.3	0.2	47	45	95	1.8	4.3	1115	237	21	0.5	0.6	70	63	90	1.2	1.0	31	35	111	1.5	2.0
Gunderdehi	1220	265	22	0.3	0.1	45	64	141	5.0	35.4	1087	225	21	0.3	0.0	62	53	86	1.0	0.4	27	32	118	1.9	4.0
Gurur	1250	264	21	0.3	0.2	45	42	93	1.8	4.6	1111	226	20	0.2	0.1	67	63	94	1.4	1.8	27	32	117	2.6	10.1
Baloda Bazar	1211	279	23	0.4	0.3	35	39	112	2.1	5.5	1095	249	23	0.5	0.8	50	49	97	1.3	1.4	31	31	101	1.5	2.5
Bhatapara	1176	291	25	0.2	-0.4	36	41	112	1.9	3.7	1060	259	24	0.3	-0.3	49	47	96	1.3	1.7	31	31	99	1.3	1.3
Bilaigarh	1311	304	23	0.6	0.6	49	45	91	1.7	3.5	1169	269	23	0.6	0.6	56	48	86	1.0	0.7	37	38	104	1.6	3.0
Kasdol	1252	289	23	0.4	0.1	42	42	101	1.9	4.2	1123	248	22	0.4	0.3	55	53	96	1.6	4.4	32	35	109	1.8	4.3
Palari	1188	315	27	0.4	-0.1	34	40	118	2.1	5.1	1074	276	26	0.5	0.1	52	55	107	2.1	6.4	28	31	113	1.6	2.5
Simga	1180	296	25	0.2	-0.2	36	40	112	1.8	3.3	1065	262	25	0.3	0.1	51	48	95	1.3	1.5	29	30	105	1.3	1.2
Balrampur	1304	303	23	0.1	-0.1	49	39	79	1.1	1.0	1126	262	23	0.1	-0.2	74	64	87	1.3	2.0	55	49	89	1.3	1.9
Rajpur	1398	293	21	0.0	-0.2	52	41	78	1.3	2.0	1216	250	21	0.1	0.0	75	61	81	1.0	0.6	55	48	87	1.4	2.3
Ramanujganj	1207	260	22	-0.1	-0.2	41	34	81	1.4	1.8	1049	226	22	-0.1	-0.1	66	57	87	1.1	0.9	51	43	84	1.0	0.4
Samri(kusmi)	1409	337	24	0.3	0.1	69	48	69	0.6	-0.6	1190	281	24	0.4	-0.1	91	74	81	1.3	2.1	59	50	85	1.3	1.2
Shankargarh	1416	306	22	0.3	0.1	63	51	81	1.4	3.4	1213	255	21	0.3	-0.1	84	70	84	1.3	1.8	56	50	89	1.3	1.2
Wadrafnagar	1190	239	20	-0.1	0.2	37	31	83	1.5	2.7	1041	208	20	-0.1	0.3	61	51	84	1.0	0.7	51	42	82	1.0	0.2
Bakavand	1544	282	18	0.4	0.5	122	66	54	2.0	7.4	1282	244	19	0.3	0.1	116	80	69	1.1	1.1	25	30	121	2.8	13.8
Bastanar	1547	286	19	0.3	0.3	121	53	43	0.6	0.7	1278	257	20	0.4	0.4	119	82	69	0.9	0.3	28	36	128	2.8	11.4
Bastar	1550	282	18	0.5	0.5	128	59	46	1.0	1.9	1276	246	19	0.4	0.4	119	82	69	1.0	0.6	28	34	124	2.8	12.5
Darbha	1593	279	18	0.3	0.2	133	55	41	0.7	0.5	1306	253	19	0.4	0.2	126	81	64	0.9	0.5	27	34	125	3.0	14.0
Jagdalpur	1621	289	18	0.4	0.4	135	62	46	1.2	2.8	1332	264	20	0.6	0.9	127	83	65	0.9	0.7	27	33	123	2.9	14.5
Lohandiguda	1538	287	19	0.4	0.4	122	54	45	0.7	1.2	1270	253	20	0.5	0.5	118	82	70	0.9	0.4	29	36	126	2.8	11.6
Tokapal	1567	287	18	0.4	0.5	137	59	43	0.7	0.8	1278	260	20	0.4	0.3	123	84	68	0.9	0.2	29	36	124	2.6	10.9
Bemetara	1167	234	20	0.4	0.3	38	39	102	2.0	4.9	1042	203	20	0.4	0.8	54	47	87	1.0	0.4	32	32	98	1.3	1.1
Berla	1184	248	21	0.3	-0.1	37	39	103	2.2	5.8	1062	221	21	0.4	0.0	54	48	88	1.1	1.2	30	32	107	1.4	1.4
Nawagarh	1187	244	21	0.2	0.5	41	38	91	1.7	3.4	1055	214	20	0.2	1.0	55	49	88	1.0	0.5	36	31	88	1.1	0.6
Saja	1177	251	21	0.3	-0.2	41	43	104	2.1	5.5	1044	218	21	0.4	0.0	58	52	91	1.0	0.4	34	36	104	1.3	1.3
Thanakhamria	1170	238	20	0.4	0.1	39	41	107	2.1	5.5	1042	207	20	0.5	0.6	56	49	88	1.0	0.5	33	34	101	1.3	1.3
Bhairamgarh	1491	308	21	0.5	1.3	76	51	68	1.0	1.0	1283	286	22	1.0	3.5	107	77	72	0.9	0.4	25	32	128	2.3	6.8
Bhopalpatanam	1435	319	22	0	-0.3	56	48	85	1.4	2.5	1260	302	24	0.1	-0.4	97	68	70	0.8	0.4	22	27	121	1.6	2.4
Bijapur	1525	347	23	0.6	0.9	74	47	63	1.4	2.9	1317	335	25	0.9	1.8	112	77	69	1.0	1.1	23	29	129	2.6	10.3
Usur	1504	386	26	0.7	0.6	79	48	60	2.0	7.4	1287	365	28	0.8	0.7	117	77	66	0.8	0.6	21	25	118	1.9	4.3
Bilaspur	1351	263	20	1.0	3.3	42	40	96	2.2	7.2	1210	239	20	1.2	4.4	58	52	91	1.0	0.6	43	38	90	1.2	1.2
Bilha	1265	235	19	0.4	0.6	42	40	94	2.0	5.4	1129	213	19	0.6	1.8	54	50	93	1.2	1.1	40	34	86	0.9	0.1
Kota	1323	243	18	0.2	0.4	45	41	90	2.2	8.0	1172	218	19	0.5	1.6	61	54	89	0.9	-0.2	45	38	84	1.1	0.8
Marwahi	1317	239	18	0.1	-0.3	54	42	78	1.7	4.3	1142	209	18	0.5	0.8	66	58	88	1.0	0.7	55	46	84	1.2	1.4
Masturi	1309	256	20	0.6	1.3	39	39	102	2.2	7.0	1178	232	20	0.8	2.3	54	50	92	1.1	1.1	38	36	94	1.3	1.6
Pendra	1331	239	18	0.3	0.4	54	42	77	1.7	5.2	1156	214	19	0.7	1.9	68	60	89	0.9	0.3	53	46	85	1.3	2.2
Pendra Road	1336	236	18	0.1	0.0	61	44	73	1.6	4.8	1148	208	18	0.5	1.1	72	63	87	1.1	1.1	56	45	80	1.1	1.1
Takhatpur	1249	237	19	0.2	0.4	44	41	92	1.8	4.7	1105	216	20	0.3	1.7	57	54	94	1.1	0.9	43	37	86	0.9	-0.2
Dantewada	1562	337	22	0.9	3.6	96	55	58	0.9	0.6	1323	321	24	1.4	6.4	117	83	71	1.1	0.6	25	37	147	3.1	12.7
Gidam	1534	334	22	0.7	1.9	100	56	56	1.0	1.2	1293	306	24	1.2	4.2	114	83	73	1.0	0.5	27	37	138	3.0	12.3
Katekalyan	1571	296	19	0.2	0.1	112	53	47	0.6	0.0	1311	270	21	0.3	0.1	123	81	66	0.9	0.4	25	35	140	3.1	13.7
Kuakonda	1564	307	20	0.3	0.2	98	53	54	0.7	0.1	1318	293	22	0.5	0.2	124	82	66	0.9	0.3	23	33	142	2.7	10.2
Dhamtari	1270	266	21	0.2	0.3	46	42	90	1.4	1.9	1130	233	21	0.2	0.1	68	65	96	1.5	2.0	27	31	117	2.5	9.2
Kurud	1287	298	23	0.2	-0.2	45	43	97	1.5	1.9	1150	266	23	0.2	0.0	65	65	100	1.6	2.6	28	32	115	1.8	3.9
Magarlod	1353	316	23	0.2	-0.2	52	52	98	1.3	0.8	1202	284	24	0.1	-0.3	71	73	104	1.8	3.8	27	33	122	1.9	4.6
Nagri	1347	291	22	0.2	-0.1	60	53	90	1.3	1.0	1188	262	22	0.2	-0.4	74	73	100	1.7	3.5	26	33	128	2.4	8.2
Dhamdha	1217	245	20	0.2	-0.2	45	50	110	3.8	22	1081	215	20	0.4	-0.1	59	52	88	1.1	0.9	32	33	103	1.4	1.6
Durg	1227	273	22	0.6	1.5	50	104	205	8.6	85.4	1087	223	21	0.3	0.1	61	55	91	1.2	1.4	29	33	113	1.5	1.9
Patan	1249	277	22	0.2	-0.2	46	39	84	1.5	2.7	1111	251	23	0.4	0.1	61	57	92	1.2	1.0	30	31	101	1.5	2.3
Gariyaban	1323	268	20	0.1	-0.1	55	49	89	1.2	0.8	1173	235	20	0.1	-0.4	69	68	98	1.8	4.8	27	32	118	2.2	7.5
Chhura	1322	280	21	0.0	-0.2	50	44	90	1.4	1.6	1180	245	21	0.0	-0.3	64	59	93	1.4	2.4	29	33	114	1.8	4.2
Deobhog	1327	304	23	0.2	0.5	79	64	81	2.0	4.9	1144	274	24	0.2	0.1	80	81	101	2.3	7.8	25	29	117	1.8	3.2
Mainpur	1259	271	22	-0.1	0.1	68	57	84	1.5	2.2	1096	237	22	0.0	0.1	73	74	101	1.9	5.1	23	28	125	2.1	4.8

Rajim	1315	297	23	-0.1	-0.2	44	44	98	1.7	3.3	1181	264	22	0.0	-0.1	61	58	95	1.5	2.5	28	33	116	1.7	2.9
Akaltara	1346	266	20	0.4	0.0	42	39	94	1.9	5.5	1208	239	20	0.5	0.3	56	54	96	1.4	1.9	41	37	91	1.3	2.0
Baloda	1420	422	30	5.8	49.8	43	49	113	3.4	16.9	1275	384	30	6.0	52.6	60	55	93	1.1	0.7	43	45	105	1.8	3.4
Champa	1372	303	22	0.4	0.1	42	40	96	2.1	6.9	1234	267	22	0.5	0.0	58	54	94	1.2	1.4	38	39	102	1.7	4.1
Dabhra	1460	309	21	0.5	2.1	53	43	82	1.5	2.7	1310	284	22	0.7	2.5	58	49	83	1.0	1.1	40	38	97	1.3	1.8
Jaijaipur	1381	293	21	0.6	0.8	47	41	88	2.0	5.8	1239	262	21	0.7	1.1	57	48	85	1.0	0.8	38	38	98	1.5	2.7
Janjgir	1367	276	20	0.3	-0.2	42	38	91	1.9	5.6	1228	244	20	0.4	-0.1	58	55	95	1.3	1.7	40	38	94	1.5	3.3
Malkharoda	1440	296	21	0.6	1.5	50	42	85	1.6	3.5	1293	270	21	0.8	2.0	58	49	84	1.1	1.0	39	38	99	1.4	2.3
Nawagarh	1319	281	21	0.5	0.3	43	41	95	2.1	5.8	1183	248	21	0.7	0.7	55	49	89	1.1	1.0	38	37	97	1.5	3.1
Pamgarh	1298	267	21	0.4	0.3	39	39	100	2.0	5.6	1168	238	20	0.6	1.0	54	52	96	1.2	1.2	37	35	96	1.5	3.2
Sakti	1432	284	20	0.4	0.2	45	39	86	1.8	4.9	1289	253	20	0.5	0.3	60	53	88	1.2	1.2	39	39	100	1.6	3.5
Bagicha	1518	304	20	0.4	0.6	73	49	67	0.7	-0.3	1296	246	19	0.6	0.9	91	75	82	1.2	1.5	58	51	88	1.4	2.0
Duldula	1549	287	19	0.3	0.5	85	48	56	0.8	0.5	1306	245	19	0.6	1.2	98	80	82	1.2	1.2	59	53	89	1.7	3.0
Farsabahar	1501	295	20	0.0	1.1	75	47	63	0.9	1.2	1287	250	19	0.2	1.6	85	71	83	1.1	0.7	54	50	93	1.7	3.1
Jashpur	1488	270	18	0.4	0.1	90	53	59	0.8	0.4	1238	235	19	0.6	0.5	100	79	79	1.0	0.3	61	54	89	1.6	2.8
Kansabel	1544	307	20	0.3	0.4	77	49	63	0.8	0.0	1319	253	19	0.5	0.8	91	77	85	1.2	1.3	57	53	93	1.7	3.0
Kunkuri	1565	303	19	0.4	0.7	80	48	60	0.7	-0.2	1331	252	19	0.6	1.2	95	78	82	1.2	1.3	59	53	89	1.6	3.0
Manora	1477	319	22	0.5	1.5	78	51	66	0.8	0.5	1243	262	21	0.6	1.4	94	74	79	1.1	0.9	61	53	86	1.4	1.9
Pathalgaon	1514	302	20	0.1	0.3	70	48	68	1.0	0.6	1306	251	19	0.3	0.5	84	70	84	1.1	0.8	53	51	95	1.7	3.2
Bodla	1141	249	22	0.9	2.1	48	43	90	2.6	11.6	977	215	22	1.4	4.0	70	62	89	1.0	0.1	46	43	92	1.3	1.3
Kawardha	1140	216	19	1.0	2.4	46	39	85	2.0	7.0	986	180	18	1.2	3.8	64	56	87	1.0	0.3	43	39	90	1.1	0.6
Pandariya	1184	216	18	0.2	-0.3	49	42	86	2.3	8.9	1024	176	17	0.4	0.3	64	56	87	0.9	0.2	47	40	85	1.1	0.7
Sahaspur Lohara	1142	248	22	1.4	4.6	44	41	93	1.9	4.3	994	213	21	1.5	5.7	64	57	89	1.1	0.8	39	39	98	1.3	1.3
Bade Rajpur	1360	275	20	0.4	0.5	71	56	78	1.0	0.2	1179	233	20	0.3	-0.2	84	75	89	1.3	1.5	26	33	125	2.6	10.0
Farasgaon	1410	279	20	0.2	-0.3	80	56	70	0.7	-0.2	1209	228	19	0.4	-0.2	95	78	82	1.0	0.4	27	35	131	2.5	8.7
Keskal	1376	289	21	0.7	1.7	67	59	87	1.2	1.0	1194	240	20	0.5	0.1	87	81	92	1.3	1.3	28	35	126	2.4	8.3
Kondagaon	1483	281	19	0.3	0.0	103	56	55	0.8	0.9	1245	237	19	0.5	0.5	109	79	73	1.0	0.7	27	34	126	2.6	10.9
Makdi	1391	259	19	0.2	0.2	91	55	60	1.2	1.2	1181	220	19	0.3	0.3	96	73	76	1.2	1.2	24	28	118	2.1	5.8
Kartala	1438	277	19	0.2	-0.2	44	38	85	1.5	3.0	1289	237	18	0.2	-0.1	63	56	89	1.2	1.1	42	43	104	1.8	4.0
Katghora	1454	340	23	3.6	24.8	44	44	99	2.4	8.7	1303	308	24	3.9	27.8	62	54	86	0.9	0.4	44	45	102	1.8	3.6
Korba	1466	284	19	0.3	-0.1	46	41	89	1.5	2.8	1307	244	19	0.3	0.3	67	57	86	1.0	0.6	46	48	104	1.9	4.1
Pali	1441	309	22	2.2	11.4	44	43	98	2.3	8.5	1289	286	22	2.5	13.1	63	57	90	1.1	1.2	45	43	95	1.6	2.6
Poundi-Uproda	1428	273	19	1.1	3.9	45	41	92	2.2	8.3	1272	247	19	1.4	5.3	63	53	83	0.8	0.1	48	43	91	1.6	2.7
Baikunthpur	1368	306	22	0.0	-0.1	43	40	91	1.4	2.1	1209	267	22	0.0	0.0	63	61	96	1.4	1.9	53	48	91	1.5	2.2
Bharatpur	1259	264	21	0.0	-0.5	35	35	100	1.6	2.7	1122	232	21	0.1	-0.3	54	49	92	1.1	1.0	48	42	86	1.1	0.8
Khadganva	1361	267	20	-0.1	-0.2	45	41	91	1.5	3.1	1202	234	20	0.2	0.3	62	58	93	1.2	1.2	52	46	89	1.4	1.8
Manendragarh	1319	272	21	-0.1	-0.5	43	42	98	1.6	3.1	1165	238	20	0.2	0.1	60	59	98	1.4	1.9	52	47	90	1.3	1.3
Sonhat	1301	275	21	0.0	-0.5	40	38	94	1.6	3.3	1148	240	21	0.2	0.0	62	57	92	1.2	1.3	51	45	87	1.3	1.5
Bagbahra	1309	293	22	0.3	0.1	47	43	92	1.5	2.2	1174	259	22	0.4	0.5	58	54	92	1.2	1.2	30	36	118	1.9	4.2
Basna	1302	299	23	0.6	0.3	52	44	86	1.5	2.4	1157	262	23	0.5	0.3	58	50	86	1.1	1.3	36	38	106	1.7	3.1
Mahasamund	1285	311	24	0.3	0.3	43	46	106	1.8	3.7	1155	271	24	0.3	0.5	57	56	98	1.4	2.0	29	34	117	1.9	3.8
Pithora	1282	286	22	0.5	0.6	48	44	91	1.5	2.5	1144	246	22	0.5	0.8	58	52	90	1.4	3.3	33	36	110	1.8	4.3
Saraipali	1374	305	22	0.4	0.2	56	42	76	1.3	2.1	1221	273	22	0.3	0.2	59	49	83	0.9	0.5	38	38	100	1.5	2.1
Lormi	1257	226	18	0.1	-0.3	52	42	81	2.0	6.4	1091	193	18	0.4	0.8	66	57	86	0.9	0.3	49	39	81	1.0	0.4
Mungeli	1200	218	18	0.5	0.9	45	38	83	1.6	4.1	1054	190	18	0.7	2.3	59	52	88	1.0	0.4	42	35	84	0.9	0.0
Pathariya	1231	242	20	0.3	0.9	45	40	89	1.6	3.8	1088	220	20	0.5	1.9	57	52	92	1.2	1.0	41	35	85	0.9	-0.1
Narayanpur	1459	292	20	0.3	-0.1	85	59	69	0.6	0.2	1245	241	19	0.5	0.2	101	80	79	1.1	0.6	28	36	133	2.6	9.6
Orchha	1476	283	19	0.0	-0.4	72	54	76	1.0	1.6	1282	237	19	0.1	-0.4	95	76	80	1.1	0.7	28	35	128	2.4	8.1
Baramkela	1463	330	23	0.3	1.6	57	42	74	1.3	2.1	1306	301	23	0.4	1.6	61	50	82	0.9	0.5	39	37	94	1.3	1.8
Gharghoda	1462	300	21	0.2	0.3	54	45	84	1.7	3.9	1301	267	21	0.3	0.4	65	56	86	1.3	1.6	43	42	98	1.7	3.0
Kharsia	1470	293	20	0.4	1.1	50	41	83	1.4	2.4	1320	267	20	0.5	1.6	60	51	84	1.2	1.4	40	40	100	1.5	2.5
Lailunga	1484	302	20	0.2	0.2	65	45	70	1.2	1.5	1297	262	20	0.4	0.4	74	61	83	1.0	0.4	48	44	92	1.6	2.5
Pusour	1483	325	22	0.3	1.5	55	42	76	1.2	1.5	1325	301	23	0.3	1.5	62	51	82	1.0	0.8	41	37	92	1.2	1.4
Raigarh	1469	323	22	0.2	1.3	55	42	78	1.2	1.6	1312	299	23	0.3	1.4	62	50	81	1.1	1.2	41	38	94	1.3	1.7
Sarangarh	1398	308	22	0.4	1.2	54	43	80	1.5	2.7	1247	278	22	0.5	1.3	58	48	83	0.9	0.6	38	37	98	1.5	2.4
Tamnar	1466	322	22	0.2	0.6	58	44	77	1.4	2.2	1300	293	23	0.3	0.8	65	53	82	1.1	0.9	43	40	93	1.4	2.2
Dharamjaigarh	1478	296	20	0.4	0.7	53	46	88	1.7	3.0	1307	256	20	0.6	1.0	73	60	83	1.1	1.0	46	46	100	1.8	3.9
Abhanpur	1279	312	24	0.2	-0.4	42	43	103	1.8	3.6	1147	281	25	0.3	0.0	62	62	100	1.6	2.8	28	32	115	1.7	2.8
Arang	1256	296	24	0.1	-0.4	39	39	100	1.6	2.4	1133	270	24	0.2	-0.1	57	55	98	1.7	3.5	28	31	109	1.6	2.3
Raipur	1241	282	23	0.2	-0.3	41	39	94	1.7	2.7	1113	259	23	0.3	-0.1	58	56	96	1.7	3.8	30	31	104	1.5	1.9
Tilda	1197	293	25	0.3	-0.1	35	39	109	1.8	3	1081	262	24	0.5	0.3	53	54	102	1.9	5.1	28	30	107	1.3	1.3
Ambagarh	1296	287	22	0.5	0.6	46	41	91	1.6	3.4	1148	255	22	0.7	1.4	69	63	92	1.4	1.8	34	37	109	1.5	1.9
Chhuikhadan	1095	248	23	0.7	0.7	42	39	93	1.6	2.5	946	210	22	1.0	2.0	66	62	94	1.1	0.7	41	43	106	1.7	3.8
Chhuriya	1282	281	22	0.5	0.8	45	41	90	1.6	2.7	1130	246	22	0.7	1.8	71	67	94	1.3	1.2	35	37	103	1.3	1.1
Dongargaon	1260	284	23	0.4	0.6	47	44	93	1.7	3.4	1109	250	23	0.6	1.2	69	64	93	1.3	1.1	35	37	107	1.3	0.9
Dongargarh	1222	257	21	0.4	0.1	43	39	89	1.5	2.1	1071	219	21	0.5	0.9	71	68	97	1.4	1.7	37	36	99	1.2	1.0
Khairagarh	1125	227	20	0.6	0.6	44	43	98	2.1	6.4	979	190	19	0.7	1.7	66	61	92	1.3	1.4	37	37	100	1.2	0.8

Manpur	1436	318	22	0.4	0.1	44	40	90	1.5	2.3	1291	293	23	0.5	0.1	71	65	92	1.4	1.8	30	36	119	1.9	3.6
Mohla	1363	292	21	0.3	0.2	46	41	89	1.6	3.3	1215	263	22	0.5	0.3	71	63	90	1.3	1.5	32	36	113	1.7	3.0
Rajnandgaon	1215	260	21	0.4	0.3	47	63	133	5.4	41.4	1073	221	21	0.5	0.4	64	58	90	1.2	1.1	31	34	110	1.5	1.8
Chhindgarh	1581	300	19	0.5	1.5	120	54	45	0.7	0.0	1308	271	21	0.6	1.6	130	82	63	0.9	0.7	24	32	137	3.2	16
Konta	1405	271	19	0.4	-0.1	94	48	51	0.5	-0.3	1149	269	23	0.4	-0.1	143	86	60	0.8	0.7	19	24	126	1.9	3.6
Sukma	1538	316	21	0.9	3.4	112	58	52	0.4	-0.5	1266	285	23	1.1	3.6	139	91	65	0.8	0.1	21	31	143	2.6	9.7
Bhaiyathan	1420	318	22	0.0	0.3	46	39	83	1.5	3.0	1249	278	22	0.0	0.5	69	62	90	1.3	1.6	55	47	85	1.4	2.3
Oudgi	1297	268	21	-0.1	0.0	40	34	85	1.5	2.7	1143	234	21	0.0	0.7	62	54	87	1.0	0.5	53	43	82	1.1	0.9
Pratappur	1311	273	21	-0.1	0.1	42	34	82	1.5	2.9	1150	239	21	0.0	0.7	66	55	84	0.9	0.2	54	45	83	1.1	0.8
Premnagar	1436	294	21	0.0	0.1	47	39	83	1.5	3.0	1268	258	20	0.0	0.1	68	58	85	1.2	1.4	52	45	87	1.6	3.0
Ramanujnagar	1415	322	23	-0.1	0.1	46	39	85	1.4	2.5	1249	282	23	-0.1	0.1	67	61	91	1.4	2.0	53	47	88	1.5	2.7
Surajpur	1456	330	23	0.1	0.2	50	41	82	1.5	3.4	1278	289	23	0.1	0.2	72	65	90	1.3	1.6	56	48	85	1.5	2.7
Ambikapur	1475	315	21	0.4	0.5	51	41	81	1.5	3.0	1294	274	21	0.4	0.3	76	64	84	1.1	1.1	54	48	89	1.7	3.5
Batouli	1506	302	20	0.5	0.6	65	48	74	1.1	0.9	1300	250	19	0.6	1.1	86	69	80	1.0	0.8	55	50	91	1.5	2.5
Lakhanpur	1476	317	22	0.3	0.5	51	42	82	1.5	3.2	1297	277	21	0.3	0.3	75	63	85	1.1	1.2	54	48	88	1.6	3.3
Lundra	1458	293	20	0.2	-0.1	59	45	77	1.2	1.5	1263	245	19	0.3	0.1	81	64	79	0.9	0.6	55	49	89	1.5	2.5
Mainpat	1501	315	21	0.7	2.2	58	49	84	1.9	5.3	1308	270	21	0.9	3.0	83	65	79	0.9	0.4	53	50	95	1.6	3.0
Sitapur	1532	311	20	0.4	0.3	70	49	71	1.0	0.8	1318	258	20	0.6	0.8	89	74	83	1.1	1.0	56	53	94	1.6	2.5
Udaypur	1468	301	21	0.3	0.4	49	41	84	1.5	2.8	1295	261	20	0.3	0.4	72	59	82	1.0	0.8	52	47	91	1.7	3.7
Antagarh	1424	286	20	0.4	0.3	64	54	84	1.2	1.6	1244	240	19	0.3	-0.2	88	77	88	1.2	0.6	28	35	126	2.5	8.7
Bhanupratappur	1391	304	22	0.5	0.7	54	47	87	1.5	3.1	1228	270	22	0.5	0.1	80	74	92	1.3	1.2	29	34	118	2.2	6.5
Charama	1302	280	22	0.5	0.6	51	46	90	1.6	2.4	1147	241	21	0.4	0.0	76	71	93	1.4	1.8	28	33	120	2.4	8.3
Durgkondal	1442	325	23	0.5	0.5	47	43	92	1.3	1.4	1294	300	23	0.6	0.5	73	68	93	1.4	1.5	28	35	125	2.1	5.5
Kanker	1344	302	22	0.7	1.7	63	57	91	1.6	3.6	1168	257	22	0.5	0.3	84	80	95	1.4	1.5	30	36	122	2.2	6.1
Narharpur	1333	289	22	0.4	0.7	58	52	89	1.5	2.2	1171	253	22	0.2	-0.1	77	74	96	1.5	2.3	27	34	124	2.4	7.8
Pakhanjur	1486	309	21	0.3	0.0	49	43	89	1.3	2.0	1333	279	21	0.4	0.1	77	71	92	1.4	1.7	28	35	125	2.0	4.3
Minimum	1095	216	18	-0.1	-0.5	34	31	41	0.4	-0.6	946	176	17	-0.1	-0.4	49	47	60	0.8	-0.2	19	24	80	0.9	-0.2
Maximum	1621	422	30	5.8	49.8	137	104	205	8.6	85.4	1333	384	30	6	52.6	143	91	107	2.3	7.8	61	54	147	3.2	16
Average	1358	319	24	2.9	24.7	86	67	123	4.5	42.4	1140	280	24	3	26.1	96	69	84	1.6	3.8	40	39	114	2.05	7.9

Spatial and Temporal Variability of Rainfall in Different ACZs

The annual average rainfall of the Northern Hills zone, Chhattisgarh Plains and Bastar Plateau are estimated as 1422.7mm, 1305.9 mm and 1482.2 mm respectively. In the Northern Hills zone, the maximum annual average rainfall occurred in the Kunkuri block (1565 mm) and the minimum annual average rainfall occurred in the Wadrafnagar block (1190 mm) respectively. Within the Chhattisgarh Plains, the maximum and minimum annual average rainfall occurred in the Lailunga block (1484 mm) and Chuhikhadan block (1095 mm) respectively. In the Bastar Plateau, the maximum and minimum annual average rainfall occurred in the Jagadalpur block (1621 mm) and Charama block (1302) respectively. The average, maximum and minimum value of annual rainfall over three different agro climatic zone is summarized in (Table 4.2). Further, spatio-temporal variability of weighted average rainfall has been illustrated in Fig. 2 (A-E). From the map it can be concluded that annual, as well as seasonal rainfall shows a large spatial variation. Among the three agroclimatic zones the maximum amount of annual average rainfall was distributed in southern part of Bastar Plateau and regions of low rainfall was distributed over central part of Chhattisgarh Plains. During pre-monsoon season, low amount of rainfall was noticed in a large extent of area over Chhattisgarh Plains and northern hills zone while high amount of rainfall was confined in east central regions of Bastar Plateau. During monsoon season, high amount of rainfall was distributed over an entire area of Bastar Plateau, north eastern parts of Chhattisgarh Plains and south eastern part of northern hills zone. Rainfall distribution during post monsoon season showed a similar distribution as that of pre monsoon season. During winter season the areas receiving higher rainfall was distributed over northern hills zone and the area receiving lowest rainfall was confined to southern parts of Bastar Plateau. Bastar Plateau. Received highest rainfall during all the time series except for the post monsoon season.

Table 2: Average, maximum and minimum rainfall over different ACZs

ACZs	Average	Maximum	Minimum
Northern Hill zone	1423	2273	687
Chhattisgarh Plain	1306	2241	659
Baster Plateau	1482	2464	809

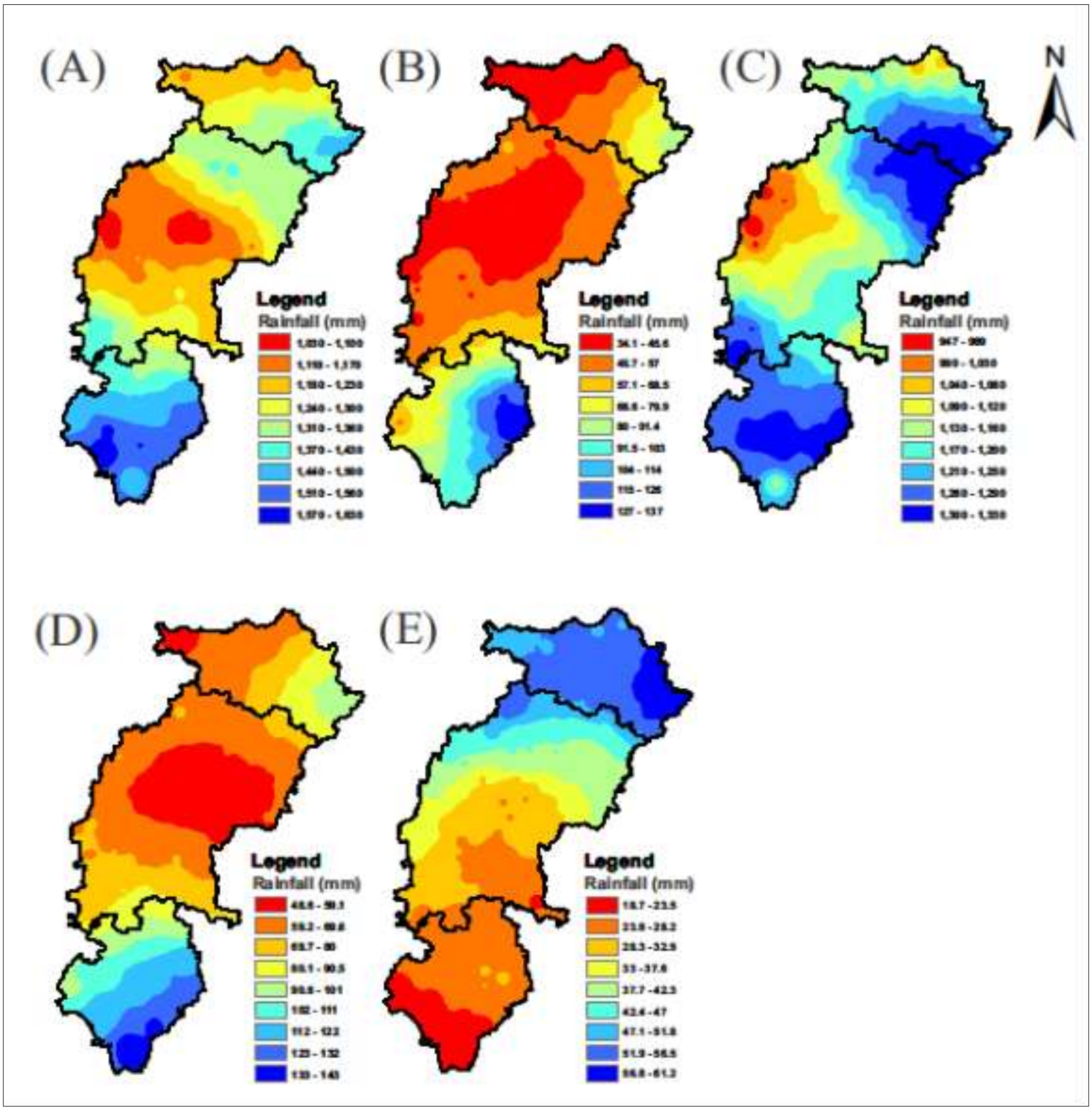

Fig 2: Spatio-temporal variability of weighted average rainfall during (A) Annual rainfall (B) Pre monsoon (C) Monsoon (D) Post monsoon (E) Winter.

Conclusion

The variability of annual and seasonal rainfall were explored for 149 blocks of Chhattisgarh state. The long term rainfall variability was assessed by calculating general statistics of rainfall from 1901 to 2020. Inverse distance weighted approach was used to find out the spatial variability of annual and seasonal rainfall using Arc GIS software. The maximum value of average annual rainfall over the state from 1901 to 2020 was noticed in Chhuikhadan and minimum value was noticed in Jagdalpur block. The co efficient of variation of annual rainfall over Chhattisgarh was 24%. Among the four seasons, the maximum and minimum rainfall were noticed during monsoon and winter season respectively. The maximum and minimum amount of co efficient of variation was seen during pre monsoon and monsoon season respectively. The annual and seasonal rainfall showed a large spatial variability. The maximum value of average rainfall was noticed in Bastar Plateau followed by northern hills zone and Chhattisgarh Plains. The outcomes of the study offers valuable information for crop planners and policy makers to formulate different strategies for water resource management and crop planning.

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