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Markov chain analysis of dry, wet weeks and statistical analysis of weekly rainfall for agricultural planning at Dhera, Central Rift Valley Region of Ethiopia

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Knowledge of rainfall pattern is very important for making decision on crop planning and water management. In the present study, Markov Chain probability model was performed to explain the long term frequency behavior of wet or dry weather spells during the main rainy season at Dhera, Central Rift Valley Region of Ethiopia. The study used 24 years (1984-2010) of rainfall data and weekly rainfall data was considered as standard to study the probabilities of occurrences of dry and wet weeks. Some reasonable and significant conclusions regarding specific time for land preparation, supplementary irrigation and soil conservation measures were obtained. The main rainy season starts on the 26th week (25th June - 1st July) and remains active upto the 40th week (1st - 7th October) this shows a total of 105 days of main rainy season that could occur. The coefficients of variation at the onset and withdrawal week are 69.4 and 99.2% respectively for the study site during the main rainy season. The probability of occurrences of initial and conditional probability is more than 50% on the 26th week at 10 mm per week threshold limit and 28th week at 20 mm per week threshold limit, therefore land preparation for planting could be undertaken in 26th and 28th weeks respectively for the main rainy season crop cultivation. Initial and conditional probabilities at 20 mm threshold limit per week showed that, supplementary irrigation and moisture conservation practice need to be practiced between 38th and 40th week for short duration crops and if the crop duration extend after 40th week it's evident that supplementary irrigation is needed. In addition, harvesting runoff water for supplementary irrigation and construction of soil erosion measures need to be practiced between 28th and 33rd weeks for better rain water management.

Key words: Markov chain model, onset week, withdrawal week, agricultural planning.

INTRODUCTION

Ethiopian farming is mainly dependant on rainfed smallholder agricultural system as a means of food and income for its population (Hordofa et al., 2008). Although agricultural production from rainfed agricultural system depends on all climatic parameters, rainfall is the most important and sensitive one. Both shortage and surplus of rainfall during the length of the crop growing period can lead to full or partial crop failure. However, agricultural

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production can be increased and risk minimized by selecting the right time for the onset of rainfall based on informed decision by analyzing the long term rainfall pattern and variability as well as harvesting excess water and utilizing it in periods of shortage as supplementary irrigation.

The rift valley region of Ethiopia has an average of 725 mm rainfall with a maximum of 1990 mm and minimum of 90 mm (FAO, 1997). Despite its high average amount, the magnitude and distribution of rainfall are highly variable across time and space (Menker and Erkosa, 2006). In addition, rainfall variability increases as rainfall quantity decreases (Menker and Erkosa, 2006). Thus, rainfall variability is greater in rift valley region where this study has been undertaken because of low agricultural production due to absence of sufficient rainfall. Rainfall variability has major implications on crop production and productivity. Hence, rainfall pattern needs to be studied for the purpose of crop planning and water management as it is the main factor for yield of a crop under rainfed condition (Singh et al., 2013). During occurrences of good rainfall years, agricultural production increased and improved farmer's livelihood. Conversely, during inadequate and variable rainfall years, partial or complete crop failures could occur (Gautam and Rao, 2007).

In the study area, farmers usually made traditional crop planning decision based on the onset of rainfall for Belg season (small amount of rain before the main rainy season). If the rain comes early, then farmers plant medium duration crops. Yet, if the rains are delayed, then farmer's plant short duration crops (Walker et al., 2010). According to Yemenu and Chemeda (2010), irregularity of onset, temporal and spatial distribution of rainfall caused low crop yield to the rainfed agricultural system. Therefore, analyzed data on the onset and withdrawal of the main rainy season can be very important for planning of agricultural activities, especially to determine time of land preparation before sowing. In the case of Bisoftu District, planning of agricultural activities is fairly simple and less risky because of stability of onset dates of the main rainy season which is at the second decade of June and the withdrawal of rainy season is at the last decade of September (Yemenu et al., 2010).

Knowledge on sequences of dry and wet spells can assist to acquire specific information for agricultural planning (Reddy et al., 2008). Understanding the events of occurrences of dry spells and intensive rainfall are crucial to decrease the adverse effects of dry spells at sensitive crop development stage and occurrences of runoff in the middle of the season from damaging the crops in the field respectively (Yemenu et al., 2013). Many studies on agricultural planning were performed by Markov Chain probability model (Pandharinath, 1991; Reddy, 1991; Dash and Senapati, 1992; Babuan and Lakshminarayana, 1997; Reddy et al., 2008; Shahraki et al., 2012; Panigrahi et al., 2002; Senthilvelan et al., 2012; Mangaraj et al., 2013; Mandal et al., 2013; Singh et al., 2013) used weekly rainfall values as a standard to determine initial, conditional and consecutive dry and wet spells analysis. Determination of dry and wet spells can prove to famers its usefulness regarding improving crop productivity and intensity (Mandal et al., 2013).

This study has been carried out to determine the onset and withdrawal of rainy season, probabilities of occurrences of onset and withdrawal of rainy seasons and the initial and conditional probabilities of dry and wet weeks using threshold limits of 10 mm and 20 mm of rainfall during the main rainy season at Dodota area, Central Region of Ethiopia.

MATERIALS AND METHODS

Study area

The study area is located at Dhera, Dodota District under the Central Rift Valley region of Ethiopia (Figure 1). Dhera has an average annual maximum temperature of 27°C, average annual minimum temperature of 8.36°C and 656.91 mm of average annual rainfall. Daily rainfall data recorded at Dhera Meteorological Station (08° 19' 10" N, 39° 19' 13" and height of 1650 m above sea level) for a period of 24 years (1984-2010) were used for the present study. Rainfall data records on 1992, 1998 and 2008 season were not included in this study due to missing of recorded data. The weekly rainfall values have been computed from daily values and were used for the present study.

Methods of computation for onset and withdrawal of main rainy season

Time of onset, withdrawal and length of rainy season were selected as key parameters to characterize the rainfall season for crop production (Punyawardena, 2002). Determination of onset, withdrawal and length of rainy season is important for crop planning, choice of suitable crop varieties and to plan compressive strategies for efficient rain water management (Mandal et al., 2013). Dash and Senapati (1992) suggested a procedure to compute the onset and withdrawal of rainy season from weekly rainfall data by forward and backward accumulation method. The present study uses the suggested procedure to compute onset and withdrawal of rainy season from weekly rainfall data. Each year is divided into 52 meteorological weeks, starting the first week from 1st to 7th January upto the last week 24th to 31st December. According to Panigrahi and Panda (2002), accumulation of 75 mm of rainfall was considered as the onset time for sowing of rainfed crops. The onset time of rainy season was determined by forward summation of weekly rainfall starting from 20th week until 75 mm of rainfall accumulated (Dash and Senapati, 1992). Results from Babuan and Lakshminarayana (1997), had chosen a 20 mm of rainfall accumulation for the withdrawal of the rainy season, which is sufficient for ploughing of fields after harvesting of the crops. The withdrawal of rainy season was determined by backward summation of weekly rainfall starting from 48th week until 20 mm of rainfall is accumulated.

The probabilities of onset and withdrawal of the main rainy season was calculated by using Weibull's formula. The percent probability (P) of each rank was calculated by arranging them in ascending order and by selecting the highest rank allotted for a particular week. The following Weibull's formula has been used for calculating percent probability of onset and withdrawal (Mandal et al., 2013). The mean, maximum, minimum, standard deviation and

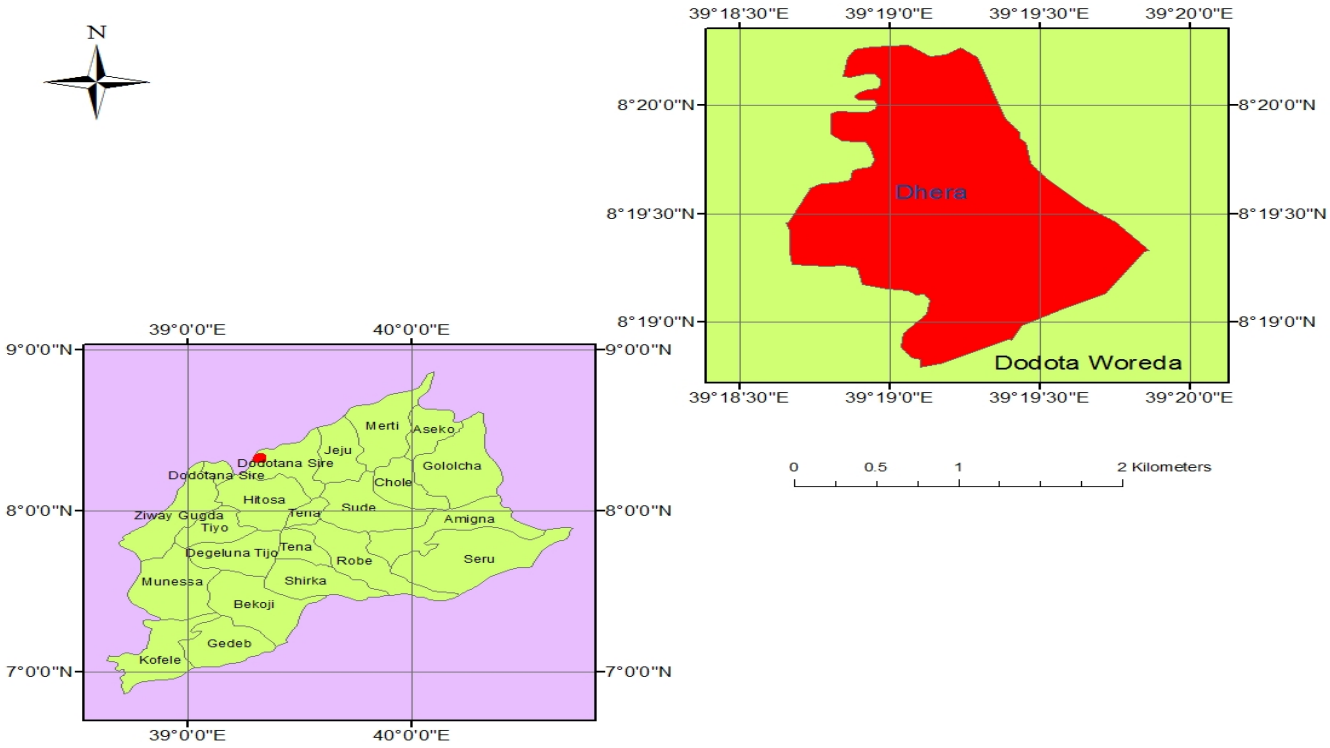

Figure 1. Study area map (Source: EMA 2012).

coefficient of variation of weekly rainfall were calculated manually.

$$P = \frac{m}{N+1} \times 100 \quad (1)$$

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

Methods of computation for initial and conditional probabilities of main rainy season

The information on initial and conditional probability were given based on weekly level using First Markov chain model (Equation 2 to 7). Probability of a week being dry or wet is under initial probability while in case of conditional probability, if a given period i is wet or dry, then the chance of $(i+k)^{th}$ period is wet and given as wet/wet or wet/dry are estimated. A threshold limit of 10 mm and 20 m of rainfall were selected as critical for different purpose of agricultural planning purpose. The weekly analysis of rainfall is very important concerning agricultural planning and week period has been considered as the optimum length of time (Reddy, 1991; Reddy et al., 2008). 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 vice versa (Pandharinath, 1991). The different formulas used for this analysis are shown below:

Initial probabilities

$$Pd = Fd/N \quad (2)$$

$$Pw = Fw/N \quad (3)$$

Conditional probabilities

$$Pww = Fww/N \quad (4)$$

$$Pwd = 1 - Pdd \quad (5)$$

$$Pdw = 1 - Pww \quad (6)$$

$$Pdd = Fdd/N \quad (7)$$

Where, Pd = probability of the week being dry, Pw =probability of week being wet, Fd = number of dry weeks, Fw = number of wet weeks, N = number of years of data, Pdd = probability of a dry week preceded by a dry week, Pww = probability of a wet week preceded by a wet week, Pwd = probability of a wet week preceded by a dry week, Pdw = probability of a dry week preceded by a wet week, Fdd = number of dry weeks preceded by another dry week, Fww = number of a wet week preceded by a wet week,

The calculation of initial and conditional probability for 10 mm and 20 mm threshold limit follow the same procedure, the initial probability (probability of a week being dry or wet) calculated by dividing the counted number of dry week or wet week to the number of years of the data, which is 24 years. The conditional probability (probability of a dry week preceded by dry week) calculated by dividing the counted number of dry week preceded by dry week to the counted number of dry week, the same goes to the calculation of probability of a wet week preceded by a wet week. Finally the probability of wet week preceded by dry week and dry week

Table 1. Characterization of the main rainy season at Dhera (1984-2010)

Particulars	Week No	Date
Mean week of onset of the main rainy season	26	25 June - 1 July
Earliest week of onset of the main rainy season	21	21 May - 27 May
Delayed week of onset of the main rainy season	29	16 July - 22 July
Mean week of withdrawal of the main rainy season	40	1 October - 7 October
Earliest week of withdrawal of the main rainy season	35	27 August - 2 September
Delayed week of withdrawal of the main rainy season	47	19 November - 25 November
Mean length of the main rainy season		15 weeks (105 days)
Duration of the main rainy season		
Longest		23 weeks (161 days)
Shortest		6 weeks (42 days)

Table 2. Probability of onset and withdrawal of the main rainy season at Dhera.

Onset													
Week	21	22	23	24	25	26	27	28	29				
P (%)	4.00	8.00	16.00	26.00	34.00	48.00	64.50	84.00	96.00				
Withdrawal													
Week	35	36	37	38	39	40	41	42	43	44	45	46	47
P (%)	4.00	8.00	12.00	32.00	56.00	68.00	78.00		84.00	88.00	92.00		96.00

preceded by wet week is calculated by subtracting probability of a dry week preceded by dry week and probability of a wet week preceded by a wet week from 100.

RESULTS AND DISCUSSION

Onset and withdrawal of main rainy season at Dhera

The onset and withdrawal of the main rainy season at the study site is 25th June and 7th October respectively. According to Table 1 the main rainy season starts on the 26th week (25th June to 1st July) and remains active upto the 40th week (1st to 7th October). This implies the mean length of the main rainy season for the study site is 15 weeks or 105 days. The earliest and delayed weeks of onset of the main rainy season are 21st week (21st to 27th May) and 29th week (16th to 22nd July), respectively. Similarly, the earliest and delayed week of withdrawal of the main rainy season are 35th week (27th August to 2nd September) and 47th week (19th to 25th November) respectively.

Probabilities of main rainy season at Dhera

The results of probabilities of onset and withdrawal of the main rainy season are presented in Table 2 and the results revel that there are a 96% chance that both the onset and withdrawal of the main rainy season will occur during at 29th and 47th week. There are no withdrawal probability occurrences of main rainy season at 42th and 46th weeks; therefore these two weeks are not included in the probability calculation.

The weekly rainfall for mean, maximum, minimum, standard deviation and coefficient of variation of Dhera area rainfall were calculated and the result is shown in Table 3, there are 12 weeks (26th to 37th week) where the rainfall exceeds more than 20 mm and 3 weeks (38th to 40th week) where rainfall is less than 20 mm during the main rainy season. The coefficient of variation during the main rainy season varies from maximum of 99.2% at 40th week to minimum of 68.4% at the 30th and 31st week. The coefficients of variation at the onset and withdrawal week are 69.4% and 99.2% respectively for the study site during the main rainy season. The threshold limit for coefficient of variation for weekly rainfall should be less than 150% (Senthilvelan et al., 2012). During the rainy season at the study site, the coefficient of variation is less than 150%, the lesser the variability of rainfall during rainy season showed the higher dependability of rainfall, therefore agricultural operation and growing rainfed crops is possible during the rainy season. This conclusion is similar to the result of Senthilvelan et al. (2012).

Initial and conditional probabilities of main rainy season at Dhera area

The initial and conditional probability of 10 and 20 mm

Table 3. Descriptive statistics on weekly rainfall data for Dhera.

Week	Mean (mm)	Max (mm)	Min (mm)	SD	CV (%)
1	2.1	19.2	0.0	3.6	169.8
2	0.0	0.3	0.0	0.0	295.4
3	3.9	16.5	0.0	4.0	101.5
4	7.4	27.5	0.0	7.6	102.4
5	1.9	21.0	0.0	3.3	178.1
6	6.8	33.7	0.0	7.1	103.9
7	2.8	31.2	0.0	4.5	163.0
8	6.4	55.9	0.0	8.6	135.6
9	7.7	41.0	0.0	9.2	119.2
10	7.2	37.5	0.0	8.0	112.0
11	11.8	66.6	0.0	12.2	102.8
12	13.7	32.1	0.0	12.0	87.6
13	13.2	35.5	0.0	11.7	88.5
14	12.4	41.2	0.0	11.2	90.5
15	10.8	40.3	0.0	9.9	91.1
16	13.2	58.5	0.0	13.3	100.8
17	13.3	42.5	0.0	11.4	86.0
18	14.7	52.5	0.0	14.2	96.6
19	11.6	40.0	0.0	10.9	94.3
20	15.6	54.8	0.0	13.6	87.1
21	9.2	45.0	0.0	8.8	95.9
22	9.2	24.2	0.0	7.8	84.1
23	12.3	33.5	0.0	10.6	86.8
24	9.2	20.0	0.0	6.9	74.6
25	14.6	67.6	0.0	13.7	93.6
26	26.4	39.5	0.0	18.3	69.4
27	20.3	31.2	0.0	14.7	72.4
28	40.2	52.0	0.0	27.3	67.9
29	32.9	49.5	0.0	23.0	70.1
30	31.9	53.2	0.0	21.8	68.4
31	25.9	39.5	0.0	17.7	68.4
32	36.7	48.2	0.0	26.8	73.1
33	39.1	72.4	0.0	28.6	73.2
34	27.7	38.8	0.0	19.6	70.6
35	27.7	39.0	0.0	19.2	69.4
36	25.9	33.3	0.0	18.2	70.2
37	22.2	36.3	0.0	15.7	70.8
38	17.8	36.7	0.0	13.4	75.2
39	9.6	28.0	0.0	7.6	78.7
40	6.7	28.0	0.0	6.6	99.2
41	5.7	25.5	0.0	6.1	107.0
42	3.8	30.0	0.0	4.7	125.0
43	3.1	20.0	0.0	3.9	125.1
44	1.8	22.0	0.0	3.1	173.4
45	2.2	24.6	0.0	3.3	148.3
46	0.3	4.8	0.0	0.7	196.5
47	1.9	12.2	0.0	2.2	116.5
48	0.8	17.0	0.0	2.1	259.7
49	3.7	37.6	0.0	6.1	162.4
50	1.9	42.0	0.0	5.2	279.6
51	1.7	28.0	0.0	3.7	217.4
52	0.1	1.4	0.0	0.2	170.2

threshold limit rainfall were summarized in Tables 4 and 5 for all 52 weeks respectively. However, this paper

Table 4. Initial and conditional probabilities at 10mm threshold limit of rainfall for Dhera.

Week	Pd	Pw	Week	Pdd	Pww	Pwd	Pdw
Initial probabilities (%)			Conditional probabilities (%)				
1	88.0	8.0	1	86.4	0.0	13.6	100.0
2	96.0	0.0	2	95.8	0.0	4.2	100.0
3	80.0	16.0	3	80.0	25.0	20.0	75.0
4	72.0	24.0	4	77.8	33.3	22.2	66.7
5	92.0	4.0	5	91.3	0.0	8.7	100.0
6	72.0	24.0	6	83.3	50.0	16.7	50.0
7	84.0	12.0	7	85.7	0.0	14.3	100.0
8	76.0	20.0	8	73.7	20.0	26.3	80.0
9	80.0	16.0	9	80.0	0.0	20.0	100.0
10	72.0	24.0	10	66.7	16.7	33.3	83.3
11	60.0	36.0	11	60.0	33.3	40.0	66.7
12	64.0	32.0	12	62.5	25.0	37.5	75.0
13	64.0	32.0	13	68.8	37.5	31.3	62.5
14	52.0	44.0	14	30.8	27.3	69.2	72.7
15	60.0	36.0	15	80.0	55.6	20.0	44.4
16	60.0	36.0	16	46.7	22.2	53.3	77.8
17	64.0	32.0	17	56.3	12.5	43.8	87.5
18	64.0	32.0	18	68.8	37.5	31.3	62.5
19	68.0	28.0	19	76.5	28.6	23.5	71.4
20	52.0	44.0	20	46.2	27.3	53.8	72.7
21	72.0	24.0	21	72.2	16.7	27.8	83.3
22	60.0	36.0	22	73.3	55.6	26.7	44.4
23	56.0	40.0	23	64.3	50.0	35.7	50.0
24	64.0	32.0	24	56.3	25.0	43.8	75.0
25	60.0	36.0	25	66.7	44.4	33.3	55.6
26	24.0	72.0	26	16.7	66.7	83.3	33.3
27	36.0	60.0	27	11.1	46.7	88.9	53.3
28	8.0	88.0	28	0.0	90.9	100.0	9.1
29	12.0	84.0	29	0.0	81.0	100.0	19.0
30	16.0	80.0	30	25.0	85.0	75.0	15.0
31	24.0	72.0	31	0.0	66.7	100.0	33.3
32	16.0	80.0	32	25.0	85.0	75.0	15.0
33	12.0	84.0	33	0.0	81.0	100.0	19.0
34	12.0	84.0	34	0.0	81.0	100.0	19.0
35	24.0	72.0	35	16.7	66.7	83.3	33.3
36	16.0	80.0	36	25.0	80.0	75.0	20.0
37	24.0	72.0	37	33.3	83.3	66.7	16.7
38	28.0	68.0	38	14.3	58.8	85.7	41.2
39	64.0	32.0	39	62.5	37.5	37.5	62.5
40	72.0	24.0	40	66.7	16.7	33.3	83.3
41	84.0	12.0	41	85.7	33.3	14.3	66.7
42	88.0	8.0	42	86.4	0.0	13.6	100.0
43	80.0	16.0	43	80.0	25.0	20.0	75.0
44	92.0	4.0	44	91.3	0.0	8.7	100.0
45	88.0	8.0	45	86.4	0.0	13.6	100.0
46	96.0	0.0	46	95.8	0.0	4.2	100.0
47	88.0	8.0	47	86.4	0.0	13.6	100.0
48	92.0	4.0	48	91.3	0.0	8.7	100.0
49	88.0	8.0	49	86.4	0.0	13.6	100.0
50	92.0	4.0	50	91.3	0.0	8.7	100.0
51	88.0	8.0	51	86.4	0.0	13.6	100.0
52	96.0	0.0	52	95.8	0.0	4.2	100.0

Table 5. Initial and conditional probabilities at 20mm threshold limit of rainfall for Dhera.

Week	Pd	Pw	Week	Pdd	Pww	Pwd	Pdw
Initial probabilities (%)			Conditional probabilities (%)				
1	92.0	4.0	1	91.3	0.0	8.7	100.0
2	96.0	0.0	2	95.8	0.0	4.2	100.0
3	92.0	4.0	3	91.3	0.0	8.7	100.0
4	72.0	24.0	4	77.8	33.3	22.2	66.7
5	92.0	4.0	5	91.3	0.0	8.7	100.0
6	84.0	12.0	6	85.7	0.0	14.3	100.0
7	92.0	4.0	7	91.3	0.0	8.7	100.0
8	84.0	12.0	8	81.0	0.0	19.0	100.0
9	84.0	12.0	9	85.7	0.0	14.3	100.0
10	80.0	16.0	10	80.0	25.0	20.0	75.0
11	68.0	28.0	11	64.7	14.3	35.3	85.7
12	72.0	24.0	12	72.2	16.7	27.8	83.3
13	72.0	24.0	13	77.8	33.3	22.2	66.7
14	64.0	32.0	14	56.3	25.0	43.8	75.0
15	76.0	20.0	15	84.2	40.0	15.8	60.0
16	68.0	28.0	16	64.7	28.6	35.3	71.4
17	76.0	20.0	17	73.7	20.0	26.3	80.0
18	76.0	20.0	18	78.9	40.0	21.1	60.0
19	72.0	24.0	19	72.2	16.7	27.8	83.3
20	64.0	32.0	20	68.8	37.5	31.3	62.5
21	84.0	12.0	21	85.7	0.0	14.3	100.0
22	80.0	16.0	22	80.0	25.0	20.0	75.0
23	76.0	20.0	23	78.9	40.0	21.1	60.0
24	88.0	8.0	24	86.4	0.0	13.6	100.0
25	76.0	20.0	25	73.7	20.0	26.3	80.0
26	36.0	60.0	26	22.2	46.7	77.8	53.3
27	56.0	40.0	27	42.9	20.0	57.1	80.0
28	24.0	72.0	28	33.3	77.8	66.7	22.2
29	28.0	68.0	29	28.6	64.7	71.4	35.3
30	24.0	72.0	30	16.7	72.2	83.3	27.8
31	40.0	56.0	31	40.0	57.1	60.0	42.9
32	20.0	76.0	32	40.0	84.2	60.0	15.8
33	24.0	72.0	33	33.3	72.2	66.7	27.8
34	44.0	52.0	34	18.2	30.8	81.8	69.2
35	52.0	44.0	35	53.8	36.4	46.2	63.6
36	36.0	60.0	36	22.2	53.3	77.8	46.7
37	56.0	40.0	37	42.9	30.0	57.1	70.0
38	60.0	36.0	38	66.7	44.4	33.3	55.6
39	80.0	16.0	39	75.0	0.0	25.0	100.0
40	80.0	16.0	40	75.0	0.0	25.0	100.0
41	84.0	12.0	41	85.7	33.3	14.3	66.7
42	92.0	4.0	42	91.3	0.0	8.7	100.0
43	96.0	0.0	43	95.8	0.0	4.2	100.0
44	92.0	4.0	44	91.3	0.0	8.7	100.0
45	92.0	4.0	45	91.3	0.0	8.7	100.0
46	96.0	0.0	46	95.8	0.0	4.2	100.0
47	96.0	0.0	47	95.8	0.0	4.2	100.0
48	96.0	0.0	48	95.8	0.0	4.2	100.0
49	92.0	4.0	49	91.3	0.0	8.7	100.0
50	92.0	4.0	50	91.3	0.0	8.7	100.0
51	92.0	4.0	51	91.3	0.0	8.7	100.0
52	96.0	0.0	52	95.8	0.0	4.2	100.0

discusses only initial and conditional probability of dry and wet week during the main rainy season (26th to 40th week). Considering 20 mm threshold limit, the initial and conditional probability of dry weeks ranges from 20 to 80% and 16.7 to 75% respectively.

At the first week of the main rainy season, the chance of occurrence of dry week (Pd) and dry week preceded by dry week (Pdd) are 36 and 22.2% respectively, similarly at the end of the main rainy season, dry week (Pd) and dry week preceded by dry week (Pdd) has a chance of 80 and 75% occurrences respectively. During the main rainy season, the initial and conditional probability of wet weeks ranges from 16 to 76% and 0 to 84.2% respectively. At the first week of the main rainy season chance of occurrence of wet week (Pw) and wet week preceded by wet week (Pww) is 60 and 46.7% respectively, similarly at the end of the main rainy season, wet week (Pw) and wet week preceded by wet week (Pww) has a chance of 16 and 0% occurrences respectively.

The detailed characterization and statistical analysis of Dhera rainfall can be useful for agricultural planning and water management. According to Senthilvelan et al. (2012) and Reddy (1991), based on threshold limit of 10 mm per week at more than 50% for initial and conditional probability during the main rainy season is adequate for crop activities like land preparation and the conditional probability of occurrences of rainfall at 20 mm per week above 50% is the right week for planting.

At 10 mm per week threshold limit, the probability of occurrences of initial and conditional probability is 72 and 66.7% respectively for 26th week at the start of the main rainy season, therefore the land preparation could be undertaken in 26th week. At 20 mm per week threshold limit, the conditional probability of wet week (Pww) during the main rainy season is more than 50% with a value of 77.8% for 28th week; therefore 28th week is the right week for planting at the study site. On 28th week a mean rainfall amount of 40.2 mm was contributed and this amount of rainfall is good for germination and there will be no moisture stress during the germination period. At rainfall amount of more than 25 mm, there won't be moisture stress and it is good for germination period (Reddy et al., 2008). Since the planting is undertaken in 28th week and the total rainy season is 84 days counting from the planting weeks, short growing duration of wheat, lowland pulses and lowland barley need to be considered by the breeder when releasing new varieties.

At 20 mm threshold, the probability of dry week (Pd) being more than 50% is during 27th, 35th and 37th to 40th week and also the chance of dry week preceded by dry week (Pdd) is more than 50% during 35th and 38th to 40th week for the main rainy season, therefore during those dry weeks specifically at the end of the main rainy season, supplementary irrigation and moisture conservation practice need to be undertaken. The probability of a wet week (Pw) being more than 75% is during 32nd week and the probability of wet week preceded by wet week (Pww) being more than 75% is during 28th and 32nd week, in addition 28th, 32nd and 33rd week has weekly rainfall more than 35 mm. Therefore, during this week's harvesting of excess amount of runoff water for supplemental irrigation and soil erosion control measures need to be practiced.

CONCLUSION AND RECOMMENDATION

This study finds out the chance of weeks for appropriate crop planning and water management. A mean of 105 days of rainy season could occur with taking 26th week as onset and 40th week as withdrawal of the main rainy season at Dhera area. Land preparation for planting and planting could be undertaken between 26th and 28th weeks for the main rainy season crop cultivation. Supplementary irrigation and moisture conservation practice need to be practiced during 38th to 40th week for short duration crops and supplementary irrigation and moisture conservation practice could be extended if the crop is long duration crop. Harvesting runoff water and construction of soil erosion measures need to be practiced during 28th to 33rd weeks for better water management.

Conflict of Interests

The authors have not declared any conflict of interests.

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