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Research Article

Analysis of Consecutive Days Maximum Rainfall Together With Dry, Wet Spell Rainfall for Crop Planning at Jorhat (Assam), India

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Abstract. In this study, frequency analyses of 1 to 6 consecutive days maximum rainfalls have been carried out. For this purpose, the daily rainfall data for 23 years has been collected from the *Indian Meteorological Department* (IMD), Guwahati for Jorhat Station. Based on L-moment, we consider the probability distributions like *Log Normal* (LN), Pearson Type III (P III), Log-Pearson Type III (LP III), and Extreme Value Type I (EVI). The best-fitting probability distribution for consecutive days maximum rainfall is discussed for estimating the rainfall in different return periods such as 2 to 100 years. Also, the daily rainfall data are converted to 52 *standard meteorological weeks* (SMW) to use the Markov Chain Probability model. Then average, maximum, minimum, standard deviation, and covariance of rainfall are calculated. By using this model, initial and conditional probabilities of dry and wet weeks are calculated. The probability of onset and withdrawal rainy season are calculated which are 95.83% chance during 23rd and 47th weeks. And, we find a relation of average rainfall and *effective rainfall* (ER) of the station.

Keywords. Markov chain; Probability; Distribution; Probabilistic model; Onset; Withdrawal

Mathematics Subject Classification (2020). 60J22; 60E05; 65C20

1. Introduction

Rainfall is a rare phenomenon that varies in both time and space. Rainfall distribution is very uneven, and it does not only vary greatly from place to place but also varies year to

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year. Rainfall is a critical and governing factor in the planning and implementation of any agricultural program in any given region. Moreover, the most important reason for low rice production in the entire country is a lack of adequate and proper water supply [16]. The rainfed food production system is under stress as a result of changing rainfall patterns and a lack of adequate land and water resource utilization [11]. Crop planning for a region is primarily influenced by several 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 areas [21].

It is essential to arrange agriculture on a scientific basis in order to optimize the utility of a region's rainfall pattern and maintain crop production at a consistent level. This entails analyzing the series of dry and wet spells in a given area to take the necessary steps to prepare a crop plan in rainfed areas. Farmers may notice that statistical prediction of a wet and dry spell analysis is beneficial in improving field and agricultural production, resulting in increased profit amount. Dry and rainy spells could be used to examine rainfall data in order to obtain specific information for crop preparation and agricultural operations.

Another important method for rainfall frequency analysis is consecutive days maximum rainfall for better crop planning as well as different hydraulic construction. Different researchers such as Upadhaya and Singh [26], Bhaskar *et al*. [5], Suribabu *et al*. [24], etc. forwarded their research work for consecutive days of maximum rainfall by taking different probability distributions for finding the best-fit one. Earlier, Rama Rao [18] investigated in his research for annual one-day maximum rainfall together with 2 to 5 days consecutive rainfall.

The Markov chain probability model has been used to determine the duration of wet and dry spells in agriculture as well as the probability of regular precipitation [27]. Former researchers have used the Markov chain model to investigate the possibility of dry and wet spells over the shortest period [23] such as daily, a week, and have also demonstrated its best nullity. The area-based dry spell analyses will contribute to the development of a drought contingency strategy. Another feature is the accumulation of rainfall in the forward and backward directions, which determines when the monsoon begins and ends. Land preparation and Kharif crop sowing are aided by pre-monsoon rainfall. The monsoon's late arrival delays crop planting, resulting in low yields. Similarly, the early end of rains has an impact on production due to several moisture stresses, especially when Kharif crops are in critical stages of grain formation and growth [8]. Parmendra Prasad Dabral *et al*. [6] used a Markov Chain model to look at the frequency of dry and wet spells in North Lakhimpur and found that irrigation supplementation is required for major crop gaining. 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. As a result, in order to maintain a given level of crop output, it is critical to construct an agriculture system on a scientific basis that takes advantage of a region's rainfall frequency distribution. This entails determining the order of a region's dry and wet spells to take the necessary steps to prepare a crop plan in rainfed areas [22]. Farmers can benefit from forecasting wet and dry spells for better cropping planning and agricultural operations to increase yield and cropping intensity. The study of the rainfall pattern and soil characteristics of Kuanria Canal for the cultivated soil and irrigation systems was done by using the Markov chain probability model [12]. Previously, the Markov chain probability model was used to investigate the frequency of wet and dry spells in Greece [25]. Earlier, several researchers used this probability model for rainfall frequency analysis. Among them, Alam *et al*. [3], Pandarinath [15], Barron *et al*. [4], Deni *et al*. [7], and Punitha *et al*. [17] used the in their research field to know the possibility of rainfall patterns in dry and wet weeks. Annual and seasonal rainfall analysis will give us a good understanding of region's rainfall pattern. Weekly as well as consecutive days maximum rainfall research, on the other hand, would provide a more precise idea of agriculture planning.

2. Study Area and Data Availability

This investigation was completed in the area Jorhat which is situated between the Brahmaputra River on the north and Nagaland on the south, Sivsagar on the east and Golaghat on the west. Jorhat is located at an average elevation of 116 meters between 26.75 °N 94.22 °E. The geological space of Jorhat is 2, 859 square kilometers, and is 3.63 percent of the state's total land area. The normal yearly temperature in Jorhat is 26 °C. In summer it is 25 °C – 35 °C and while in winter it is 2 °C – 10 °C. In this examination, we take the day-by-day precipitation information recorded at Jorhat city (Assam), situated in the central part of the Brahmaputra Valley for a period of 23 years (1996-2019). This information is gathered from Indian Meteorological Department (IMD, Assam). This information is then changed over to 52 SMW as well as 1 to 6 consecutive days maximum rainfall.

The environment in Jorhat is warm and mild. In summers there is a great deal of precipitation, while the colder time of the year has practically nothing. Each year, a total of 2484.3 mm of maximum precipitation falls with 15 mm of rain, December is the driest month. Most of the precipitation here falls in July, an average of 368.3 mm. The primary yields in the Jorhat are rice, different vegetables, fruits, and tea. For crop arranging reasons it is significant for month-to-month precipitation recurrence investigation. But in some cases, it isn't an incomplete practice as precipitation is variable from one year to another, month-to-month. Thus, consecutive days maximum, week by week precipitation, initial and conditional frequency investigation is a vital instrument for better development. We are attempting to discuss the variability of precipitation in this paper, which is crucial in light of the fact that many big and small tea gardens are located in Jorhat that rely on precipitation water, and tea is a popular item in India and throughout the world from which we may improve our economy. A large number small tea grower develops their mini tea garden in this region by investing low amount of money. So, they need a proper rainfall calendar for taking strategies for future development.

The major objective of this research is to find out continuous rainfall patterns together with consecutive dry and wet weeks during the year to help the poor farmers to maintain their cultivation in the right direction.

3. Methods

3.1 Different Probability Distributions Utilizing in Our Investigation

We use here five probability distributions under L-moment which was used earlier by Hosking and Wallis [10], and Rao and Hamid [19]. The five distributions are given below:

3.1.1 Gumbel or Extreme Value I Distribution

$$f(x) = \alpha^{-1}\exp\left\{-\frac{x-\xi}{\alpha}\right\}\exp\left[-\frac{x-\xi}{\alpha}\right], \quad -\propto < x < \propto ,$$
$$F(x) = \exp\left[-\exp\left\{-\frac{x-\xi}{\alpha}\right\}\right], \tag{3.1}$$
$$x(F) = \xi - \alpha\log(-\log F)$$

Parameter estimation:

$$\alpha = \frac{\lambda_2}{\log 2} \text{ and } \xi = \lambda_1 - \gamma\alpha. \tag{3.2}$$

3.1.2 Lognormal Distribution

$$f(x) = (2\pi)^{-1/2}\alpha^{-1}\exp^{ky-\frac{y^2}{2}}, \quad \text{where } y = -k^{-1}\log\left\{1-\frac{k(x-\xi)}{\alpha}\right\},\ k \neq 0$$
$$F(x) = \varnothing\left[\frac{\{\log(x-\gamma)-\mu\}}{\sigma}\right], \quad \gamma = x < \propto \tag{3.3}$$

and with the parameters

$$k = -\sigma,\ \alpha = \sigma e^{\mu},\ \xi = \gamma + e^{\mu}. \tag{3.4}$$

3.1.3 Pearson Type III Distribution

$$f(x) = \frac{(x-\xi)^{\alpha-1}e^{-(x-\xi)/\beta}}{\beta^{\alpha}G(\alpha)}, \quad \xi \le x < \propto , \tag{3.5}$$
$$F(x) = \gamma\left(\alpha, \frac{x-\xi}{\beta}\right)/G(\alpha) \text{ and } x(F) \text{ has no explicit form.}$$

Here,

$$\gamma(\alpha, x) = \int_0^x t^{\alpha-1}e^{-t}dt \text{ represents the incomplete gamma function} \tag{3.6}$$

and the parameters can be obtained from

$$\beta = \frac{\pi^{\frac{1}{2}}\lambda_2 G(x)}{G\left(\alpha+\frac{1}{2}\right)}, \quad \xi = \lambda_1 - \alpha\beta \text{ and } \tau_3 = 6I_{\frac{1}{3}}(\alpha, 2\alpha) - 3. \tag{3.7}$$

3.1.4 Log-Pearson Type III

Log-Pearson Type III distribution is a member of the family of Pearson Type III distribution, and is also referred to as the Gumma distribution.

The CDF and PDF are defined by Hosking as

if $\gamma \neq 0$, let $\alpha = \dfrac{4}{\gamma^2}$ and $\xi = \mu - 2\sigma/\gamma$;

$$\text{if } \gamma > 0, \text{ then } F(x) = \frac{G\left(\alpha, \frac{x-\xi}{\beta}\right)}{G(\alpha)} \text{ and } f(x) = \frac{(x-\xi)^{\alpha-1}\, e^{-(x-\xi)/\beta}}{\beta^{\alpha} G(x)}; \tag{3.8}$$

$$\text{if } \gamma = 0, \text{ the distribution is Normal and } F(x) = \phi\left(\frac{x-\mu}{\sigma}\right),\ f(x) = \phi\left(\frac{x-\mu}{\sigma}\right);$$

$$\text{if } \gamma < 0, \text{ then } F(x) = 1 - \frac{G\left(\alpha, \frac{\xi-x}{\beta}\right)}{G(\alpha)} \text{ and } f(x) = \frac{(x-\xi)^{\alpha-1} e^{-(\xi-x)}}{\beta^{\alpha} G(\alpha)},$$

where μ is the location parameter, σ is the scale parameter, and the shape parameter γ.

3.2 L-moment Method

The L-moment method is linear combination of *Probability Weighted Moments* (PWM). The main advantage of PWMs over conventional moments is that PWMs, being linear combinations of data sets, suffer less from the effect of sampling variability.

The PMWs of a random variable X were properly described by Greenwood *et al*. [9] as

$$M_{p,r,s} = E[X^p \{F(x)\}^r \{1-F(x)\}^s] = \int x^p \{F(X)\}^r \{1-F(X)\}^s dF\{x\}, \tag{3.9}$$

where $F(x)$ the CDF is means cumulative distribution function of X. The quantities $M_{p,r,s}$ may be used to described and characterize probability distributions.

A functional case is

$$\beta_r = M_{1,r,0}\,. \tag{3.10}$$

Therefore,

$$\beta_r = \int_0^1 x(F) F^r dF\,, \tag{3.11}$$

where $F = F(x)$ cumulative distribution function of a random variable is x and r is a nonnegative integer of real number that is $r = 0, 1, 2, 3, \dots$.

The general form of L-moments in terms of PWM is given by Hosking and Wallis [10] as

$$\lambda_{r+1} = \sum_{k=0}^{r} p^*_{r,k} \beta_k\,, \tag{3.12}$$

where $p^*_{r,k}$ defined by Hosking and Wallis [10] as

$$p^*_{r,k} = \frac{(-1)^{r-k}(r+k)!}{(k!)^2 (r-k)!}\,. \tag{3.13}$$

Therefore the first four L-moments, which are the linear combination of PWMs, are

$$\left.\begin{aligned} \lambda_1 &= \beta_0 \\ \lambda_2 &= 2\beta_1 - \beta_0 \\ \lambda_3 &= 6\beta_2 - 6\beta_1 + \beta_0 \\ \lambda_4 &= 20\beta_3 - 30\beta_2 + 12\beta_1 - \beta_0 \end{aligned}\right\} \tag{3.14}$$

The L-moments have no units of measurement, which are called the L-moments ratio and these are given by Hosking and Wallis [10] as:

$$\left.\begin{aligned} &\text{Coefficient of L-variation, } \tau = \tfrac{\lambda_2}{\lambda_1} \\ &\text{Coefficient of L-skewness, } \tau_3 = \tfrac{\lambda_3}{\lambda_2} \\ &\text{Coefficient of L-kurtosis, } \tau_4 = \tfrac{\lambda_4}{\lambda_2} \end{aligned}\right\} \tag{3.15}$$

The sample estimation of L-moments can be defined as:

$$\lambda^{\wedge}_{r+1} = \sum_{k=0}^{r} p^{*}_{r,k} b_k \tag{3.16}$$

with

$$b_r = n^{-1} \sum_{j=r+1}^{n} \frac{(j-1)(j-2)\dots(j-r)}{(n-1)(n-2)\dots(n-r)} x_j . \tag{3.17}$$

3.3 Markov Chain Probability Model for Dry and Wet Week Analysis

Weekly rainfall values are 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, a week with 20 mm or more of rainfall is considered wet, while one with less is considered dry, and the threshold limit is set at 20 mm. Different formulae followed in this analysis are given below.

3.3.1 Initial Probability

$$P(d) = F(d)/N, \quad P(w) = F(w)/N, \tag{3.18}$$

where $P(d)$ indicates dry weeks probability, $F(d)$ indicates dry weeks frequency, $P(w)$ indicates wet weeks probability, $F(w)$ indicates wet weeks frequency, an N indicates an aggregate number of years for which data has been employed.

3.3.2 Conditional Probability

$$P(dd) = F(dd)/F(d), \tag{3.19}$$

$$P(ww) = F(ww)/F(w), \tag{3.20}$$

$$P(wd) = 1 - P(dd), \tag{3.21}$$

$$P(dw) = 1 - P(ww), \tag{3.22}$$

where $P(dd)$ represents the probability dry week such that the previous week is also a dry, $P(ww)$ represents the probability the probability of a wet week such that previous week also a wet, $F(dd)$ represents the frequency of a dry week such that previous week also a dry week, $F(ww)$ represents the frequency of a wet week such that the previous week also week, $P(wd)$ represents the probability of a wet week such that previous week also is a dry week, $P(dw)$ represents the probability of a dry week such that previous week also is a wet dry week.

3.3.3 Consecutive Dry and Wet Week Probabilities

$$P(2d) = P(dW^1) \times P(ddW^2), \tag{3.23}$$

$$P(3d) = P(dW^1) \times P(ddW^2) \times P(ddW^3), \tag{3.24}$$

$$P(2w) = P(wW^1) \times P(wwW^2), \tag{3.25}$$

$$P(3w) = P(wW^1) \times P(wwW^2) \times P(wwW^3), \tag{3.26}$$

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 such that the previous week is dry, $P(3d)$ represents the probability of three consecutive dry weeks,

$P(ddW^3)$ represents the probability of the 3rd dry week such that the previous is dry week, $P(2w)$ 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 such that the previous week is also wet, $P(3w)$ represents three consecutive wet weeks, and $P(wwW^3)$ represents the probability of 3rd wet week such that the previous week is also wet.

The probability of the main rainy season especially arrival and withdrawal were calculated using Weibull's approach. 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 (3.26) was used to calculate the percentage possibility of onset and withdrawal using Weibull's formula. Mandal *et al*. [13], Wubengeda *et al*. [1], and many researchers used this technique to calculate percentage probabilities,

$$P = \frac{m}{N+1} \times 100, \tag{3.27}$$

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

The formulas from (3.18) - (3.26) are used to determine initial, conditional and consecutive days probabilities based on the weekly range. The possibility of a week either dry or wet is determined by initial probability, however in conditional probability, if a given period j is wet or dry, the possibility of the $(j+k)$th period being wet is calculated and expressed as wet/wet or wet/dry.

4. Data Analysis

4.1 Parameters of the Distributions by Using L-moments for Consecutive Day's Maximum Rainfall

Table 1. Consecutive day's maximum rainfall for Location, Scale and Shape under four distributions

Dist.	Gumbel (EV1)		Log Normal		Pearson Type III			Log-Pearson Type III		
Parameters	Location	Scale	Location	Scale	Location	Scale	Shape	Location	Scale	Shape
1-day	75.2636	20.6966	1.9228	0.1303	87.2100	25.7892	0.6657	1.9228	0.1304	0.1553
2-days	85.5262	21.2487	1.9762	0.1159	97.7900	26.7580	0.8998	1.9762	0.1162	0.2742
3-days	96.8259	25.5351	2.0316	0.1207	111.5600	32.6856	1.1560	2.0316	0.1210	0.2956
4-days	123.8966	29.1486	2.1350	0.1083	140.7217	37.6930	1.2845	2.1350	0.1091	0.4818
5-days	133.0801	38.6756	2.1733	0.1319	155.4043	49.4418	1.1299	2.1733	0.1326	0.4069
6-days	147.7292	46.0328	2.2208	0.1397	174.3000	59.2295	1.2194	2.2208	0.1405	0.4337

4.2 Chi-square Value for the Goodness of Fit Test

Here we use the chi-square test to determine goodness of fit by using the following formula. The test compares the actual number of observations and the expected number of observations.

$$\chi_c^2 = \sum \frac{(O-E)^2}{E}, \tag{4.1}$$

where O is the observed value from Weibull's approach and E is the predicted value from the probability distribution function. Mohanty *et al*. [14] used this test for finding the best-fit probability distribution for daily maximum yearly rainfall at Nagpur. The best probability distribution function was determined by comparing chi-square values obtained from each distribution and selecting the function that gives the smallest chi-square value.

Table 2. Chi-square value

Distribution/days	1-day	2-days	3-days	4-days	5-days	6-days
Gumbel (EV1)	**3.2723**	2.4396	4.3204	1.7253	1.9170	0.9162
Log-Normal	4.7947	2.0429	4.6460	**1.3595**	2.0511	**0.8205**
Pearson Type III	4.7476	2.2451	4.2277	2.5453	**1.8924**	2.9366
Log-Pearson Type III	4.6067	**1.7976**	**4.2230**	2.3079	2.8737	1.8736

For a 5% level of significance for the degree of freedom 2, the chi-square value is 5.991. It has been observed that all the distributions for 1 to 6 consecutive days maximum rainfall satisfy the chi-square test. From the above table, the smallest chi-square value for 1-day is obtained as EV1 distribution hence it has been considered as the best fitting distribution for 1-day. Similarly, Long-Pearson type III as for 2-days, as well as 3-days and Lognormal, is for 4-days and 6-days and Pearson type III is for 5-days best fitting distribution.

4.3 Estimation of Quartiles for the return period

Table 3. Return periods for 2, 5, 10, 50, and 100 years

Days/Return periods	2-years	5-years	10-years	50-years	100-years
1-day	82.85	106.31	121.84	156.02	170.47
2-days	93.53	118.00	134.30	170.40	186.10
3-days	106.00	135.30	154.90	199.00	218.00
4-days	136.5	168.30	187.8	227.7	243.70
5-days	146.29	192.07	221.70	283.82	308.95
6-days	166.30	218.00	251.10	321.9	351.40

Result and Discussion

We have observed that all distribution functions are significantly fitted and may be used to predict the quantity of rainfall that would fall in the future, which is essential for better crop production. Frequency analysis will be utilized as a basic technique in the design of small dams, bridges, culverts, and drainage operations, among other things. The findings of this study will be useful to agricultural scientists, policymakers, and decision-makers Table 3, it is clearly shows that from 23 years data we can predict the amount of rainfall for coming up to 100 years. A maximum of 82.85 mm in 1 day, 93.53 mm for 2 days, 106.00 mm for 3 days, 136.50 mm for 4 days, 146.29 mm for 5 days and 166.30 mm in 6 days is expected to occur at Jorhat district, Assam every 2 years. The expected maximum rainfall in 100 years in 1 day, 2, 3, 4, 5 and 6 days are respectively 170.47 mm, 186,10 mm, 218.00 mm, 243.70 mm, 308.95 mm and 351.40 mm, and we know that 2 to 100 years rainfall frequency analysis is recommended for soil and water conversation measures and also these be used to planning irrigation system.

4.4 Analysis of Rainfall Data of the Jorhat Region for Markov Chain Model

Table 4. Weekly rainfall: Average, Maximum, Minimum, Std. Deviation and Co-variance of Jorhat

SMW	Ave.	Max.	Min.	Std. Dev.	Co-Var.	SMW	Ave.	Max.	Min.	Std. Dev.	Co-Var.
1	1.15	8.10	0	2.16	187.79	27	78.40	296.70	2.8	61.31	78.20
2	2.95	29.60	0	7.23	245.26	28	95.63	219.90	37.5	57.72	60.36
3	3.08	12.10	0	3.92	127.46	29	72.33	242.40	3.5	51.42	71.09
4	4.44	21.30	0	6.74	151.76	30	83.72	149.40	15.3	33.15	39.60
5	1.79	8.60	0	2.31	128.72	31	69.09	135.60	12.7	36.88	53.38
6	3.68	21.20	0	7.07	191.95	32	84.81	309.60	4.7	68.18	80.39
7	11.32	55.40	0	14.08	124.37	33	63.07	140.30	10.6	33.96	53.84
8	8.10	37.40	0	9.92	122.51	34	67.19	156.00	1.5	42.06	62.60
9	10.39	56.30	0	14.64	140.94	35	62.58	127.90	12.7	38.19	61.02
10	5.52	30.60	0	8.51	154.09	36	58.90	164.10	1	45.50	77.24
11	9.54	66.30	0	15.97	167.39	37	55.13	175.80	0	45.20	81.98
12	24.33	86.70	0	26.67	109.63	38	46.45	126.60	0	35.84	77.15
13	31.81	115.90	0	30.19	94.90	39	48.20	124.70	9.3	32.09	66.59
14	32.80	99.90	1.5	25.86	78.83	40	36.04	102.00	0	36.62	101.60
15	39.71	200.90	0	47.45	119.48	41	29.60	142.60	0	35.50	119.92
16	62.60	258.60	0	60.68	96.94	42	17.79	108.60	0	26.23	147.43
17	50.59	105.50	3.9	36.24	71.64	**43**	14.76	57.00	0	17.93	121.48
18	50.26	165.60	0	40.88	81.33	44	10.40	165.30	0	34.47	331.58
19	54.70	129.40	2.6	40.46	73.97	45	1.77	16.50	0	3.95	223.09
20	55.57	161.10	0	41.21	74.16	46	5.21	40.70	0	9.99	191.71
21	54.03	120.80	3.6	33.19	61.43	47	6.35	42.40	0	10.30	162.17
22	74.95	264.10	13.2	56.05	74.79	48	0.39	7.40	0	1.54	399.01
23	53.38	124.80	0.8	32.89	61.61	49	1.89	18.90	0	4.98	263.52
24	53.73	206.30	1.5	42.02	78.20	50	4.96	54.90	0	12.33	248.61
25	59.83	195.90	9.7	41.37	69.14	51	2.49	29.60	0	7.44	298.61
26	90.34	220.60	21.4	51.77	57.31	52	2.61	43.50	0	9.10	348.29

Table 5. SMW wise Initial probabilities of Jorhat for dry and wet weeks

SMW	Percentage of Initial Porb.		Percentage of Conditional Prob.				SMW	Percentage of Initial Porb.		Percentage of Conditional Prob.			
	$P(d)$	$P(w)$	$P(dd)$	$P(d)$	$P(w)$	$P(dd)$	$P(ww)$	$P(dw)$	$P(dd)$	$P(d)$	$P(w)$	$P(dd)$	1
100.0	0.0					27	13.0	87.0	0.0	100.0	100.0	0.0	2
95.7	4.3	100.0	0.0	0.0	100.0	28	0.0	100.0	0.0	100.0	87.0	13.0	3
100.0	0.0	95.7	4.3	0.0	100.0	29	4.3	95.7	0.0	100.0	100.0	0.0	4
91.3	8.7	100.0	0.0	0.0	100.0	30	8.7	91.3	0.0	100.0	95.2	4.8	5
100.0	0.0	91.3	8.7	0.0	100.0	31	13.0	87.0	33.3	66.7	95.0	5.0	6
91.3	8.7	100.0	0.0	0.0	100.0	32	13.0	87.0	0.0	100.0	85.0	15.0	7
78.3	21.7	94.4	5.6	20.0	80.0	33	4.3	95.7	0.0	100.0	86.4	13.6	8
82.6	17.4	78.9	21.1	25.0	75.0	34	17.4	82.6	0.0	100.0	94.7	5.3	9
87.0	13.0	80.0	20.0	0.0	100.0	35	13.0	87.0	0.0	100.0	80.0	20.0	10
95.7	4.3	86.4	13.6	0.0	100.0	36	30.4	69.6	14.3	85.7	87.5	12.5	11
87.0	13.0	95.0	5.0	0.0	100.0	37	26.1	73.9	50.0	50.0	76.5	23.5	12
56.5	43.5	84.6	15.4	10.0	90.0	38	21.7	78.3	40.0	60.0	77.8	22.2	13
30.4	69.6	71.4	28.6	50.0	50.0	39	17.4	82.6	0.0	100.0	73.7	26.3	14
34.8	65.2	37.5	62.5	73.3	26.7	40	47.8	52.2	9.1	90.9	75.0	25.0	15
52.2	47.8	41.7	58.3	72.7	27.3	41	52.2	47.8	58.3	41.7	63.6	36.4	16
17.4	82.6	75.0	25.0	52.6	47.4	42	65.2	34.8	40.0	60.0	25.0	75.0	17
34.8	65.2	12.5	87.5	80.0	20.0	43	69.6	30.4	68.8	31.3	42.9	57.1	18
21.7	78.3	40.0	60.0	66.7	33.3	44	91.3	8.7	71.4	28.6	50.0	50.0	19
17.4	82.6	25.0	75.0	78.9	21.1	45	100.0	0.0	91.3	8.7	0.0	100.0	20
17.4	82.6	25.0	75.0	84.2	15.8	46	91.3	8.7	100.0	0.0	0.0	100.0	21
17.4	82.6	25.0	75.0	84.2	15.8	47	87.0	13.0	90.0	10.0	0.0	100.0	22
8.7	91.3	50.0	50.0	85.7	14.3	48	100.0	0.0	87.0	13.0	0.0	100.0	23
13.0	87.0	0.0	100.0	90.0	10.0	49	100.0	0.0	100.0	0.0	0.0	100.0	24
13.0	87.0	33.3	66.7	90.0	10.0	50	91.3	8.7	100.0	0.0	0.0	100.0	25
17.4	82.6	25.0	75.0	89.5	10.5	51	91.3	8.7	90.5	9.5	0.0	100.0	26
0.0	100.0	0.0	100.0	82.6	17.4	52	95.7	4.3	90.9	9.1	0.0	100.0	

Table 6. SMW wise Probabilities of Jorhat for Consecutive dry and wet weeks

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	27	0.0	0.0	75.6	75.6
2	91.5	91.5	0.0	0.0	28	0.0	0.0	100.0	95.2
3	100.0	91.3	0.0	0.0	29	0.0	0.0	91.1	86.5
4	83.4	83.4	0.0	0.0	30	2.9	0.0	86.7	73.7
5	100.0	94.4	0.0	0.0	31	0.0	0.0	73.9	63.8
6	86.2	68.1	1.7	0.4	32	0.0	0.0	75.1	71.1
7	61.8	49.4	5.4	0.0	33	0.0	0.0	90.6	72.5
8	66.1	57.1	0.0	0.0	34	0.0	0.0	66.1	57.8
9	75.1	71.3	0.0	0.0	35	1.9	0.9	76.1	58.2
10	90.9	76.9	0.0	0.0	36	15.2	6.1	53.2	41.4
11	73.6	52.6	1.3	0.7	37	10.4	0.0	57.5	42.4
12	40.4	15.1	21.7	15.9	38	0.0	0.0	57.7	43.2
13	11.4	4.8	51.0	37.1	39	1.6	0.9	62.0	39.4
14	14.5	10.9	47.4	25.0	40	27.9	11.2	33.2	8.3
15	39.1	4.9	25.2	20.1	41	20.9	14.3	12.0	5.1
16	2.2	0.9	66.1	44.1	42	44.8	32.0	14.9	7.5
17	13.9	3.5	43.5	34.3	43	49.7	45.4	15.2	0.0
18	5.4	1.4	61.8	52.0	44	83.4	83.4	0.0	0.0
19	4.3	1.1	69.6	58.6	45	100.0	90.0	0.0	0.0
20	4.3	2.2	69.6	59.6	46	82.2	71.5	0.0	0.0
21	8.7	0.0	70.8	63.7	47	75.6	75.6	0.0	0.0
22	0.0	0.0	82.2	74.0	48	100.0	100.0	0.0	0.0
23	4.3	1.1	78.3	70.0	49	100.0	90.5	0.0	0.0
24	3.3	0.0	77.8	64.3	50	82.6	75.1	0.0	0.0
25	0.0	0.0	68.2	68.2	51	83.0		0.0	
26	0.0	0.0	100.0	87.0	52				

Table 7. 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 June -10th June)
Mean week of withdrawal of rainy season	43 (22nd October - 28th October)
Earliest week of withdrawal of rainy season	40 (1st October - 7th October)
Delayed week of withdrawal of rainy season	47 (19th November - 25th November)

Table 8. 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

Monthly *effective rainfall* (ER) are calculated by using the following formulae

$$P_c = \frac{P_t(125-0.2P_1)}{125}, \quad \text{for } P_t < 250\,\text{mm} \tag{4.2}$$

$$P_c = 125+0.1P_t, \quad \text{for } P_t \geq 250\,\text{mm} \tag{4.3}$$

where P_c and P_t represents monthly ER and total monthly rainfall in mm. These two equations are from USDA Soil Conversation Service (USDA-SCS) method, broadly used for calculating monthly ER. All India Coordinated Research Project [2] also used this method for finding ER at different rainfed districts. Mandal *et al*. [13] took this method for calculating ER in their research work.

Table 9. Average rainfall, effective rainfall, and percentage (%) of error of Jorhat

Months	Jorhat		
	Average Rainfall (mm)	Effective Rainfall (mm)	% ER
January	12.4	11.9	95.97
February	29.9	27.7	92.64
March	73.8	61.7	83.60
April	192.5	118.5	61.56
May	255.4	141.4	55.36
June	269.2	145.4	54.01
July	368.3	161.4	43.82
August	306.7	153.4	50.02
September	230.5	136.7	59.31
October	106.5	79,0	74.18
November	15.8	15.1	95.57
December	12.0	11.4	95.00

By using this data set we construct the following figure to express the ER and monthly average rainfall.

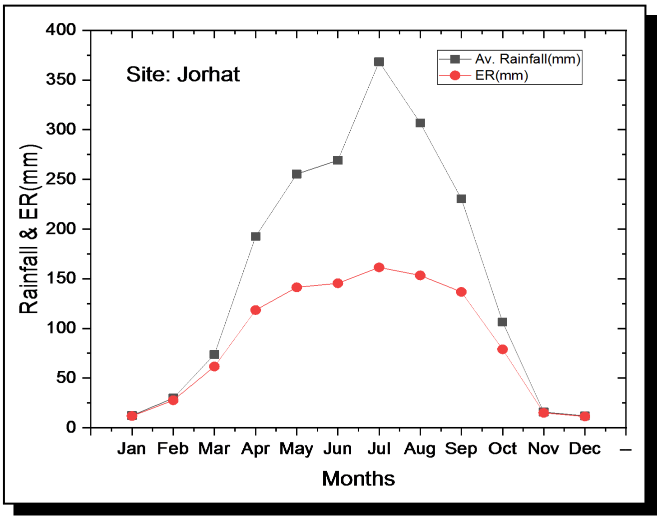

Figure 1

Results and Discussion

The amount of are the followings:

Annual average of Jorhat = 1873.00 mm, Annual Minimum = 1225.2 mm,
Annual Maximum = 2484.3 mm and Std. Deviation = 291.4 mm

The Average, Maximum, Minimum, Standard deviation and Coefficient of variations of rainfall at Jorhat:

Table 4 displays mean, maximum, minimum, standard deviation, and *coefficient of variation* (CV) for weekly rainfall at Jorhat. The 32nd week had the most rainfall (309.60 mm), proceeded by the 27th week (296.70 mm), and the 36th week had the least rainfall (1 mm), proceeded by 0.8 mm in the 23rd week. The percentage CV is a measure of rainfall dependability. The rainy season lasts 23 weeks, from the 21st to the 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 39.60 percent at the 30th week to 147.43 percent at the 42nd week. For our sample region during the rainy season, the CV at the onset and withdrawal weeks is 61.43 percent and 121.48 percent, respectively. As we know, the CV of weekly rainfall should not exceed 150 percent [20] which is valid in our study region.

SMW wise probabilities *of initial and conditional for dry and wet weeks in the rainy season at Jorhat:*

In Table 5, the initial and conditional probability of the permissible limits of 20 mm of rainfall for all 52 SMW of the year is calculated. The key rainy season, which ranges from the 21st to 43rd week, is the focus of this article. Dry weeks have a probability 0 to 69.6 percent and a conditional probability of 0 to 68.8 percent, respectively. The chance of a dry week $P(2d)$ and the dry week followed by another dry week $P(dd)$ during the first week of the rainy season are 17.4 percent and 25 percent, respectively. Again, $P(d)$ and $P(dd)$ towards the ending of the main rainy season respectively, have a 69.6 percent and 68.8 percent chance of occurring.

In the case of wet weeks $P(w)$ and $P(ww)$ in the main rainy season, the chance of the initial and the conditional probabilities are respectively 30.4 percentage to 100 percent and 25 percent to 100 percent. In the first 7 days of the main rainy season, the chance of $P(w)$ and $P(ww)$ is 82.6 percent and 84.2 percent, respectively. And towards the ending of the monsoon period, 30.4 percent and 42.9 percent have a chance for $P(w)$ and $P(ww)$.

During the rainy season (20 mm threshold limiting point), the possibility of a dry week is greater than 50 percent in the 41st, 42nd and 43rd weeks, as well as the probability of dry week followed by another dry week in the 41st and 43rd weeks. During the 21st to 35th weeks and the 38th, 39th weeks, however, the possibility of the rainy week is greater than 75 percent. And from the 21st to 38th weeks, the possibility of a rainy week followed by another wet week $P(ww)$ is greater than 75 percent.

SMW wise probability *of consecutive dry and wet weeks at Jorhat*:
The analyses of successive dry and rainy spells can be found in Table 6. Within the first 12 weeks of the year, there was a 40.4 percent to 100 percent chance of $P(2d)$. Similarly, the possibility of $P(3d)$ means 3 consecutive dry weeks were 15.1 percent to 95.7 percent, indicating a high probability. The comparable values of $P(2w)$ and $P(3w)$, the consecutive 2 and 3 rainy weeks were 0 to 21.7 percent and 0 to 15.9 percent respectively, which is quite low. The chances of $P(2d)$ and $P(3d)$ are respectively 0 to 49.7 percent and 0 to 45.4 percent during the main rainy season (21st to 43rd). It was noticed as the rainy season came to an end. In this time, the chances of $P(2w)$ and $P(3w)$ were 12 to 100 percent and 0 to 95.42 percent, respectively.

SMW wise rainfall analysis during rainy the period at Jorhat for onset and withdrawal:
In Table 7, we observe that the monsoon period of our study site starts from 21st May to 28th October. This period runs from 21st week to 43rd week. The length of this period is 23 weeks means 161 days. The early and later weeks of the main rainy season, respectively, are the 20th week from 21st May to 27th May and the 23rd week from 4th June to 10th June in the onset. On the other hand, 40th week from 1st October to 7th October is the earliest and the 47th week from 19th November to 25th November is the withdrawal in the monsoon season for a delayed week.

Probability of onset *and withdrawal of main rainy seasons at Jorhat:*
The onset and completion of the major rainy season are depicted in Table 8, have a 95.83 percent risk of occurring during the 23rd and 47th weeks, respectively. Figure 1 displays the average monthly and effective rainfall in the Jorhat area over the last 23 years. Table 9 shows that the average rainfall in July was 368.3 mm, the highest of the year, and contributed 22.92 percent to the annual average rainfall (1607 mm). The rainfall in August is a little less than in July (19.09 percent of annual average rainfall). The lowest rainfall occurred in December, accounting for 0.75 percent of the annual average.

5. Conclusion

The rainfall pattern of Jorhat was analyzed by using the Markov chain model. The major rainy season, which was recorded here, was 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 starting from 21st May and ending 28th October which was onset and withdrawal. It is observed that 883 mm rainfall was used throughout the year called *effective rainfall* (ER) which was 54.95 percent of total rainfall. And the remaining part (724 mm) was lost in different ways like deep leaching, vaporization, flash flood to the river, etc. July month rainfall is slightly longer than August month and the difference is 61.6 mm which is 3.83 percent of the total annual average rainfall. From this information on precipitation recurrence investigation, one can choose the various kinds of harvest planting date and dry season period can be offset with the high precipitation time frame, drainage works, construction of small dams, etc. It also supports farmers by providing knowledge on the prospect of exceeding a given amount of rainfall during a crop's planting season or in a month that is unsuitable for agricultural practices in a dry area. Crop preparation should be undertaken so that the crop's crucial growth stage does not coincide with two or three consecutive dry spells that diminish the yield. As a result, the above study of dry and wet spells is necessary. Also, consecutive days of maximum rainfall analysis will give more benefits for agricultural planning and give information for designing civil engineering construction.

Our main aim should be to decrease the deficiency of yearly precipitation by building up the repositories framework for the dry spell period. For that, we can dig out pond-type water harvesting constructions that can be intended to work with the water system during the no precipitation time frame with contributing least sum and can help the helpless ranchers and also helpful to reduce the crisis of drinking water to some extent.

6. 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, from January 1, 1996 to December 31, 2018.

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Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

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