



Research Article

Spatial Analysis of Rainfall and Rainy Days in Chhattisgarh State, India

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ABSTRACT

Among climatic factors, rainfall is the most important single factor which determines the cropping pattern of an area in general and the type of crop to be cultivated and its success or failure in particular. The present study has been carried out to characterize seasonal and annual variability of rainfall in different districts of Chhattisgarh state and also its spatial distribution. Results indicated that the mean annual rainfall of the state is 1167 ± 147 mm, of which the winter, summer, southwest and post-monsoon period contribute 20, 30, 1050 and 67 mm, respectively. The district Surajpur lying in Northern Hills Agro-Climatic Zone (ACZ) receives the highest annual rainfall (1411 mm) as well during southwest monsoon season (1311 mm) whereas Kabirdham district in Chhattisgarh Plain ACZ records the lowest annual (885 mm) and southwest monsoon period (778 mm). Spatial distribution of southwest monsoon rainfall over different districts revealed that the districts like Kabirdham, Durg, Bemetara, Mungeli, Rajnandgaon receives low rainfall with high inter-annual variability and rice is cultivated in 80% of cultivated area posing high risk of crop failure in the event of failure of monsoon rainfall. Excess rainfall during southwest monsoon can be saved in farm pond, community reservoirs and percolation tank (to increase ground water recharge) and conserved water can be utilized for life saving irrigation during dry spells in *kharif* season and also for low water demand crops like pulses / oil seeds during *rabi* season in rice fallow lands which would increase farm income as well livelihood of farming community.

Key words: agro-climatic zones, cropping pattern, rainfall variability, southwest monsoon, spatial distribution

Introduction

In general, climate determines the cropping pattern of a particular region and weather determines the crop productivity. Among the climatic elements, rainfall is crucial for all walks of life and especially for agriculture. It is

important to analyze the spatial as well as temporal distribution of rainfall over the region / state for better crop planning. Rainfall during the monsoon season is unequal both in time and space. So it is important to analyze the rainfall variation (Rathod and Aruchamy, 2010). Studies of rainfall variation focusing on large areas would be of no use for local agriculture, particularly in places where rainfall is highly variable (Murugan

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et al., 2008). Chhattisgarh state is predominantly agriculture based and it supports livelihood of almost 60% population. It is one of important rice growing states in the country. Wide diversification of crops and cropping system is important feature of Chhattisgarh state. Though rice is major crop of the state, potato is cultivated during *kharif* in northern hill agro-climatic zone while planation crops (coconut, coffee), spices, medicinal crops as well as tuber crops are cultivated in southern region of the state (Pandey *et al.*, 2012). The state receives average annual rainfall of 1400 mm and around 80% of annual rainfall is being received during June to September and meager rainfall in remaining months of the year leads to scarcity of water (Chakraborty *et al.*, 2013). In general rainfall decreases from east to western part of the state and districts in western parts of the state (Durg, Rajnangaon, Kabirdham) are falling under rain shadow region receives lowest rainfall. Increasing agricultural production of the state is great challenge since 75% of the rice cultivated area is under rainfed situation which is vulnerable to vagaries of monsoon rainfall amount and distribution. Problems like climate change, degradation of natural resources and dominance of marginal and small farmers are making situation further complicated. Knowledge on spatio-temporal variation of rainfall at state level is essential for effective agricultural crop planning and management of water resources. Michaelides *et al.* (2009) reported that spatio-temporal analysis of precipitation is vital not only for agricultural planning, water resource assessments but also for flood frequency analysis, flood hazard mapping, hydrological modeling, climate change impacts and other environmental assessments. Some studies were found in literature on rainfall analysis (spatial distribution, probability and trend) by using one district or major station rainfall data or district-wise (16 districts) rainfall data (Vijay Singh and Issac, 2012; Chakraborty *et al.*, 2013; Murali and Afifi, 2014; Chaudhary *et al.*, 2015). Rao *et al.* (2011a) assessed the rainfall trends at macro ($1^\circ \times 1^\circ$ grid data covering area of 111 km) and micro level (1128 rain gauge stations) over Andhra Pradesh and opined that

rainfall analysis with micro level data is better for planning. Hence, the present study is aimed to understand seasonal / annual pattern of rainfall and its spatial distribution over Chhattisgarh State using 84 rain gauge stations data.

Materials and Methods

Study area

Chhattisgarh is located in the central part of India, between latitudes of $17^\circ 46'$ N and $24^\circ 5'$ N and longitudes of $80^\circ 15'$ E and $84^\circ 20'$ E. It is landlocked by Madhya Pradesh, Maharashtra, Telangana, Odisha, Jharkhand and Uttar Pradesh. The state has three Agro-Climatic Zones (ACZ), Chhattisgarh Plains, Bastar Plateau and Northern Hills (Fig. 1). The state has 27 districts with 149 tehsils spreading over a geographical area of 137.90 lakh hectares.

Daily rainfall data of 84 rain gauge stations for the period of 54 years from 1960 to 2013 (different for stations based on data availability) has been collected from weather database of Department of Agrometeorology, Indira Gandhi Krishi Viswavidyalaya (IGKV), Raipur, Chhattisgarh, India. Long term mean seasonal and annual rainfall pattern along with rainy days has been calculated using weather cock software (Rao *et al.*, 2011b) for 84 rain gauge stations that have been taken for the study. Number of rainy days was worked out following India Meteorological Department (IMD) for Indian region (a day with rainfall amount ≥ 2.5 mm is considered as rainy day). The standard deviation (SD) and coefficient of variation (CV) were also worked out. The collected data were analyzed and various maps were generated using ArcGIS software version 10.0. In this study, meteorological seasons and its period is followed as per the India Meteorological Department glossary (www.imdpune.gov.in): Winter season: January – February; Summer season: March – May; Southwest Monsoon season: June – September; Post Monsoon season: October – December.

Interpolation method

Shape file of Chhattisgarh state map used in the study were collected from Department of Soil

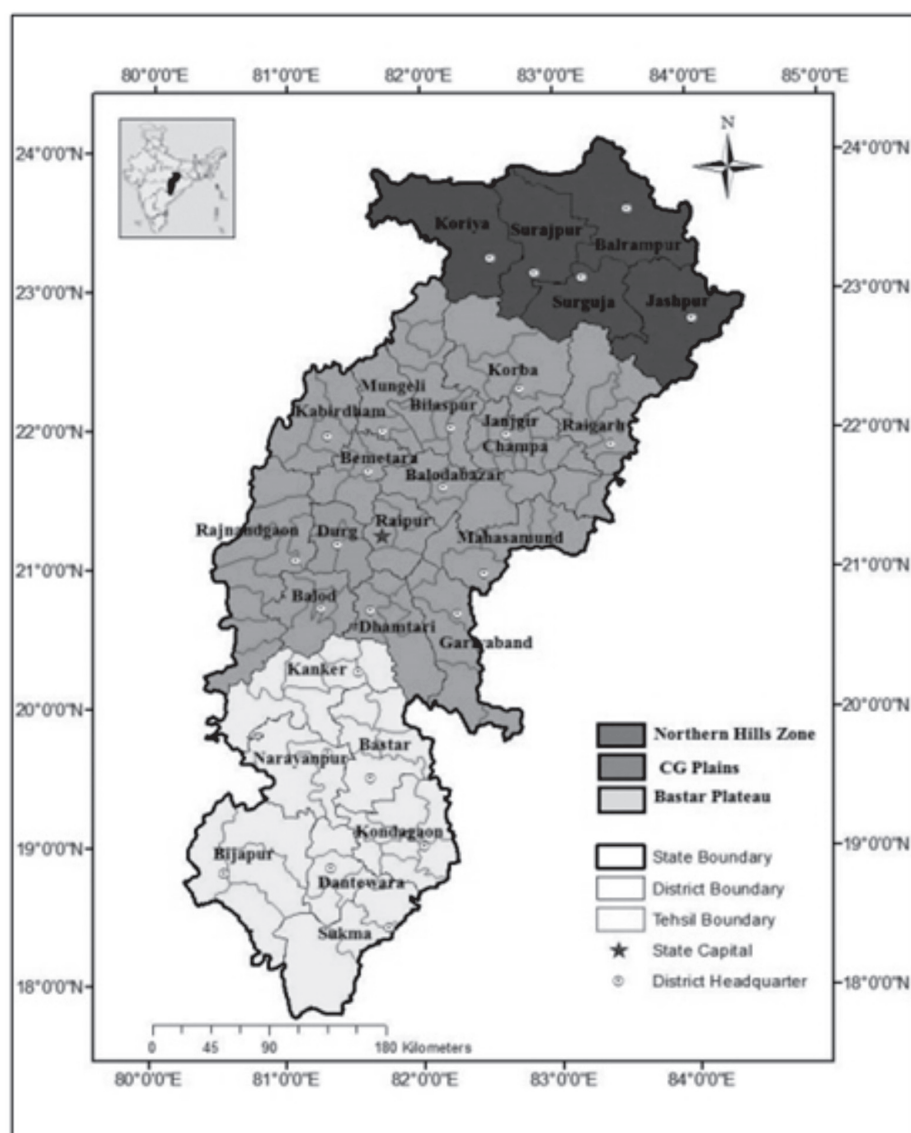


Fig. 1. Location map of Chhattisgarh state with agro-climatic zones

and Water Engineering, Faculty of Agricultural Engineering, IGKV, Raipur from which we have drawn tehsils, districts and state boundary with the help of a geo-referenced state map. Grid representation of surface is considered to be a functional surface because for any given x (UTM Easting), y (UTM Northing) location that exported from an excel sheet with the Object Identifier (OID), districts and stations name, northing, easting of stations and rainfall data (annual and seasonal mean, SD, CV) for each locations. Chhattisgarh state comes under projection zone UTM zone 44N. The ordinary

kriging method with spherical semivariogram model from 3D analyst tools available in ArcGIS v10.0 was utilized for developing the various raster images providing information of pixel based rainfall information. Geostatistical interpolation method was adopted as traditional method (Thiessen, Inverse Distance Weighted, and regression) does not take into account the pattern of spatial dependence (Mair and Fares, 2011). The cell size of 1560 was taken for the output raster as per the UTM projection coordinate system of the base map. The base map was prepared using the SOI toposheets and LANDSAT image with

30 m spatial resolution downloaded for the complete state. Rainfall data is used as point elevation and state boundary used as interpolation boundaries.

Results and Discussion

Spatial variability of annual rainfall

Mean annual rainfall of the state is 1167 ± 147 mm which is received in 56 ± 8 numbers of rainy days with a co-efficient of variation 13 % during the study period 1960 – 2013 (Table 1). Mean annual rainfall of the state is almost equal to average annual rainfall (1178 mm) of the Country (www.imdpune.gov.in). However coefficient of variation of annual rainfall of the state is little higher than at all India level (9%) and within the state variation in annual rainfall is observed like annual rainfall variation among different states in India. Among the districts, mean annual rainfall varied from 885 mm (Kabirdham district) to 1411 mm (Surajpur district). It is inferred that lowest annual rainfall is noticed in the west central part of the state (Kabirdham, Bemetara and Durg) while highest annual rainfall is recorded in northern (Surajpur and Surguja) and southern part (Bastar and Narayanpur) of the state (Fig. 2A). Gupta (2002) reported that the distribution of rainfall in Chhattisgarh is orographically determined and districts like Kabirdham and Rajnandgaon chronically drought prone areas owing to rain shadow region. Among the three agro-climatic zones of the State, Bastar Plateau experiences highest mean annual rainfall (1323 mm) and Chhattisgarh Plains receives lowest (1074 mm). It is intermediate in Northern Hills (1279 mm). Reason for high annual rainfall in southern parts of the state can be attributed to early start of southwest monsoon and significant amount of rainfall is received during post-monsoon season when compared to other parts. Guhathagurta and Saji (2012) studied monthly, seasonal and annual rainfall at district level over Maharashtra state to relate to agriculture planning and water management. Bhelawe *et al.*, (2013) divided the state into three zones viz., low (<1100 mm), medium (1100-1400 mm) and high rainfall zone (>1400 mm); maximum area was under medium rainfall zone. In case of variability,

lowest CV of annual rainfall is recorded in Kondagaon (16%) and Sukma (20%) districts while highest was in Janjgir Champa, Balrampur (32%) and Raipur, Durg and Balod (31%) districts indicating high inter annual variability. Overall, annual rainfall variability is seen between 20 and 30% in almost 70-75% of area of the state signifying that the variability is at moderate level (Fig. 2B). Nearly 15-20% area of the state covering central part of the state and some parts of Balrampur, Surajpur, Korias and Jashpur districts has 30-40% annual rainfall variability. Number of rainy days is important parameter explaining the distribution of rainfall in a year. Among the districts, highest number of rainy days in a year is observed in Bastar district (76) indicating good rainfall distribution, while lowest is in Durg and Bemetara districts (43). Approximately 60% area of the state receives annual rainfall in 50-60 days while annual rainfall is received in 60 days or more in about 20-25% area of the state (southern and north east part of the state). Some portion of the Durg, Raipur, Bemetara and Balod districts are receiving annual rainfall only in less than 40 days indicating about 1000 mm rainfall is being received at the rate 25 mm per day (Fig. 2C). Sastri *et al.* (1997) studied district-wise rainfall distribution and its changing pattern and they also stated that Raipur district has lowest annual number of rainy days.

Spatial variability of southwest monsoon rainfall

This is the wettest period of the year in the state. Almost 90% of annual rainfall is received during southwest monsoon (SWM) season (1050 ± 123 mm) in 48 rainy days with 12% variability (Table 1), explaining delay / break monsoon condition leading to rainfall deficiency which affects agricultural production as well economy and socio-economic status of the farming community. Within the state, monsoon season rainfall varied from 778 mm in Kabirdham district to 1311 mm in during Surajpur district indicating significant variation in rainfall among the districts. It is understood that monsoon rainfall is lower (<700 mm and 700-900 mm) in west central (comprising entire Kabirdham district and

Table 1. Seasonal and annual average rainfall (mm) of different districts of Chhattisgarh state with its SD and CV

S. No	Districts	No. of years	Winter			Summer			SWM			Post-monsoon			Annual		
			Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)
1	Balod	48	11	28	274	13	24	194	938	288	31	55	64	116	1017	309	31
2	Balodabazar	46	13	21	158	16	30	194	929	235	26	50	57	114	1008	257	26
3	Bemetara	51	8	21	315	9	19	262	890	241	27	41	48	117	948	251	26
4	Durg	49	6	16	279	12	27	253	891	260	31	46	59	128	954	282	31
5	Dhamtari	51	22	25	123	39	42	110	1012	255	25	60	65	109	1133	289	26
6	Mahasamund	45	16	42	258	20	34	246	1033	313	31	48	57	123	1117	326	29
7	Kanker	28	17	24	146	30	62	215	1032	268	26	74	82	111	1152	324	28
8	Gariaband	49	11	24	258	18	37	244	1065	306	29	46	61	132	1140	323	28
9	Raipur	54	11	22	245	18	29	252	954	298	31	52	63	124	1035	321	31
10	Mungeli	48	26	34	135	29	32	111	928	219	24	71	61	86	1055	252	24
11	Kabirdham	35	29	43	150	25	34	175	778	197	26	53	55	104	885	221	26
12	Rajnandgaon	51	17	36	199	21	36	188	1004	327	33	63	70	112	1105	336	30
13	Bilaspur	50	47	55	117	56	59	111	935	207	22	58	58	96	1096	232	21
14	Korba	43	19	33	196	30	41	135	1018	261	26	46	56	122	1113	274	25
15	Janjgir-Champa	52	29	38	132	27	36	134	1095	334	31	77	87	114	1228	383	32
16	Raigarh	50	21	30	148	43	79	158	1061	287	27	68	73	105	1192	310	26
17	Jashpur	51	24	35	157	42	52	136	1174	310	27	78	75	99	1318	342	27
18	Koriya	40	25	40	162	20	44	218	1113	261	23	67	71	107	1225	311	25
19	Surajpur	09	12	22	193	10	21	208	1311	382	29	78	71	92	1411	368	26
20	Surguja	33	47	41	88	48	47	96	1170	321	27	83	61	73	1348	342	25
21	Sukma	33	6	16	271	49	53	108	1199	261	22	88	74	85	1342	268	20
22	Bastar	34	22	22	98	143	71	49	1129	232	21	113	93	82	1408	289	21
23	Bijapur	35	28	54	185	31	38	151	1167	297	25	64	60	97	1290	321	25
24	Kondagaon	10	18	23	126	27	26	93	1121	173	15	85	79	93	1252	196	16
25	Narayanpur	35	15	28	188	29	55	190	1235	245	20	88	69	79	1366	289	21
26	Dantewara	33	14	37	260	6	13	208	1170	355	30	91	75	83	1282	334	26
27	Balrampur	07	13	22	176	9	19	215	1009	304	30	63	53	84	1094	351	32
	State		20	10	53	30	26	86	1050	123	12	67	18	26	1167	147	13

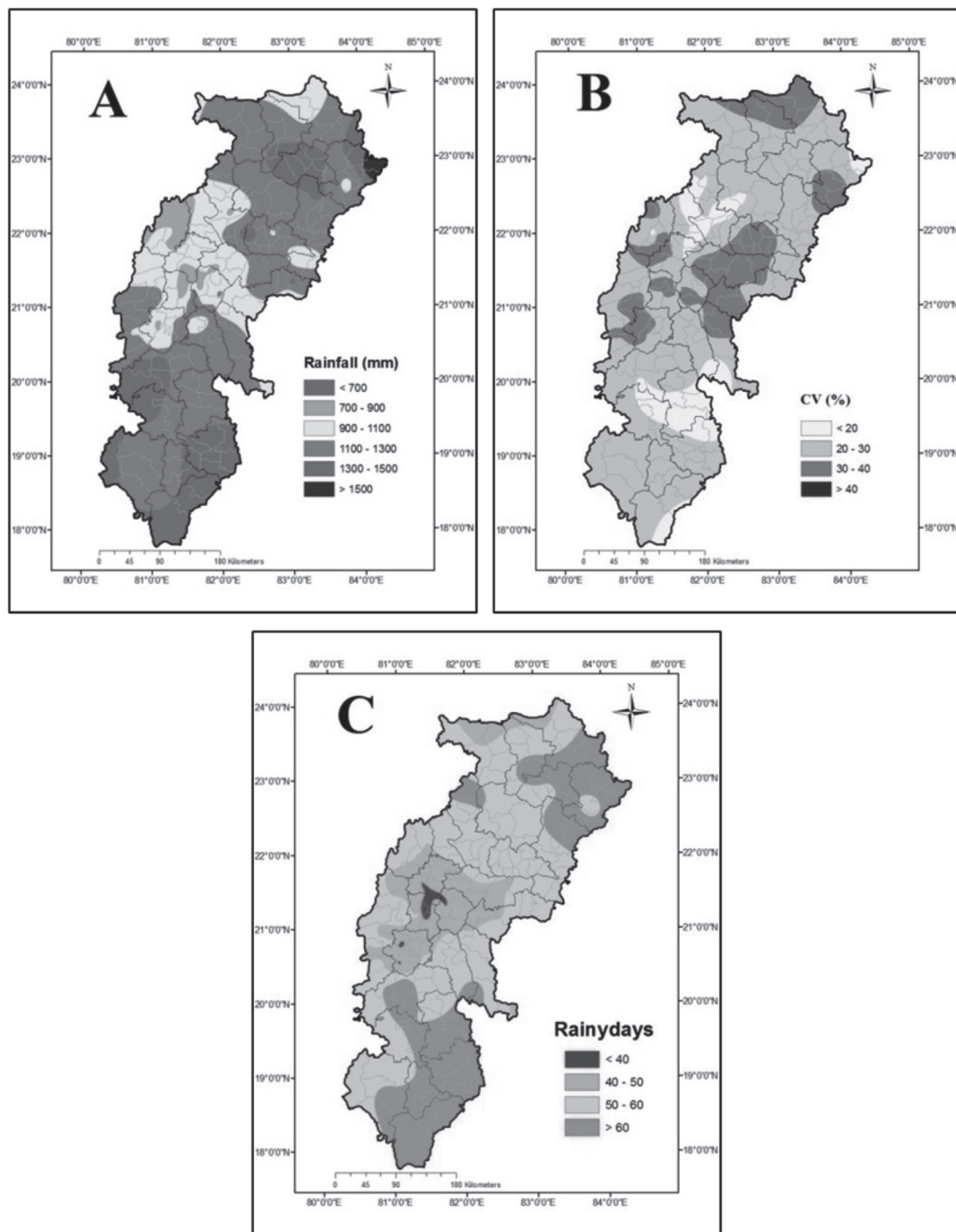


Fig. 2. Spatial variability of annual mean rainfall (A), annual rainfall CV (B) and annual rainy days (C) over Chhattisgarh State

parts of Bemetara, Bilaspur, Rajnandgaon, Durg, Balod, Raipur, Baloda Bazar and Mahasamund districts) than northern and southern part of the state where it is > 1100 mm (Fig. 3A). Gupta (2002) also reported that Kabirdham and Rajnandgaon districts and some pockets of Durg,

Bilaspur, Bemetara, Raipur districts received low rainfall than other districts. Thus main issues to farming in these districts are onset of monsoon and distribution of rainfall during monsoon months. In general, monsoon sets in around 10th June in the southern tip of the State (Bastar area)

and covers the entire state by 20th June. The monsoon onset is very crucial for agricultural operations as rainfed agriculture is predominant in 74, 97 and 95% of cultivated area under Chhattisgarh Plains, Bastar Plateau and Northern Hills ACZ, respectively and nearly 70% of net sown area is covered by rice during *kharif* season (Pandey *et al.*, 2012). Hence, crop failure is common in this part due to late onset of or break in or early withdrawal of monsoon. Sastri *et al.*, (1999) indicated that rice yield declined by 27% in the years of late onset of monsoon compared to normal monsoon. The SWM rainfall is received in 48 numbers of rainy days for the state and highest number of rainy days is observed in Jashpur district (58), while lowest is found in Durg district (39). Sastri *et al.* (1997) reported lowest number of rainy days during southwest monsoon in Durg district. The variation is 15-33% with the highest CV recorded in Rajnangaon (33%), followed by Balod, Durg, Raipur, Mahasamund and Janjgir-Champa (31%) indicating high inter annual variability. Lowest variation is recorded in Kondagaon district (15%) indicating high reliability. It is very imperative to note that even though low seasonal rainfall and high inter-annual variability in some districts especially west central part of the state (consisting Kabirdham, Durg, Bemetara, Mungeli, Rajnandgaon districts), rice is cultivated in 80% of cultivated area (with irrigated area of 26.4% in Kabirdham) during *kharif* season (Pande *et al.*, 2012) involving high risk of crop loss. In these parts of state, soybean is second most important crop during *kharif*, which requires less water and can be promoted. Although lack of recommended soybean production technology was one of the production constraints in Rajnandgaon (Deshmukh, 2008). Kumar (2008) reported that the overall technological gap in following recommended soybean practices among the farmers of Kabirdham district was 71% owing to lack of training / non availability of information.

Spatial variability of post-monsoon season rainfall

Mean post-monsoon rainfall in the state is 67±18 mm with 26% of coefficient of variation

(Table 1). Among the districts, seasonal rainfall varied from 41 mm in Bemetara to 113 mm in Bastar district with high co-efficient of variation (Fig. 3B). During this season, southern part of the state (Bastar Plateau ACZ) receives more rainfall (88 mm), which may be attributed to late withdrawal of southwest monsoon. Districts under Chhattisgarh Plains ACZ receive very low rainfall (< 50 mm) while parts of Jashpur district in north and Bastar district in south gets >100 mm rainfall. Low water requirement crops *viz.* lathyrus, chickpea, peas, lentil, linseed and wheat are grown in many districts wherever substantial irrigation facility is available, and rice is also cultivated by utilizing canal irrigation in Dhamtari, Janjgir-Champa, Raipur, Durg and Bilaspur districts. However, large area is still under fallow after *kharif* rice cultivation, where low water demanding crops like pulses can be grown from conserved rain water in farm ponds, community reservoirs and percolation tank, through financial support from local government agencies. Satellite data estimates 2.936 Mha of land is rice fallow in Chhattisgarh (Pande *et al.*, 2012) and eleven districts (Bilaspur, Dhamtari, Kanker, Jashpur, Raipur, Durg, Rajgarh, Kabirdham, Korba, Mahasamud and Rajnandgaon) have 0.88 Mha of potential area for cultivation of pulses as rice fallow (MoA, 2009). A report from National Academy of Agricultural Sciences (NAAS, 2013) also indicated that huge impact on rural livelihood can be made through policy interventions by increasing area of rice fallow under short duration pulses/oil seeds.

Spatial variability of summer and winter season rainfall

During the pre-monsoon season, the state receives 30±26 mm rain with 86% CV (Table 1). It contributes only 3% to annual rainfall. Rain during this season mainly occurs due to convection effect. During this season, Bastar district receives maximum rainfall of 143 mm (Fig. 3C). In general, one or two heavy showers may be expected in this season and this enhances soil moisture level and can be effectively utilized for summer ploughing.

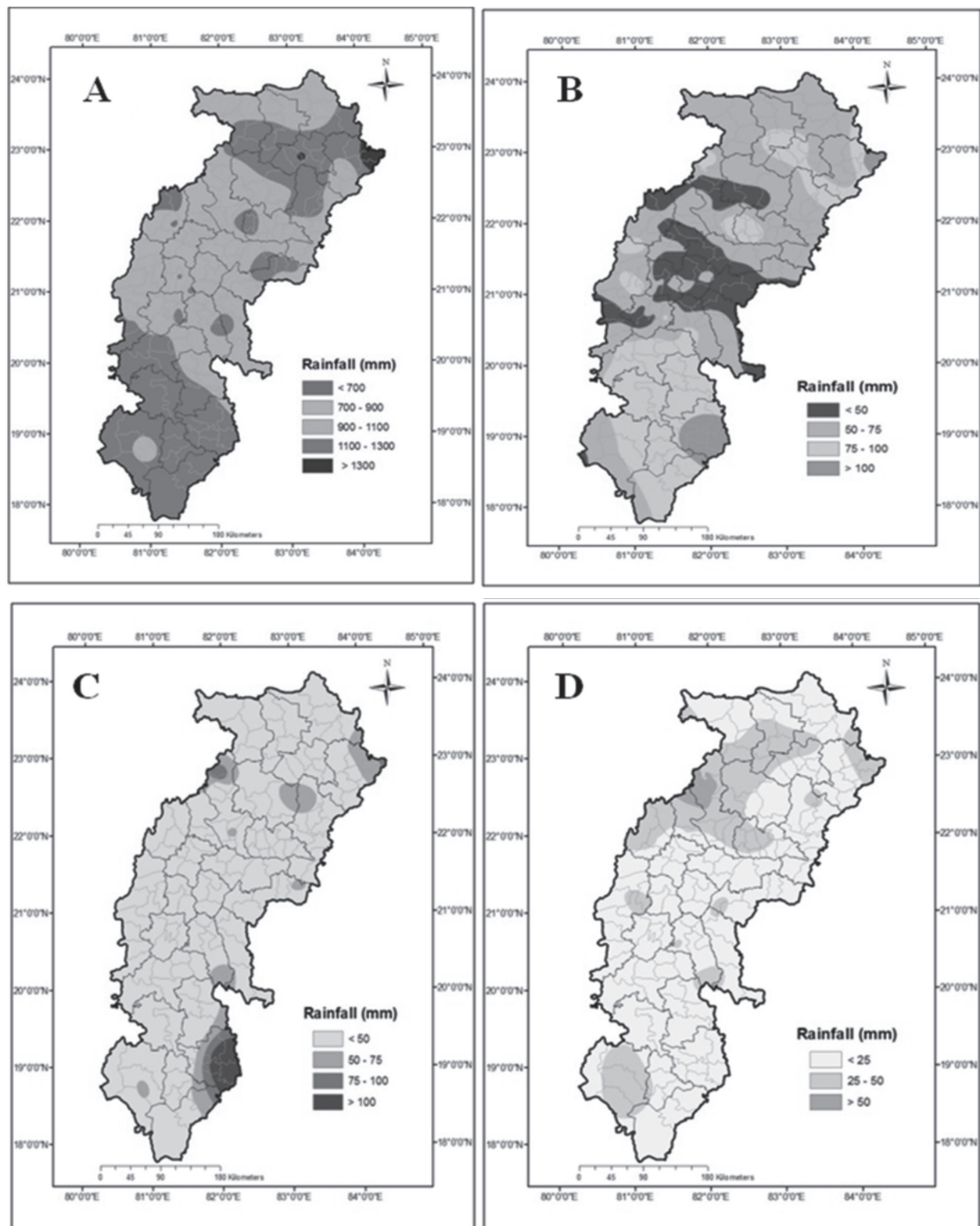


Fig 3. Spatial distribution of Southwest monsoon (A), Post monsoon (B), Summer (C), Winter season (D) rainfall in Chhattisgarh State

Winter (Jan–Feb) is the driest season of the state (20±10 mm rainfall with 53% of variability) (Table 1) and contributes only 2% to mean annual rainfall. Among the districts, Surguja receives highest rainfall (47 mm) during this season. Comparatively more rainfall is recorded at northern hills ACZ (24 mm) due to influence of western disturbances than Chhattisgarh plain ACZ (19 mm) and minimum is observed at Bastar plateau ACZ (17 mm) (Fig. 3D).

Conclusions

West central part of the state (consisting Kabirdham, Durg, Bemetara, Mungeli, Rajnandgaon districts) receives low seasonal rainfall with high inter-annual variability. In these districts, rice is cultivated in 80% of area posing high risk of crop failure. Soybean may be promoted as a *kharif* crop which requires less water. During *rabi* season, large area in the state is under fallow after *kharif* rice cultivation, and has potential to grow low water demand crops like pulses, with excess rainfall conserved in ponds and reservoirs.

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