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Rainfall variability and probability pattern for crop planning of Roorkee region (Uttrakhand) of India

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सार – कृषि मौसम वेधशाला के 30 वर्षों (1979–2008) के दैनिक वर्षा के आँकड़ों का उपयोग करते हुए डब्ल्यू. आर. डी. और एम. विभाग, आई. आई. टी. रूड़की और उत्तराखंड़ में कम जोखिम पर वर्षा आधारित फसल को विकसित करने के लिए इनकी संभाव्यता और परिवर्तनशीलता का विश्लेषण किया गया है। इसके लिए वार्षिक, मौसमी, मासिक और साप्ताहिक अवधियों के लिए माध्य वर्षा, मानक विचलन, विचरण गुणांक तैयार किए गए। मार्कोव चेन संभावनाओं (प्रति सप्ताह 30 मि. मी. से अधिक अथवा उसके बराबर वर्षा) का आकलन तैयार किया गया। 983.5 मि. मी के माध्य की तुलना में 1514.2 मि. मी. और 1278.4 मि. मी. की वार्षिक और खरीफ की फसल के समय वर्षा सन् 2000 में सबसे अधिक थी। 97 प्रतिशत की संभावना सहित 1514 मि. मी (2000) की वर्षा होने का अनुमान लगाया गया जबकि 1164 मि. मी (1995), 948.9 मि. मी. (1997) और 824.4 मि. मी (1993) की वर्षा क्रमशः 75, 50 और 25 प्रतिशत की संभावना के साथ वर्षा के होने का अनुमान लगाया गया। जुलाई माह (272.4 मि. मी.) के बाद अगस्त माह (271.4 मि. मी) सबसे अधिक वर्षा वाला माह था। नवम्बर माह में सबसे कम वर्षा (6.0 मि. मी) हुई। जून माह के दूसरे सप्ताह में खरीफ की फसल बोई जाती है। रूड़की क्षेत्र में चावल की पौद लगाने के लिए जुलाई माह अनुकुल माना जाता है। 23 से लेकर 39 तक प्रत्येक मानक सप्ताह में 20 मि. मी से अधिक वर्षा हुई जिससे पता चला है कि जून के दूसरे सप्ताह से लेकर सितम्बर के अन्तिम सप्ताह तक फसल में बढ़ोतरी हुई है।

ABSTRACT. Daily rainfall data of 30 years (1979-2008) of Agro meteorological Observatory, Department of WRD&M, IIT, Roorkee, and Uttrakhand has been analyzed for the probability and variability to evolve rainfall based cropping system with minimum risk. The mean rainfall, standard deviation, coefficient of variation for annual, seasonal, monthly and weekly periods were worked out. Markov Chain probabilities (≥30 mm rainfall per week) were computed. Annual and *kharif* rainfall of 1514.2 mm and 1278.4 mm were the highest in 2000, compared to mean of 983.5 mm. The rainfall amount of 1514 mm (2000) could be expected with 97 per cent probability while 1164 mm (1995), 948.9 mm (1997) and 824.4 mm (1993) of rainfall may be expected with 75, 50 and 25 per cent probability respectively. July was the wettest month (272.4 mm) followed by August (271.4 mm). November was the least rainfall (6.0 mm) contributing month. Sowing of kharif crop is advanced from 2nd week of June month. The July month is regarded suitable for transplanting of rice crop in Roorkee region. Each standard week from 23rd to 39th received rainfall more than 20 mm indicating the crop growing period from June 2nd week to September last week.

Key words – Rainfall, Drought, Seasonal rainfall, Kharif season, Rabi season, Monthly rainfall and weekly probability by Markov Chain models.

1. Introduction

Food production from dryland agriculture is always uncertain, due to large temporal and spatial variation in rainfall. Crop productivity has increased in past four decades due to use of improved seeds, fertilizers and sustainable agrotechniques. According to Vairavan *et al.* (2002) to minimize risk the climatological data of a location becomes very important to provide necessary information. According to Pandey *et al.* (2002), seventy per cent rainfall occurs during the monsoon period, out of which the crops use only small amount and a large portion is lost as surface runoff. Considering these problems under dryland situation and to identify, the highest rainfall probability weeks for timely seeding of dryland crops, the rainfall data was analyzed as suggested by Jadhav *et al*. 1999. At Ludhiana the rainfall analysis for the past 95 years (Hundal and Kaur 2002) showed an increasing trend over normal for both annual as well as kharif season rainfall in last 30 years. At Igatpuri (Maharashtra), about

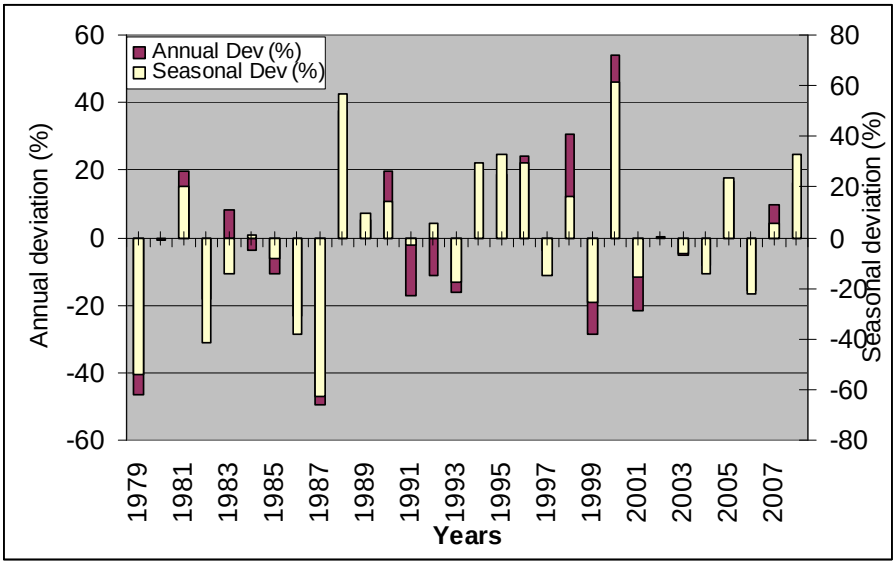

Fig. 1. Annual and seasonal monsoon rainfall deviations from the normal at Roorkee (1979-2008)

90 per cent of annual rainfall is received from southwest monsoon, 8 percent from October to February and 2 percent in the pre monsoon season. The productivity of rice in this region is reported (Jayabhaye, *et al*. 2003) to vary according to quantum and distribution of monsoon rainfall over the year.

2. Material and methods

Daily rainfall data of 30 years (1979-2008) of Agro meteorological Observatory, Department of WRD&M, IIT, Roorkee (Uttrakhand) which is located at 29° 51′ 0″ N latitude, 77° 53′ 0″ E longitude and 274 meters a. m. s. l., were used for analysis of the probability and variability. The data were aggregated to weekly, monthly, seasonal and annual totals. The mean rainfall, standard deviation and coefficient of variation for these periods were worked out following Deka and Nath, 2000, Gouranga Kar, 2002 and Parasuraman, 2003.

The months were classified as drought, normal and excessive rainfall months. If X is the mean monthly rainfall and A_1= X/2 and A_2 = 2X (Pimpale and Thiware, 2001) then a month receiving rainfall less than A_1 is defined as drought month, between A_1 and A_2 as normal and above A_2 is excessive month. Similar criteria were used to describe weeks. The annual and seasonal rainfall was classified based on IMD (India Meteorological Department) as given in Table 1.

TABLE 1

IMD criteria for rainfall classification

Mean Annual Rainfall (%)	Classified
>19	Excess
+19 to –19	Normal
< -19	Deficit

The number of drought, normal and excessive rainfall or flood months and weeks in a year were listed in descending order of magnitude and probability analysis were carried out by using Weibell's formula, (Chow, 1964).

$$P = m / (n + 1)$$

where P is plotting positions per cent, m is the rank of magnitude and n is the total no. of years for which analysis was carried out. Rainfall probability analysis was based on first order Markov Chain as done by Virmani *et al*., (1980 and 1982), Victor (2000), Gabriel and Newman (1962), Singh and Bhandari (1998), Patil and Kale (1988) and Singh, (2005).

The weekly probability of rainfall was estimated for receiving 30 mm rainfall in a given week and results are

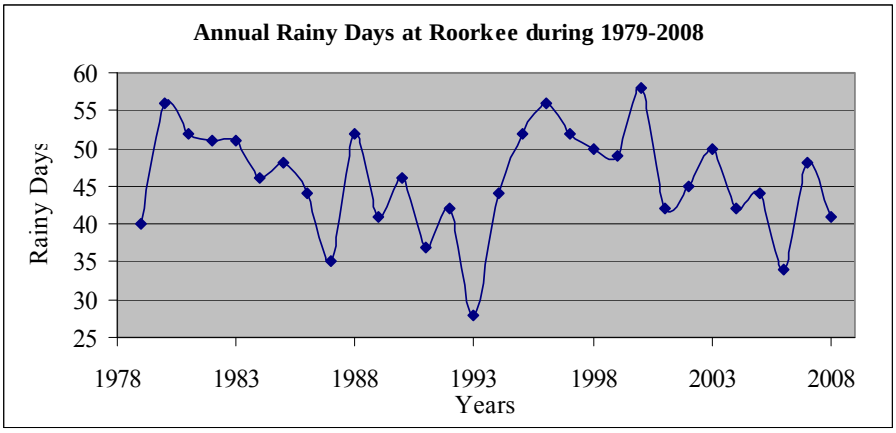

Fig. 2. Annual rainy days (≥ 2.5 mm/ day) at Roorkee (1979-2008)

reported for initial and conditional probabilities of a wet week, P (W) followed by a wet week, P (W/W).

P(W) = Probability of wet weeks

P(D) = Probability of dry weeks

P(W/W) = Probability of preceding wet week/wet week

P(D/W) = Probability of preceding dry week/wet week

P(D/D) = Probability of preceding dry week/dry week

P(W/D) = Probability of preceding wet week/dry week

3. Results and discussion

The daily rainfall data for the period from 1979-2008 was analyzed and the results are presented in Table 2 and the per cent deviation of south-west monsoon *vis-a-vis* annual rainfall is in Fig. 1.

During the monsoon period of 30 years, there were about 20 % of drought, 30 % of excessive and 50 % of normal occurrences. The annual and kharif rainfall was the lowest (496 mm and 293 mm) in 1987 (Table 2); the annual and kharif rainy days were the lowest (32 and 17) in 1991 (Fig. 2). The mean annual rainfall was 983.5 mm with coefficient of variation of 23.5 % and standard deviation is 230.7 mm. The seasonal rainfall analysis showed highest rainfall of 1278 mm in the year 2000.

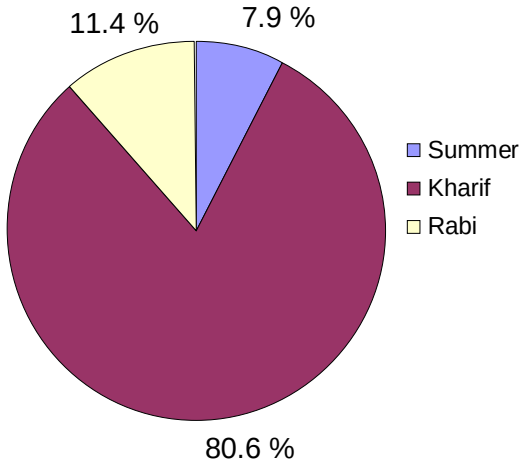

Fig. 3. Mean seasonal rainfall (mm) at Roorkee (1979-2008)

The seasonal rainfall analysis is presented in Table 3. The mean rainfall of 793.1 mm is received in *kharif* season contributing 80.6 per cent to total annual rainfall with coefficient of variations of 32.6 per cent and standard deviation of 232.6 mm indicating its dependability. *Rabi* rainfall also contributes an amount of 112.3 mm (11.4 per cent of the total annual rainfall); summer rainfall contributes an amount of 78.2 mm (7.9 per cent of the total annual rainfall) as shown in Fig. 3.

Frequency of normal, excess and deficient months and percentage of normal, excess and deficient months are presented in Table 4. July is the wettest month, which receives on an average 272.4 mm of rainfall with low variability (CV= 45 %). The wettest month next to July is August with average rainfall 271.4 mm. It is the main

TABLE 2

Rainfall features during monsoon months and distribution of classification at Roorkee (1979-2008)

Year	Annual Rainfall (mm)	CV (%)	SD	Seasonal Rainfall (mm)	CV (%)	SD
1979	526.7	186.7	18.9	366.4	223.8	33
1980	974.3	170.1	31.9	787.9	328.1	78.6
1981	1176.2	186.3	42.1	953.8	361.6	133.2
1982	804.4	161.4	25	463.4	195.2	6
1983	1066.3	162.9	33.4	679.6	282.1	73.6
1984	946.7	173.7	31.6	803.5	372.6	82
1985	880.6	188.6	31.9	729.6	289.1	80.6
1986	757.9	139.8	20.4	489	194.6	48.1
1987	496	226.5	21.6	293.7	139.3	28.2
1988	1351.5	221.7	57.6	1241.3	472.4	59.8
1989	1033.5	295.6	58.8	867.1	282.9	61.2
1990	1176.8	192.9	43.6	905.7	343.1	22.6
1991	815.5	254.8	40	771.8	252.4	123.2
1992	872.9	219.5	36.8	837.1	457.4	43.8
1993	824.2	211.7	33.6	651.1	351.4	41.7
1994	1174.5	252.6	57.1	1027.2	633.2	11
1995	1164.8	193.3	43.3	1052.1	451.5	116.4
1996	1221.8	192.9	45.3	1026.6	453.6	61
1997	948.9	168.3	30.7	673.5	328.2	34
1998	1284.3	170.4	42.1	922.9	405.9	74.4
1999	703.6	162.4	22	588.2	271.6	35.8
2000	1514.2	175.9	51.2	1278.4	446.6	91
2001	768.6	238.3	35.2	671.4	292.4	0
2002	984.2	233.3	44.1	793	403.6	39.4
2003	934.2	153.7	27.6	743.7	282.8	58.4
2004	904.3	206.3	35.9	680.8	306.8	35.2
2005	1146.1	197.3	43.5	982.6	374.5	93.4
2006	831.3	260	41.6	618.2	428	33.2
2007	1080.3	185.9	38.6	840.3	309.5	41.2
2008	1141	202.2	44.4	1053.1	410.9	110
Mean	983.5			793.1		
SD	230.7			258.4		
CV (%)	23.5			32.6		

source of kharif rainfall in Roorkee area and brings rain from 1st week of June. November is the driest month with meager amount (6.0 mm) of average rainfall. It has also the highest value of coefficient of variation (186.3 per cent), which shows the erratic pattern of rainfall. In the period of 30 years the southwest monsoon in Roorkee region starts from the month of June and continues up to September. However, the pre-monsoon showers normally

TABLE 3

Statistical analysis of seasonal rainfall at Roorkee

Season	Rainfall			Rainy days		
	Mean (mm)	SD (mm)	CV (%)	Mean (mm)	SD (mm)	CV (%)
Winter (Jan to Feb)	69	43.2	62.6	4.9	2.7	55.3
Summer (Mar to May)	78.2	60.6	77.5	6	3.7	62.1
Kharif (Jun to Sep)	793.1	232.6	29.2	32	6.7	21
North East Monsoon (Oct to Nov)	43.3	49.2	113.7	2	2.3	117.2

TABLE 4

Normal, above normal and drought statistics based on monthly and seasonal rainfall analysis for Roorkee

Months	Mean (mm) (A)	SD (mm)	CV (%)	Mean/2 (mm) (A_1)	2 × mean (mm) (A_2)	No. of dry month (DM)	No. of normal month (NM)	No. of above normal month (AM)	DM (%)	NM (%)	AM (%)
Jan	32.1	30.9	96.3	16.1	64.2	10	13	7	33	43	23
Feb	36.9	34.2	92.6	18.4	73.8	11	12	7	37	40	23
Mar	26.5	36.8	139.0	13.2	52.9	15	10	5	50	33	17
Apr	17.9	32.5	181.7	8.9	35.8	19	6	5	63	20	17
May	33.8	29.7	87.9	16.9	67.6	9	18	3	30	60	10
Jun	106.9	85.9	80.4	53.4	213.7	8	18	4	27	60	13
Jul	272.4	122.6	45.0	136.2	544.8	2	27	1	7	90	3
Aug	271.4	119.9	44.2	135.7	542.9	4	26	0	13	87	0
Sep	142.4	118.1	82.9	71.2	284.9	10	16	4	33	53	13
Oct	23.7	39.0	164.6	11.8	47.4	19	4	7	63	13	23
Nov	6.0	11.1	186.3	3.0	11.9	20	4	6	67	13	20
Dec	13.6	19.8	145.5	6.8	27.3	18	5	7	60	17	23

start from mid May. During 360 months in 30 years, deficient rains occurred only in two months in July and four in August (Table 4). During the study period deficient, normal and excessive rainfall months were 145 (40 %), 159 (44.5 %) and 56 (15.5 %) respectively.

The weekly rainfall variability was relatively less with coefficient of variation of 72.2% to 84 % in standard meteorological week from 30^{th} to 34^{th} week during kharif season (Table 5). Sowing of the kharif crops are therefore undertaken during this period. Mean rainfall of different weeks, its extremes and coefficient of variation have been also worked out (Table 5). It is observed that the quantum of rainfall received during 26^{th} to 36^{th} week would normally be sufficient to sustain any kharif crop within that period. It is also seen that an average rainfall 76.0 mm is received during 33^{rd} week. Thus, the 32^{nd} and 33^{rd} week are the critical weeks for the growing stage of the kharif crop.

Initial and conditional probability of receiving > 30 mm rainfall per week was estimated using Markov Chain probability model (Table 5). Initial rainfall probabilities are absolute probabilities and the conditional probabilities depend upon a previous week to be dry or wet. These probabilities indicate that more than 70 per cent probability could be expected from 27^{th} and 30^{th} to 31^{st} week during kharif. Rainfall probability is <50 % during 35^{th} week which indicates the chance of dry spell during this period in the Roorkee region.

TABLE 5

Initial and conditional probabilities of rainfall (30 mm) at Roorkee (1979-2008)

Week	Rainfall (mm)	SD	CV (%)	Max Rainfall (mm)	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	6.5	11.64	179.1	45	7	93	0	100	92	8
2	8	16.82	209.5	67.2	7	93	50	50	96	4
3	4.1	7.57	184.8	30.6	3	97	0	100	96	4
4	8.9	16.23	183.3	60	13	87	0	100	86	14
5	7.6	14.43	189.9	52.9	13	87	25	75	88	12
6	10.9	18.8	172.4	68.2	17	83	0	100	81	19
7	9.1	12.39	136.3	39.6	10	90	0	100	88	12
8	7.8	12.42	159.0	48	10	90	33	67	93	7
9	10	18.76	188.1	69.6	13	87	0	100	85	15
10	5.2	10.59	203.7	41.9	3	97	25	75	100	0
11	6.7	11.98	179.9	44.2	10	90	0	100	90	10
12	8.7	20.18	230.9	99	7	93	0	100	93	7
13	2	3.97	196.2	16	0	100	0	100	100	0
14	4.4	10.58	242.6	49.8	3	97	0	0	97	3
15	2.2	9.3	424.8	51	3	97	0	100	97	3
16	6.2	18.85	302.8	97.6	7	93	100	0	97	3
17	4.4	14.87	337.9	80	3	97	0	100	96	4
18	5.5	9.7	175.4	31	3	97	0	100	97	3
19	10.4	16.56	159	74.2	13	87	100	0	90	10
20	7.5	11.7	155.9	40.8	10	90	0	100	88	12
21	5.1	7.7	149.8	29.5	0	100	0	100	100	0
22	10	15.67	156.9	60.8	10	90	0	0	90	10
23	20.9	45.45	217.9	224.8	20	80	67	33	85	15
24	26.5	45.34	171.0	186.5	30	70	33	67	71	29
25	22.7	34.93	154.0	136.6	30	70	33	67	71	29
26	35	45.51	130.1	215	33	67	0	100	52	48
27	54.7	67.84	124.0	302.2	50	50	40	60	45	55
28	65.9	53.71	81.5	201.2	70	30	60	40	20	80
29	64.3	72.08	112.3	351	67	33	71	29	44	56
30	68.9	53.76	78.4	276.6	80	20	80	20	20	80
31	76.9	55.5	72.2	187.9	77	23	79	21	33	67
32	50.4	37.44	74.7	136.7	63	37	61	39	29	71
33	76	54.47	71.7	220.4	83	17	89	11	27	73
34	50.3	42.24	84.0	126.3	67	33	72	28	60	40
35	52.7	76.62	145.3	386.6	43	57	45	55	60	40
36	52.6	74.58	141.7	286.6	37	63	54	46	76	24
37	23.8	27.06	113.5	92.2	37	63	55	45	74	26
38	21.1	27.62	130.6	101.5	37	63	45	55	68	32
39	26.4	58.64	222.0	232.2	20	80	36	64	89	11
40	4.5	11.5	252.9	60	3	97	0	100	96	4
41	10.4	25.61	245.2	99.4	13	87	0	100	86	14
42	5.7	25.36	444.1	139	3	97	0	100	96	4
43	1.7	9.24	542.2	50.6	3	97	0	100	97	3
44	2.8	10.63	381.8	45.1	7	93	0	100	93	7
45	0.3	1.31	446.1	7	0	100	0	100	100	0
46	0.5	1.52	294.0	7	0	100	0	0	100	0
47	2.6	6.53	253.2	29	0	100	0	0	100	0
48	1.1	3.11	282.5	12.4	0	100	0	0	100	0
49	1.5	5.92	395.3	32	3	97	0	0	97	3
50	3.5	8.52	241.8	37	3	97	100	0	100	0
51	2	6.7	342.7	34	3	97	0	100	97	3
52	6.6	15.5	233.9	70.4	10	90	0	100	90	10

Conditional probabilities (W/W) exceeding 70 % (>30 mm rainfall week) are observed in week 29th to 31st and 33rd to 34th week in kharif crop while conditional probabilities (W/D) exceeding 80 per cent 28th and 30th week which shows the suitability of 28th week for dry seeding in the Roorkee region of Uttrakhand.

The probability of occurrence of dry week is high (50 to 100 per cent) in 1st week to 26th week and from 39th to 52nd week (80 to 100 %). The conditional probability of dry week proceeded by a dry week is also high upto 26th week and from 34th to 52nd week (Table 5).

The probability rainfall pattern could be utilized for growing rainy season crops like maize cowpea, groundnut, black gram etc. in the second fortnight of June with commencement of southwest monsoon in this region. To utilize monsoon rain most effectively rice can be substituted with other low water requiring high value crops like; maize, cowpea, groundnut etc. through sole or intercropping, provided, proper weed management is followed.

Seed sowing in nursery in the Roorkee region generally takes places immediately after onset of monsoon (23-25 weeks) and transplanting is carried out around 27th or 28th standard meteorological week. The tillering, 50 % flowering and dough stage are observed during 32-33rd, 37-38th and 40-41st weeks respectively.

However in a few years productivity of rice does not match with quantum of rainfall received for rainfed rice. Yield variations are attributed to the precipitation received during critical anthesis and reproductive phases. Such influence is observed during low, medium or high yield years.

4. Crop planning

The sowing of long duration photosensitive rice verities like Saket, Saket-4, Chabhi, Pant, Pusa etc. can be done during 22 to 23rd weeks, as rain received during this period is sufficient for land preparation and sowing of rice crop. While, the sowing of rice varieties of 90-105 days duration like IR-36, Turel Basmati, Basmati etc. can be done during 25th week (middle June) as early monsoon rain helps quick establishment of rice crop. The 31st, 34th and 39th weeks would be tillering, panicle initiation and maturity respectively. The transplanting of paddy could be completed in the last week of July. Intercropping of rice + pigeon pea and groundnut + pigeon pea and bajra + groundnut etc. in the upland can also be done during this period. A second crop of horse gram or green gram or mustard or black gram can be taken immediately after the harvest of upland rice during second fortnight of October.

5. Conclusion

The July month is regarded suitable for transplanting of rice crop in Roorkee region. Each standard week from 23rd to 39th receives rainfall of more than 30 mm indicating favourable crop growing period from June 2nd week to September last week. Rainfall probability is <50 per cent during 35th which indicates the chance of dry spell during this period at Roorkee region to be high. The conditional probability of dry week proceeded by a dry week also high upto 26th week and from 34th to 52nd week.

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