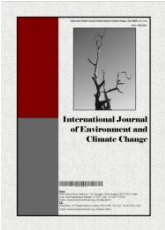

International Journal of Environment and Climate Change

12(11): 2520-2529, 2022; Article no.IJECC.91814
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Rainfall Probability Analysis for Crop Planning of Unakoti and West Tripura District of Tripura, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2022/v12i1131245

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/91814

Original Research Article

Received 05 July 2022
Accepted 10 September 2022
Published 15 September 2022

ABSTRACT

Rainfall is one of the most important climatic variables that determine the spatial and temporal patterns of climate variability of a region, which provides useful information for the planning of agricultural production. For the purpose of crop planning, rainfall data of two districts of Tripura *viz.,* Unakoti and West Tripura for aperiod of 20 years (2001-2020) were collected and used to analyze probability of weekly rainfall. The incomplete Gamma distribution probability analysis using the method suggested by Victor (2000) was used to find and analyze weekly rainfall probability for the studied districts. The investigation revealed that total annual rainfall of Unakoti at 90%, 75% and 50% probability is predicted to be 1640 mm, 1686 mm and 1722 mm respectively. The total annual rainfall of the West Tripura at 90%, 75% and 50% probability is likely to be 1631 mm, 1847 mm and 2108.4 mm respectively. Crops found suitable for *kharif* season are blackgram, greengram, *aman* rice. The crops which can be grown in *rabi* season include cole crops, tomato, chilli, potato, pea, toria etc. Based on the study, crops suited to summer season include short duration greengram, *aush* rice, sesame, jute in all land situations.

Keywords: Rainfall probability; gamma distribution; crop planning; cropping pattern.

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1. INTRODUCTION

Rainfall analysis is important for crop planning for any region. In order to stabilize crop yields at reasonable levels in rainfed situation, it is essential to plan rainfed crops and their management practices in consonance with the rainfall pattern prevalent in the region [1]. The rainfall pattern determines the development of crops, their varieties, reception of cultural operations and gathering of overabundance rain water of any district [2-4]. The cropping pattern is generally recommended considering the rainfall probabilities at various levels [5]. Studies on rainfall probability in India have additionally been completed before by numerous workers [6,7]. Rainfall is the single most significant factor in rainfed farming. The variation in monsoon and yearly rainfall is notable and its yearly inconstancy extensively affects crop production, water management and energy generation. Analysis of yearly, seasonal and monthly rainfall of an area is valuable for configuration of water harvesting structures. Likewise week by week rainfall analysis gives more valuable data in crop planning [8]. There have been various strategies for deciding probability distribution on rainfall analysis and to find best fit probability distribution function like typical, log-ordinary, Gumbel, Weibull and Pearson type etc. by various research workers [9]. Various studies have been done for area explicit agricultural planning and crop planning specifically by analyzing day by day, week after week, month to month, seasonal and yearly rainfall information. Stern and Coe [10] broke down day to day rainfall information for crop planning in semi-arid and tropics. Comparable analysis of rainfall information has been done for crop planning in coastal, semi-arid, dry farming, sub-humid and Himalayan foothill regions by Panigrahi [7] and Sharda and Das [11]. Rainfed farming possesses around 51% of nation's net sown area and records for almost 40% of the total food production (Department of Agriculture, Cooperation and Farmers Welfare, Govt. of India) [12]. Indian agriculture is ascribed to the changeability of seasonal rainfall and the vulnerability in the sum and dissemination of the same [13].

The cropping pattern in Tripura is portrayed by two particular cultivating frameworks which are settled development in the plain areas and shifting cultivation in the hills. Paddy, Pulses and Oilseeds are the significant crops cultivated. Paddy is grown in 55% of gross cropped area in three seasons viz. *Aus* (pre kharif), *Aman* (*kharif*) and *Boro* (summer) while pulses and oilseeds along with different other crops cover around 5% region. Leafy foods are grown in 21% of gross cropped area, 10% region is under rubber and 9% under other different crops like tea, medicinal plants and so forth. The major *kharif* crops are rice, maize, pigeon pea, blackgram, greengram, cowpea, ground nut, sesame, jute, mesta, cotton, and *kharif* vegetables. Various crops grown during *rabi* season are rice, wheat, pea, greengram, lentil, rapeseed-mustard, potato, and *rabi* vegetables.

2. MATERIALS AND METHODS

Daily rainfall data of two districts namely Unakoti (24°14' N latitude and 92°1' E longitudes) and West Tripura (23°16′ N to 24°14′ N latitude and 91°09′ E to 91°47′ E longitudes) of Tripura for 20 years (2001-2020) was collected from Weather Stations of Kailasahar and Agartala which are under Airport Authority of India through Regional Meteorological Centre, Guwahati. The daily data was converted to weekly values and subsequently to monthly, seasonal and annual values. The rainfall database for each district was analyzed to find the mean, standard deviation (SD) and coefficient of variation (CV) on weekly, monthly, seasonal and annual basis.

The incomplete Gamma distribution probability analysis as suggested by Victor (2000) was used to obtain the weekly rainfall probability. The probability was calculated using WEATHER COCK software developed by ICAR-CRIDA, Hyderabad. The probability values on weekly basis was evaluated at 3 different probability levels which are 90%, 75% and 50%. Similar work has been carried out in Odisha district using Weather Cock software [14]. The probability analysis was done on SMW (Standard Meteorological Week).

The general formula for the probability density function of the gamma distribution is

$$f(x)=\frac{\left(\frac{x-\mu}{\beta}\right)^{\gamma-1}\exp\left(-\frac{x-\mu}{\beta}\right)}{\beta\,\Gamma(\gamma)} \qquad x\geq\mu;\gamma,\beta>0 \qquad \text{(i)}$$

3. RESULTS AND DISCUSSION

3.1 Annual Rainfall

The daily rainfall data recorded at both the district for the period of 20 years (2001 – 2020) for Unakoti and West Tripura was summed up and presented in Table 1. The data indicates that

the mean annual rainfall of Unakoti (2597.5 mm) was moderately higher than the mean annual rainfall of West Tripura (2138.4 mm) for last 20 years. The CV value (20.1%) of West Tripura is higher than Unakoti (18.1%) while for SD, it was higher in Unakoti (470.5 mm) then West Tripura (426.7 mm).

3.2 Seasonal Rainfall

Seasonal mean rainfall and CV of Unakoti and West Tripura has been presented in Figs. 1 and 2. The analysis of mean seasonal rainfall revealed that during monsoon season total mean rainfall in Unakoti and West Tripura district was 1510.7 mm and 1272.5 mm, in Post monsoon 206.3 mm and 199.8 mm, in Pre monsoon 854.3 mm and 566.8 mm while in winter it was recorded 42.1 mm and 75 mm respectively. The percentage contribute on of the seasonal rainfall to the total rainfall of Unakoti and West Tripura district was in the following order. Approximately, in winter 1.6% and 3.5%, in Pre monsoon 32.9% and 26.5%, in post monsoon 7.9% and 9.3% whereas maximum percent was recorded in monsoon 58.2% and 59.5% respectively for Unakoti and West Tripura. The seasonal co-efficient of variation (CV) of Unakoti and West Tripura district in monsoon was 18.2% and 26%, in post monsoon it was 52.7% and 47.6%, in pre monsoon it was 29.3% and 30.6% while in winter it was recorded 112.1% and 88.9% respectively.

3.3 Monthly Rainfall

Monthly mean rainfall and CV of Unakoti and West Tripura has been presented in Figs. 3 and 4. The data on mean monthly rainfall of Unakoti district revealed that during the month of May highest mean rainfall of 500.2 mm was recorded contributing about 19.3% to the total annual rainfall while in West Tripura during the month of June highest mean rainfall of 450.3 mm was recorded contributing about 21.1% to the total annual rainfall. The least rainfall of 5.5 mm and 2.7 mm was recorded in the month of January in Unakoti and West Tripura districts respectively with similar contribution of 0.2% to total rainfall. The co-efficient of variation due to monthly rainfall ranges from 33.3% (May) to 204.5% (December) in Unakoti while in West Tripura it ranges from 28.8% (August) to 197.5% (December).

Table 1. Annual rainfall variability of two districts

Districts	Mean rainfall (mm)	SD (mm)	CV (%)
Unakoti	2597.5	470.5	18.1
West Tripura	2138.4	426.7	20.0

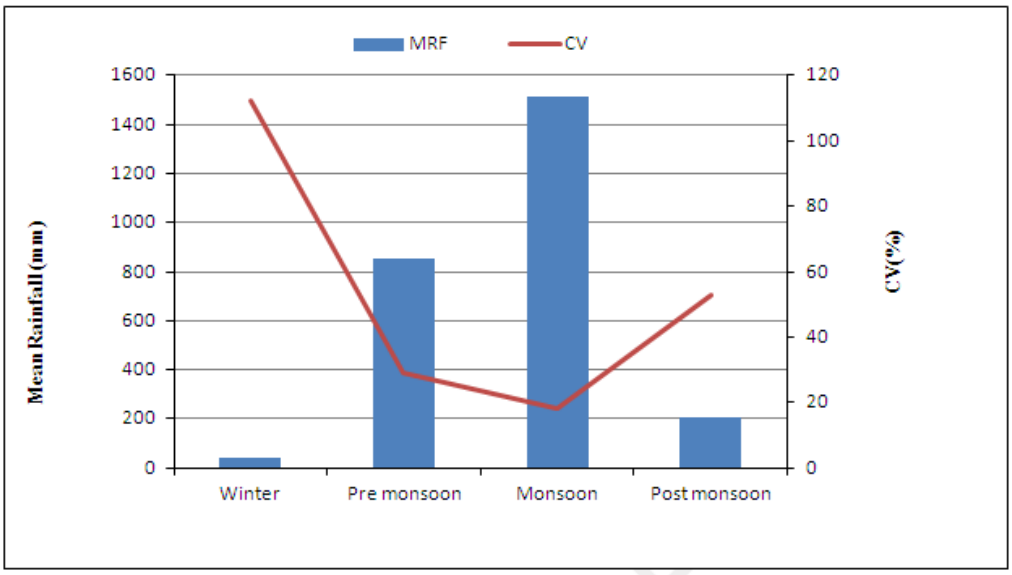

Fig. 1. Seasonal mean rainfall and CV of Unakoti

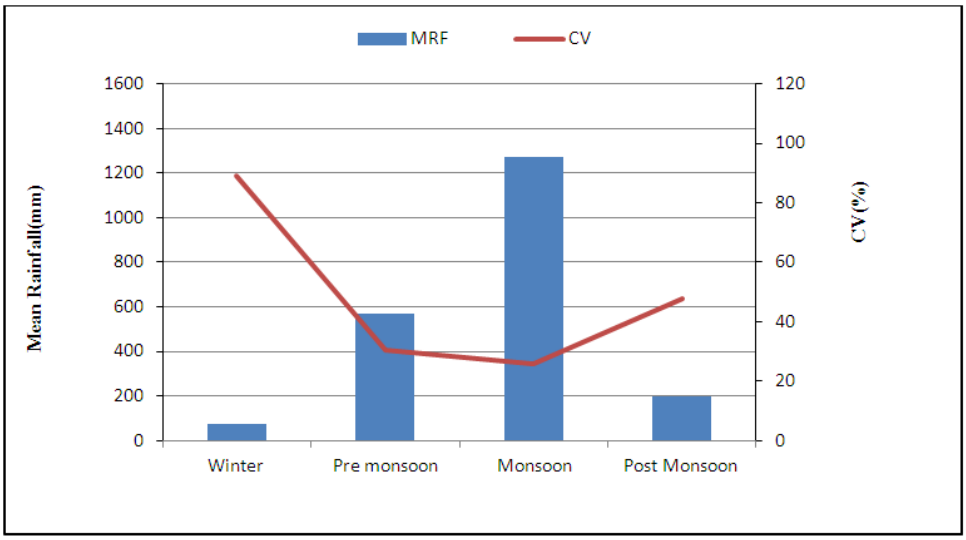

Fig. 2. Seasonal mean rainfall and CV of West Tripura

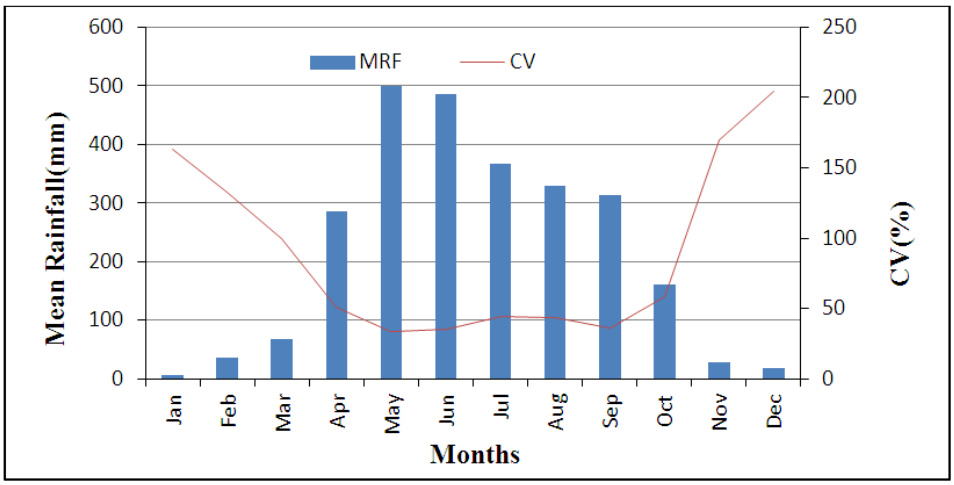

Fig. 3. Monthly mean rainfall and CV of Unakoti

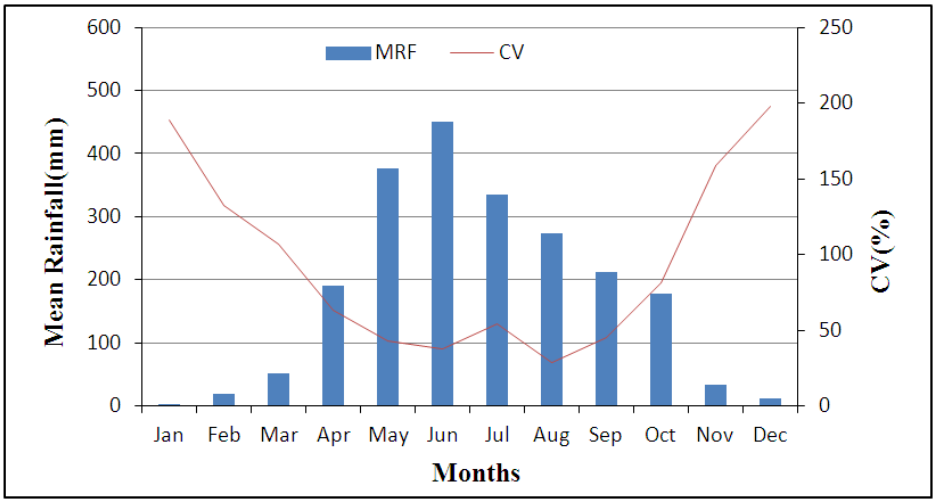

Fig. 4. Monthly mean rainfall and CV of West Tripura

3.4 Weekly Rainfall

Weekly mean rainfall and CV of Unakoti and West Tripura has been presented in Figs. 5 and 6. Highest rainfall was observed in 23rd SMW (149.5 mm) and 24th SMW (123.3 mm) in Unakoti and West Tripura respectively. 47th, 48th and 52nd SMW was recorded as dry in Unakoti while 47th and 48th week was for West Tripura. However maximum rainfall occurred during 13th to 43rd SMW for both the districts. The total rainfall received during this period was 2475.8 mm representing 95.3% of the mean annual rainfall in Unakoti and 2032 mm representing 95% of the mean annual rainfall in West Tripura. The Coefficient of variation of rainfall rose from 3.85% in 49th week to 471.4% in 1st week in Unakoti and from 62.9% in 49th week to 425% in 1st week in West Tripura. However it was less than 100 maximally during the period from 21st week to 40th week i.e. from May to September in Unakoti and from 13th week to 39th week which were distributed from March to September in West Tripura.

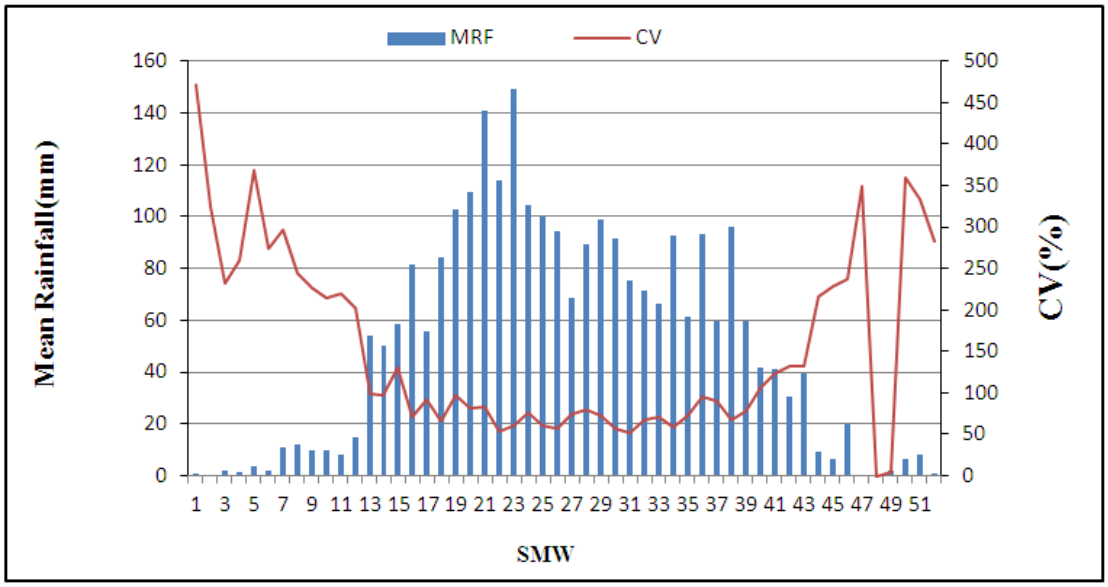

Fig. 5. Weekly mean rainfall and CV of Unakoti

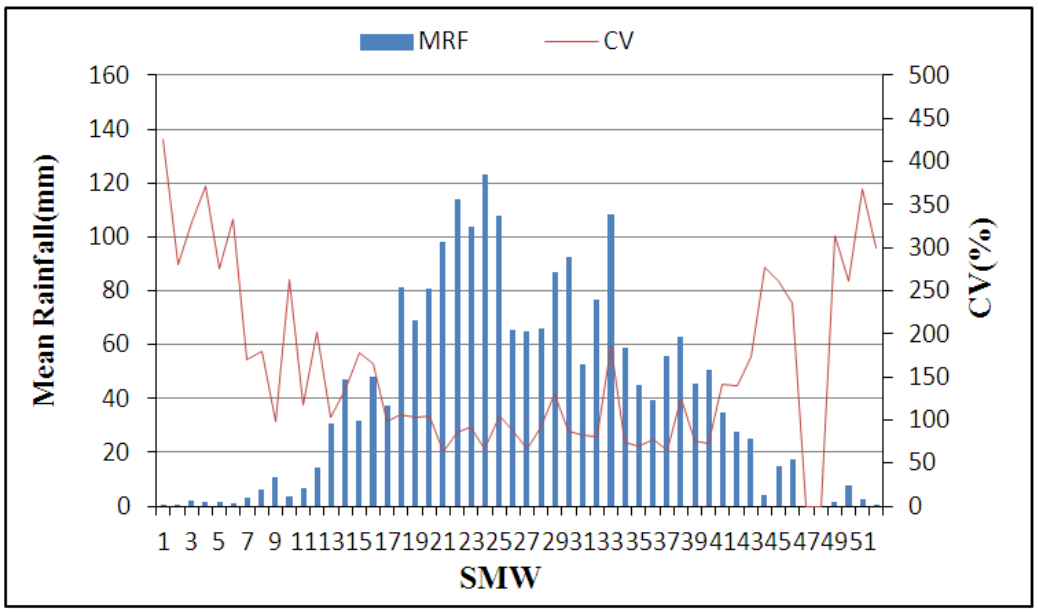

Fig. 6. Weekly mean rainfall and CV of West Tripura

Table 2. Weekly rainfall probability of Unakoti

SMW	Rainfall probability levels			Mean (mm)
	90%	75%	50%	
1	0.3	0.7	1.3	0.7
2	0.5	0.8	1.3	0.4
3	0.3	0.8	2.0	1.9
4	0.3	0.8	1.8	1.5
5	0.1	0.7	2.5	3.9
6	0.0	0.0	1.9	1.9
7	0.0	0.0	10.8	10.8
8	0.0	0.0	12.1	12.1
9	0.2	1.0	4.8	9.7
10	0.2	1.2	5.2	9.9
11	0.2	1.2	4.5	8.0
12	0.4	1.9	7.8	14.8
13	2.2	9.3	30.7	53.8
14	4.5	13.3	34.1	50.0
15	2.5	10.4	33.9	58.7
16	20.6	38.3	68.3	81.4
17	4.9	14.6	37.7	55.8
18	16.4	34.2	67.0	84.2
19	9.9	28.2	70.2	102.5
20	21.4	44.6	87.1	109.6
21	11.9	36.0	93.6	141.0
22	40.3	64.5	101.8	114.2
23	51.7	83.4	132.5	149.5
24	23.7	46.2	85.6	104.4
25	31.9	53.4	87.6	100.0
26	33.7	53.7	84.4	94.4
27	15.6	30.4	56.3	68.4
28	25.7	45.1	76.7	89.2
29	33.9	55.0	87.8	98.9
30	34.2	53.4	82.5	91.4
31	28.5	44.4	68.3	75.5
32	24.0	39.4	63.5	71.6
33	16.1	30.5	55.4	66.5
34	32.9	52.6	82.8	92.6
35	16.0	29.4	52.1	61.5
36	17.4	36.9	73.3	93.0
37	10.7	23.2	46.8	59.5
38	28.9	49.7	83.3	96.2
39	9.8	22.1	45.9	59.4
40	3.7	11.1	28.5	41.8
41	1.3	6.3	22.4	41.0
42	1.1	5.0	17.2	30.5
43	0.5	3.4	17.0	39.3
44	0.2	1.1	4.9	9.4
45	0.2	1.1	4.0	6.5
46	0.1	1.2	7.5	19.8
47	0.6	0.8	1.1	0.2
48	0.5	0.7	0.9	0.0
49	0.2	0.6	1.8	2.0
50	0.1	0.6	3.1	6.7
51	0.1	0.6	3.5	7.9
52	0.4	0.8	1.3	0.6

Table 3. Weekly rainfall probability of West Tripura

SMW	Rainfall probability levels			Mean (mm)
	90%	75%	50%	
1	0.3	0.7	1.4	0.8
2	0.5	0.8	1.3	0.5
3	0.2	0.7	1.9	2.0
4	0.2	0.7	1.6	1.4
5	0.3	0.8	1.9	1.6
6	0.0	0.0	0.9	0.9
7	0.0	0.3	3.0	3.0
8	0.0	0.0	6.3	6.3
9	0.2	1.2	5.4	10.9
10	0.2	0.9	2.7	3.7
11	0.2	0.9	3.7	6.5
12	0.3	1.7	7.3	14.5
13	0.7	3.9	15.6	30.6
14	3.2	10.7	30.0	46.8
15	0.9	4.4	16.7	31.6
16	3.7	11.7	31.7	48.3
17	2.0	7.6	22.9	37.4
18	4.6	16.7	49.6	81.2
19	4.5	15.3	43.6	69.2
20	9.9	25.3	58.3	80.8
21	31.8	52.9	86.3	98.3
22	23.6	47.8	91.6	113.9
23	10.9	29.9	72.5	103.9
24	39.8	66.3	108.0	123.3
25	13.8	34.7	78.5	107.8
26	14.3	28.4	53.4	65.4
27	17.6	31.7	55.4	65.0
28	11.2	24.9	51.2	66.0
29	7.6	22.7	58.5	87.0
30	17.6	37.1	73.3	92.6
31	13.9	25.4	44.7	52.6
32	13.9	30.0	60.1	76.5
33	11.7	31.8	76.1	108.4
34	11.9	24.4	47.3	58.7
35	13.2	23.0	39.1	44.8
36	7.2	15.5	31.1	39.2
37	5.7	15.9	39.0	55.9
38	10.2	23.2	48.4	62.9
39	6.7	15.9	34.5	45.6
40	5.8	15.4	36.3	50.6
41	1.6	6.5	20.6	34.6
42	0.6	3.4	14.0	27.8
43	0.3	2.2	11.0	25.3
44	0.2	0.9	3.0	4.3
45	0.1	1.0	6.0	15.1
46	0.1	0.8	6.0	17.6
47	0.0	0.3	0.0	0.0
48	0.0	0.3	0.0	0.0
49	0.3	0.7	1.7	1.4
50	0.1	0.7	3.6	7.8
51	0.2	0.7	2.2	2.8
52	0.6	0.8	1.2	0.3

3.5 Weekly Rainfall Probability

At 75% probability, significantly less rainfall (<10mm) before the onset of summer that is before 14th Standard Meteorological Weak (SMW) for both the districts was observed. After SMW 22 in Unakoti and SMW 23 in West Tripura a very good amount of rainfall may be received up to SMW 38 and decreased thereafter upto 40th week (becoming less than 10 mm after that) which indicates withdrawal of monsoon for both districts. In SMW 23 the Unakoti district may receive highest rainfall of 83.4 mm while it is SMW 24 for West Tripura with rainfall of 66.3 mm. Also, SMW 6, 7 and 8 may not receive any rainfall in Unakoti and SMW 6 and 8 may not receive any rainfall in West Tripura.

3.6 Proposed Cropping Pattern

Bhatia et al. [15] & Sharma et al. [8] suggested that weekly rainfall analysis gives more important data regarding crop planning & so crop planning is done based on weekly rainfall data analysis. Regarding summer, crops that are suitable growing in this season are green gram, aush rice, maize, sesame and Jute. Summer ploughing can be done from 15th SMW for receiving less than 10 mm and can be continued up to 18th SMW. Short duration greengram can be sown from 14-16 SMW as rainfall at 75% level is less than 10 mm and also that at pod initiation and development, sufficient rainfall is available at 16-18 SMW at Unakoti but irrigation is to be provided at West Tripura as it shows less rainfall during that time. Direct seeded aush rice done from 14th SMW as at 75% rainfall probability level rainfall which is available is >10 mm. At critical stages i.e., at 18th SMW (Unakoti) and 20th SMW (West Tripura) onwards at 75% probability level rainfall is >20 mm. Aush rice varieties that are recommended includes NDR-97, MTU-1010 etc. Early varieties of aush can also be done from 10th to 11th SMW. In a similar study by Deka et al. [1], it was suggested to sow summer crops from 11th SMW onwards in UBVZ as there was higher probability of receiving more than 10 mm rainfall. During harvesting period, as rainfall at 75% probability level is >20 mm and 30 mm and so proper drainage is recommended. Maize can also be grown from 14th to 15th SMW and harvested at 28th to 29th SMW. Jute can also be planted from 9th to 21st as districts are likely to get 150 mm to 250 mm rainfall which is required for production of Jute.

Prior to monsoon at 22nd to 23rd week, sowing of direct seed rice in medium and low land can be carried out within 19th to 21st SMW for better germination by getting 1st monsoon showers and also due to monsoon departure in 39th week onwards medium duration rice in medium land and non paddy crops in upland can be harvested in 41st week. Rai et al. [16] found that the Initial and conditional rainfall probability analysis at Damoh reinforced that Initial probabilities {P (W)} of getting 10 mm rainfall per week was 76% during 25th (18-24 June) SMW. At the reproductive stage, dependable rainfall (75%) was much higher than water requirements. Good drainage should be provided to reduce water stagnation. Similar results were found by Doorenbos et al. [17]. The sowing of aush rice can be advanced upto 14th or 15th week as rainfall at 75% probability is >10 mm which is optimum. Senapati et al. [18] revealed that the duration of monsoon period is 92 days and short duration crops of 90 - 95 days should be preferred to be grown in rainfed uplands. In medium land, however rice can be taken of 130 days duration so that vegetables like cole crops can be grown as second crop. Crops like aman rice, kharif greengram, blackgram, sesame, jute found to be good in kharif. Blackgram and greengram at 38th to 41st SMW with low temperature tolerant varieties can be grown by using residual moisture at critical stages. Surface drainage should be done as when required. Rainfed lowland rice often prone to submergence and so submergence tolerant varieties like Ranjit sub-I, Bahadur sub I etc should be preferred. Late aman rice at 31st to 33rd SMW of short duration can be done and harvested at 41st to 43rd week.

As little chances of rainfall occur after 46th week so no crop is advised after that in upland and medium land. During winter for sowing rabi crops, moisture conservation is essential after ample water harvesting at July to September which can be used as life saving irrigation during critical stages of crop growth. For medium and upland crops like peas, potato, lentil, rabi vegetables along with rapeseed and mustard, sowing can be done from 44th SMW. Sarmah et. al. [19] and Deori et al. [20] also suggested similar type of management practice and crop planning for Lakhimpur and Kokrajhar district of Assam respectively. During critical growth stages (2 - 6 SMW), rainfall at 75% probability level is less than 10 mm and irrigation must be provided. Potato harvesting is to be completed within 13th SMW as from 14th SMW rainfall at 75% probability level is more than 10 mm which is not

suitable and rotting occurs. Sowing of vegetable crops like bitter gourd, pumpkins are done after harvesting aman paddy using residual moisture. Transplanting vegetables should be done from 41st SMW as at 75% probability level rainfall received is less than 10 mm. For Ginger and turmeric, sowing is to be done from 14th SMW because at 75% probability level rainfall is >10 mm. Also, rabi maize can be grown from 41st to 44th SMW.

4. CONCLUSION

The risk proof crop which can be best suitable for *kharif* season are blackgram, greengram in medium and upland, *aman* rice in medium land and late *aman* can be grown in lowland condition. The crops which can be grown in *rabi* season are vegetables like cole crops, tomato, chilli etc along with potato, pea, toria. The crops grown in summer include short duration greengram, *aush* rice, sesame, jute in all land situations while early *aush* can be grown in lowland. During the winter season (40th week onwards), negligible rainfall is recorded at 75% probability level. So the surface soil would become dry with rare chances of getting adequate soil-moisture in the seeding zone. Hence, it was also revealed that the rabi crops have to be raised under moisture stress conditions. The crops should be able to use residual soil profile. Proper irrigation at critical stages recommended at winter season as rainfall is less. Vegetable crops to be sown immediately after harvesting of *aman* paddy to utilize residual soil moisture. Most erratic rainfall occurs in winter season.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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