



Rainfall and drought characteristics for crop planning in Plain zone of Chhattisgarh

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Daily rainfall data of 55 years (1960-2015) of Raipur district of Chhattisgarh have been considered to analyse the long term average and its temporal variability on weekly, monthly, seasonal and annual basis. The average annual rainfall at Raipur was 1158 mm with 29 per cent coefficient of variation indicating thereby that the rainfall was not much stable over the years. July was the highest rainfall recipient month (616 mm) followed by August (519 mm) during the monsoon period. Trend analysis on rainfall of past 55 years exhibited a decreasing pattern of 8.33 mm and 7.04 mm per year in annual and kharif season rainfall, respectively. Agricultural drought was most frequently observed in early (23-26 SMW) as well as late (37-40 SMW) stages of kharif crops. Meteorological droughts of different intensities, viz., no drought, moderate drought and severe drought over the observed periods showed that station is prone to mild-moderate type of drought. Short duration, low water requiring but high value crops like maize, pulses, oilseeds and some vegetables can be opted for this region to minimize the production risk.

INTRODUCTION

Rainfall being a nature's blessing and drought a curse for the whole living world are decisive weather phenomenon for ensuring or threatening our food security. Characterisation of these weather events would certainly be helpful in framing out the strategies to minimise the risk toward sustainable production. Interpretation of rainfall records in relation to the local agricultural practice that are followed is necessary to bring out the implications of rainfall variability in agricultural planning and management. Raipur, located in the Western Plateau sub-zone (zone V) of Jharkhand state, is a unique district to have a typical monsoon climate which often becomes a rain-shadow area. The region is classified as dry sub-humid zone of Jharkhand. Frequent occurrence of drought with uneven spatial and temporal distribution of rainfall has been affecting the sustainable development of society and economy of the district. Climatological data of a location is of utmost importance towards minimising production risk (Vairavan *et al.*, 2002). In this context, the concept of estimating probabilities with respect to a given amount of rainfall is extremely useful for planning appropriate agricultural operations/activities. The Markov chain model has been extensively used to study the probabilities of rainfall occurrence (Gaberial and Newman, 1962; Victor and Sastry, 1979; Kar 2002; Singh *et al.*, 2008). In a given crop growing season, many a times, decisions have to be taken based on the probability of receiving certain amount of rainfall during a given week. Agriculture is mainly rainfed and rice is the main crop of the region. Knowledge of frequency and intensity of drought is essential for crop selection, their management and over all

agricultural planning of a region (Gichangi and Gatheru, 2018; Joab Onyango Wamari, 2019). Patel and Sastri (2004) suggested management of rainfed rice under drought situation. Water need in agricultural sector is going to be very high, as several thousand tones of water is required to produce each metric ton of food grain. Hence, there is a felt need for effective monitoring of agricultural drought – its onset, progression and impact on crops to minimize the damages.

DATA METHODOLOGY

Fifty five years (1960-2015) daily rainfall data of Raipur district, recorded at the meteorological observatory of IGKV, Raipur, were collected and analyzed for the purpose of the present study. The station Chianki is located at 23.76° N latitude, 84.41° E longitude and 351m above msl. Coefficient of variation which is indicative of dependability of rainfall expressed in percentage was used for annual, seasonal, monthly and weekly basis. The CV value being well within the threshold limits of variability is considered that the rainfall is dependable. These threshold levels for CV for any interpretation are < 25% (yearly), < 50% (seasonal), < 100% (monthly) and < 150% (weekly) as reported by Veeraputhiran *et al.*, 2003. The weekly initial probabilities of wet week P(W) and conditional probabilities of a wet week provided the last week was wet P(W/W) were estimated using Markov Chain process for receiving 10, 20 and 50 mm rainfall in a given week. Based on annual rainfall deficit from normal, following the criteria adopted by India Meteorological Department (IMD), years were classified as mild, moderate and severe drought years when rainfall deficit was upto 25, 26-50 and > 50 per cent, respectively. Similarly, at least four consecutive weeks receiving less than half of the normal rainfall (> 5 mm) during kharif season were considered as agricultural drought.

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RESULTS AND DISCUSSION

Annual and seasonal rainfall

The mean annual rainfall of Raipur is 1158 mm with highest and lowest values of 499 mm and 1729 mm, respectively, spread over 55 rainy days with a standard deviation of 220 mm and coefficient of variation 19 per cent. The annual rainfall analysis indicated that the rainfall cannot be considered to be dependable because of the higher CV than the threshold value (level 25%). The trend analysis reflects that annual ($Y = 0.478x + 1131$) as well as kharif ($Y = 5.957x + 730.3$) rainfall over past 55 years have been in an increasing trend. Ten year moving averages of annual rainfall showed cyclic pattern with short period decreasing and increasing trends till 1995 and later it dipped below the long term average (Fig. 1). The seasonal rainfall analysis of the region in terms of winter (January-February) summer (March-May), SW monsoon, i.e., kharif (June-September) and NE monsoon (October-December) indicates that except kharif season, rainfall is not dependable in any season as their CV values were higher than the seasonal threshold level (50%). However, the kharif season rainfall seems to be much dependable with the lowest CV value of 34.8% with a mean kharif season rainfall of 998.7 mm.

Monthly and weekly rainfall

Monthly rainfall is highest (304.6 mm) with 34.1% CV in July (Table 1). August, the second highest rainfall (265.7 mm) receiving month is more dependable with least CV (38.7%). The CV of seven months, i.e., November to May is higher than the threshold level (100%), highest being in November followed by December and March indicating higher variation in rainfall in winter season. Monthly rainfall over last six decades (Fig. 2) showed sharp decline in monthly rainfall of July and August months which are crucial for the crop performance of kharif mainly rice crops.

The stable rainfall period for crop planning is presented in Fig. 3. The peak value of average weekly rainfall (76.1 mm) occurs in 29th week (16-22 July) with a CV of 105 per cent. The stable rainfall period was found to prevail from 24 to 40 SMW (11 June-7 October) with their corresponding CV of less than 150% (threshold level). Thus, the total average growing period is of 17 weeks at Raipur region. This reflects that for successful crop production during kharif, the crop duration should fit the above stable rainfall period when there is assured moisture regime.

Probabilities of weekly rainfall

Initial and conditional probabilities of receiving 10, 20 and 50 mm rainfall per week for the region are presented in Table 2. Soil of the region is characterized by undulating topography, deep ground water with varying texture from sandy loam to clay loam with inherent poor soil fertility. It is very tough to till the land for sowing of kharif crops in absence of pre-monsoon shower. At least 10 mm of weekly rainfall is required to start land preparation, sowing work and other cultural practices in agriculture. Probability of getting 10 mm or more rainfall exceeded 50 per cent for 17 weeks during 24-40 SMW. For successful crop production the normal requirement of rainfall is considered as 20 mm/week in general and 50mm/week in particular for rice crops. Probability of receiving 20 and 50 mm rainfall per week are more than 50 per cent for 14 (25-38 SMW) and 9 weeks (27-35 SMW) duration, respectively, except in 34th week (20-26 Aug) when probability for getting 50 mm rain is 43 per cent only. After the onset of monsoon 25th standard week (18-24 June) can be considered for final land preparation and sowing of upland kharif crops. Maize can be sown in 24-25th

standard week with low risk, as rainfall of 10 mm or more exceeds 50 per cent probability. The conditional probability P (W/W) of getting 10 and 20 mm rainfall is above 50 per cent during 23-40 SMW. It can be very well observed that earlier sowing of the rice crop by broadcasting seeds around 25th to 26th week (18-31 June) are favourable and transplanting of rice should be completed by the middle of July. Probability of getting 50mm P (W/W) rainfall exceeds 50 per cent between 26-34 SMW except in 30th week where it is only 45 per cent. In regions where rainfall is highly erratic and short, dry period can be expected within the wet season. If such period coincides with a sensitive phenological stage, this can affect the crop development but dry period at the ripening stage of the rice crop are sometimes beneficial. The peak vegetative growth stage and reproductive stage can be completed around 37th standard week. As the P(W/W) became considerably low from 38th standard week, it becomes necessary that the sowing/transplanting be so adjusted that reproductive stage of rice crop does not fall in this moisture stress period. This stage is very crucial to water stress and has detrimental effect on crop yield.

In many years, only a few weeks have been found to have the wet periods causing persistent drought condition in this region. In order to mitigate the effects of such monsoon anomalous situations the existing cropping pattern would need a suitable modification/change, preferably the contingent crop planning would be needed.

Meteorological drought

Meteorological droughts of different intensities, viz., mild, moderate and severe over the observed periods (56 years) showed that Raipur region experienced 32 drought years out of which 16 were mild, 15 moderate and one severe accounting for 29%, 27% and 2%, respectively (Table 3). Increase in number of drought years and drought intensity over the decades has been depicted through Fig. 4. Frequency of occurrence of mild drought was more during 1961-1990. However, the subsequent decades 1991-2000 and 2001-2010 registered higher intensity of moderate droughts. There were 8 mild droughts during the decade 1981-90 whereas the decade 1991-2000 had 3 mild and 5 moderate droughts. The recent decade 2001-2010 experienced maximum number of drought years (9) of which seven were moderate droughts.

Agricultural drought

Prevalence of agricultural drought, adopting the IMD's criterion, has been worked out and presented in Table 4. Percentage of years experiencing agricultural drought was 50% at Raipur which were most frequently observed in early (23-26 SMW) as well as late (37-40 SMW) stages of kharif crops which coincided with the seedling and reproductive stages of rice crop, respectively. In recent decade (2001-10) eight years were encountered by agricultural drought during different SMW which limited the rice production in this region. Meteorological as well as agricultural droughts in two consecutive years 2009 and 2010 restricted the rice crop coverage in this area thereby causing a heavy shortfall of nearly 50% in rice production. However, the increased crop coverage under maize and other crops, like pulses and oilseeds, out of the farmers own wisdom compensated the loss to some extent.

CONCLUSION

Having characterized the region in terms of rainfall and drought it seems essential to give a rethinking on the existing cropping pattern which has been often subjected to have been adversely affected by rainfall anomalies and droughts. There is an urgent need of reconsidering the

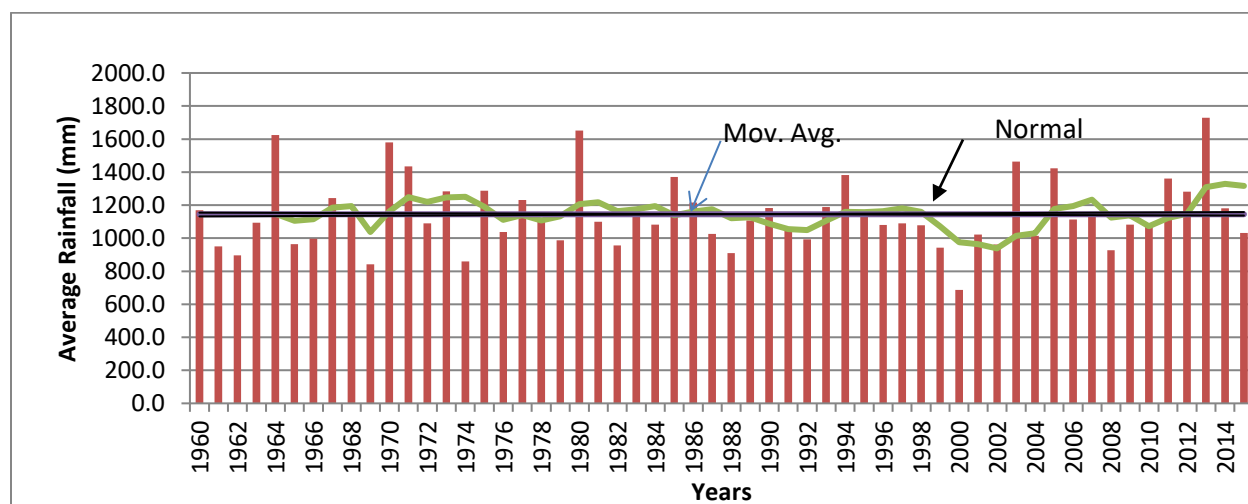


Figure 1 Annual rainfall variability of Raipur district

Table 1 Minimum, maximum and mean monthly, seasonal and annual rainfall (mm) with standard deviation (SD) and coefficient of variation (%) at Raipur (1955-2015)

Months	Minimum	Maximum	Mean	S. D.	CV %
January	0	107.9	29.4	27.9	94.9
February	0	233	30.2	37.3	123.5
Winter season	2.8	170	59.6	53.1	88.9
March	0.3	261.8	32.6	42.6	100.0
April	0	136.3	28.9	32.7	113.1
May	0.8	233.4	33.6	39.1	116.4
Summer season	0.4	175.6	95.1	91.0	95.7
June	15.5	495.8	186.6	107	57.3
July	88.1	616.9	304.6	103.9	34.1
August	55.6	519.1	265.7	102.8	38.7
September	27.1	422.8	148.3	80.9	54.6
SW monsoon (Kharif)	45.1	499.1	900.2	180.4	20.0
October	2.3	158.4	49.9	36.9	99.4
November	0	109.2	29	26.6	91.7
December	0	130.4	27.8	30.1	108.3
NE monsoon	3.4	147.1	34.4	70.2	68.0
Annual	219.9	1728.8	1158.2	219.9	19.0

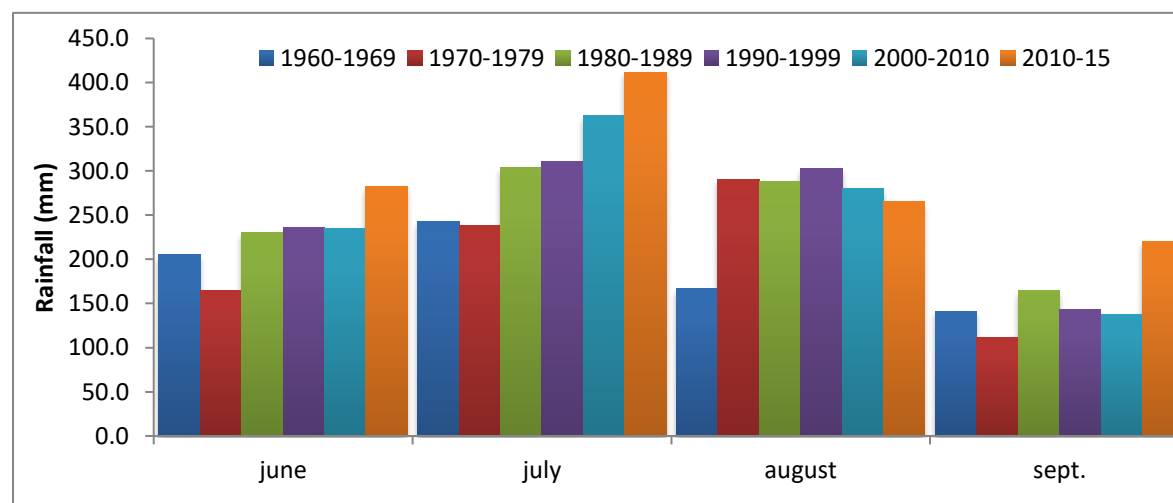
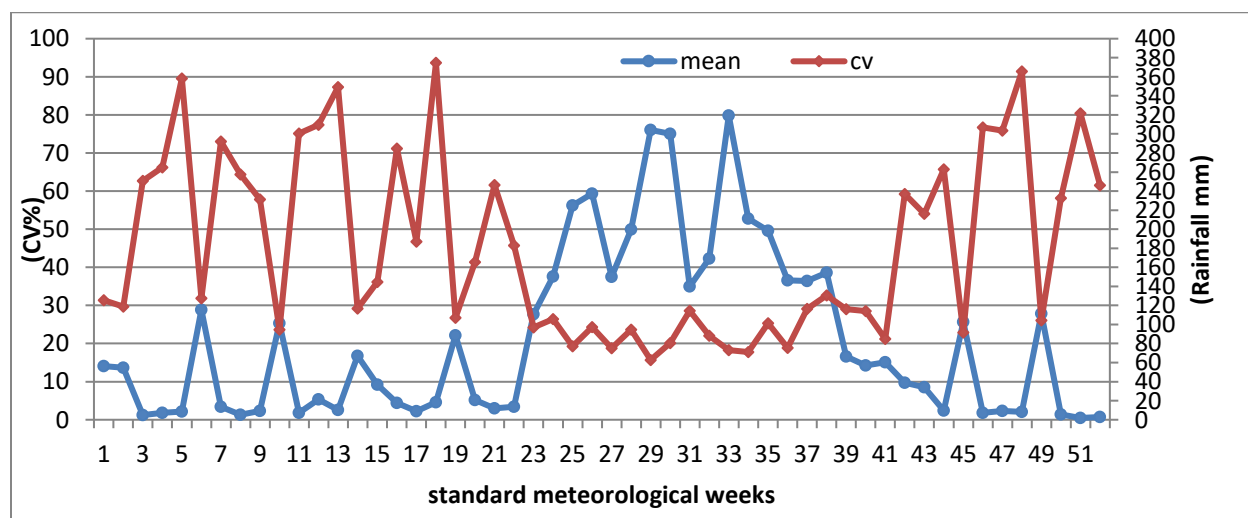


Figure 2 Decadal variation in monthly rainfall (June-September)

Table 2 Initial and conditional probability (%) of receiving weekly rainfall of 10, 20 and 50 mm in kharif season at Raipur

Std. week	Mean rainfall (mm)	SD	CV (%)	Initial probability P(W)			Conditional probability P(W/W)		
				10 mm	20 mm	50 mm	10 mm	20 mm	50 mm
				7	4	0	20	33	0
23	27.7	26.8	97	75	48	14	75	100	0
24	37.6	39.7	105.6	73	61	21	74	56	38
25	56.2	43.4	77.1	86	80	50	88	88	75
26	59.3	57.7	97.2	86	75	43	88	76	50
27	37.5	28.2	75.3	84	75	27	83	74	21
28	49.9	47.2	94.5	91	80	34	89	81	33
29	76.1	47.8	62.8	95	86	64	96	89	58
30	75	60.3	80.4	89	84	57	91	85	56
31	35	40.1	114.5	77	57	18	80	64	22
32	42.3	37.3	88.2	86	66	29	86	59	30
33	79.8	58.2	73	93	88	61	94	92	69
34	52.8	37.6	71.2	86	79	50	90	82	59
35	49.6	50.2	101.2	79	64	38	85	68	43
36	36.6	27.6	75.5	86	75	18	84	75	24
37	36.5	42.4	116.4	71	48	30	71	48	40
38	38.6	50.4	130.6	64	46	27	73	56	35
39	16.6	19.2	116.1	46	30	7	47	31	7
40	14.3	16.3	114	43	25	7	46	18	0
41	15.1	12.8	84.9	57	34	2	58	36	0
42	9.7	23.1	236.9	23	13	5	25	11	0
43	8.5	18.4	216.1	23	15	4	15	0	0
44	2.4	6.4	262.7	7	4	0	4	0	0

**Figure 3** The stable rainfall period for crop planning

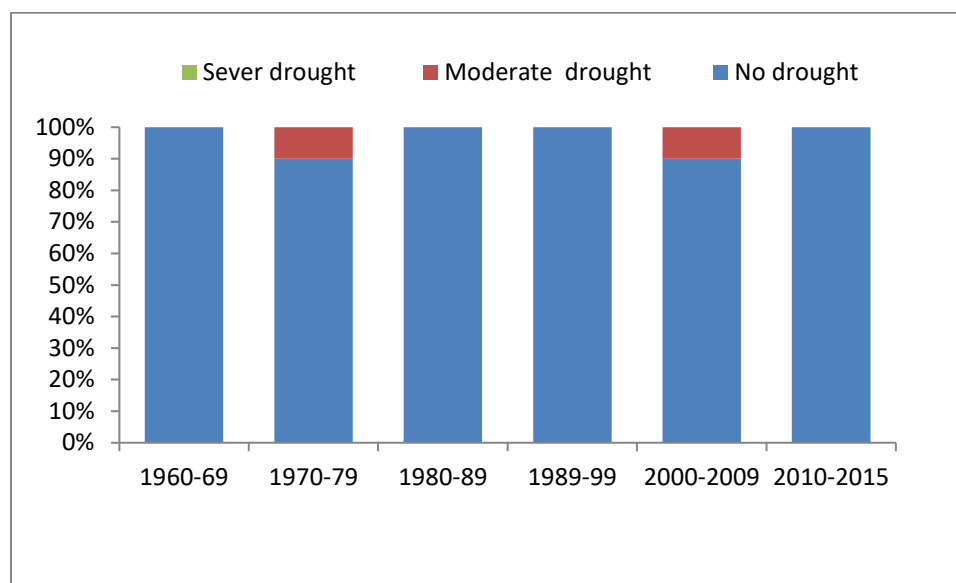


Figure 4 Decade wise frequency and intensity of drought over Raipur (1960-2015)

Table 4 Agricultural drought during kharif season at Raipur region

Year	Week	Year	Week
1961	28 - 31	1974	37 - 40
	33 - 36	1982	37 - 40
1962	32 - 42	1984	37 - 40
1965	39 - 42	1992	37 - 40
1966	34 - 42	1996	38 - 41
1968	39 - 42	2000	31 - 34
1969	39 - 42		36 - 39
1971	31 - 34	2005	38 - 41
	37 - 41	2009	23 - 26
		2010	39 - 42

cropping pattern, selection of crops, their varieties and management practices for the Raipur region to minimize the risk involved in food production. The entire agriculture being based on rainfall pattern, it is recommended to cultivate only those varieties which do not have crop duration of more than 13 or 14 weeks. Short duration varieties like Vandana, Birsa Vikas Dhan 109 and 110 for upland, Naveen, Sahbhagi and Kanchan for medium land and Birsamati, Rajshree and Tez for lowland should be grown in the area. Transplanting of rice should be completed by the first fortnight of July when the probability of getting 50 mm rainfall is above 50 per cent level. System of Rice Intensification (SRI) should be encouraged as it requires lesser water and other inputs. Maize and pulses crops with lesser water requirement would be better option for farmers as contingent food crop under variable rainfall conditions. Maize can be sown upto 25th week (18-24 June) with the recommended varieties like HQPM, Birsa Vikas Macca-2, Suwan etc. Cultivation of ICPH2671, Birsa Arhar 1 and Asha 170 are appropriate varieties of pigeon pea under upland condition. Inter-cropping of maize with Arhar in different recommended combinations should also get priority to minimize the risk.

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