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Study of rainfall variability for efficient crop planning - a case study

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ABSTRACT

Daily rainfall data of 12 years (1981-1992) recorded at Regional Research Sub-station, Bidhan Chandra Krishi Viswavidyalaya, Raghunathpur (23^{0}36'N, 86^{0}42'E, 169 m), Purulia, West Bengal, India were analysed for determining annual, seasonal, monthly and weekly rainfall averages of the region, which were compared with corresponding values of the current period of 5 years (2003-2007). Mean annual rainfall was 1156.0 mm, of which July recorded highest rainfall (313.3 mm) and January lowest rainfall (1.8 mm). Mean rainfall for pre-kharif, kharif and rabi season were 106.6 mm (9.22%), 1010.7 mm (87.43%) and 38.7 mm (3.35%), respectively. The changes in rainfall pattern between two periods of 1981-1992 and 2003-2007 were very little during pre kharif (-1.7%) and kharif (+1.0%) seasons, but moderate during rabi season (-22.7%). Mean week of onset and withdrawal of south-west monsoon were 24th (11-17 June) standard meteorological week (SMW) and 40th SMW (1-7 October) and average length of rainy season was 18 weeks (126 days) with a variation between 15 and 24 weeks. Mid season drought was likely to occur during 33rd-34th SMW and terminal droughts during 37-40th SMWs at <10 and 10-25% probability levels, respectively. Rice was the main crop in the region during kharif season along with maize and arhar in some areas, while short duration pulses, oilseeds and wheat could be grown with residual soil moisture and live-saving irrigations during rabi season.

***Keywords*:** Crop planning, Marcov-chain probability, rainfall and variability

Rainfall variability is a major factor influencing the agricultural production in a region. Rainfall studies, particularly week-wise distribution pattern, probability analyses, onset and withdrawal of monsoon, etc., are of great importance in crop management practices and contingent crop planning for sustaining crop production, while Markov-chain probability model is suitable for studying the long-term frequencies of wet and dry spells in the area of study (Hann *et al.*, 1976). The random and variable nature of rainfall suggests the necessity of sound statistical analysis and logical interpretation (Pimale and Hiwase, 2001) to integrate with long-term technical policies (Parasuraman, 2003). In the context, Raghunathpur region in Purulia district of West Bengal, being characterized by terraced land, low productive soil and drought-prone area within Red and Laterite Zone is selected to study on rainfall distribution pattern, occurrence of dry spells, vis-a-vis future planning for sustainable cropping system in the region.

MATERIALS AND METHODS

Daily rainfall data of 12 years (1981-1992) and 5 years (2003-2007) collected from Regional Research Sub-station, Red and Lateritic Zone, Bidhan Chandra Krishi Viswavidyalaya, Raghunathpur (23^{0}36'N, 86^{0}42'E, 169m above MSL), Purulia, West Bengal, India were analyzed to describe monthly, seasonal and weekly rainfall distribution pattern, onset and withdrawal of monsoon, severity of aberrations, variability between two periods.The start of rainy season was computed following Morris and Zandstra (1979), where weekly rainfall was summed by forward accumulation (22+23+……..…weeks) until a certain amount of rainfall (75 mm) is accumulated. On the other hand, the end of rain season was determined by backward accumulation of rainfall (44+43+……weeks) upto 10 mm.

Rainfall probability analysis was carried out using first order Marcov-chain model as suggested by Gabriel and Neumann (1962), Gates and Tong (1976) and Hann *et al.* (1976). In the study, weekly rainfall data of N (=12) years were considered for threshold limits of either 10 mm or 20 mm or 40 mm / week. The initial probabilities like the probability of a given week i either wet (W_i) or dry (D_i) were calculated by the following formulae:

$$W_i = [n/N] \times 100, \%$$
$$D_i = [100 - W_i], \%$$

where n = No. of years getting wet week for a particular threshold level of rainfall

The conditional probabilities like probabilities of a wet or dry week (i + 1) followed by a wet week (i) as well as probabilities of a wet or dry week (i + 1) followed by a dry week (i) were determined by the following formulae:

$$[W/W]_i = [n'/n] \times 100, \%$$

$$[D/W]_i = [100 - [W/W]_i, \%$$

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$[W/D]_i = [n''/(N-n)] \times 100, \%$

$[D/D]_i = 100 - [W/D]_i, \%$

where N – n = No. of years getting dry week for a particular threshold level of rainfall

n' = No. of years getting wet week followed by a wet week for a particular

threshold level of rainfall

n'' = No. of years getting dry week followed by a dry week for a particular

threshold level of rainfall

RESULTS AND DISCUSSION

Annual, monthly and seasonal rainfall

The historical rainfall data of 12 years (1981-1992) indicated that the region received mean annual rainfall of 1156.0 mm (Table 1) with a variation from 792.3 mm (1992) to 1667.8 mm (1984). The inter-year probability revealed that chances of receiving rainfall in normal range (936.4-1375.6 mm) were 50%, whereas moderately deficit and moderately surplus rainfall years were 25% each in the study (Table 3). The highest rainfall was recorded during the month of July (313.3 mm) with lowest co-efficient of variation (31.5%), which was followed by August (237.7 mm), June (200.7 mm) and September (191.1 mm). On the contrary, the highest rainfall was received during September followed by October and August at Bengaluru in Karnataka (Ravindrababu *et al.*, 2010). The months having positive values of skewness, except September confirmed that large number of rainfall observations were on higher side of median value. The months with positive values of kurtosis were having sharp peaks and nearby zero or negative values had flatness at their modes.

The monthly rainfall averages over years increased from January (1.8 mm) to July (313.3 mm) and declined progressively thereafter up to December (9.7 mm). The unimodal distribution of monthly rainfall could be coded as $E_4D_1(B_1A_1B_1C_1)\ D_1E_2$; where monthly rainfall categories were: A e'' 300 mm, B = 200-300 mm, C = 100-200 mm, D = 50-100 mm and E d'' 50 mm and the letter within parentheses referred to rainfall for 4 monsoon months (June-September) at Raghunathpur. Thus, the contribution of monsoon months at Raghunathpur was about 942.8 mm, which was 81.6% of average annual rainfall during the period of 1981-1992. The changes in monthly rainfall pattern between two periods of 1981-1992 and 2003-2007 were found to vary between -32.3 and +45.0% during *kharif*, -67.0 and +166.7% during *rabi* and -25.5 and +28.3% during *pre-kharif* season.

Mean rainfall of *pre-kharif*(March–May), *kharif* (June–October) and *rabi* (November–February) seasons were 106.6 mm (9.22%), 1010.7 mm (87.43%) and 38.7 mm (3.35%), respectively in 1981-1992 period (Table 2). The variation in seasonal rainfall was observed between 47.3 and 214.2 mm during *pre-kharif*, 695.4 and 1581.7 mm during *kharif* and 3.0 and 101.4 mm during *rabi* season. There was negligible change in rainfall pattern between two periods (*i.e.* 1981-1992 and 2003-2007) during *pre-kharif* (-1.7%) and *kharif* (+1.0%), while it was about -22.7% during *rabi* season.

Weekly rainfall, monsoon and occurrence of dry spells

Mean weekly rainfall received during the first 18 standard meteorological weeks (SMWs) were low (<10 mm / week) (Table 4), which was also observed at 42nd SMW onwards period. However, >40 mm weekly rainfall was found between a period from 24th SMW (11-17 June) to 36th SMW (3-9 September) and corresponding co-efficient of variation was less than 100% in most of weeks. So, it was a stable period of getting moderate rainfall due to south-west monsoon.

Data on onset, end and length of rainy season and its variability in the study region are presented in table-5. It indicated that the mean week of onset and withdrawal of rainy season were 24th SMW (11-17 June) and 40th SMW (1-7 October), respectively. The start of rainy season in the study varied between 23rd SMW (4-10 June) and 27th SMW (2-8 July), while cessation of rainy season between 37th SMW (10-16 September) and 42nd SMW (15-21 October). Mean length of rainy season was 18 weeks (126 days), with a variation between 15 and 21 weeks. Similar rainy season characteristics for Konkan region was reported by Dixit *et al.*(2005).

The >50% probability of getting weekly rainfall of e''10 and e''20mm *i.e.* wet weeks found during the period from 22nd to 41st SMW and 23rd to 39th SMW, respectively (Table 6). The 100% chances of dry weeks with rainfall inspective of <10 or <20 mm were noted at 1, 2, 3, 4, 5, 43, 44, 45, 47, 49 and 51st SMW in the study (data not shown)

Mid-season drought was likely to occur during 33-34th (13-26 August) at both <10 and <20mm weekly rainfall at <10% probability level due to break in monsoon, while terminal droughts were found during

Table 1: Monthly rainfall-related variables at Raghunathpur, Purulia district of West Bengal

Month	1981-1992								2003-2007	
	Mean rainfall (mm)	% of Annual rainfall (mm)	Highest rainfall (mm)	Lowest rainfall (mm)	SD (%)	CV (%)	Skewness	Kurtosis	Mean rainfall (mm)	Changeover 1981-1992 (%)
January	1.8	0.15	9.8	0	3.0	165.9	2.09	4.69	4.8	+166.7
February	19.8	1.71	83.0	0	26.2	132.0	1.53	1.93	18.8	-5.1
March	19.1	1.65	66.9	0	22.7	118.7	1.04	-0.06	24.5	+28.3
April	28.9	2.50	84.4	0	24.4	84.3	1.09	1.05	36.5	+26.3
May	58.5	5.06	136.3	11.9	39.8	68.1	0.64	-0.38	43.6	-25.5
June	200.7	17.36	614.2	37.0	145.7	72.6	2.23	6.63	193.1	+3.8
July	313.3	27.10	560.7	187.6	98.6	31.5	1.50	2.87	271.6	-13.3
August	237.7	20.56	540.3	71.1	119.6	50.3	1.34	3.25	344.6	+45.0
September	191.1	16.53	348.8	32.3	95.4	49.9	-0.01	-0.74	129.3	-32.3
October	67.9	5.88	198.4	0	66.0	97.2	0.70	-0.56	82.4	+21.4
November	7.4	0.64	38.8	0	11.7	158.5	2.00	4.37	3.2	-56.8
December	9.7	0.84	46.0	0	17.4	178.8	1.69	1.47	3.2	-67.0
	Total	1156.0								1155.6

Table 2: Seasonal rainfall-related variables at Raghunathpur, Purulia district of West Bengal

Season	1981-1992						2003-2007	
	Mean rainfall (mm)	% of annual rainfall (mm)	Highest rainfall (mm)	Lowest rainfall (mm)	SD	CV (%)	Main rainfall (mm)	Change (%) over 1981-1992
Pre-kharif	106.5	9.22	214.2	47.3	43.4	40.7	104.7	-1.7
Kharif	1010.7	87.43	1581.7	695.4	284.3	28.1	1021.0	+1.0
Rabi	38.7	3.35	101.4	3.0	30.0	77.4	29.9	-22.7

Note: Pre-kharif:(March-May), Kharif:(June-October), Rabi:(November-February)

Table 3: Threshold criteria for delineating aberrations in annual rainfall at Raghunathpur, Purulia district of West Bengal

Threshold criteria (from normal)	Scale	Number of years	% of years
Less than -0.59	Severely deficit	0	–
-0.59 to - 0.19	Moderately deficit	3	25.0
-0.19 to + 0.19	Normal	6	50.0
+0.19 to + 0.59	Moderate surplus	3	25.0
More than + 0.59	Highly surplus	0	–

Table 4: Weekly rainfall-related variables at Raghunathpur, Purulia district of West Bengal

Meteorological week	1981-1992			2003-2007		Meteorological week	1981-1992			2003-2007	
	Mean rainfall (mm)	Highest rainfall (mm)	C.V. (%)	Mean (mm)	Changeover 1981-1992 (%)		Mean rainfall (mm)	Highest rainfall (mm)	C.V. (%)	Mean % (mm)	Changeover 1981-1992 (%)
1	0	0	–	0.9	–	27	74.0	227.5	94.0	91.1	+30.1
2	0.6	3.7	198.6	0	-100.0	28	67.5	232.6	101.2	80.1	+18.7
3	1.2	9.8	256.0	1.2	0	29	65.0	130.5	56.8	36.6	-43.7
4	0	0	–	1.9	–	30	81.0	181.8	68.1	41.0	-49.4
5	0	0	–	1.1	–	31	81.1	197.4	76.3	80.1	-1.2
6	5.4	62.0	331.0	2.3	-57.4	32	58.7	164.5	80.2	55.0	-6.3
7	6.2	24.0	140.8	7.6	+22.6	33	44.8	155.9	85.7	142.2	+217.4
8	4.8	33.3	204.2	8.0	+66.7	34	48.3	168.2	109.7	49.9	+3.3
9	2.3	13.0	179.8	4.8	+108.7	35	39.5	132.7	91.7	43.2	+9.4
10	0.7	3.0	184.6	4.1	+485.7	36	50.6	108.7	70.9	31.9	-37.0
11	5.9	30.0	173.7	10.8	+83.1	37	24.9	82.4	94.1	51.7	+107.6
12	7.6	42.3	171.6	1.6	-78.9	38	36.5	136.0	115.4	27.8	-23.8
13	3.3	16.7	193.1	3.8	+15.2	39	64.1	150.9	76.8	9.0	-86.0
14	8.4	47.0	208.9	11.3	+34.5	40	25.0	140.4	171.6	18.8	-24.8
15	4.1	24.8	196.2	0.6	-85.4	41	27.3	88.5	102.1	12.1	-55.7
16	8.6	33.0	143.5	5.2	-39.5	42	14.5	120.0	241.6	30.0	+106.9
17	6.7	29.9	123.0	19.5	+191.0	43	0.4	4.3	346.4	20.4	+5000.0
18	6.1	31.2	171.0	7.4	+21.3	44	0.6	6.6	346.4	1.1	+83.3
19	16.3	91.6	171.4	6.4	-60.7	45	2.2	17.5	247.7	1.2	-45.5
20	13.6	58.3	127.8	4.5	-66.9	46	2.7	32.2	346.4	1.6	-40.7
21	12.7	41.8	110.9	19.9	+56.7	47	0	0	–	0	–
22	16.6	55.8	117.1	8.4	-49.4	48	2.0	13.0	234.5	0	-100.0
23	38.8	199.3	146.5	39.0	+0.5	49	0	0	–	0	–
24	46.7	96.7	73.9	48.5	+3.9	50	4.1	30.8	242.3	0	-100.0
25	60.3	254.7	108.0	80.1	+32.8	51	0.8	9.8	346.4	1.8	+125.0
26	58.5	178.9	92.8	27.7	-52.6	52	4.8	46.0	274.7	1.4	-70.8

Table 5: Variability and probability in start and end of rainy season at Raghunathpur, Purulia district of West Bengal

Start of rainy season			End of rainy season			Length of rainy season	
Parameter	Meteorological week	Probability (%)	Parameter	Meteorological week	Probability (%)	Parameter	Week
Average	24		Average	40		Average	18
Early	23		Early	37		Maximum	21
Late	27		Late	42		Minimum	15
Range	23	33.3	Range	37	16.7		
	24	25.0		38	–		
	25	16.7		39	8.3		
	26	16.7		40	8.3		
	27	8.3		41	41.7		
				42	25.0		

Table 6: Mean weekly rainfall and probability levels during kharif season at Raghunathpur

Meteorological week	Mean weekly rainfall (mm)	Probability of receiving rainfall >X mm / week, %								
		X= 10mm			X= 20mm			X= 40mm		
		W	W/W	W/D	W	W/W	W/D	W	W/W	W/D
22	16.6	50	67	50	33	50	50	17	50	20
23	38.8	58	86	40	50	83	33	33	100	38
24	46.7	67	100	100	67	75	100	58	57	40
25	60.3	100	83	0	83	80	50	50	50	50
26	58.5	83	80	100	75	78	67	50	50	67
27	74.0	83	70	100	75	86	100	58	57	80
28	67.5	75	100	100	67	88	100	67	75	75
29	65.0	100	92	0	92	91	100	75	78	67
30	81.0	92	100	100	92	91	100	75	78	67
31	81.1	100	100	0	92	91	0	75	56	33
32	58.7	100	92	0	83	80	100	50	67	33
33	44.8	92	100	0	83	70	0	50	50	33
34	48.3	92	91	100	58	71	40	42	60	29
35	39.5	92	82	100	58	86	60	42	80	43
36	50.6	83	70	100	75	44	67	58	14	20
37	24.9	75	67	33	50	80	50	17	0	60
38	36.5	58	100	40	50	100	50	50	83	50
39	64.1	75	56	33	75	33	33	67	25	0
40	25.0	50	83	50	33	75	50	17	50	20
41	27.3	67	38	0	58	29	0	25	0	11
42	14.5	25	0	0	17	0	0	8	0	0
43	0.4	0	0	0	0	0	0	0	0	0
44	0.6	0	0	8	0	0	0	0	0	0

Table 7: Probability in occurrence of two consecutive dry weeks (<10 and <20 mm) at Raghunathpur, Purulia district of West Bengal

Probability (%)	<10	10-25	25-50	>50
Dry Week (<10 mm)	33-34	23-24, 37-38, 38-39, 39-40 and 40-41	41-42	–
Dry Week (<20 mm)	25-26, 33-34, 34-35 and 36-37	37-38,38-39 and 39-40	40-41, 41-42	–

37-38th (10-23 September), 38-39th (17-30 September) and 39-40th (24 September-7 October) SMWs at 10-25% probability level (Table 7).

Crop planning and management

The major crop of Raghunathpur region was paddy during *kharif* season with having about 120-140 days duration for high-yielding and indigenous varieties. Rainfall received during May could be utilized for land preparation and sowing of rainfed rice could be done during June after onset of monsoon. The optimum transplanting period of *kharif* paddy would be 29th-31st SMW (16 July-5August) with average weekly rainfall of 65.0, 81.0 and 81.1 mm, respectively at e"75 % probability level. Saha *et al.* (2004) suggested similar type of rice growing approach in coastal Orissa, while Saha *et.al.* (2011) reported the impact of weather variables on weed infestation in wet season rice in West Bengal. Other crops like arhar and maize could be grown successfully in medium uplands of the region by early sowing during 24th-25th SMWS (11-24 June) to avoid moisture stress during later phase of crop growth.

As mean rainfall for *rabi* season was very low (38.7 mm), it would be advocated to grow short duration pulses (blackgram, lathyrus, etc.) or oilseeds (mustard / rapeseed) immediately after harvest of *kharif* crop using of residual moisture and wheat in some cases, where surface water available for live-saving irrigations. In addition, vegetables might be cultivated during the period in small plots adjacent to ponds or dug wells in the rigion.

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