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Analysis of dry and wet weeks of rainfall by using Markov Chain - A case study at Jorhat (Assam), India

RUBUL BORA, ABHIJIT BHUYAN* and BIJU KUMAR DUTTA

Department of Mathematics, The Assam Kaziranga University, Jorhat, Assam – 785 006, India

*Department of Commerce, C.K.B. College, Teok, Jorhat, Assam – 785 112, India

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e mail : rubulboracnbc@gmail.com

सार – सफल कृषि योजना और जल संरक्षण तकनीकों के लिए साप्ताहिक शुष्क और नम दौर की वर्षा विश्लेषण का ज्ञान होना महत्वपूर्ण है। जोरहाट स्टेशन से 1996-2018 की अवधि के दौरान वर्षा के आंकड़ों का विश्लेषण किया गया है और प्रत्येक 52 मानक मौसम विज्ञान सप्ताह (एसएमडब्ल्यू) के लिए औसत, अधिकतम, न्यूनतम, मानक विचलन और भिन्नता के गुणांक की गणना की गई। मार्कोव चेन संभाव्यता मॉडल को लागू करके शुष्क और आर्द्र सप्ताह की प्रारंभिक और सशर्त संभावनाओं की जांच की गई। यह देखा गया कि पहले 12 मानक मौसम विज्ञान सप्ताह (एसएमडब्ल्यू) के दौरान, दो और तीन लगातार शुष्क सप्ताह की संभावना क्रमशः 40 से 100% और 15 से 96% तक थी, जबकि दो और तीन लगातार आर्द्र सप्ताह की संभावना क्रमशः 0 से 20% और 0 से 16% तक थी। 20वां मानक मौसम विज्ञान सप्ताह (एसएमडब्ल्यू) (14 से 20 मई) वर्षा ऋतु आगमन का सबसे अग्रिम और 23वां मानक मौसम विज्ञान सप्ताह (एसएमडब्ल्यू) (4 से 10 जून) सबसे विलंबित सप्ताह है। साथ ही, 40वां मानक मौसम विज्ञान सप्ताह (एसएमडब्ल्यू) (1 से 7 अक्टूबर) सबसे अग्रिम और 47वां मानक मौसम विज्ञान सप्ताह (एसएमडब्ल्यू) (19 से 25 नवंबर) दक्षिण-पश्चिम मानसून की वापसी का सबसे विलंबित सप्ताह है। वर्षा ऋतु की अवधि 161 दिन (21 मई से 28 अक्टूबर) की होती है। 41वें से 43वें मानक मौसम विज्ञान सप्ताह (एसएमडब्ल्यू) में सूखा पडने की 50 प्रतिशत संभावना थी। स्टेशन की मासिक प्रभावी वर्षा (ईआर) की गणना की गई और पाया गया कि कुल वार्षिक प्रभावी वर्षा (ईआर) इस क्षेत्र की औसत वार्षिक वर्षा का केवल 47% है।

ABSTRACT. Knowledge of the weekly dry and wet spell rainfall analysis is an important aspect for successful agricultural planning as well as water conservation techniques. The rainfall data during the period 1996-2018 from Jorhat station has been analyzed and the average, maximum, minimum, standard deviation and co-efficient of variation for each 52 Standard Meteorological Weeks (SMWs) were calculated. The initial and conditional probabilities of dry and wet weeks were investigated by employing Markov Chain probability model. It was observed that, during the first 12 SMWs, the chance of two and three consecutive dry weeks was ranged from 40 to 100% and from 15 to 96%, respectively, while the chance of two and three consecutive wet weeks was ranged from 0 to 20% and 0 to 16%, respectively. The 20th SMW (14th to 20th May) is the earliest and the 23rd SMW (4th to 10th June) is the most delayed week of the onset of rainy season. Also, the 40th SMW (1st to 7th Oct) is the earliest and the 47th SMW (19th to 25th Nov) is the latest of withdrawal of southwest monsoon. The length of the rainy season is 161 days (21st May to 28th Oct). The 41st to 43rd SMWs were vulnerable to 50% probability for dryness. The monthly effective rainfall (ER) of the station was calculated and it was observed that, the total annual ER accounts only 47% of the average annual rainfall of this region.

Key words – Markov Chain, Dry Weeks, Wet Weeks, Effective rainfall, Onset and withdrawal.

1. Introduction

Rainfall is a peculiar phenomenon that varies in both space and time. Rainfall is a crucial and dominating component in development and implementation of any agricultural program. Moreover, the lake of adequate and proper water supply is the most important reason for low rice production in the entire country (Panigrahi Panda, 2002). The rainfed food production system would be under stress as a result of changing rainfall patterns and a lack of adequate land and water resource utilization (Khan and Hanjra, 2009). Crop planning for a region is primarily

influenced by a number of factors, including irrigation process, drainage, irrigation system quality, soil characteristics, topography and socioeconomic conditions. However, rainfall magnitude and distribution in space and time are the most important factors in rainfed crop production (Shetty *et al*., 2000).

It is important to organize agriculture on a scientific (technical) basis in order to make the best use of a region's rainfall pattern to keep crop production stable at a certain level. This entails analyzing the series of dry and wet spells in order to take the necessary steps to prepare a crop plan in rainfed areas. Scientific forecasting of a wet and dry spell analysis is beneficial to improving farmer's fields and cropping strength, thus improving their economic condition.

The Markov chain theory can be used to understand the time interval of wet and dry weeks and precipitation variability (Victor and Sastry, 1979). Stern (1982), employed the Markov model to investigate the rainfall pattern for a short term as day, week and showed its unique character. The dry spell studies, which are based on an area, will aid in the planning of a drought contingency plan. Another feature is the accumulation of rainfall in the forward and backward directions, which determines when the monsoon begin and ends. Pre-monsoon showers assist in land preparation and *Kharif* crop planting. The monsoon's late arrival delays crop planting, resulting in low yields (Mandal *et al*., 2014). Similarly, the early end of rains has an adverse impact on production due to several moisture stresses, especially when *kharif* crops are in critical stages of grain formation and growth (Dixit *et al*., 2005). Dabral *et al*. (2014) employed the Markov chain model for studying dry and wet spells in North Lakhimpur of Assam and found that irrigation supplementations is required for improved crop production. Annual and seasonal rainfall analysis will provide a general picture of the region's rainfall pattern; however, weekly rainfall analysis would be extremely useful for agricultural planning (Mandal *et al*., 2013). The evaluation of rainfall pattern on monthly basis is helpful and essential for the purpose of crop planning. Nonetheless, this evaluation do not provide any evidence of the danger involved in farming practice because there is high variation in rainfall over years. The information about such danger is brought to light by initial and conditional probability analysis based on weekly rainfall (Vaidya *et al*., 2008). In order to stabilize crop production at a specific level, it is important to design an agriculture system on a scientific basis that makes the best use of a region's rainfall frequency analysis (Shetty *et al*., 2000) This entails determining the order of a region's dry and wet spells in order to take the necessary steps to prepare a crop plan in rainfed areas (Srinivasaredy *et al*., 2008).

Farmers can be benefited from forecasting the dry and wet spells rainfall frequency analysis during SMW season for advanced crop planning models in future (Halder *et al*., 2016). Mandal *et al*. (2013) studied the rainfall pattern and soil characteristic of Kuanria Canal irrigation systems by using the Markov chain probability model and found that agricultural operations can be planned in advance, and corrective and contingency actions can be performed during dry periods to avoid crop loss or yield reduction owing to soil moisture stress. Alam *et al*. (2015) studied the rainfall patterns by using different probability distributions for 21 SMW at Shivalik region for rainfed crop planning and noticed that the 40 percent probability level of minimum promised weekly rainfall was determined to be more indicative of long-term average rainfall data. Previously, this model was considered to study the frequency of rainfall pattern for dry and wet spells in Greece (Tolika and Maheras, 2005). Several researchers used this model to understand the possibility of rainfall pattern in dry and wet weeks Pandarinath, 1991; Barron *et al*., 2003; Deni *et al*., 2010; Punitha *et al*., 2017.

Rainfed agriculture's productivity was strongly influenced by the onset and withdrawal of the monsoon. Advanced understanding of this aids help in determining cropping patterns and selecting acceptable crop types and planning complete rainwater management systems to increase crop productivity per unit of water availability (Das *et al*., 1998).

The major objective of this research is to find out continuous rainfall patterns together with consecutive dry and wet weeks, finding actual time of the onset and withdrawal of monsoon during the year. Also, the estimation of the Effective rainfall (ER), which is a portion of net rainfall that enters the root zone and remains there for utilization by crop. The study of ER is essential to understand optimal cropping design, developing the irrigations system for dry situations, real-time estimation will help the farmers to maintain their cultivation in the right direction.

2. Material and methods

2.1. *Study area*

This study was conducted at Jorhat district, Assam state, India. This district is situated between the Brahmaputra river on the north and Nagaland state on the south, Charaideo and Golaghat districts of Assam on the east and west, respectively. It is located 26° N to 94° E and 116 m above sea level. The geological area of Jorhat district is 2,859 sq km which is 3.63% of the total area of Assam. In this examination, we took daily precipitation

data recorded at Jorhat City from Indian Meteorological Department (IMD). Further, the daily data has been converted into weekly datasets.

The predominant crops of Jorhat district are rice, vegetables, fruits and tea. The monthly precipitation recurrence investigation is vital for crop planning. But it isn't a complete practice in some cases as precipitation is variable from one year to another, month to month. Thus, initial and conditional frequency investigation of weekly rainfall is a vital for planning better crop development. We made an attempt to discuss the variability of rainfall in this paper, which is crucial for tea plantations in Jorhat. The small scale tea planters need a proper rainfall calendar for taking better crop management strategies.

2.2. *Markov chain probability model for dry and wet week analysis*

Weekly rainfall were extracted from daily rainfall data and used in a Markov chain probability model to analyze original, conditional, and consecutive dry and wet spells. In this process, weeks receiving 20 mm or more of rainfall are considered as wet and the remaining weeks as dry. Different formulae followed in this analysis are given below.

2.2.1. *Initial probability*

$$P(d) = F(d)/N \tag{1}$$

$$P(w) = F(w)/N \tag{2}$$

where, $P(d)$, $F(d)$, $P(w)$, $F(w)$ and N stands for dry weeks probability, indicates dry week frequency, indicates wet weeks probability, indicates wet weeks frequency, and indicates total number of years respectively.

2.2.2. *Conditional probability*

$$P(dd) = F(dd)/F(d) \tag{3}$$

$$P(ww) = F(ww)/F(w) \tag{4}$$

$$P(wd) = 1 - P(dd) \tag{5}$$

$$P(dw) = 1 - P(ww) \tag{6}$$

where, $P(dd)$ represents the probability for a dry week such that the previous dry week precede by dry week, $P(ww)$ represents the probability for wet week preceded by wet week, $F(ww)$ represents the Frequency of wet week preceded by wet week, $P(wd)$ represents the probability for wet week preceded by a dry week, $P(dw)$ represents the probability for dry week preceded by wet week.

2.2.3. *Consecutive dry and wet week probabilities*

$$P(2d) = P(dW^1) \times P(ddW^2) \tag{7}$$

$$P(3d) = P(dW^1) \times P(ddW^2) \times P(ddW^3) \tag{8}$$

$$P(2w) = P(wW^1) \times P(wwW^2) \tag{9}$$

$$P(3w) = P(wW^1) \times P(wwW^2) \times P(wwW^3) \tag{10}$$

where, $P(2d)$ represents the probability of two consecutive dry weeks, $P(dW^1)$ represents probability 1st dry week, $P(ddW^2)$ represents the probability of the 2nd dry week preceded by dry week, $P(3d)$ represents probability three consecutive dry weeks, $P(2w)$ represents the probability of two consecutive dry weeks, $P(wW^1)$ indicates the probability of 1st wet week, $P(wwW^2)$ represents the probability of 2nd wet week preceded by wet week, $P(3w)$ represents three consecutive wet weeks, and $P(wwW^3)$ represents the probability of 3rd wet week preceded by wet week.

2.3. *Computation for onset and withdrawal of the rainy season*

Weekly rainfall data is used to determine the rainy season's onset and withdrawal using a forward and backward accumulation procedure. In this process, 75 mm of rainfall is considered as the onset for rainfed crops (Panigrahi and Panda, 2002) by forward accumulation (20+21+⋯ +52 Weeks) of rainfall. The backward accumulation of 20 mm rainfall (48+47+⋯+30 weeks) is considered for withdrawal time. After crop harvesting, this timing is appropriate for plowing fields (Babu and Lakshminarayana, 1997). Weibull's method was used to calculate the odds of the principal rainy season's arrival and withdrawal. By rearranging the ranks in increasing order and picking the highest rank allotted for a given week, the percentage of probability of each rank was computed. The following formula (11) was used to calculate the percentage possibility of onset and withdrawal using Weibull's formula and it has been used in earlier studies [Mandal *et al.* (2013); Admasu *et al.* (2014)],

$$P = \frac{m}{N+1} \times 100 \tag{11}$$

where, m and N are rank number and number of years, respectively.

The formulas from (1) to (10) were used to determine initial and conditional probabilities based on the weekly rainfall. The possibilities of a week for either dry or wet were determined by initial probability. The Markov
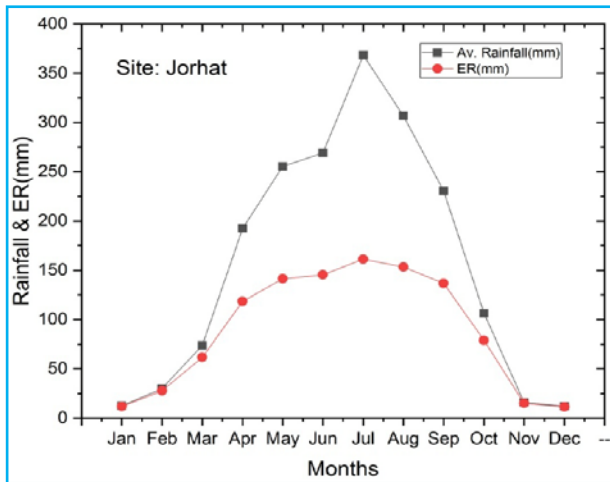
Fig. 1. Average monthly rainfall and effective rainfall (ER) for the study area, Jorhat

chain approach is used to analyze rainfall using these initial and conditional probabilities. An important interest of agricultural planning is the evaluation of rainfall on a weekly basis and week period has been deemed as the best length of time (Reddy *et al.*, 2008).

2.4. *Method for calculating monthly effective rainfall*

Effective Rainfall (ER) is a portion of net rainfall that enters the root zone and remains there for utilization by crop. A majority of rainfall received during monsoon is lost occurring to evaporation, deep percolation, and surface runoff. If the rainfall is of high magnitude, only a small portion of rainfall undergoes and is reserved in the root zone. Monthly effective rainfall (ER) was calculated by using USDA Soil Conversation Service (USDA-SCS) method in India as this approach is mostly used to calculate monthly effective rainfall. Sharma *et al.* (2010) used this method for finding ER of rainfed district in India. For finding out ER more accurately USDA-SCS method can be used (Dastane, 1975).

$$P_c = \frac{P_t(125 - 0.2P_t)}{125} \text{ for } P_t < 250\text{mm} \qquad (12)$$

$$P_c = 125 + 0.1P_t \text{ for } P_t \geq 250\text{mm} \qquad (13)$$

Where, P_c and P_t represent monthly ER and total monthly rainfall in mm. All India Coordinated Research Project on water management (AICRP, 2009) used this method for finding ER at different rainfed districts. Mandal *et al.* (2014) took this method for calculating ER in their research work at Daspalla region in Odisha.

3. Data analysis

3.1. *Annual and effective rainfall (ER) at Jorhat*

The Annual rainfall at Jorhat was ranged from 1225 to 2484 mm during the period 1996-2019. The average annual rainfall is 1873 mm and the coefficient of variation is 16%. The years with rainfall greater than or equal to the sum of average and standard deviation are considered as surplus years (Sharma and Kumar, 2003). It was observed that the years 1997, 2010 and 2017 were found as surplus years based on this criteria. Only 13% of the total rainfall years studied received more than 2164 mm of rain while the remaining 87% of the overall years experienced less. These 87% of years are referred to as deficit years. Fig. 1 displays the average monthly and effective rainfall at Jorhat. The average rainfall in July was 368 mm, the highest of the year, and contributes 20% to the annual rainfall and the lowest in December (0.64% of annual rainfall). The annual effective rainfall (ER) is found 883 mm, (47% annual rainfall).

3.2. *Results and discussion*

3.2.1. *SWM rainfall*

Table 1 displays mean, maximum, minimum, standard deviation, and coefficient of variation (CV) for weekly rainfall at Jorhat during SMW season. The highest rainfall was observed during 32nd week (310 mm), followed by 27th week (297 mm). The lowest was observed during 23rd week (0.8 mm), followed by 1mm in the 36th week. The rainy season spans between 21st to 43rd week. During the rainy season, there are 21 weeks (21st to 41st) with the average rainfall of more than 20 mm and two weeks (42nd and 43rd) with rainfall of less than 20 mm. During the weeks, the CV varies from 40% during 30th week to 147% during 42nd week. As we know, the CV of weekly rainfall should not exceed 150% (Senthilvelan *et al.*, 2012) which is valid in our study region.

3.2.2. *Initial and conditional probability*

In Table 2, the initial and conditional probability for the threshold of 20 mm rainfall during all 52 SMW are calculated. The rainy season, which ranges from 21st to 43rd week, is the focus of this article. There is a probability of 0 to 70% of occurring dry weeks and conditional probability of 0 to 69%. The chance for dry week P (d) and dry week followed dry week P (dd) during the first week of rainy season is 17% and 25%, respectively. Again, P (d) and P (dd) towards the ending of rainy season have a probability of 70% and 69%, respectively. In the case of wet weeks P (w) and P (ww) during the rainy season, the probabilities range between 30 to 100%

TABLE 1

SMW wise Average, Maximum, Minimum, Std. Deviation and Co-variance of Jorhat for the period 1996-2018

SMW	Ave.	Max.	Min.	Std. Dev.	Co.-Var.	SMW	Ave.	Max.	Min.	Std. Dev.	Co.-Var.
21	54.03	120.80	3.6	33.19	61.43	33	63.07	140.30	10.6	33.96	53.84
22	74.95	264.10	13.2	56.05	74.79	34	67.19	156.00	1.5	42.06	62.60
23	53.38	124.80	0.8	32.89	61.61	35	62.58	127.90	12.7	38.19	61.02
24	53.73	206.30	1.5	42.02	78.20	36	58.90	164.10	1	45.50	77.24
25	59.83	195.90	9.7	41.37	69.14	37	55.13	175.80	0	45.20	81.98
26	90.34	220.60	21.4	51.77	57.31	38	46.45	126.60	0	35.84	77.15
27	78.40	296.70	2.8	61.31	78.20	39	48.20	124.70	9.3	32.09	66.59
28	95.63	219.90	37.5	57.72	60.36	40	36.04	102.00	0	36.62	101.60
29	72.33	242.40	3.5	51.42	71.09	41	29.60	142.60	0	35.50	119.92
30	83.72	149.40	15.3	33.15	39.60	42	17.79	108.60	0	26.23	147.43
31	69.09	135.60	12.7	36.88	53.38	43	14.76	57.00	0	17.93	121.48
32	84.81	309.60	4.7	68.18	80.39						

TABLE 2

SMW wise Initial probabilities of Jorhat for dry and wet weeks of Jorhat

SMW	Percentage of Initial Porb.		Percentage of Conditional Prob.				SMW	Percentage of Initial Porb.		Percentage of Conditional Prob.			
	P (d)	P (w)	P (dd)	P (d)	P (w)	P (dd)		P (ww)	P (dw)	P (dd)	P (d)	P (w)	P (dd)
21	17.4	82.6	25.0	75.0	84.2	15.8	33	4.3	95.7	0.0	100.0	86.4	13.6
22	8.7	91.3	50.0	50.0	85.7	14.3	34	17.4	82.6	0.0	100.0	94.7	5.3
23	13.0	87.0	0.0	100.0	90.0	10.0	35	13.0	87.0	0.0	100.0	80.0	20.0
24	13.0	87.0	33.3	66.7	90.0	10.0	36	30.4	69.6	14.3	85.7	87.5	12.5
25	17.4	82.6	25.0	75.0	89.5	10.5	37	26.1	73.9	50.0	50.0	76.5	23.5
26	0.0	100.0	0.0	100.0	82.6	17.4	38	21.7	78.3	40.0	60.0	77.8	22.2
27	13.0	87.0	0.0	100.0	100.0	0.0	39	17.4	82.6	0.0	100.0	73.7	26.3
28	0.0	100.0	0.0	100.0	87.0	13.0	40	47.8	52.2	9.1	90.9	75.0	25.0
29	4.3	95.7	0.0	100.0	100.0	0.0	41	52.2	47.8	58.3	41.7	63.6	36.4
30	8.7	91.3	0.0	100.0	95.2	4.8	42	65.2	34.8	40.0	60.0	25.0	75.0
31	13.0	87.0	33.3	66.7	95.0	5.0	43	69.6	30.4	68.8	31.3	42.9	57.1
32	13.0	87.0	0.0	100.0	85.0	15.0							

and 25 to 100% respectively. In the first week of main rainy season, the chance of P (w) and P (ww) are 83% and 84%, respectively, and during the end of the season it is, 30% and 43% respectively.

During the rainy season, the probability for dry week is greater than 50% during 41st to 43rd SMWs, as well as the probability for dry week followed by another dry week during 41st to 43rd SMWs. So, extra irrigation and moisture preservation practices should be implemented during those weeks. However, during 21st to 35th weeks

and the 38th, 39th SMW, the probability for wet week is greater than 75%. The probability for rainy week followed by another wet week P (ww) is greater than 75% during 21st to 38th SMWs.

3.2.3. *Analysis of successive dry and rainy weeks*

The analyses of consecutive dry and wet weeks are furnished in Table 3. During the first 12 SMWs of the year, there was a 40 to 100% chance for P (2d). Similarly, the probability for P (3d) ranged from 15 to 96%. So,

TABLE 3

SMW wise Probabilities of Jorhat for Consecutive dry and wet weeks of Jorhat

SMW	Prob. of Consecutive dry week in percentage		Prob. of Consecutive wet week in percentage		SMW	Prob. of Consecutive dry week in percentage		Prob. of Consecutive wet week in percentage	
	P (2d)	P (3d)	P (2w)	P (2d)		P (2d)	P (3d)	P (2w)	P (2d)
1	100.0	95.7	0.0	0.0	23	4.3	1.1	78.3	70.0
2	91.5	91.5	0.0	0.0	24	3.3	0.0	77.8	64.3
3	100.0	91.3	0.0	0.0	25	0.0	0.0	68.2	68.2
4	83.4	83.4	0.0	0.0	26	0.0	0.0	100.0	87.0
5	100.0	94.4	0.0	0.0	27	0.0	0.0	75.6	75.6
6	86.2	68.1	1.7	0.4	28	0.0	0.0	100.0	95.2
7	61.8	49.4	5.4	0.0	29	0.0	0.0	91.1	86.5
8	66.1	57.1	0.0	0.0	30	2.9	0.0	86.7	73.7
9	75.1	71.3	0.0	0.0	31	0.0	0.0	73.9	63.8
10	90.9	76.9	0.0	0.0	32	0.0	0.0	75.1	71.1
11	73.6	52.6	1.3	0.7	33	0.0	0.0	90.6	72.5
12	40.4	15.1	21.7	15.9	34	0.0	0.0	66.1	57.8
13	11.4	4.8	51.0	37.1	35	1.9	0.9	76.1	58.2
14	14.5	10.9	47.4	25.0	36	15.2	6.1	53.2	41.4
15	39.1	4.9	25.2	20.1	37	10.4	0.0	57.5	42.4
16	2.2	0.9	66.1	44.1	38	0.0	0.0	57.7	43.2
17	13.9	3.5	43.5	34.3	39	1.6	0.9	62.0	39.4
18	5.4	1.4	61.8	52.0	40	27.9	11.2	33.2	8.3
19	4.3	1.1	69.6	58.6	41	20.9	14.3	12.0	5.1
20	4.3	2.2	69.6	59.6	42	44.8	32.0	14.9	7.5
21	8.7	0.0	70.8	63.7	43	49.7	45.4	15.2	0.0
22	0.0	0.0	82.2	74.0	44				

additional irrigation is essential during this period. The comparable values of $P (2w)$ and $P (3w)$, the consecutive 2 and 3 wet weeks were 0 to 22% and 0 to 16%, respectively, which is quite low. The chances of $P (2d)$ and $P (3d)$ are from 0 to 50% and from 0 to 45%, respectively rainy season (21st to 43rd SMWs). The probabilities for $P (2w)$ and $P (3w)$ were 12 to 100% and 0 to 95%, respectively during the end of the season.

In the case of rainfed rice during summer rainy season, the analysis of consecutive wet weeks and

consecutive dry weeks revealed that supplementary irrigation was required to keep adequate soil moisture during critical growth stages.

3.2.4. *Analysis of onset and withdrawal of rainy seasons*

In Table 4, we observed that the rainy period of our study region spans from 21st May to 28th October (from 21st week to 43rd SMWs). The length of this period is 23 weeks (161 days). The early and later onset of main rainy

TABLE 4

SMW wise rainy seasons of Jorhat

Particulars	Week No. & Date
Mean week of onset of rainy season	21 (21st May-27th May)
Earliest week of onset of rainy season	20 (14th May-20th May)
Delayed week of onset of rainy season	23 (4th Jun -10th Jun)
Mean week of withdrawal of rainy season	43 (22nd Oct- 28th Oct)
Earliest week of withdrawal of rainy season	40 (1st Oct-7th Oct)
Delayed week of withdrawal of rainy season	47 (19th Nov-25th Nov)

TABLE 5

Probability of onset and withdrawal week of rainy seasons of Jorhat

Onset SMW	20	21	22	23				
Probability (%)	16.67	66.67	91.67	95.83				
Withdrawal SMW	40	41	42	43	44	45	46	47
Probability (%)	4.17	20.83	33.33	54.17	66.67	70.83	83.33	95.83

season, 20th SMW (from 21st to 27th May) and 23rd SMW (from 4th to 10th June), respectively. On the other hand, 40th SMW (from 1st to 7th October) is the earliest and 47th week (from 19th to 25th November) is the latest withdrawal of the rainy season.

This indicates that, the period from 20th to 22nd weeks is the optimum time to start wetland rice field preparation for short duration varieties, because they may attain maturity before end of the season. Hence, there is little risk of rice yield reduction owing to water stress. When monsoon occurs early, then farmers can take initiative to store the untimely rainwater in the reservoirs and later use them as supplemental irrigation during the critical growth stages of the summer crop season to balance proper soil moisture and also be used as stagnant water for rainfed rice. Also, due to the continuous soil moisture after the monsoon period of 161 days, another short-term winter crop could be started after harvesting the rice.

The probability of onset and removable of the major rainy season is depicted in Table 5 by using Weibull's formula of Equation No. (11). It has a 96% risk of occurring during 23rd and 47th weeks, respectively.

4. Conclusion

The analysis of rainfall data of Jorhat during the period 1996-2018 has been carried out by using the Markov chain model. The major rainy season, which was observed from 21st to 43rd SMW together with dry and wet spells probabilities, could be helpful for programming the crop pattern and timing the water requirement period of the crops. The length of the rainy season is 161 days (from 21st May and 28th October) which was onset and withdrawal. It was observed that 883 mm rainfall was the annual effective rainfall (ER) which was 47% of average annual rainfall. The rainfall in July is slightly higher than that of August by 62 mm. The possibilities of two and three consecutive dry weeks are 0 to 50% and 0 to 45%, respectively during the end of rainy season. During 21st to 35th weeks and 38th to 39th weeks, the chance of wet week is greater than 75%. Also, from 21st to 38th SMW, the chance of P (ww) is greater than 75%. So, in this period extra water supply is not required and excess water can be preserved for the remaining period of the season.

Results obtained clearly reflect the usefulness of this study for the peasant class of the area by giving them ample knowledge of water management planning.

The study clearly suggests the practice of a rainwater storage reservoir among the farming fraternity. It will help them in storing the rainwater in the reservoir and utilizing them as supplementary irrigation to the crops of post-monsoon. The farmers can also select crops for the post-monsoon and winter season based on the stored water availability in the reservoir.

Disclaimer : The contents and views expressed in this research paper/article are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

Data Report

Rainfall data for the research site Jorhat was collected on May 14, 2019 from IMD, Guwahati, Assam, for a period of 23 years (01-01-1996 to 31-12-2018).

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