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Meteorological Drought Occurrences in Ri-Bhoi District of Meghalaya

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Abstract: A large area under rainfed agriculture is expected to suffer due to change in rainfall pattern, temperature and extreme events over the next several decades. Ri-bhoi district of Meghalaya one of the major rice producing belts in the state and its agriculture is mostly under rainfed condition. Daily point rainfall data of sixteen years (1990-2005) were analysed to study monthly, seasonal and yearly drought occurrence using India Meteorological Department (IMD) protocols. The average annual rainfall of Nongpoh- head quarter of Ri-Bhoi district is 2,114 7 mm with 117 numbers of rainy days. During the sixteen years period no extreme and moderate drought incidents were observed, however, there were mild drought occurrences in eight years. A decreasing trend in annual rainfall for this station was also observed. The frequency of drought month for the January, February, November and December was 9, 8, 8 and 11; respectively.

Key words: *Climate change, drought year, extreme weather events, meteorological drought, rainfall analysis*.

Introduction

Maintaining food security for growing population of our country, India is one of the major challenges in the present scenario of climate change. Since the per unit area productivity in irrigated areas is reaching almost a plateau, it is often argued that, bulk of the future increase in food production has to come from rain-fed areas. Around 60% of the cultivable area in India is rain-fed (Gautam and Rao 2008; Mongi *et al.* 2010; Sohoulande *et al.* 2019).

Temporal and spatial variability of rainfall distribution is observed in India (Dash *et al*. 2007; Harrington and Tow 2011; Dkhar *et al*. 2017; Kala, 2017). In India around 75% of the rainfall occurs during June to September spread over with an average 120 number of rainy days in a year. Extreme conditions of rainfall are also observed in certain years. Floods and droughts are the two extremes of rainfall distribution. Deficiency of rainfall is the basic cause of drought. As such no general method is available which can be applied for the drought prediction (Salas 1986). Depending on the climate, the incidence of drought varies from place to place.

Point rainfall has been analysed by various researchers to derive conclusions on distribution of rainfall (Satapathy *et al*. 1998; Satapathy *et al*. 1999; Chakraborty and Mandal 2008; Jakhar *et al*. 2011; Ray *et al*. 2012a; Ray *et al*. 2013d; Ray *et al*. 2014 a,b; Ray *et al*. 2015 b), maximum probable rainfall (Ray *et al*. 2012a; Ray *et al*. 2013b), contingency crop planning (Sinha 1986; Sharma *et al*. 1987a, 1987b; Ray *et al*. 2014 c; Ray *et al*. 2019) and impact of drought on livelihood (Shrivastava *et al*. 2008; Singh *et al*. 2013). Several researchers have done meteorological drought analyses based on rainfall data (Ray *et al*. 1987; Kumar and Kumar 1989; Dabral 1996; Shrivastava *et al*. 2008; Marathe *et al*.

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2001; Tiwari *et al*. 2007; Ray *et al*. 2012b; Ray *et al*. 2013a, c; Ray *et al*. 2015a). Similarly, (Sharma *et al*. 1979, 1987a. and 1987b); Salas 1986 analyzed the rainfall using the definition of drought month as a month in which the actual rainfall is less than 50% of the average monthly rainfall. Drought year is the year receiving rainfall less than or equal to the average rainfall minus twice standard deviation of the series. (Shrivastava *et al*. 2008) used this definition to assess meteorological droughts in North Lakhimpur district of Assam. Similar analysis has been done by various researchers for meteorological drought analysis at various places in India.

This research paper describes about the frequency of drought occurrence at Ri-Bhoi district of Meghalaya using the data recorded at Nongpoh station which the headquarter of the Ri-bhoi district.

Materials and Methods

Nongpoh is located at $91^0_4 0'16"$ East Longitude and $25^0_4 0`$ to $26^0 20`$ North Latitude with an altitude of 620 m above mean sea level. The behavioral pattern of rainfall with reference to the amount of rainfall and number of rainy days at Nongpoh were analyzed using probabilistic approach (Weibull method) from historic daily rainfall records (1990-2005) (Eq.1).

Weibull`s formula.

$$p = \frac{m}{n+1} \qquad \ldots (1)$$

Where,
p - probability of occurrence,
m - rank number and
n - number of years of data used

The monthly rainfall, seasonal rainfall June to September-monsoon; October to December and January to May) and yearly rainfall were analyzed. The average monthly, seasonal and yearly rainfall was determined. The variation of rainfall for each month, season and year from the mean was determined and the deviation for the seasons was calculated. Total numbers of drought months, seasons and year were determined using the following definition:

Drought month: if the actual rainfall is less than 50% of the average monthly rainfall (Sharma *et al*. 1979). Drought season: if the annual rainfall is deficient by more than twice the mean deviation of the season (Marathe *et al.* 2001). Drought year: if the annual rainfall is deficient by 20-60% of the average yearly rainfall and if the deficient is more than 60% of the average yearly rainfall it is known as scanty drought year (IMD 1971). The yearly intensity of drought was also determined using the criteria suggested by IMD (1971) which is based on the percentage deviation of rainfall from its long term mean and it is given by (Eq.2).

$$D_i = \left(\frac{P_i - \mu}{\mu} \right) \times 100 \qquad \ldots (2)$$

Where,
D_i is the percentage deviation from the long-term mean,
P_i is the annual rainfall, mm and
μ is the long term mean of the annual rainfall, mm
Drought codification based on percentage departure of rainfall from normal is presented in Table-1. The percentage of deviation (D_i) is then used to categorise the drought.

Table 1. Drought based on percentage departure of rainfall from normal value

% departure of rainfall from normal	Intensity of drought	Code
0.0 or above	No drought	M_o
0.0 to -25.0	Mild drought	M_1
-25.0 to -50.0	Moderate drought	M_2
-50.0 to -75.0	Severe drought	M_3
-75.0 or less	Extreme drought	M_4

Results and Discussion

Descriptive statistical analysis of monthly rainfall was done for Nongpoh station, Meghalaya. The quantum of rainfall available on standard meteorological week (SMW) basis was calculated and is shown in Fig.1. It may be noted from the figure that, the amount of assured rainfall decreases as the probability level increases. However, during 22nd to 36th SMW, there is an assured rainfall. The weekly extreme and normal rainfall, standard deviation (SD), coefficient of variation (CV) and percentage of contribution were determined (Table 2).

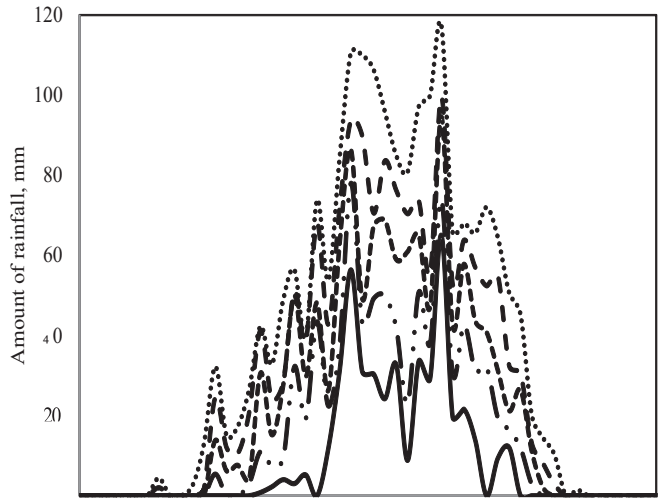

Fig.1 Probability distribution of amount of rainfall in a standard week

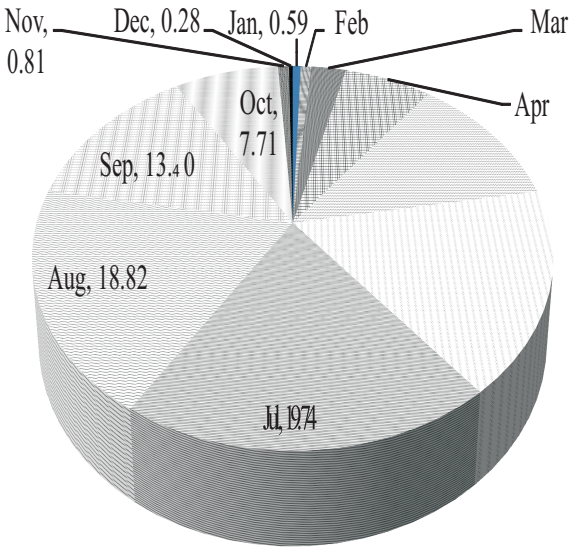

Fig. 2 Monthly distribution of rainfall

The coefficient of variation was found less than 100% between 16th to 39th SMW. The maximum recorded rainfall was in 40th SMW amounting to 326.4 mm. The normal weekly rainfall was found almost more than 100 mm between 25th to 33rd SMW. The weekly drought analysis is presented in Table 3. It may be noted from the Table-3 that the percentage drought week are less than 10% and 33rd SMW was always a wet week. The monthly percentage rainfall distribution is shown in Fig.2. The June, July and August months contribute around 69% of rainfall in Ri-Bhoi district. The coefficient of variation is more than 100% for the month of January, February, November and December both for amount of rainfall and number of rainy days. Standard deviation was maximum for the month of August and minimum for the month of December. The monthly rainfall analysis for drought is presented in Table 4. The highest normal rainfall of 423.83 mm was observed in the month of July and the lowest 6.02 mm in the month of December.

Table 2. Weekly Extreme and Normal rainfall, SD, CV and Percentage of contribution

Standard Met Week (SMW)	Extreme value		Normal (mm)	Standard Deviation (mm)	Coefficient of Variation (%)	Percentage of Contribution (%)
	Minimum (mm)	Maximum (mm)				
1.	0.0	4.0	0.25	1.00	400.00	0.01
2.	0.0	69.9	4.98	17.37	348.67	0.23
3.	0.0	15.4	2.15	4.73	219.78	0.10
4.	0.0	38.8	4.43	10.67	240.86	0.21
5.	0.0	18.0	3.49	5.88	168.70	0.16
6.	0.0	18.2	1.94	4.70	241.70	0.09
7.	0.0	19.6	2.64	5.32	201.54	0.12
8.	0.0	45.8	8.31	12.76	153.45	0.39
9.	0.0	16.6	2.64	4.63	175.10	0.12
10.	0.0	22.8	3.26	6.40	196.42	0.15
11.	0.0	37.0	7.03	10.19	144.93	0.33
12.	0.0	74.8	18.91	24.11	127.48	0.88
13.	0.0	59.4	30.07	21.72	72.24	1.40
14.	0.0	82.4	19.48	22.05	113.25	0.91
15.	0.0	120.2	23.12	29.65	128.27	1.08
16.	0.0	87.4	27.89	27.01	96.84	1.30
17.	0.8	141.4	56.99	41.63	73.04	2.65
18.	2.2	137.6	46.31	42.67	92.15	2.16
19.	4.0	237.4	57.65	57.46	99.66	2.69
20.	3.0	108.3	61.33	30.02	48.95	2.86
21.	5.2	79.2	46.86	25.64	54.71	2.18
22.	0.0	121.0	67.31	31.25	46.43	3.14
23.	11.8	131.8	57.37	35.32	61.57	2.67
24.	31.2	174.2	86.38	41.95	48.57	4.02
25.	56.4	221.3	116.90	46.56	39.83	5.44
26.	31.0	266.2	103.60	62.66	60.49	4.83
27.	30.4	243.6	102.75	57.61	56.06	4.79
28.	24.2	203.2	94.79	45.37	47.86	4.42
29.	32.8	188.0	96.95	51.23	52.84	4.52
30.	8.8	150.2	76.34	38.47	50.39	3.56
31.	33.6	174.0	97.73	43.87	44.89	4.55
32.	29.2	234.2	95.95	62.44	65.07	4.47
33.	65.0	158.8	108.49	26.85	24.75	5.05
34.	19.6	196.4	75.65	47.46	62.74	3.52
35.	21.6	208.8	86.94	54.41	62.59	4.05
36.	13.8	136.1	63.41	30.40	47.95	2.95
37.	0.0	227.4	82.24	60.73	73.84	3.83
38.	9.4	132.4	63.34	39.68	62.66	2.95
39.	12.0	150.8	52.24	37.13	71.09	2.43
40.	0.0	326.4	70.19	83.07	118.35	3.27
41.	0.0	130.4	31.93	37.89	118.70	1.49
42.	0.0	186.4	39.47	61.67	156.25	1.84
43.	0.0	78.0	18.30	24.80	135.51	0.85
44.	0.0	56.4	7.66	16.16	210.89	0.36

45.	0.0	18.4	4.28	6.34	148.23	0.20
46.	0.0	58.8	4.14	14.69	355.12	0.19
47.	0.0	29.2	5.91	9.97	168.59	0.28
48.	0.0	17.0	1.78	4.79	268.84	0.08
49.	0.0	5.4	0.59	1.45	247.51	0.03
50.	0.0	27.2	1.95	6.80	348.69	0.09
51.	0.0	4.8	0.56	1.54	273.95	0.03
52.	0.0	22.8	2.20	6.14	279.06	0.10

Table 3. Weekly rainfall analysis for drought

Standard week	Average rainfall, mm	Half of the average rainfall, mm	No of drought week	Percentage of drought week
523 (4 th to 10th June)	57.4	28.68	5	8.47
24 (11th to 17th June)	86.4	43.19	4	6.78
25 (18th to 24 th June)	116.9	58.45	1	1.69
26 (25th to 1st July)	103.6	51.80	5	8.47
27 (2ndto 8th July)	102.8	51.38	3	5.08
28 (9th to 15th July)	94.8	47.40	2	3.39
29 (16th to 22nd July)	97.0	48.48	4	6.78
30 (23rd to 29th July)	76.3	38.17	3	5.08
31(30th to 5th August)	97.7	48.86	2	3.39
32 (6th to12th August)	96.0	47.98	5	8.47
33 (13th to 19th August)	108.5	54.24	0	0.00
34 (20th to 26th August)	75.7	37.83	4	6.78
35 (27th to 2nd September)	86.9	43.47	3	5.08
36 (3rd to 9th September)	63.4	31.70	3	5.08
37 (10th to 16th September)	82.2	41.12	5	8.47
38 (17th to 23rd September)	63.3	31.67	5	8.47
39 (24 th to 30th September)	52.2	26.12	5	8.47

Table 4. Monthly normal and extreme rainfall (number of rainy days) along with SD, CV and percentage contribution

Month	Normal (mm)	Extreme Value		Standard Deviation (mm)	Coefficient of Variation (%)	Percentage contribution (%)
		Minimum (mm)	Maximum (mm)			
January	12.69	0	75.5	20.48	161.44	0.59
	(0.94)	(0)	(3)	(1.18)	(126.02)	(0.80)
February	17.00	0	64.2	17.84	104.93	0.79
	(1.88)	(0)	(6)	(1.86)	(99.06)	(1.61)
March	55.08	5.4	131.6	40.95	74.35	2.57
	(4.38)	(1)	(9)	(2.75)	(62.94)	(3.75)
April	138.08	32.2	326.4	84.38	61.11	6.43
	(9.88)	(4)	(17)	(3.90)	(39.46)	(8.46)
May	254.33	113.8	471.4	86.44	33.99	11.85
	(14.88)	(9)	(21)	(3.22)	(21.66)	(12.75)
June	365.47	215.2	600.4	102.86	28.15	17.02
	(18.25)	(13)	(24)	(3.15)	(17.27)	(15.64)
July	423.83	249	621.7	108.54	25.61	19.74
	(20.75)	(13)	(27)	(3.34)	(16.08)	(17.78)
August	404.00	249	583.4	98.67	24.42	18.82
	(20.44)	(16)	(26)	(2.71)	(13.25)	(17.51)
September	287.63	128	470.4	90.07	31.31	13.40
	(15.25)	(11)	(23)	(3.55)	(23.28)	(13.07)
October	165.57	46.8	347.2	101.09	61.05	7.71
	(8.00)	(4)	(15)	(3.18)	(39.79)	(6.86)
November	17.36	0	68.8	20.05	115.51	0.81
	(1.38)	(0)	(3)	(1.36)	(98.92)	(1.18)
December	6.02	0	42.8	12.01	199.62	0.28
	(0.69)	(0)	(4)	(1.40)	(203.77)	(0.59)

The seasonal and monthly drought analysis is presented in Table 5. The frequency of drought was observed to be the highest with a magnitude of 11 times in 16 years in December, while it is 9, 8, 8 and 6 times in 16 January, February, November and March month; respectively (Table 5). It indicates that, there is a need for assured irrigation in the above months. The average monthly rainfall is 138.08, 254.33, 365.47, 423.83, 404.00, 287.63 and 165.57 mm for the month of April, May, June, July, August, September and October, respectively. The maximum average rainfall is received during the month of July to a tune of 423.83 mm and the minimum average rainfall is received during the month of December to a tune of 6.02 mm. The seasonal distribution

of rainfall is shown in Fig.3. From the seasonal analysis of the rainfall, it is evident that 22.2% of rainfall was received during pre-monsoon, 69% during monsoon and 8.8 % during post-monsoon season. For growing winter season crops during post-monsoon season assured irrigation facilities need to be provided, simultaneously ample emphasis may be given to rainwater harvesting during the monsoon season as a high runoff is anticipated during this seasons. No drought was observed during monsoon and, pre-monsoon seasons. However for post-monsoon period there was mild drought occurrence.

The yearly intensity of drought for Nongpoh, Meghalaya is presented in Table 6. There is a decreasing trend in annual rainfall as shown in Fig.4 . The average annual rainfall of Nongpoh is 2,14 7.05 mm with a maximum of 2,4 96.7 mm corresponding to the year 1991 and a minimum of 1,766.8 mm corresponding to the year 1996. The years are codified according to IMD specification as described in the Table 1. It is found from the Table-6 that, there was no severe drought occurrence. However, for the year 194 ; 1996; 1998; 2001; 2002; 2003; 204 and 2005 mild drought occurrence was found for Ri-Bhoi district of Meghalaya.

Table 5. Analysis of monthly and seasonal rainfall for drought

Month/ Season	Name of month/season	Average rainfall, mm	Half of the average rainfall, mm	No. of drought, month/season/ year	Percentage of drought months
Month	Jan	12.69	6.34	9	16.98
	Feb	17.00	8.50	8	15.09
	Mar	55.08	27.54	6	11.32
	Apr	138.08	69.04	4	7.55
	May	254 .33	127.17	1	1.89
	Jun	365.4 7	182.73	0	0.00
	Jul	4 23.83	211.91	0	0.00
	Aug	4 04 .00	202.00	0	0.00
	Sep	287.63	14 3.82	1	1.89
	Oct	165.57	82.78	5	9.4 3
	Nov	17.36	8.68	8	15.09
	Dec	6.02	3.01	11	20.75
			(Twice the mean dev value, mm)		
Season	Pre monsoon	4 77.18	238.6	0	
	Monsoon	14 80.93	74 0.5	0	
	Post monsoon	188.95	94 .5	9	
			(80% of average rainfall)		
			1717.64	2	
			(4 0% of average rainfall)		
			858.82(Scanty)	0	

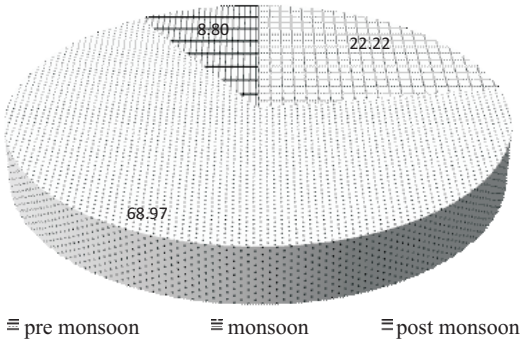

Fig. 3 Yearly distribution of rainfall

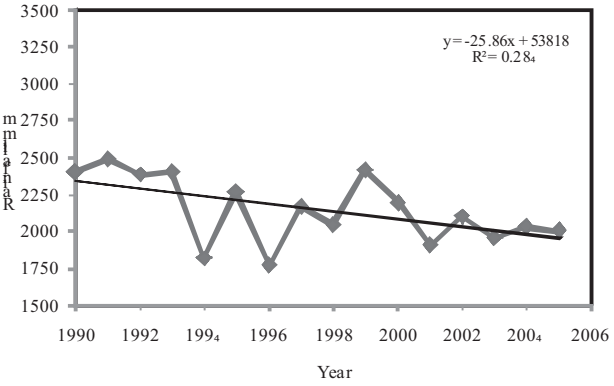

Fig. 4 Trend in Yearly distribution of rainfall

Table 6. Yearly intensity of drought

Year	Annual rainfall, mm	Mean Rainfall, mm	% deviation	Category	Intensity of Drought
1990	2400.7	2147.05	11.81	M_o	No drought
1991	2496.6	2147.05	16.28	M_o	No drought
1992	2388.4	2147.05	11.24	M_o	No drought
1993	2407.6	2147.05	12.14	M_o	No drought
1994	1815.4	2147.05	-15.45	M_1	Mild drought
1995	2267.6	2147.05	5.61	M_o	No drought
1996	1766.8	2147.05	-17.71	M_1	Mild drought
1997	2172.4	2147.05	1.18	M_o	No drought
1998	2042.6	2147.05	-4.86	M_1	Mild drought
1999	2414.9	2147.05	12.48	M_o	No drought
2000	2194.1	2147.05	2.19	M_o	No drought
2001	1905.6	2147.05	-11.25	M_1	Mild drought
2002	2096.9	2147.05	-2.34	M_1	Mild drought
2003	1957	2147.05	-8.85	M_1	Mild drought
2004	2026.8	2147.05	-5.60	M_1	Mild drought
2005	1999.4	2147.05	-6.88	M_1	Mild drought

It has been observed that, there is a significant decrease of annual rainfall for Nongpoh station, Meghalaya. Under the scenario of climate change this indicates a serious concern for the rice based farmers of this region. The amount of rainfall is not decreasing; it has a direct impact on the grain yield potential. The annual variation of rainfall at Nongpoh station is very erratic. The annual average rainfall of this region is 2,147.05 mm. The year 1996 received a less amount of rainfall of 1766.8 mm and the year 1991 received a maximum of 2,496.7 mm but later it goes on decreasing. The drought analysis of the station, suggests going for short duration rice variety as vivek dhan, and assuring supplementary irrigation for rice during sensitive stage of the crop to overcome the difficulties of yield reduction.

Conclusions

The drought analysis of Nongpoh made according to deficiency of rainfall shows that out of sixteen years there was no severe drought occurrence in this region. However, for the year 199₄; 1996; 1998; 2001; 2002; 2003; 200₄ and 2005 there was mild drought occurrence. For growing rain-fed rice during monsoon farmers of this region may depend on monsoon rainfall as there was hardly any drought occurrence. Since the post-monsoon seasonal rainfall is very less, for growing winter season crops arrangement may be made for assured irrigation with proper rainwater harvesting methods.

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