



Dry and Wet Spell Probability by Markov Chain Model for Agricultural Planning at Parbhani

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Abstract

Rainfed agriculture plays and will continue to play a dominant role in providing food and livelihoods for an increasing world population. Rainfall analyses are helpful for proper crop planning under changing environment in any region. An attempt has been made to analyse 42 years of rainfall (1971–2012) at the Parbhani region in Maharashtra, India for forecasting the probable time of onset and withdrawal of monsoon, probability of dry spells by using Markov chain model and finally crop planning for the region. The successive dry weeks indicate the need of supplemental irrigations and moisture conservation practices whereas, successive wet weeks gives an idea of excessive runoff water availability for rainwater harvesting and to take up suitable measures to control soil erosion. The average annual rainfall at Parbhani was observed as 928.4 mm with coefficient of variation (CV) of 32.8%. The data on onset and withdrawal of rainy season indicated that the monsoon started effectively from 24th SMW (11-17th June) and remained active up to 43rd SMW (22-28th October). During rainy season the probability of occurrence of wet week was observed more than 35% during 23-24th SMW (4th June–17th June) and average weekly rainfall ranged from 27.4 to 41.9 mm, this rain can be utilized for summer ploughing and initial seed bed preparations. Results obtained through this analysis would be utilised for agricultural planning and mitigation of dry spells at the Parbhani region in Maharashtra, India.

Keywords: Markov chain, probability, onset and withdrawal of rainy season

1. Introduction

India's economy is mainly dependent on agriculture, which is based on monsoon rainfall and its distribution. Fluctuation in rainfall directly influence the growth, development and yield of crops. India ranks first among the countries that practice rainfed agriculture both in terms of extent (86 mha) and value of production (Sharma et al., 2010). To meet the future food demands and growing competition for water among various sectors, a more efficient use of water in rainfed agriculture will be essential. The most important factor for low yield is the lack of assured water supply (Panigrahi and Panda, 2002). Increased climate variability has made rainfall patterns more inconsistent and unpredictable (Kumar et al., 2005). The demand of water in other sectors especially to meet the increasing demand for rapid growing industrialisation and urbanisation will dwindle the share of water available for agriculture in the future. Further, depletion of groundwater and reduced stream flows (Khan et al., 2008) affect drinking water supplies, health and rural livelihoods (Meijer

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et al., 2006); for instance, in India, the implications for social equity for the poor and groundwater-dependent communities for drinking and irrigation are quite large (EPW, 2007). Rainwater management and its optimum utilisation is a prime issue of present-day research for sustainability of rainfed agriculture. Kothari et al. (2007) opined that on the basis of water harvesting, water can be utilised for saving of crops during severe moisture stress. In order to address the issue, detailed knowledge of rainfall distribution can help in deciding the time of different agricultural operations and designing of water harvesting structures for providing round the year full irrigation (Srivastava, 2001; Srivastava et al., 2009). For sustainable crop planning, rainfall was characterised based on its variability and probability distribution by previous researchers (Mohanty et al., 2000; Sharda and Das, 2005; Bhakar et al., 2008; Jain and Kumar, 2012) for different regions of India. For successful agricultural management and planning of soil water conservation measures, information about occurrence of dry and wet periods along with onset and withdrawal of rainy season is important. Panigrahi and Panda (2002) and Kar (2003) applied Markov Chain method for calculating initial and conditional probability of dry and wet spells of different duration for various climatic situations and have evaluated its practical importance in crop planning. Researchers (Pandarinath, 1991; Banik et al., 2002; Barron et al., 2003 and Deni et al., 2010) have used Markov chain model to study the probability of dry and wet spell analysis in terms of the shortest period like week and also demonstrated its practical utility in agricultural planning.

The onset and withdrawal characteristics of monsoon largely determine the success of rainfed agriculture. Late onset of monsoon delays sowing of crops leading to poor yields. Similarly, early withdrawal of rains adversely affect the yield due to severe moisture stress especially when the *kharif* crops are at critical growth stages of grain formation and grain development (Dixit et al., 2005). In the present study an attempt has been made to analyze the probable week of onset and withdrawal of monsoon, initial and conditional probability of dry and wet spells and also the probability of 2 and 3 consecutive dry and wet spell weeks using Markov chain model for Parbhani district of Maharashtra.

2. Materials and Methods

2.1. Study area

The study was conducted in the Department of Agricultural Meteorology, Vasantrao Naik Marathwada Agricultural University (VNMKV), Parbhani, Maharashtra, India situated at 17° 36' N latitude and 76° 47' E longitude with an elevation of 406 m amsl. The Parbhani has uneven, erratic rainfall. Weekly rainfall values for a period of 42 years (1971–2012) have been computed from daily values and were used for the present analysis.

Rainfall data were categorised into four seasons, viz. pre-monsoon (March–May), monsoon (June– September), post-monsoon (October–December) and winter (January–

February) season. Monthly effective rainfall was calculated using Eqs. 1 and 2 following the USDA Soil Conservation Service method. This method is being widely used in India for calculation of monthly effective rainfall. The same method has been used for calculation of effective rainfall for rainfed districts of India by Sharma et al., 2010.

$$P_e = P_t (125 - 0.2P_t) / 125 \quad (\text{When } P_t < 250 \text{ mm}) \quad (1)$$

$$P_e = (125 + 0.1P_t) / 125 \quad (\text{When } P_t \geq 250 \text{ mm}) \quad (2)$$

Where P_e = Monthly effective rainfall (millimetres) and P_t = total monthly rainfall (millimetres).

2.2. Computation method for the onset and withdrawal of rainy season

Onset and withdrawal of rainy season was computed from weekly rainfall data by forward and backward accumulation methods respectively. In this method weekly rainfall was summed by forward accumulation (20+21+...+52 weeks) until a certain amount of rainfall was accumulated. Seventy five millimetres of rainfall accumulation has been considered as the onset time for the growing season of dry seeded crops and land preparation (Babu and Lakshminarayana, 1997; Panigrahi and Panda, 2002). The withdrawal of rainy season was determined by backward accumulation of rainfall (48+47+46+...+30 weeks) data. Twenty millimetres of rainfall accumulation was chosen for the end of rainy season, which is sufficient for ploughing of fields after harvesting the crops (Babu and Lakshminarayana, 1997). For determining the probability of onset and withdrawal of monsoon in particular week, the forward and backward accumulated rainfall were noted as per case and assigned with rank number. The following Weibull's formula has been used for calculating percent probability:

$$P = m / (N + 1) \times 100 \quad (3)$$

Where, m is the rank number and N is the number of years of data used.

2.3. Computation of dry and wet spells using Markov chain probability models

The dry and wet spell analysis was carried out using weekly rainfall based on Markov Chain Model considering less than 20 mm rainfall in a week as a dry week and 20 mm or more as a wet week (Pandharinath, 1991). Markov chain is a stochastic process to predict the succeeding situation of day solely based on situation of previous day. The different notations followed in this analysis are given below.

a) Initial probability

$$P_d = F_d / N \quad (4)$$

$$P_w = F_w / N \quad (5)$$

Where P_d = probability of the week being dry, F_d = frequency of dry weeks, P_w = probability of the week being wet, F_w = frequency of wet weeks and N = total number of years of data being used.

b) Conditional probabilities

$$P_{DD} = F_{DD} / F_d \quad (6)$$



$$P_{ww} = F_{ww} / F_w \tag{7}$$

$$P_{wd} = 1 - P_{dd} \tag{8}$$

$$P_{dw} = 1 - P_{ww} \tag{9}$$

Where P_{dd} =probability of a week being dry preceded by another dry week, F_{dd} =frequency of dry week preceded by another dry week, P_{ww} =probability of a week being wet preceded by another wet week, F_{ww} =frequency of wet week preceded by another wet week, P_{wd} =probability of a wet week preceded by a dry week and P_{dw} =probability of a dry week preceded by a wet week.

c) Consecutive dry and wet week probabilities

$$P_{2D} = P_{Dw1} \times P_{DDw2} \tag{10}$$

$$P_{3D} = P_{Dw1} \times P_{DDw2} \times P_{DDw3} \tag{11}$$

$$P_{2W} = P_{Ww1} \times P_{WWw2} \tag{12}$$

$$P_{3W} = P_{Ww1} \times P_{WWw2} \times P_{WWw3} \tag{13}$$

Where P_{2D} =probability of two consecutive dry weeks starting with the week; P_{Dw1} =probability of the first week being dry; P_{DDw2} =probability of the second week being dry, given the preceding week being dry; P_{3D} =probability of three consecutive dry weeks starting with the week; P_{DDw3} =probability of the third week being dry, given the preceding week dry; P_{2W} =probability of two consecutive dry weeks starting with the week; P_{Ww1} =probability of the first week being wet; P_{WWw2} =probability of the second week being wet, given the preceding week being wet; P_{3W} =probability of three consecutive wet weeks starting with the week; and P_{WWw3} =probability of the third week being wet, given the preceding week wet.

3. Results and Discussion

3.1. Average rainfall, effective rainfall, distribution over seasons and analysis of rainy days

Total annual rainfall in the Parbhani region ranged between 517.6 mm (the lowest during the year 1972) and 1711.0 mm (the highest during the year 1990). The average annual rainfall is around 928.4 mm with 47 rainy days (32.8% coefficient of variation). If rainfall received in a year was equal to or more than the average rainfall plus standard deviation for 42 years of rainfall (i.e. $928.4 + 304.2 = 1232.6$ mm), it was considered as excess rainfall year (Sharma and Kumar, 2003). During eight years i.e. 1975, 1983, 1987, 1989, 1990, 1998, 2005 and 2010, this region received rainfall of more than 1233 mm and considered as excess rainfall years. Only 19% of total years of analyses under this study received rainfall of more than 1233 mm. Out of 42 years, 17 years recorded annual rainfall in excess of average or normal (928.4 mm) while 25 years (i.e. 59% of the total years of rainfall record) recorded below normal rainfall (Figure 1). Monthly average and effective rainfall of the Parbhani region for 42 years are presented in Figure 2.

Considering monthly rainfall distribution, it was revealed that mean rainfall of August was 235.7 mm, which was the highest

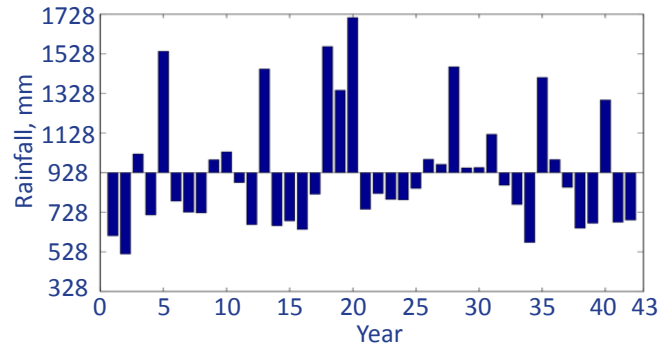


Figure 1: Annual variability of annual rainfall over normal at Parbhani (1971-2012)

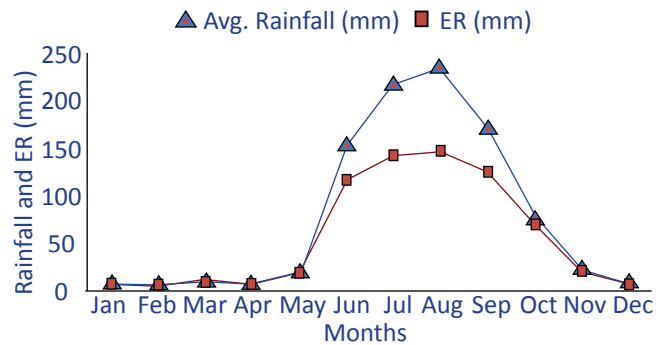


Figure 2: Average monthly rainfall and effective rainfall for the study area, Parbhani; ER is the effective rainfall

and its contribution was 25.4% annual average rainfall. July rainfall was slightly lower than that in August (i.e. 23.4% of annual average rainfall). December was the lowest rainfall month. Total annual effective rainfall (ER) was 668.6 mm which was 72.0% of the total annual rainfall. It was also observed that 259.8 mm of rainfall water was lost in the form of surface runoff, deep percolation and evaporation.

The distribution of rainfall for different seasons showed that the normal southwest monsoon, which delivered 83.6% of annual rainfall, extended from June to September (Table 1). This is also the main season (rainy season) for cultivation of rainfed crops. Winter season contributes only 1.3% of the total annual rainfall; 3.7 and 11.4% of the total annual rainfall occurred during pre- and post-monsoon season, respectively with the lowest coefficient of variation during monsoon(36.3%) followed by post-monsoon (82.7%) , pre-monsoon (93.5%) and winter (150%). The occurrence of rainy days were categorized into four groups viz. 0-40, 41-50, 51-60 and 61-70 days (Table 2). The analysis showed that maximum numbers of rainy days were observed under 41-50 days category followed by 0-40 and 51-60 days. Numbers of rainy days under 61-70 days category were found only 7.1%.

The weekly rainfall attributes showing mean, maximum, minimum, standard deviation, coefficient of variation and percentage of weekly rainfall contribution towards annual rainfall are presented in Table 3. Data revealed that, there were total of 18 weeks (23rd to 40th SMW) where rainfall exceeded more than 20 mm. During rainy season the mean

Table 1: Rainfall distribution in the Parbhani region over different seasons (data of 42 years for the period 1971–2012)

Seasons	Average rainfall (mm)	Percentage of total rainfall	SD	CV (%)
Pre-monsoon (March–May)	34.4	3.7	32.1	93.5
Monsoon (June–September)	776.5	83.6	282.3	36.3
Post-monsoon (October–December)	105.6	11.4	87.2	82.7
Winter (January–February)	11.9	1.3	17.8	150

SD: Standard deviation; CV: Coefficient of variation

Table 2: Number of years under different magnitude of rainy days

Annual rainy day	Number of years	Rainy day (%)
0-40	9	21.4
41-50	21	50.0
51-60	9	21.4
61-70	3	7.1

weekly rainfall was found to be more than 40 mm during 24th - 27th, 30th -32nd, 34th–36th and 38th SMW and found to be less than 20 mm during 41st–43rd SMW. The coefficient of variation during rainy season varied from 95.8% (24th SMW) to 262.3% (43rd SMW).

3.2. Analyses of rainfall for onset and withdrawal of monsoon season

The results of forward and backward accumulation of weekly rainfall for onset and withdrawal of effective monsoon are presented in Table 4. Weekly rainfall data (1971–2012) indicated that the monsoon started effectively from the 24th SMW (11th–17th June) and remained active up to the 43rd SMW (22nd–28th October). Therefore, mean length of rainy season was found to be 20 weeks (140 days). The earliest and delayed onset of rainy season was 21st SMW (21st–27th May) and 27th SMW (2nd–8th July), respectively. Similarly, the earliest and delayed week of cessation of rainy season was 39th SMW (24th–30th September) and 48th SMW (26th November–2nd December), respectively. The probabilities of the onset and withdrawal of rainy season were calculated by using Weibull's formula considering forward and backward accumulation of weekly rainfall (Table 5). The results forward accumulation starting from 20th week revealed that there was 95% chance onset of effective monsoon i.e. probability of getting cumulative rainfall ≥ 75 mm in 27th week. Similarly, the 93% chance of withdrawal i.e. the probability of getting cumulative rainfall ≤ 20 mm in 48th SMW, considering backward accumulation of

weekly rainfall into account starting from week 48th.

3.3. Markov chain model

The results of initial and conditional probabilities of dry and wet weeks and consecutive dry and wet weeks are presented in Table 6 and 7 respectively for all the 52 standard meteorological weeks. The results showed that the probability of occurrence of dry week was high until the end of the 23rd SMW. The initial probability of dry week (P_D) and conditional probability of dry week preceded by another dry week (P_{DD}) varied between 30.9 -100% and 30.8–100% respectively during 1st–52nd SMW. Similarly the initial probability of wet week (P_W) and conditional probability of wet week preceded by another wet week (P_{WW}) varied between 0.0 - 69.1% and 0.0–84.2% respectively during 1st–52nd SMW. For main rainy season (24th - 43rd week), the initial probability of dry week (P_D) and conditional probability of dry week preceded by another dry week (P_{DD}) ranged from 30.9–85.7% and 30.8–90.0% respectively. At the first week of main rainy season i.e. 24th week, the chance of occurrence of dry week (P_D) and conditional probability of dry week preceded by another dry week (P_{DD}) were 38.1 and 44.5% respectively, similarly at the end of main rainy season (43rd week), dry week (P_D) and conditional probability of dry week preceded by another dry week (P_{DD}) had chance of 85.7 and 90.0% occurrences respectively.

For main rainy season, the initial probability of wet week (P_W) and conditional probability of wet week preceded by another wet week (P_{WW}) varied from 14.3–69.1% and 25.0–84.2% respectively. At the first week of main rainy season, the chance of occurrence of wet week (P_W) and conditional probability of wet week preceded by another wet week (P_{WW}) were 61.9 and 73.4% respectively, similarly at the end of main rainy season, wet week (P_W) and conditional probability of wet week preceded by another wet week (P_{WW}) had chance of 14.3 and 25.0% occurrences respectively. It is clear from results that, probability of occurrence of wet week is more than 35% during 23-24th SMW (4th June–17th June) and average weekly rainfall ranges from 27.4 to 41.9 mm, this rain can be utilized for summer ploughing and initial seed bed preparations. The mean onset of rainy season was found to be 24th SMW. So, during 24th SMW (11th June–17th June), the sowing operations can be taken up since, the probability of wet week is more than 50% and average weekly rainfall is 41.9 mm. Sowing operations taken at 24th SMW helps for good germination of seeds and helps in avoiding moisture stress for germination period during 25th–28th SMW. In the event of delayed start of rainy season, the sowing operations can be taken up latest by 27th SMW (2nd July–8th July) and further delay in sowing may cause very low productivity and crop failure. Since, mean length of rainy season was observed to be 20 weeks (140 days), during kharif, short duration crops of groundnut, pigeon pea, maize, sorghum, green gram, soybean, sunflower, field bean, cowpea and other low water required crops which have high return value can be taken up. Another advantage of growing short duration cereals, pulses and oilseeds in first fortnight of June is that these can be harvested by the end of



Table 3: Weekly rainfall attributes at Parbhani (1971–2012)

SMW	Mean	Max	Min	SD	CV	% of MAR	SMW	Mean	Max	Min	SD	CV	% of MAR
1	1.2	33.2	0	5.3	457.0	0.1	27	42.3	176.9	0	45.9	108.5	4.6
2	2.9	41.4	0	8.6	294.4	0.3	28	39.6	214.9	0	47.1	118.9	4.3
3	2.1	51.6	0	8.4	407.2	0.2	29	35.9	161.1	0	41.9	116.7	3.9
4	1.0	24	0	4.2	404.5	0.1	30	76.2	500.3	0	100.0	131.3	8.2
5	0.4	11	0	2.0	468.1	0.0	31	58.3	342.8	0	71.0	121.7	6.3
6	2.1	29.6	0	6.1	286.5	0.2	32	53.8	271.2	0	68.5	127.3	5.8
7	1.0	35	0	5.4	568.0	0.1	33	37.9	204.8	0	45.6	120.4	4.1
8	1.1	19.4	0	3.7	338.2	0.1	34	67.8	326.4	0	74.6	110.0	7.3
9	0.6	16.2	0	2.7	428.0	0.1	35	51.0	181.6	0	53.9	105.6	5.5
10	3.8	53.8	0	10.7	282.0	0.4	36	46.9	187.8	0	48.1	102.4	5.1
11	3.0	56	0	10.8	359.0	0.3	37	29.1	166.5	0	38.0	130.5	3.1
12	0.9	12	0	2.4	278.2	0.1	38	40.3	144.3	0	44.7	110.8	4.3
13	1.0	19	0	3.2	331.6	0.1	39	37.6	180.2	0	49.9	132.6	4.1
14	1.4	11	0	3.3	235.7	0.1	40	30.1	190.3	0	46.3	153.8	3.2
15	2.1	25.6	0	5.8	274.1	0.2	41	19.7	137.6	0	37.1	188.6	2.1
16	0.8	10.4	0	2.1	277.0	0.1	42	14.5	141.4	0	28.3	195.6	1.6
17	1.3	15	0	3.1	239.2	0.1	43	10.8	123.2	0	28.3	262.3	1.2
18	1.9	21	0	4.6	246.0	0.2	44	4.9	49.8	0	11.4	235.4	0.5
19	1.3	18	0	3.4	252.2	0.1	45	4.5	52.9	0	11.3	250.9	0.5
20	4.9	92	0	15.0	304.7	0.5	46	2.7	30.2	0	7.4	279.6	0.3
21	6.6	85.2	0	15.4	234.8	0.7	47	6.6	80	0	16.7	252.5	0.7
22	11.0	99	0	20.8	188.9	1.2	48	5.1	108	0	19.1	377.7	0.5
23	27.4	186.2	0	45.0	164.1	3.0	49	2.4	54.3	0	10.1	427.7	0.3
24	41.9	181.8	0	40.1	95.8	4.5	50	0.9	27.6	0	4.4	482.6	0.1
25	40.2	201.3	0	43.1	107.2	4.3	51	0.9	33	0	5.1	592.4	0.1
26	44.1	170.4	0	45.3	102.9	4.7	52	2.7	48.2	0	9.2	344.0	0.3

MAR: Mean annual rainfall

Table 4: Characterisation of rainy season at Parbhani (1971–2012)

Particulars	Week no.	Date
Mean week of onset of rainy season	24	11–17 June
Earliest week of onset of rainy season	21	21-27 May
Delayed week of onset of rainy season	27	02-08 July
Mean week of withdrawal of rainy season	43	22–28 October
Earliest week of withdrawal of rainy season	39	24–30 September
Delayed week of withdrawal of rainy season	48	26 Nov.-02 Dec.
Mean length of rainy season	20 weeks (140 days)	

September (39th SMW) and short duration *rabi* crops can be sown during 40th-43rd SMW (1st-28th October). Since, winter rainfall is uncertain and erratic than south west monsoon also it contribute only 11.4% of total rainfall. Therefore growing of high value *rabi* crops without supplementary irrigation would be very high risky during *rabi* season.

During main rainy season, the probability of dry week (P_D) being more than 50% were observed during 29th, 37th and 40th to 43rd SMW and also chance of dry week preceded by another dry week (P_{DD}) were more than 50% during 28th, 29th and 37th to 43rd SMW. Therefore during those dry weeks especially at the end of main rainy season, supplementary irrigation and moisture conservation practice need to be undertaken. The significant contribution of weekly rainfall i.e. 42.2% of total annual rainfall during 30th–36th SMW and high consecutive wet week probability during 30th–35th SMW, indication for

Table 5: Probability of onset (Forward accumulation from 21st week) and withdrawal of effective monsoon (Backward accumulation from 48th week)

Probability of onset and withdrawal										
Onset (Forward accumulation starting from 21 th week)										
Week	20	21	22	23	24	25	26	27		
P (%)	2.3	4.65	11.6	20.9	44.2	76.7	88.4	95.3		
Withdrawal (Backward accumulation starting from 48 th week)										
Week	39	40	41	42	43	44	45	46	47	48
P (%)	9.31	18.6	27.9	37.2	48.8	58.1	72.2	79.1	86.1	93.0

potential scope of harvesting excess runoff water for future supplemental irrigations and also drives attention towards soil erosion measures to be taken up for soil erosion control. The analyses of consecutive dry and wet spells (Table 6) revealed

that there were 28.6 to 100% chances that two consecutive dry weeks (P_{2D}) would occur within the first 23 weeks of the year. Similarly, the probabilities of occurrence of three consecutive dry weeks (P_{3D}) were also very high (10.7–100%)

Table 6: Initial and conditional probabilities of dry and wet spells of rainfall at the study site, Parbhani region

SMW	Initial probabilities (%)		Conditional probabilities (%)				SMW	Initial probabilities (%)		Conditional probabilities (%)			
	PD	PW	PDD	PWD	PWW	PDW		PD	PW	PDD	PWD	PWW	PDW
1	97.6	2.4	97.5	2.5	0.0	100.0	27	45.2	54.8	42.1	57.9	52.2	47.8
2	95.2	4.8	95.1	4.9	0.0	100.0	28	40.5	59.5	52.6	47.4	69.6	30.4
3	97.6	2.4	97.5	2.5	0.0	100.0	29	54.8	45.2	70.6	29.4	56.0	44.0
4	97.6	2.4	97.6	2.4	0.0	100.0	30	30.9	69.1	43.5	56.5	84.2	15.8
5	100	0	100.0	0.0	0.0	100.0	31	35.7	64.3	30.8	69.2	62.1	37.9
6	95.2	4.8	95.2	4.8	0.0	100.0	32	40.5	59.5	40.0	60.0	59.2	40.8
7	97.6	2.4	97.5	2.5	0.0	100.0	33	42.8	57.2	41.2	58.8	56.0	44.0
8	100	0	97.6	2.4	0.0	100.0	34	33.4	66.6	33.4	66.6	66.7	33.3
9	100	0	100.0	0.0	0.0	100.0	35	38.1	61.9	42.8	57.2	64.3	35.7
10	92.8	7.2	92.8	7.2	0.0	100.0	36	35.7	64.3	43.7	56.3	69.2	30.8
11	92.8	7.2	92.5	7.5	0.0	100.0	37	57.1	42.9	60.0	40.0	44.5	55.5
12	100	0	100.0	0.0	0.0	100.0	38	47.6	52.4	54.2	45.8	61.2	38.8
13	100	0	100.0	0.0	0.0	100.0	39	50.0	50	60.0	40.0	59.1	40.9
14	100	0	100.0	0.0	0.0	100.0	40	64.3	35.7	80.9	19.1	52.4	47.6
15	97.6	2.4	97.6	2.4	0.0	100.0	41	76.2	23.8	85.2	14.8	40.0	60.0
16	100	0	100.0	0.0	0.0	100.0	42	71.4	28.6	71.9	28.1	30.0	70.0
17	100	0	100.0	0.0	0.0	100.0	43	85.7	14.3	90.0	10.0	25.0	75.0
18	97.6	2.4	97.6	2.4	0.0	100.0	44	88.1	11.9	88.9	11.1	16.7	83.3
19	100	0	100.0	0.0	0.0	100.0	45	90.5	9.5	89.2	10.8	0.0	100.0
20	92.8	7.2	92.8	7.2	0.0	100.0	46	92.8	7.2	92.1	7.9	0.0	100.0
21	90.5	9.5	89.7	10.3	0.0	100.0	47	88.1	11.9	87.2	12.8	0.0	100.0
22	83.4	16.6	86.4	13.6	50.0	50.0	48	92.8	7.2	97.3	2.7	40.0	60.0
23	64.3	35.7	65.7	34.3	42.8	57.2	49	95.2	4.8	97.5	2.5	33.4	66.6
24	38.1	61.9	44.5	55.5	73.4	26.6	50	97.6	2.4	100.0	0.0	50.0	50.0
25	40.5	59.5	37.5	62.5	57.7	42.3	51	97.6	2.4	97.6	2.4	0.0	100.0
26	45.2	54.8	35.3	64.7	48.0	52.0	52	95.2	4.8	95.1	4.9	0.0	100.0



in the first 23 weeks of the year. The corresponding values of two and three consecutive wet weeks (i.e. P_{2W} and P_{3W}) from the 1st to 23rd SMW were very low with values ranging from 0 to 26.2% and 0 to 15.1%, respectively. From the 24th to 38th SMW, the chances of occurrence of two and three

consecutive dry weeks were only within 7 to 30.9% and 2.8 to 24.5%, respectively. Similarly, there were chances of 28.6 to 42.9% and 14.9 to 29.6% that the weeks from the 24th to 38th SMW would be getting sufficient rain with two and three consecutive wet weeks, respectively.

Table 7: Analyses of consecutive dry and wet week probabilities of rainfall at the study site, Parbhani

SMW	Consecutive dry week probabilities (%)		Consecutive wet week probabilities (%)		SMW	Consecutive dry week probabilities (%)		Consecutive wet week probabilities (%)	
	P_{2D}	P_{3D}	P_{2W}	P_{3W}		P_{2D}	P_{3D}	P_{2W}	P_{3W}
1	92.8	90.5	0.0	0.0	27	23.8	16.8	38.1	21.4
2	92.8	90.6	0.0	0.0	28	28.6	12.4	33.3	28.1
3	95.2	95.2	0.0	0.0	29	23.8	7.3	38.1	23.6
4	97.6	92.9	0.0	0.0	30	9.5	3.8	42.9	25.4
5	95.2	92.8	0.0	0.0	31	14.3	5.9	38.1	21.3
6	92.8	90.6	0.0	0.0	32	16.7	5.6	33.3	22.2
7	95.3	95.3	0.0	0.0	33	14.3	6.1	38.2	24.5
8	100.0	92.8	0.0	0.0	34	14.3	6.2	42.8	29.6
9	92.8	85.8	0.0	0.0	35	16.6	10.0	42.8	19.1
10	85.8	85.8	0.0	0.0	36	21.4	11.6	28.6	17.5
11	92.8	92.8	0.0	0.0	37	30.9	18.6	26.3	15.5
12	100.0	100.0	0.0	0.0	38	28.6	23.1	31.0	16.2
13	100.0	97.6	0.0	0.0	39	40.5	34.5	26.2	10.5
14	97.6	97.6	0.0	0.0	40	54.8	39.4	14.3	4.3
15	97.6	97.6	0.0	0.0	41	54.8	49.3	7.1	1.8
16	100.0	97.6	0.0	0.0	42	64.3	57.1	7.2	1.2
17	97.6	97.6	0.0	0.0	43	76.2	68.0	2.4	0.0
18	97.6	90.6	0.0	0.0	44	78.6	72.4	0.0	0.0
19	92.8	83.2	0.0	0.0	45	83.4	72.7	0.0	0.0
20	83.2	71.9	0.0	0.0	46	80.9	78.7	0.0	0.0
21	78.2	51.4	4.8	2.0	47	85.7	83.6	4.8	1.6
22	54.8	24.4	7.1	5.2	48	90.5	90.5	2.4	1.2
23	28.6	10.7	26.2	15.1	49	95.2	92.9	2.4	0.0
24	14.3	5.0	35.7	17.1	50	95.3	90.6	0.0	0.0
25	14.3	6.0	28.6	14.9	51	92.8	90.4	0.0	0.0
26	19.0	10.0	28.6	19.9	52	92.9	88.3	0.0	0.0

4. Conclusion

During rainy season probability of dry week (P_D) being more than 50% was observed during 29th, 37th and 40th to 43rd SMW. Therefore during those dry weeks especially at the end of main rainy season, supplementary irrigation and moisture conservation practice need to be undertaken. The significant contribution of weekly rainfall i.e. 42.2% of total annual rainfall during 30th–36th SMW, hints for potential scope of harvesting excess runoff water for future supplemental irrigations.

5. References

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