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Dry and wet spell analysis for agricultural planning in Durg district of Chhattisgarh

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ABSTRACT

Daily rainfall data of 20 years (1991-2010) for Durg, Dhamdha and Patan blocks of Durg district in Chhattisgarh were analyzed for the purpose of agricultural planning. Study revealed that on an average, 138, 139 and 137 days were observed as dry days (rainless days) in Durg, Dhamdha and Patan blocks, respectively during entire monsoon season. Similarly, almost equal numbers of dry days were found in all the three blocks at individual growth stages of rice crop. During complete reproductive phase, including flowering stage, 22-23 dry days occurred at the three study blocks out of 28 days of this phase that fell during 37 to 40 standard meteorological weeks (SMWs). Probability analysis of continuous dry days based on Gamma distribution revealed that during flowering stage (37-38 SMW), an expected dry spell of 7 days at Durg, of 5 days at Dhamdha, and of 4 days may be experienced at 25% probability of exceedance that was considered for rice crop planning, indicating less proneness of drought condition at Patan in comparison to Durg and Dhamdha blocks. At reproductive phase, 3 to 4 days dry spell might occur at all the study blocks. Markov Chain modeling of dry spells indicated that during nursery and reproductive stages of rice crop, the initial and conditional probabilities of dry weeks were as high as 71-90% indicating severe shortage of rainfall and supplemental irrigation was a must for realizing good yields at all the blocks. During seedling and vegetative growth stages, probability of getting wet weeks was found higher and during that period excess rainwater needs to be harvested in on-farm water harvesting structures that could be recycled during flowering and reproductive stages. It was also suggested to plant rice crop in such a way that critical growth stages may coincide, as far as possible, to the period when probability of rainwater occurrence is higher.

1. INTRODUCTION

Amongst all natural resources, rainfall is regarded as the fundamental natural resource so far as progress of the society is concerned. Rather, it has been treated as a fundamental sector for the total development of the society. Due to larger dependence of Indian agriculture on amount and distribution of rainfall, the prior knowledge of rainfall distribution is important to assess the probabilities of dry and wet spells that are likely to occur on weekly basis during crop growth period. Erratic rainfall pattern such as delayed onset of monsoon, breaks in monsoon activity, prolonged dry spells during crop season and continuous flooding due to heavy rains affect the crop production (Subash *et al.*, 2012). Application of the knowledge of probable behavior of rainfall at the place in question can be of great help in effective crop planning, judicious and efficient use of rainwater, conservation of groundwater and increasing the agricultural productivity. Although many researchers have attempted studies on probable behavior of rainfall at different places (Chakravorty and Mandal, 2008; Chand *et al.*, 2011; Jakhar *et al.*, 2011; Jat *et al.*, 2010) but very little work has been done in the state of Chhattisgarh on rainfall analysis. Amongst other characteristics of rainfall, the occurrence of dry and wet spells at critical growth stages of crops, particularly rice crop is very important for crop and water resources planning and management. If the dry spells coincide with critical growth stages of the crops, it may prove detrimental to potential yields, whereas it is considered beneficial to most of the crops if occur during maturity stages. On the other hand, if wet spells coincide with the critical crop growth stages, it may benefit the crops in terms of increased yields and groundwater conservation

(Pali, 2006). Probability concept is usually used to demonstrate the importance of dry and wet spells for planning weather sensitive agricultural operations (Shrivastav *et al.*, 2004). Therefore, for effective crop and water resources planning, it is necessary to assess the sequences of dry and wet spells during different growth stages of a crop. The dry and wet spell study can be effectively utilized to adjust the phenophases of the crops in such a way that critical moisture requiring growth stages are likely to coincide with wet spells.

The present study pertains to Durg district of Chhattisgarh state. In Chhatisgarh, the average annual rainfall is about 1200 mm, which is quite ample to grow rice crop during *kharif* season. Though, the average annual rainfall appears to be ample, the in-season droughts, especially at reproductive phase of rice crop during mid September to mid October are recurring features in the state (Pali, 2006). Long dry spells during this stage usually result in reduced rice yields in rainfed farming. On the other hand, heavy rain spells often occur at starting period of rice crop, when rice seedlings are small and tender and suffer significant damage due to inundation and flooding by uprooting and rotting. It, therefore, becomes imperative to investigate the occurrence of dry and wet spells by analyzing long term historical records of rainfall in order to have the prior knowledge of probable occurrence of dry and wet spells to plan the crop accordingly.

In this study, dry and wet spells were determined by analyzing daily rainfall data in a sequence of dry and wet spells. The largest positive sequence in the period of interest was extracted for each year of rainfall of 20 years (1991-2010). The proportion of year with dry spell greater than a given length was worked out directly from daily rainfall data. If a long dry spell overlapped two periods of interest, it was contributed to both periods. The extracted dry spells were then fitted to Gamma distribution to determine the expected length of dry spells at different probability levels of occurrence (Kumar *et al.,* 2007). Besides this, probability analysis was also carried out by applying well known Morkov chain model as applied by many researchers, such as Rath *et al.* (1996); Singh and Bhandari (1998); Panigrahi and Panda (2002). Weekly rainfall data were used to establish drought frequency during the weeks considering less than 50 mm weekly rainfall as a dry week and equal to or more than 50 mm rainfall as a wet week.

2. MATERIALS AND METHODS

Details of the Study Area

Three blocks, namely Durg, Dhamdha and Patan of district Durg in Chhattisgarh were selected for the present study. These blocks represent Chhattisgarh Plains agro-climatic zone of the state as per NARP classification. The study area (district Durg) is geographically located between $81^0$10' to $81^0$36' E longitudes and $20^0$54' to $21^0$32' N latitude, at an altitude of 317 m above msl (Fig.1). The study blocks together have a total geographical area of about 2238 sq km. The whole study area falls in tropical zone of Indian subcontinent. Rainy season begins from middle of June and starts terminating by the end of September. Summer season is hot reaching a peak temperature of 45^0C in second fortnight of May. The month of December in winter usually experiences a minimum temperature of 7-8^0C. The RH is very low (19%) in summer and goes up to 80% during monsoon period. The winds blow with moderate speed of about 5-6 km h^{-1}. The mean monthly values of meteorological parameters are given in Table 1. The characteristic toposequence is *kanhar* (vertisols) found in the lowest land portion, *dorsa* (alfisols) situated just upstream of *kanhar* soils, *matasi* (inceptisols) found just upstream side of *dorsa* soils and *bhata* (entisols) encountered at the top of the toposequence. The largest cultivated area in Durg district is occupied by *matasi* soils. Rice is the main *kharif* crop that covers 80-90% of total cultivated area in monsoon season. Farmers of the area, generally grow long and medium duration photosensitive tall rice varieties, which flower by mid to late September and mature by mid to late November depending upon the duration of the rice varieties grown.

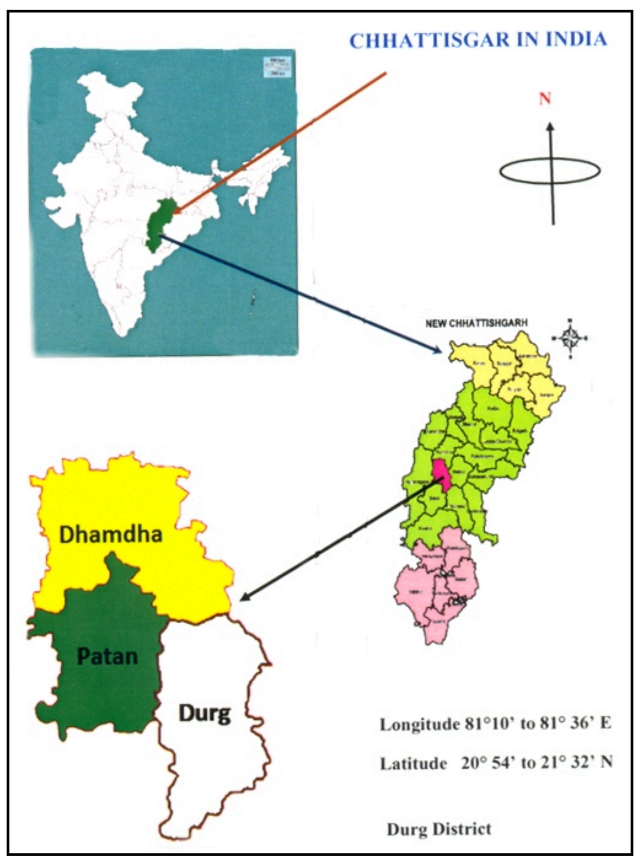

Fig. 1. Location map of the study area

Table: 1
Mean monthly value of meteorological parameters of the study area (1985-2008)

Month	Max. Temp. (^{0}C)	Min. Temp. (^{0}C)	RH (%)	Wind Speed (km h^{-1})	Sunshine (h)	Evaporation (mm)
Jan	28.33	17.28	38.33	2.77	8.31	2.82
Feb	30.49	19.74	32.77	3.57	8.92	7.07
Mar	36.24	24.61	24.18	4.54	9.17	5.92
Apr	39.55	28.56	18.60	6.35	9.18	8.89
May	43.25	32.82	20.58	8.41	8.71	10.98
Jun	36.95	29.83	46.55	10.86	4.64	7.81
Jul	32.22	27.60	74.54	10.43	2.81	3.80
Aug	30.97	27.11	79.70	8.87	2.97	3.06
Sep	31.00	26.41	71.37	5.47	5.41	3.34
Oct	31.95	25.01	56.94	3.30	8.31	3.41
Nov	29.41	19.69	39.32	2.62	8.26	2.82
Dec	28.46	17.09	35.96	2.34	5.22	2.58
Average	33.24	24.65	44.9	5.79	7.08	4.96

Average Number of Dry Days

The prior knowledge of average number of dry days based on long term rainfall records is helpful in the planning and protection of crops at different critical growth stages. The average number of dry days occurring in monsoon months *viz.*, June, July, August, September and October, during whole monsoon period *i.e.,* 23-43 Standard Meteorological Week (SMW) and at transplanting, reproductive and flowering stages were worked out as given in Table 1.

Probability Distribution of Dry Days

Apart from the rainless day, a day was designated as a dry day, if the rainfall of the day was less than 7.5 mm because at least 7.5 mm rainfall would be necessary to make the upper soil crust moist in transplanted rice areas. The two consecutive days on which rainfall occurred were considered dry only if the sum of the 2 days rainfall was less than 10 mm (Gupta, 1982). In the study, continuous dry days during different growth stages were extracted from daily rainfall data and Gamma distribution was applied to them to determine expected number of dry days at different probability levels. The probability density function for Gamma distribution is given as:

$$f(x, \alpha, \beta) = \frac{1}{\beta\sqrt{\alpha}} x^{\alpha-1} e^{x/\beta} \qquad ...(1)$$

Table: 2
Average number of dry days at the study area

Period	Average number of dry days		
	Durg block	Dhamdha block	Patan block
June (4-30 June)	19	20	19
July	19	16	17
August	17	18	17
September	23	23	22
October (1-21 Oct)	19	19	19
Transplanting (27-28 SMW)	9	8	9
Flowering (37-38 SMW)	22	23	23
Reproductive (37-40 SMW)	11	11	11
Monsoon (23-43 SMW)	138	139	137

Where, α and β are regression parameters of Gamma distribution and x is the variable for which distribution is required. The expected lengths of dry spells at the three study blocks of Durg district are given in Table 2.

Markov Chain Model for Dry and Wet Spells

For analyzing the weekly rainfall for dry and wet spells by Markov chain model, first a criterion of dry/wet week was decided. Dash and Senapati (1992) and Pandarinath (1991) used 30 mm or more rainfall in 10 days period for a wet spell and below 30 mm rainfall in 10 days for a dry spell. Dash and Senapati (1992) assumed 20 mm or more rainfall in a week as wet week and weekly rainfall below 20 mm as dry week. In the present study, however, the above criteria were not considered appropriate but a minimum of 50 mm or more weekly rainfall was taken as a wet week and below 50 mm as a dry week as suggested by Choudhary (1998) because for effective growth of rice crop, a minimum weekly rainfall amount of 50 mm is necessary. This is due to the fact that on daily basis, 3-4 mm of evapotranspiration loss takes place. In early crop stages, percolation losses are found to be high as compared to later stages. On the contrary, the ET requirement is less at early stages and increases in later stages. This amounts to 7 mm of water loss per day or approximately 50 mm of water loss per week. Thus, a week receiving equal to or more than 50 mm rainfall was assumed a wet week and a week receiving less than 50 mm rainfall was considered a dry week. Probability analysis of dry and wet weeks was also made using Markov chain process.

Markov chain model is applicable, when dependence exists between sequential events in a random process and the dependence is such that the next step depends only on the present state and not on the preceding past states. In general, a Markov process describes only step-by-step dependence, called a first order process. The probability relationships for a Markov process must provide for the conditional probabilities of the process moving from any state at period 't' to any subsequent state at period 't+1'. Two conditions must be defined to describe the Markov process completely. One is the initial state and the other is the complete matrix of transition state. The probabilities can be computed as follows:

Initial Probability

$$P(D) = F(D)/n \text{ and } P(W) = F(W)/n \quad ...(2)$$

Where, *P(D)* is the probability of occurrence of a dry week, *P(W)* is the probability of occurrence of a wet week, *F(D)* is the frequency of a dry sweek, *F(W)* is the frequency of a wet week and n is the number of years of records.

Conditional Probabilities

$$P(D/D)=\frac{F(D/D)}{F(D/D)+F(W/D)}=\frac{F(D/D)}{F(D)} \quad ...(3)$$

$$P(D/W)=\frac{F(W/W)}{F(W/W)+F(D/W}=\frac{F(W/W)}{F(W)} \quad ...(4)$$

$$P(D/W)=\frac{F(D/W)}{F(W)}=1-P(W/W) \quad ...(5)$$

$$P(W/D)=1-P(D/D) \quad ...(6)$$

Where, *P(D/D)* is the probability of occurrence of a dry week provided the preceding week was a dry week, *P(D/W)* is the probability of occurrence of a dry week provided the preceding week was a wet week, *P(W/W)* is the probability of occurrence of a wet week provided the preceding week was a wet week, and *P(W/D)* is the probability of occurrence of a wet week provided the preceding week was a dry week.

The first letter in the conditional probability indicates the present week and the second letter indicates the past week.

Probability of Consecutive Wet and Dry Weeks

Probability of wet run and dry run of two weeks and three weeks can be calculated as:

$$P(2W)=P(W)*P(W/W)_2 \quad ...(7)$$

$$P(2D)=P(D)*P(D/D)_2 \quad ...(8)$$

$$P(3W)=P(2W)*P(W/W)_3 = P(W)*P(W/W)_2*P(W/W)_3 \quad ...(9)$$

$$P(3D)=P(2D)*P(D/D)_3 = P(D)*P(D/D)_2*P(D/D)_3 \quad ...(10)$$

Where, $P(2W)$ is the probability of two consecutive wet weeks, $P(3W)$ is the probability of three consecutive wet weeks, $P(2D)$ is the probability of two consecutive dry weeks, $P(3D)$ is the probability of three consecutive dry weeks, $P(W)$ is the initial wet probability, $P(D)$ is the initial dry probability, $P(W/W)_2$ is the conditional wet probability of second week (next week), $P(W/W)_3$ is the conditional wet probability of third week (second next week), $P(D/D)_2$ is the conditional dry probability of second week (next week), and $P(D/D)_3$ is the conditional dry probability of third week (second next week)

In the study, the initial and conditional probabilities of dry and wet weeks along with probabilities of consecutive 2 dry and wet weeks for Durg, Dhamdha and Patan block, respectively are given in Table 4 to Table 6.

3. RESULTS AND DISCUSSION

Average Dry Days

The average numbers of dry days (rainless days) on the basis of 20 years (1991-2010) rainfall data were worked out (Table 2). During monsoon as a whole on an average, 138, 139 and 137 days are found to be rainless days for Durg, Dhamdha and Patan blocks, respectively indicating almost equal length of monsoon season at all the three places. The monsoon months *i.e.,* June-October also experienced almost equal dry days at all the places, but the distribution of the dry days could be different at different places. Similarly, no significant difference in average numbers of dry days has been observed at any place during individual growth stages of rice crop. On an average, 8-11 days are observed as dry days during transplanting and flowering stages. However, during complete reproductive stage, very high numbers of dry days (22-23 days) have been observed at all the places within 28 days (37-40 SMW) duration of reproductive stage. Reproductive phase is considered the most critical crop stage and any shortage of water at this stage may result in great reduction of yield. Thus, supplemental irrigation from any water source is a must at this stage at the three study places for obtaining optimum rice yields.

Probability Distribution of Dry and Wet Spells

The expected lengths of dry spells at different probability levels were determined using Gamma distribution for the study blocks (Table 3). It is evident that the flowering stage (37-38 SMW) is likely to experience a dry spell of 7 days at Durg block, 5 days at Dhamdh block and 4 days at Patan block at 25% probability level. Gupta (1982) suggested that to be on safer side, the 25% probability of exceedance of dry spell should be used for planning of crop and water resources. Dry spell exceeding 7 days during flowering or complete reproductive phase could be quite detrimental to rice productivity (Sahu, 1993 and Pal *et al.*, 1994). Thus, the flowering stage is just on 7 day's threshold at Durg block. This means, the flowering stage at Durg block, is more vulnerable to rainwater unavailability as compared to the other two blocks. These block also may suffer from dry spell of 4-5 days during flowering stage, but the crop may tolerate it. However, supplemental irrigation, if available, may boost up the rice yield.

Markov Chain Analysis

Durg block

Markov chain model returned the initial and conditional probabilities of wet and dry weeks at Durg block, which have been given in Table 3. Table 3 shows that

Table: 3
Expected continuous dry days at different probability levels at the study area

Prob	Durg block				Dhamdha block				Patan block			
	Trans	Flow	Repro	Mons	Trans	Flow	Repro	Mon	Trans	Flow	Repro	Mon
25%	3	7	4	19	4	5	4	17	3	4	3	19
40%	2	6	4	15	3	4	3	13	2	3	2	14
50%	2	5	3	13	3	4	3	11	2	3	2	12
60%	2	4	3	10	2	3	2	9	2	3	2	10
75%	1	3	2	7	2	3	2	7	1	2	2	7
80%	1	3	2	6	2	3	2	6	1	2	1	6

Prob- Probability; Trans- Transplanting; Flow- Flowering; Repro- Reproductive; Mon- Monsoon

Table: 4
Initial and conditional probabilities of dry and wet weeks during monsoon at Durg block

SMW	Initial probability (%)		Conditional probability (%)				Probability of consecutive 2 dry and wet weeks (%)	
	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)	P(2W)	P(2D)
23	0	100	0	100	95	5	0	95
24	40	60	50	50	67	33	20	40
25	40	60	50	50	67	33	20	40
26	35	65	28	72	69	31	10	45
27	55	45	45	55	33	67	25	15
28	35	65	40	60	46	54	0	30
29	65	35	69	31	57	43	45	20
30	50	50	50	50	50	50	25	25
31	50	50	40	60	30	70	20	15
32	55	45	54	46	56	44	30	25
33	60	40	58	42	37	63	35	15
34	75	25	67	33	0	100	50	0
35	55	45	63	37	56	44	35	25
36	35	65	14	86	54	46	5	35
37	15	85	33	67	82	18	5	70
38	25	75	20	80	73	27	5	55
39	10	90	0	100	83	17	0	75
40	20	80	0	100	69	31	0	55
41	10	90	0	100	83	17	0	75
42	10	90	0	100	83	17	0	75
43	10	90	0	100	83	17	0	75

Table: 5
Initial and conditional probabilities of dry and wet weeks during monsoon at Dhamdha block

SMW	Initial probability (%)		Conditional probability (%)				Probability of consecutive 2 dry and wet weeks (%)	
	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)	P(2W)	P(2D)
23	6	94	20	80	88	12	0	83
24	28	72	38	62	77	23	6	56
25	44	56	14	86	50	50	17	28
26	39	61	45	55	45	55	6	28
27	61	39	40	60	29	71	28	11
28	56	44	62	38	25	75	22	11
29	72	28	60	40	0	100	44	0
30	56	44	33	67	50	50	33	22
31	33	67	67	33	58	42	11	39
32	50	50	25	75	67	33	33	33
33	44	56	38	62	50	50	11	28
34	44	56	70	30	40	60	17	22
35	56	44	33	67	50	50	39	22
36	33	67	0	100	67	33	11	44
37	22	78	0	100	71	29	0	56
38	17	83	0	100	80	20	0	67
39	11	89	0	100	81	19	0	72
40	11	89	0	100	88	12	0	78
41	0	100	0	100	94	6	0	94
42	11	89	0	100	81	19	0	72
43	6	94	0	100	88	12	0	83

Table: 6
Initial and conditional probabilities of dry and wet weeks during monsoon at Patan block

SMW	Initial probability (%)		Conditional probability (%)				Probability of consecutive 2 dry and wet weeks (%)	
	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)	P(2W)	P(2D)
23	22	78	0	100	79	21	0	61
24	33	67	33	67	58	42	11	39
25	39	61	29	71	45	55	11	28
26	3	97	17	83	58	42	6	39
27	56	44	50	50	25	75	28	11
28	61	39	73	27	43	57	44	17
29	67	33	58	42	17	83	39	6
30	78	22	64	36	0	100	50	0
31	78	22	86	14	75	25	67	17
32	44	56	37	63	50	50	17	28
33	61	39	55	45	28	72	33	11
34	61	39	55	45	28	72	33	11
35	50	50	44	56	44	56	22	22
36	50	50	67	33	56	44	33	28
37	22	78	0	100	71	29	0	56
38	17	83	0	100	80	20	0	67
39	11	89	0	100	81	19	0	72
40	0	100	0	100	94	6	0	95
41	6	94	0	100	88	12	0	83
42	17	83	0	100	73	27	0	61
43	11	89	0	100	87	13	0	78

during the period from 29-35 SMW, the initial probabilities of getting wet weeks range from 50 to 75% and conditional probabilities during the same period ranges from 40 to 63%. Within the span of 29-35 SMW, it was observed that 29, 33 and 34 SMWs have the highest (>60%) initial probabilities, while conditional probabilities are higher in 29, 34 and 35 SMWs, ranging from 63 to 69%. This suggests that chances of getting good amounts of rainfall are higher during the period and the vegetative stage of rice crop may not suffer from water deficiency. Any excess water to ET requirement can be harvested in on-farm storages structures for later use during moisture stress period. The probability of getting 2 consecutive wet weeks is 45% in 29th SMW and 50% in 34th week. In other weeks, the chances of 2 consecutive wet weeks are from 0 to 35% only. Therefore, one can expect enough and continuous rainfall in 29th and 34th week, which could be harvested at farm level.

The first week (23 SMW) of the nursery stage is likely to be surely a dry week as the probability of being dry week is 100%. Therefore, supplemental irrigation is necessary to raise good and healthy nursery. 30th and 31st SMWs that fall in vegetative stage have 50% chance of being dry. Initial and conditional probabilities of getting dry spell during reproductive phase (37-40 SMW) are very high (Initial probability: 75-90%; Conditional probability: 69-83%). With regard to probability of being 2 consecutive dry weeks, it is seen that 23rd SMW has the probability as high as 95%. Similarly, 37th and 39th SMWs exhibit probability of 2 consecutive dry weeks as 70 and 75%, respectively indicative of no rains during this period.

Dhamdha block

It is found that during 27 to 30 SMW, the initial probabilities of being wet week ranges from 56-72%, indicating a good number of wet spells during vegetative growth period of rice crop. The surplus rainwater may be stored in water harvesting structures for later use during moisture requiring period. During reproductive stage (37-40 SMW), the initial probability of getting wet weeks is from 11 to 22% only. The conditional probability of wet weeks is 62% in 28th week and 60% in 29th week during which continuous rains may occur. In 31st and 34th SMWs also, the probability of wet week is high *i.e.* 67 and 70%, respectively. It means in Dhamdha block also, good amounts of rainfall may be received and thus, the excess rainwater can be harvested in storage structures. The probability of 2 consecutive weeks to be wet is below 44% throughout the rice crop season.

The 23rd to 26th SMW stage has an initial probability of dry week as high as 56 to 94%, indicating water stress during nursery period at Dhamdha block also and supplemental irrigation will be required. During vegetative growth period (31-34 SMW) also, the initial probabilities of dry weeks is high (50-67%). This indicates that during vegetative growth period also, a little supplemental irrigation might be needed. Conditional probabilities of dry weeks are also higher during the same period. During 23-24 SMW at nursery stage and during 37-40 SMW at reproductive stage, the probabilities of getting 2 consecutive dry weeks are higher (Nursery: 56-83%; Reproductive phase: 56-78%).

Patan block

Almost similar situation is observed at Patan block also during nursery and reproductive stages. From 23rd to 25th SMW, the probability of getting wet week is below 40%. In other words, the probability of getting dry weeks is above 60% and may reach to 97% in 26th SMW. From 27th-34th SMW except 32 SMW, the probability of wet weeks is higher (56-78%) and good rain-spells are expected during this period, indicating good possibility of rainwater harvesting. During reproductive phase, continuous dry spells with 78 to 100% probabilities are expected at Patan block, indicating the need for supplemental irrigation from stored rainwater. Probability of getting 2 consecutive wet weeks is from 50 to 67% during 30th-31st SMW during vegetative stage. At reproductive phase, higher probabilities (56-95%) of 2 consecutive dry weeks occur from 37th to 40th SMW.

4. CONCLUSIONS

The concept of estimating probabilities of wet and dry spells with respect to the given amount and time of occurrence of rainfall is extremely useful for effective crop and water resources planning in rainfed agriculture. The study revealed that though the average rainfall of Durg district (three study blocks) appears to be sufficient for meeting evapotranspiration (ET) demands of rice crop, the probable distribution during the crop period at different growth stages is not uniform. Moderate to severe drought conditions are most likely to occur in Durg district during complete reproductive phase of the rice crop. Being the most critical growth stage, long dry spell might cause large reduction in rice yields under rainfed condition, if supplemental irrigation is not provided at this stage. Similarly, there are higher chances of getting dry spells during nursery stage. For raising good and healthy rice nursery at the three study blocks, supplemental irrigation is an essential input. Wet spells are likely to occur at the study blocks during seedling and vegetative stage of the rice crop. Hence, the excess rainwater needs to be harvested for recycling during water stress period. The situation, thus, calls for creation of some kinds of water harvesting structures at farm level for obtaining good rice yields under rainfed agriculture.

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