Original Research Article

Dry and wet spell analysis and MAI estimation for assessing the agro climatic potentiality for crop planning in the Central Brahmaputra Valley Zone (CBVZ) of Assam, India

Comment [PSD1]: Define MAI in full

ABSTRACT

Analysis of rainfall and other weather parameters helps to develop and modify the management practices for stabilizing crop production and crop planning in the rainfed ecosystem at certain level. The present study has been undertaken with the objectives to investigate probable occurrence of dry and wet spell and to find out the Moisture Adequacy Index (MAI) for the districts of Nagaon and Morigaon under Central Brahmaputra Valley Zone (CBVZ) of Assam. In this study, Markov Chain model was used to estimate the initial, conditional probabilities of dry and wet weeks along with the probability of two and three consecutive wet and dry weeks considering 20 mm rainfall as threshold limit. MAI was calculated using Thronthwaite's (1955) soil water balance method. The average rainfall of Nagaon and Morigaon were found to be 1775.27 mm and 1734.37 mm respectively. The study indicated that in CBVZ, probability of occurrence of dry week is higher from 1st week to 14th week. The range of probability varies from 56.7 per cent to 100 per cent during this period. The period from 25th week to 30th week is best suited for transplanting of *sali* rice with 100 per cent probability of wet spell and also continuously high MAI value of 1.0 throughout the period. The MAI value increases from 15th week with onset of pre-monsoon and ranges between 0.9-1.0 throughtt the *kharif* period and then decreases with withdrawal of rainfall. Based on MAI values, the area is suitable for growing of a third crop using residual soil moisture. There is an ample scope for water harvesting from July to September, which can be utilized as crop saving irrigation as well as pre-sowing irrigation for succeeding *rabi* crops, which are generally sown on residual soil moisture. The results through analysis have been used for agricultural planning at CBVZ region.

Keywords: Markov Chain Model, Dry spell, Wet spell, Thornthwaite water balance, MAI.

1. INTRODUCTION

Agricultural production in India mainly depends upon the occurrence of rainfall during the cropping season. Timely onset of monsoon rainfall along with its proper distribution and quantum during the season is the key for better agricultural production in any part of the country (Varshneya *et al.,* 2011)[14]. ~~Maximum~~ Majority of the population of

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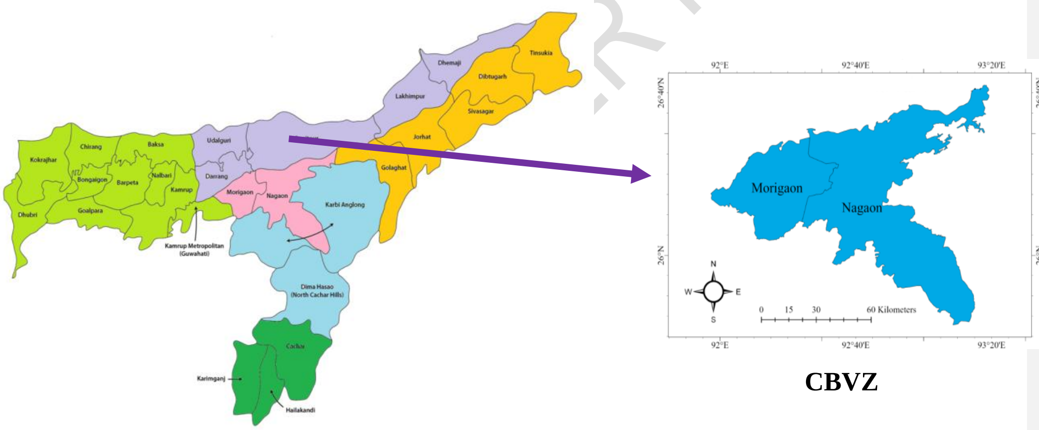
Assam is dependent on agriculture and most of the area is under rainfed agriculture where crop production is solely determined by the prevailing weather condition during the crop growing season. Nearly, 80 per cent of the total annual rainfall of India is received during monsoon seasons (June to September) and uncertainty in the monsoon rainfall causes yield variability (Deo *et al*., 2015)[5]. Hazarika *et al.* (2019)[10] have carried out dry and wet spell analysis using Markov chain model for crop planning in UBVZ of Assam, where they have found that probability of occurrence of rainfall ~~in~~ is more during the months from June - September and is most suitable for rainfed crop cultivation.

The cropping patterns are basically dependent on MAI. MAI is a prime factor of crop planning, both in dryland as well as rainfed regions. MAI can be used for various purposes such as land use planning, identification of crop growing periods, choice of cropping pattern, resource allocation etc. Monthly MAI values are not suitable for crop planning as a month is longer period for crop planning and cultural operation. Moreover, if dry spells occur and causes crop failure, the monthly MAI may not represent the scenario. Hence, weekly MAI values were found to be more suitable in such systems. Many researchers like Vaidya *et al.* (2008)[12], Gangane *et al.* (2017)[7] carried out works on MAI for crop planning in various parts of the country. But, Central Brahmaputra Valley Zone (CVBZ) of Assam lacks such type of study. Keeping these points in view the study was carried out with an objective to find out the probability of occurrence of dry and wet spells along with the ~~Moisture Adequacy Index~~ (MAI~~)~~ in the region to suggest viable cropping pattern.



CBVZ

Fig 1: Map of Agro-climatic Zones of Assam

Daily rainfall data of Nagaon (30 years) and Morigaon (25 years) districts of CBVZ of Assam were collected from Regional Agriculture Research Station (RARS), Shillongoni, Nagaon, Krishi Vigyan Kendra, Morigaon under AAU, Jorhat, Assam and IMD, Pune respectively starting from 1990. Daily temperature data of Nagaon was collected for the same period from RARS, Shillongoni, Nagaon and this data was used to calculate potential evapotranspiration of the whole CBVZ as spatial and temporal variation of temperature within the zone is very less (Gogoi, 2001)[8].

2. MATERIAL AND METHODS

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The present research was carried out in undivided CBVZ of Assam. Undivided CBVZ consist of two districts *viz*., Nagaon (26.3480° N, 92.6838° E) and Morigaon (26.2600° N, 92.2630° E) and it covers a geographical area of 3991sq.km corresponding to 5.08 percent of total area of the state. The soils of the region vary from sandy loam to clayey in nature with varying water holding capacity. Rice is one of the major crops grown in the region, mainly the *kharif* paddy but a significant portion of area is also under *rabi* crop cultivation (Agricultural Contingency Plan, Nagaon and Morigaon, Assam, 2011)[1]. Assam is a paradise for many forms of agriculture, producing a wide range of crops, and then manufacturing things from them. Some of the main crops other than rice include sugarcane, tea, toria, various vegetables, jute etc.

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2.1 Rainfall probability analysis

The daily rainfall data were converted to weekly data and used for analysis of dry and wet spell. The dry and wet spell analysis was carried out based on Markov Chain Model (WMO Technical Note, 1982)[15] using weather cock 1.0 software developed by CRIDA, Hydrebad. A standard meteorological week (SMW), was considered as one spell and a threshold value of 20 mm, was considered to classify the spells as dry or wet because this amount of weekly rainfall is relevant for agricultural operations and crop growth (Pawar *et al.,* 2015;[11] Dugal *et al.,* 2018[5]).

2.1.1 Initial probability of wet P (W) and dry week P (D)

$$P(W) = \frac{F(W)}{F(W) + F(D)}$$

$$P(D) = \frac{F(D)}{F(W) + F(D)}$$

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Where,
P(W) = probability of week being wet
P(D) = probability of week being dry
F(W) = frequency of wet week
F(D) = frequency of dry week

2.1.2 Conditional probability of wet P (W) and dry week P (D):

1. Conditional Probability (W/W) of occurrence of wet week preceded by a wet week.

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

2. Conditional Probability (D/D) of occurrence of dry week preceded by a dry week.

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

Where, F (D) = Frequency of dry week
F (W) = Frequency of wet week
F (W/W) = Frequency of wet week given that previous week was wet
F (D/W) = Frequency of dry week given that previous week was wet
F (D/D) = Frequency of dry week given that previous week was dry
F (W/D) = Frequency of wet week given that previous week was dry

2.1.3 Consecutive probability of wet P (W) and dry week P (D):

I. P (2D) is the probability of occurrence of dry spell of 2 consecutive weeks

P (2D) = P (Dw1) × P (DDw2)

II. P (3D) is the probability of occurrence of dry spell of 3 consecutive weeks

$$P(3D) = P(Dw1) \times P(DDw2) \times P(DDw3)$$

III. P (2W) is the probability of occurrence of wet spell of 2 consecutive weeks

$$P(2W) = P(Ww1) \times P(WWw2)$$

IV. P (3W~~D~~) is the probability of occurrence of ~~dry~~ wet spell of 3 consecutive weeks

$$P(3W) = P(Ww1) \times P(WWw2) \times P(WWw3)$$

Where,

P (Dw1) = initial probability of first SMW being dry
P (DDw2) = conditional probability (D/D) of second consecutive week
P (DDw3) = conditional probability (D/D) of third consecutive week
P (Ww1) = initial probability of first week being wet
P (WWw2) = conditional probability (W/W) of second consecutive week
P (WWw3) = conditional probability (W/W) of third consecutive SMW

2.2 Computation of weekly Moisture Adequacy Index (MAI)

Weekly moisture availability was estimated by calculating the Moisture Adequacy Index (MAI) with the help of water balance model of Thronthwaite and Mather (1955)[13] using the formula:

$$MAI = \frac{AET}{PET}$$

Where, AET = Actual evapotranspiration
PET = Potential evapotranspiration

PET was calculated using Thronthwaite's (1948) method of estimating evapotranspiration and AET was estimated using the water balance model of Thornthwaite and Mather (1955). Weather Cock 1.0 software developed by Central Research Institute for Dry land Agriculture (CRIDA) was used to calculate weekly actual evapotranspiration (AET). MAI was calculated for different types of soil considering different water holding capacities (WHC) *viz.* sandy loam soil having 150 mm WHC, silt loam soil having 200 mm WHC and clay loam soil having 250 mm WHC as extracted from (Thronthwaite and Mather, 1955)[13].

3. RESULTS AND DISCUSSION

The average annual rainfall was found to be 1775.27 mm and 1734.37 mm for the districts of Nagaon and Morigaon respectively (Table 1). CBVZ being a rain shadow area, the average annual rainfall received in this region is less than other zones of the state, where annual rainfall is around 2000 mm. Rainfall received during pre-monsoon season is more than 300 mm indicating sufficient moisture for cultivation of summer crops. Monsoon season receives the highest amount of rainfall, contributing more than 65 per cent of total rainfall received, indicating abundant moisture during this season. Post monsoon rainfall along with residual moisture of soil coupled with supplemental irrigation allows growing of a third crop effectively. Coefficient of Variation (CV) of seasonal rainfall was found to be highest in the winter season and lowest in the monsoon season indicating stable rainfall.

Table 1. Seasonal mean rainfall and Coefficient of Variation of Nagaon and Morigaon District

Station	Nagaon	Morigaon
Pre monsoon rainfall	391.76 mm	348.70 mm
CV (%)	22.46	26.33
Monsoon rainfall	1220.37 mm	1196.05 mm
CV (%)	21.44	19.82

Post monsoon rainfall	125.69 mm	139.44 mm
CV(%)	64.51	66.74
Winter rainfall	37.45 mm	50.18 mm
CV(%)	89.78	96.96
Annual rainfall	1775.27 mm	1734.37 mm

3.1 Probability of wet weeks and dry weeks

The initial, conditional and consecutive probabilities of a week being wet have been shown in Table 2. Threshold limit of 20 mm per week at more than 50 per cent of initial probability during the rainy season is adequate for crop activities like land preparation and the conditional probability of occurrence of rainfall at 20mm per week above 50 per cent is ~~the~~ sufficient for sowing/planting. The initial probability of occurrence of wet week at Nagaon (Table 2) is high (probability value ≥ 50 per cent) from 15th SMW (9th April – 15th April) and remains high upto 40th SMW (1st – 7th Oct), whereas, in case of Morigaon (Table3) the probability is high (probability value ≥ 50 per cent) from 16th SMW (16th Apr- 22nd Apr) to 40th SMW (1stOct – 7th Oct). Conditional probability of wet week preceded by wet week is high (probability value ≥ 50 per cent) from week 14th (2nd April – 8th April) to 41st week (8th Oct – 14th Oct) (Table 2 & 3) for both the districts and probability of two consecutive wet weeks is more than 70 per cent from 25th SMW in Nagaon (Table 2) and from 22nd SMW in Morigaon district (Table 3). There is more than 80 per cent probability of getting three consecutive wet weeks from 26th to 29th SMW in Nagaon (Table 2) and from 25th to 27th SMW in Morigaon (Table 3) which may lead to flood like condition in the districts. So, harvesting of the excess moisture as well as provision of drainage in the crop field is suggested during the aforesaid period.

Probability of getting dry weeks remains high during beginning and end of the year. The probability of getting dry week is more than 50 per cent from 1st SMW to 14th SMW and 15th SMW in Nagaon and Morigaon districts respectively (Table 2 & 3) and decreases (probability less than 50 per cent) gradually with onset of pre-monsoon season and the probability of getting dry week again increases (probability more than 50 per cent) from 41st SMW in both the district (Table 2 & 3). Probability of getting dry week preceded by a dry week is high (probability value ≥ 50 per cent) from 1st SMW to 17th SMW and from 40th SMW to 52nd SMW (Table 2 & 3) in both the districts. Probability of getting two consecutive dry weeks is more than 50 per cent from 1st SMW to 11th SMW and from 42nd SMW to 52nd SMW in both the districts (Table 2 & 3).

Table 2. Initial, conditional and consecutive probabilities of Nagaon at 20 mm threshold limit.

SMW	Period	P(W)	P(D)	P(W/W)	P(D/D)	P(2D)	P(3D)	P(2W)	P(3W)
1	1 Jan – 7 Jan	6.9	93.1	0.0	92.9	93.1	93.1	3.5	0.0
2	8 Jan – 14 Jan	3.3	96.7	0.0	100.0	96.7	90.2	0.0	0.0
3	15 Jan – 21 Jan	0.0	100	0.0	100.0	93.3	90.0	0.0	0.0
4	22 Jan – 28 Jan	6.7	93.3	0.0	93.3	90.0	86.9	0.0	0.0
5	29 Jan – 4 Feb	3.3	96.7	0.0	96.4	93.3	90.1	0.0	0.0
6	5 Feb – 11 Feb	3.3	96.7	0.0	96.6	93.3	86.7	3.3	0.0
7	12Feb – 18Feb	6.7	93.3	0.0	96.6	86.7	86.7	0.0	0.0
8	19 Feb – 25 Feb	6.7	93.3	0.0	92.9	93.3	93.3	0.0	0.0
9	26 Feb - 4 Mar	0.0	100	0.0	100.0	100.0	90.0	0.0	0.0

10	5 Mar – 11 Mar	0.0	100	0.0	100.0	90.0	70.0	0.0	0.0
11	12Mar – 18 Mar	10.0	90.0	0.0	90.0	70.0	39.6	3.3	1.0
12	19 Mar – 25 Mar	23.3	76.7	33.3	77.8	43.3	26.5	6.7	3.3
13	26 Mar – 1 Apr	40.0	60.0	28.6	56.5	36.7	15.1	20.0	9.2
14	2 Apr – 8 Apr	43.3	56.7	50.0	61.1	23.3	13.3	20.0	13.8
15	9 Apr – 15 Apr	53.3	46.7	56.2	41.2	26.7	14.4	36.7	30.2
16	16 Apr – 22 Apr	56.7	43.3	68.8	57.1	23.3	0.0	46.7	32.7
17	23 Apr – 29 Apr	66.7	33.3	82.4	53.9	0.0	0.0	46.7	36.9
18	30 Apr – 6 May	80.0	20.0	70.0	0.0	6.7	0.0	63.3	44.1
19	7 May – 13 May	76.7	23.3	79.2	33.3	0.0	0.0	53.3	41.7
20	14 May –20 May	76.7	23.3	69.6	0.0	10.0	1.3	60.0	46.4
21	21 May– 27 May	73.3	26.7	78.3	42.9	3.3	1.1	56.7	56.2
22	28 May–3 June	80.0	20.0	77.3	12.5	6.7	2.2	66.7	57.2
23	4 June–10 June	80.0	20.0	83.3	33.3	6.7	1.5	56.7	51.3
24	11 June– 17 June	70.0	30.0	70.8	33.3	6.7	0.0	63.3	58.5
25	18 June –24 June	86.7	13.3	90.5	22.2	0.0	0.0	80.0	71.4
26	25 June –1 July	93.3	6.7	92.3	0.0	0.0	0.0	83.3	80.3
27	2 July – 8 July	90.0	10.0	89.3	0.0	3.3	0.0	86.7	86.7
28	9 July– 15 July	93.3	6.7	96.3	33.3	0.0	0.0	93.3	84.0
29	16 July– 22 July	100	0.0	100.0	0.0	0.0	0.0	90.0	80.0
30	23 July–29 July	90.0	10.0	90.0	0.0	0.0	0.0	80.0	75.0
31	30 July–5 Aug	90.0	10.0	88.9	0.0	6.7	1.1	76.7	70.3
32	6 Aug – 12 Aug	80.0	18.0	85.2	15	3.3	0.0	73.3	59.8
33	13 Aug – 19 Aug	90.0	10.0	91.7	16.7	0.0	0.0	73.3	61.6
34	20 Aug – 26 Aug	83.3	16.7	81.5	0.0	6.7	1.1	70.0	52.5
35	27 Aug –2 Sep	80.0	20.0	84.0	40.0	3.3	0.0	60.0	44.4
36	3 Sep –9 Sep	76.7	23.3	75.0	16.7	0.0	0.0	56.7	42.5
37	10 Sep – 16 Sep	75.0	25.0	73.9	0.0	6.7	2.5	60.0	30.0
38	17 Sep–23 Sep	73.3	26.7	75.0	33.3	10.0	7.1	36.7	20.6
39	24 Sep–30 Sep	53.3	46.7	50.0	37.5	33.3	23.5	30.0	18.5
40	1 Oct–7 oct	52.0	48.7	56.3	71.4	40.0	25.9	26.7	10.3
41	8 Oct–14 Oct	43.3	56.7	61.5	70.6	36.7	29.0	16.7	7.6
42	15 Oct– 21 Oct	36.7	63.3	38.5	64.7	50.0	47.6	16.7	1.9
43	22 Oct– 28 Oct	30.0	70.0	45.5	79.0	66.7	59.5	3.3	0.0
44	29 Oct–4 Nov	6.7	93.3	11.1	95.2	83.3	77.2	0.0	0.0
45	5 Nov–11 Nov	10.0	90.0	0.0	89.3	83.3	83.3	0.0	0.0
46	12 Nov– 18 Nov	6.7	93.3	0.0	92.6	93.3	93.3	0.0	0.0
47	19 Nov–25 Nov	0.0	100	0.0	100.0	100.0	96.7	0.0	0.0
48	26 Nov–2 Dec	0.0	100	0.0	100.0	96.7	93.3	0.0	0.0
49	3 Dec–9 Dec	3.3	96.7	0.0	96.7	93.3	90.1	0.0	0.0
50	10 Dec– 16 Dec	3.3	96.7	0.0	96.6	93.3	90.1	0.0	0.0
51	17 Dec–23 Dec	3.3	96.7	0.0	96.6	93.3	83.3	0.0	0.0
52	24 dec–31 Dec	3.3	96.7	0.0	96.6	93.3	93.3	0.0	0.0

Table 3. Initial, conditional and consecutive probabilities of Morigaon at 20 mm threshold limit.

SMW	Period	P(W)	P(D)	P(W/W)	P(D/D)	P(2D)	P(3D)	P(2W)	P(3W)
1	1 Jan – 7 Jan	4.8	95.2	0.0	92.9	90.7	90.7	4.8	0.0

2	8 Jan – 14 Jan	9.1	90.9	0.0	100.0	90.9	82.6	0.0	0.0
3	15 Jan – 21 Jan	0.0	100.0	0.0	100.0	90.9	86.4	0.0	0.0
4	22 Jan – 28 Jan	9.1	90.9	0.0	93.3	86.4	78.1	0.0	0.0
5	29 Jan – 4 Feb	4.6	95.5	0.0	96.4	86.4	77.7	0.0	0.0
6	5 Feb – 11 Feb	9.1	90.9	0.0	96.6	81.8	69.6	0.0	0.0
7	12Feb – 18Feb	9.1	90.9	0.0	96.6	77.3	77.3	0.0	0.0
8	19 Feb – 25 Feb	13.6	86.4	0.0	92.9	86.4	86.4	0.0	0.0
9	26 Feb - 4 Mar	0.0	100.0	0.0	100.0	100.0	95.5	0.0	0.0
10	5 Mar – 11 Mar	0.0	100.0	0.0	100.0	95.5	63.6	0.0	0.0
11	12Mar – 18 Mar	4.6	95.5	0.0	90.0	63.6	36.4	4.6	2.8
12	19 Mar – 25 Mar	36.4	63.6	28.6	77.8	36.4	26.5	22.7	8.3
13	26 Mar – 1 Apr	40.0	50.0	36.4	56.5	36.4	21.8	18.2	5.2
14	2 Apr – 8 Apr	31.8	68.2	62.5	61.1	40.9	20.5	9.1	4.6
15	9 Apr – 15 Apr	36.4	63.6	56.4	41.2	31.8	17.4	18.2	11.6
16	16 Apr – 22 Apr	50.0	50.0	50.0	57.1	27.3	2.7	31.8	23.9
17	23 Apr – 29 Apr	54.6	45.5	63.6	53.9	4.6	1.1	40.9	22.7
18	30 Apr – 6 May	61.8	18.2	75.0	0.0	4.6	1.5	45.5	31.5
19	7 May – 13 May	59.1	40.9	55.6	33.3	13.6	3.9	40.9	30.0
20	14 May –20 May	68.2	31.8	69.2	0.0	9.1	0.0	50.0	37.5
21	21 May– 27 May	72.7	27.3	73.3	42.9	0.0	0.0	54.6	52.5
22	28 May–3 June	81.8	18.2	75.0	12.5	4.6	3.0	72.7	65.1
23	4 June–10 June	86.4	13.6	88.9	33.3	9.1	4.6	77.3	73.0
24	11 June– 17 June	81.8	18.2	89.5	33.3	9.1	0.0	77.3	73.2
25	18 June –24 June	86.4	13.6	94.4	22.2	0.0	0.0	81.8	81.8
26	25 June –1 July	95.5	4.6	94.7	0.0	0.0	0.0	95.5	91.1
27	2 July – 8 July	100.0	0.0	100.0	0.0	0.0	0.0	95.5	81.8
28	9 July– 15 July	95.5	4.6	95.5	33.3	0.0	0.0	81.8	73.2
29	16 July– 22 July	86.4	13.6	85.7	0.0	0.0	0.0	77.3	65.7
30	23 July–29 July	90.9	9.1	89.5	0.0	4.6	1.1	77.3	64.4
31	30 July–5 Aug	81.8	18.2	85.0	0.0	4.6	1.1	68.2	60.6
32	6 Aug – 12 Aug	81.8	18.2	83.3	15	4.6	0.0	72.7	57.4
33	13 Aug – 19 Aug	86.4	13.6	88.9	16.7	0.0	0.0	68.2	56.8
34	20 Aug – 26 Aug	81.8	18.2	79.0	0.0	4.6	1.1	68.2	64.4
35	27 Aug –2 Sep	81.8	18.2	83.3	40.0	4.6	0.0	67.3	46.4
36	3 Sep –9 Sep	90.9	9.1	94.4	16.7	0.0	0.0	54.6	39.0
37	10 Sep – 16 Sep	63.6	36.4	60.0	0.0	9.1	3.0	45.5	28.4
38	17 Sep–23 Sep	72.7	27.3	71.4	33.3	9.1	1.1	45.5	26.0
39	24 Sep–30 Sep	63.6	36.4	66.7	37.5	4.6	2.6	36.4	17.0
40	1 Oct–7 oct	68.2	31.8	62.5	71.4	18.2	12.1	31.8	9.6
41	8 Oct–14 Oct	45.5	54.6	57.1	70.6	36.4	31.5	13.6	2.0
42	15 Oct– 21 Oct	31.8	68.2	46.7	64.7	59.1	59.1	4.6	3.0
43	22 Oct– 28 Oct	13.6	86.4	30.0	79.0	86.4	73.4	9.1	0.0
44	29 Oct–4 Nov	9.1	90.9	14.3	95.2	77.3	79.1	0.0	0.0
45	5 Nov–11 Nov	13.6	86.4	0.0	89.3	77.3	73.4	0.0	0.0
46	12 Nov– 18 Nov	9.1	90.9	0.0	92.6	86.4	82.3	0.0	0.0
47	19 Nov–25 Nov	4.6	95.5	0.0	100.0	90.9	90.9	0.0	0.0
48	26 Nov–2 Dec	4.6	95.5	0.0	100.0	95.5	91.1	0.0	0.0
49	3 Dec–9 Dec	0.0	100.0	0.0	96.7	95.5	95.5	0.0	0.0
50	10 Dec– 16 Dec	4.6	95.5	0.0	96.6	95.5	95.5	0.0	0.0
51	17 Dec–23 Dec	0.0	100.0	0.0	96.6	100.0	95.5	0.0	0.0
52	24 dec–31 Dec	0.0	100.0	0.0	96.6	100.0	95.5	0.0	0.0

3.2 Moisture Availability Index (MAI*)*

In order to assess the water potential for crop planning, moisture adequacy index was studied to understand the soil moisture availability and its variation during the year. The crop growth period is considered as the period when MAI > 0.5 during active growth period. MAI value between 0.5 and 0.3 is considered to be moderate drought period and MAI value less than 0.25 is considered as severe drought period. In the present study, the weekly MAI values for Nagaon district (Fig. 2, 3, 4) and Morigaon district (Fig. 5, 6, 7) ranges between 0.3 – 0.5 during beginning and end of the year in all types of soil. The analysis revealed that the period from 26th SMW (25th June – 01st July) onwards is most suited sowing time of *kharif* crops as MAI reaches 1 on 26th SMW in all types of soil for both the districts. As per the study, there is very less chance of occurrence of moisture stress during the whole crop growth period. In case of sandy loam soil, the weekly MAI dropped below 0.5 towards 48th and 49th SMW (Fig 3 & 4) in Nagaon and Morigaon respectively indicating that terminal moisture stress condition for post-monsoon crop. Weekly values of MAI suggest possibility of growing *rabi* crops after *kharif* crops. The probable time of sowing of *rabi* crops are assumed to be the week when the soil moisture storage is sufficient to meet the full evaporation demand. A study by Gupta *et al*. (1975)[9] revealed that 50 per cent probability level is the maximum limit for taking risk and can be effectively used to determine the moisture availability period for crop planning.

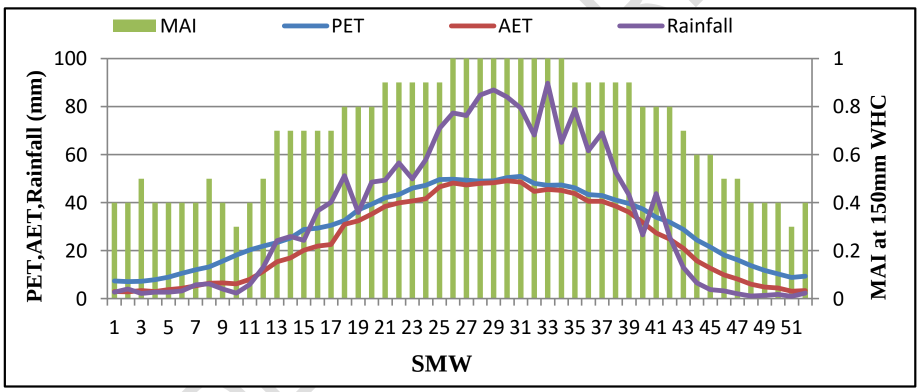

Fig. 2: Weekly MAI in Nagaon at 150 mm WHC.

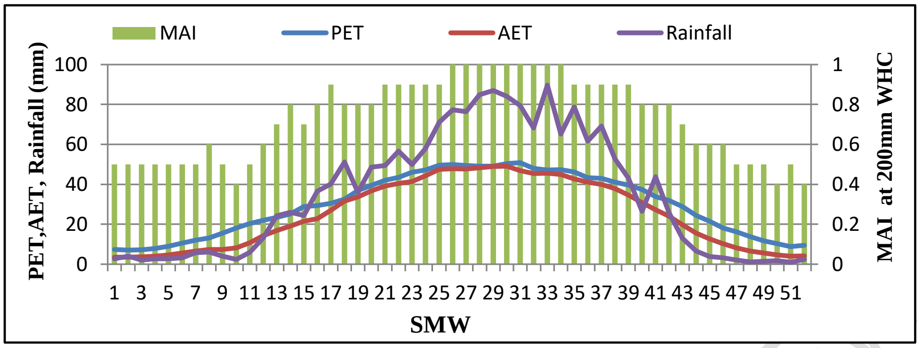

Fig. 3: Weekly MAI in Nagaon at 200 mm WHC

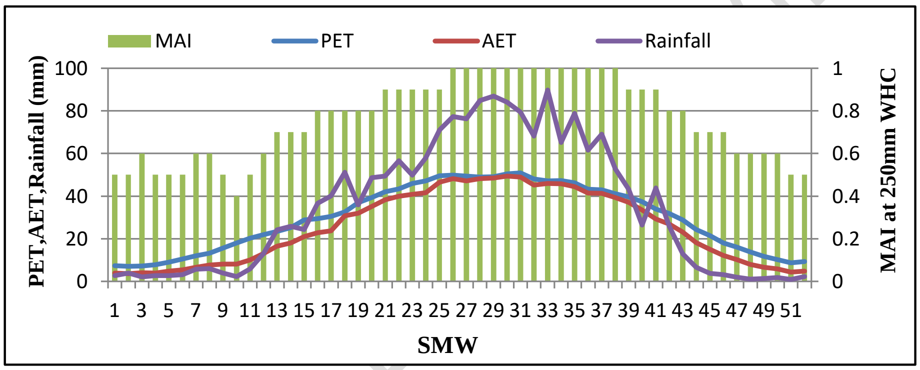

Fig. 4: Weekly MAI in Nagaon at 250 mm WHC.

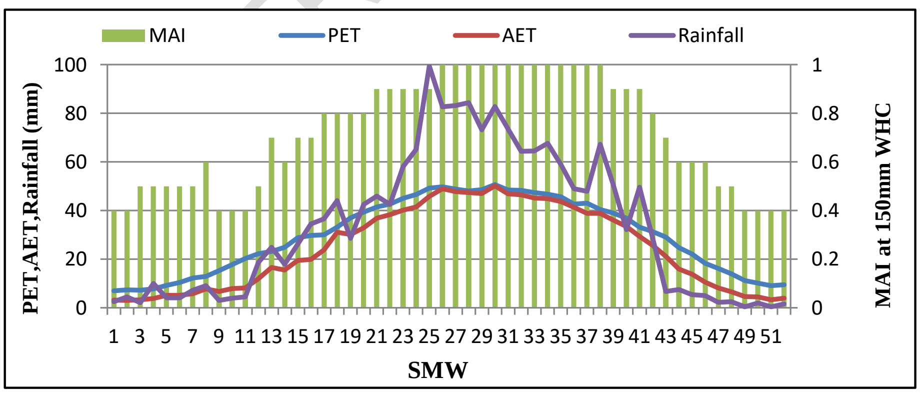

Fig. 5: Weekly MAI in Morigaon at 150 mm WHC

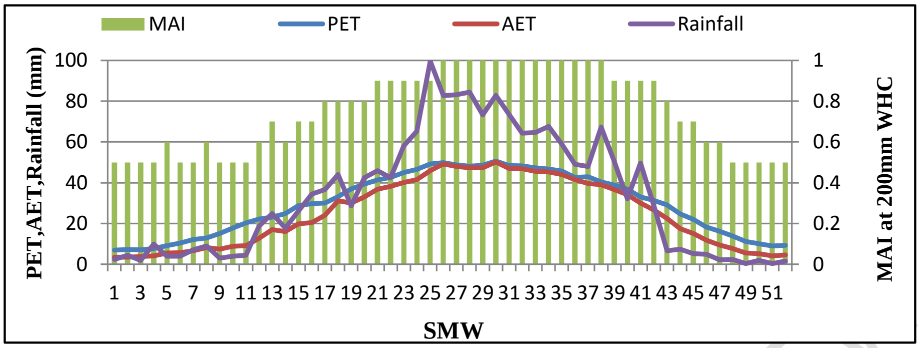

Fig. 6: Weekly MAI in Morigaon at 200 mm WHC

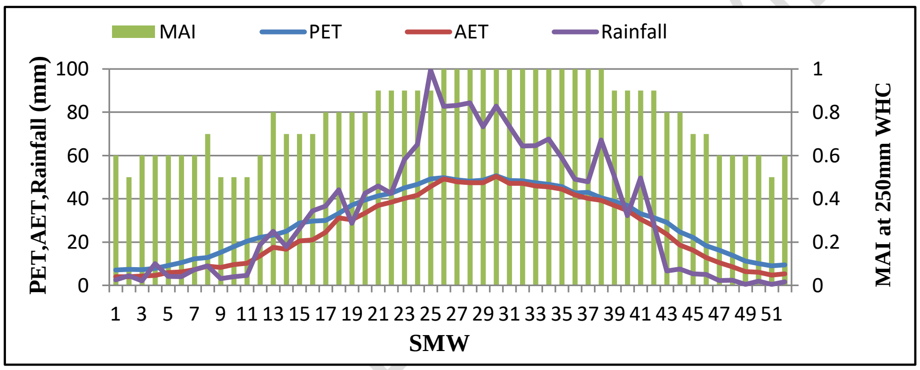

Fig. 7: Weekly MAI in Morigaon at 250 mm WHC

3.3 Crop Planning

Agro-climatic conditions of the whole study area is quite similar, hence crops and cropping patterns in both the districts are same and do not vary much. In CBVZ, *kharif* season is most suitable for crop production as there will be no shortage of moisture during this period. Farmers in the area *i.e.,* CBVZ generally follow mono-cropping. Major crops grown in the region include rice, sugarcane, rapeseed, tea, winter vegetables etc.

From the results obtained, it is seen that, summer crops can be sown ~~form~~ from the month of February - March utilizing the pre-monsoon shower. Summer greengram and blackgram can be grown from 13th SMW (26th March – 1st April) onwards with pre-sowing irrigation as there is more than 50 per cent probability of receiving dry week till 14th and 15th SMW in Nagaon and Morigaon districts (Table 2 & 3) respectively. Similar results have been found by Deka *et al.* (2000)[4] in Upper Brahmaputra Valley zone of Assam where it has been suggested to sow rainfed summer ~~corps~~ crops from 11th SMW. Sowing of direct – seeded ahu rice in low land areas can also be started from 13th SMW onwards in both the districts as MAI value of 0.7 exist during that period (Fig 4 & 7) and from 15th SMW (9th April – 15th April) onwards probability of wet week is more than 50 per cent (Table 2 & 3) in both the districts. Paddy is not recommended in uplands because there may be moisture deficit during the initial stages and it requires high amount of water throughout its growth period. In case of transplanted ahu rice, sowing in nursery beds can be done from 13^{th} SMW. As the probability of wet week increases from 15^{th} – 16^{th} SMW (Table 2 & 3) transplanting can be done.

Sali rice requires high temperatures and large amount of water. Fig. 2 - 7 shows that, *Sali* rice can be successfully grown from mid June to Mid September where the value of MAI is 100 per cent and the areas for rice cultivation will not require supplemental irrigation. Preparation of nursery beds for long duration *sali* rice can be started form 20^{th} - 21^{th} SMW in both the districts as the probability of receiving wet weeks is more than 70 per cent (Table 2 & 3). Dabral *et al.* (2014)[3] also suggested similar dates for land preparation of wet land rice in North Lakhimpur district of Assam. Transplanting may be done during 25^{th} - 30^{th} SMW as MAI value remain between 0.9 – 1.0 (Fig 2 - 7) with probability of wet weeks more than 70 per cent. Banik *et al.* (2009)[2] also suggested transplanting of rice by 27^{th} – 28^{th} week in eastern plateau of India.

Sowing of short duration sesame may be done during 30^{th} – 31^{st} SMW (23^{rd} July – 5^{th} Aug) with high MAI value of 1.0. In the state of Assam, maize is grown in the *rabi* season with length of growing period ranging between 80-110 days. Sowing of *rabi* maize may be done during 40^{th} – 43^{rd} SMW (1^{st} – 28^{th} Oct) when MAI ranges between 0.8 to 0.9 in both the districts.

Based on results obtained, it was revealed that the *rabi* crops have to be raised under moisture stress conditions. The crops should be able to use residual soil moisture more judiciously as reliability of getting adequate weekly rainfall is low. Oil seed crops like rapeseed and mustard, linseed, niger can be sown in the *rabi* sown from October to November. Rapeseed requires relatively cool temperature and grows well in areas having less rainfall and so it perfectly fits in *rabi* season.

Post monsoon rainfall is highly uncertain and it is highly risky to grow water consuming crops during this period without supplemental irrigation. Transplanting of vegetable crops such as broccoli, cabbage, knolkhol, cauliflower, tomato and commercially important flowers like gerbera, tuberose, gladiolus can be done from 40^{th} SMW (1^{st} – 7^{th} Oct) onwards in both the districts as there is equal to or more than 60% chance of getting dry weeks. Supplemental irrigation has to be provided while transplanting of such crops. Sowing of tuber crops like potato can be started from 43^{rd} SMW with MAI ranging between 0.6 – 0.7 indicating presence of residual moisture in the soil. Hazarika *et al.* (2019)[10] also suggested transplanting of potato from 43^{rd} week as probability of getting dry week is high from that period. Since rainfall during *rabi* season is less, it would be advantageous to adopt moisture conservation practices like mulching, timely sowing, optimum plant population to increase and stabilize production.

Few suggested cropping patterns for the studied area is presented in ~~table~~ Table 4.

Table 4: Suggested cropping patterns for the region

Uplands		
Summer	*Kharif*	*Rabi*
Green gram / balck gram / sesame	*Kharif* vegetables / pigeon pea / black gram / greengram	Rabi veg / toria/ maize / oats
Ginger / turmeric / green gram / black gram	-	Potato / pea / toria / lathyrus / oats / maize
Medium lands		
Summer	*Kharif*	*Rabi*
Jute / ahu rice / maize / green gram / black gram	*Sali* rice / green gram / black gram	Toria /wheat / pea / potato / vegetables / lentil
Ahu Rice	Pigeon pea	-
Lowlands and flood prone condition		

Summer	*Kharif*	*Rabi*
Early Ahu (irrigated)	Late *sali*	-
Green gram / black gram	*Sali* rice	Pea / potato / toria / vegetables / wheat

4. CONCLUSION

The present investigation estimated the rainfall probability and soil moisture availability in the study area throughout the year along with climatological risk of dry spells. Weekly rainfall is found to be stable during the monsoon period and highly variable during winter season. The region received sufficient amount of rainfall from pre-monsoon season itself with probability of wet weeks more than 50 per cent from 15th week, hence summer crops can be grown in rainfed condition. But harvesting of summer crops becomes a problem due to heavy rainfall as probability of initial, conditional and consecutive wet weeks is more than 60 per cent during the harvesting period of summer crops. So, sowing of summer crops is suggested to be done as ~~as~~ early as possible so that harvesting can be done early. MAI value indicates abundant moisture availability in the *kharif* season with MAI value of 1 and moderate moisture stress during *rabi* and summer season. The analysis revealed that the period from 26th SMW (25th June – 1st July) and onwards as most suited sowing time of *kharif* crops. Period from 41st – 42nd SMW is ideal time for transplanting of vegetable crops and other *rabi* crops as probability of wet weeks from that period is less than 50 per cent. Results obtained in this study will be useful for various stakeholders of this region for better crop management and planning.

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