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Impact and Assessment of Meteorological Drought on Rice Based Farming System in *East Garo Hills* District of Meghalaya, India

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ABSTRACT

A study was carried out to learn about the drought pattern and its impact on rice mono cropping in Williamnagar (East Garo Hills district of Meghalaya) having rice based mono cropping system. The rainfall analysis was done based on twelve years (1998-2009) daily rainfall data to study monthly, seasonal and yearly drought of Williamnagar based on India Meteorological Department (IMD) protocols. The average annual rainfall of Williamnagar is 3246 mm with 115 numbers of rainy days. During the twelve years period no extreme and moderate drought years were experienced, but there were mild drought occurrences in nine years. The frequency of drought month recorded for the January, February, November and December was 8, 6, 7 and 10, respectively out of 12 years of record. This study revealed that for growing rain-fed rice during monsoon farmers of this region may depend on monsoon as there was hardly any drought occurrence. This study reveal that, winter rice, may needs assured irrigation, because there is fair chance of occurrence of moderate drought during November to February due to very less post monsoon rainfall.

Keywords: Climate change, meteorological drought, rainfed rice, drought year, Meghalaya

INTRODUCTION

Meghalaya is one of the highest rainfall receiving states of India which has rice based mono cropping system. Rain-fed rice cultivation is mostly practiced in Meghalaya. Williamnagar (East Garo Hills district of Meghalaya) is the major rice producing belt of this state. Climate change triggered by global warming is one of the major environmental stresses; the world is facing currently (Singh *et al.*, 2012). Drought is one of the major environmental stresses limiting rainfed agriculture (Singh and Kumar, 2009). Hilly states of India are mostly rainfed and are more or less coming under high rainfall zones. Rainfall plays a pivotal role in agricultural production (Singh *et al.*,2008).The mean global temperatures are expected to rise over the next few decades, leading to increased evaporation rates (Houghton *et al.*, 2001; European Environment Agency, 2004), causing a concern in the rainfed areas. Water scarcity and its increased competition among different sectors are forcing the planners and farmers to consider alternative practices to overcome such situations (Costa *et al.*, 2007). Out of 143 mha of India`s cultivable land 80 mha is rainfed supporting 40% human and 60% livestock population (Jat *et al.*, 2013). Rainfall availability is not well assured at all the place and time. Around 75% of the rainfall is occurring during June to September spread over with a 120 rainy days. Extreme conditions of rainfall are also observed in certain years. 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 necessary conclusion on characteristics distribution of rainfall (Satapathy *et al.* 1998; Satapathy *et al.* 1999; Chakraborty and Mandal, 2008; Jakhar *et al.*, 2011; Ray *et al.*, 2011; Ray *et al.*, 2013a; Ray *et al.*, 2013d; Ray *et al.*, 2014), maximum probable rainfall (Ray *et al.*, 2012a and Ray *et al.*, 2013b) contingency crop planning

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(Sinha, 1986; Sharma *et al.*, 1987a, 1987b), trend in rainfall (Ray *et al.*, 2012c) and impact of drought on livelihood (Singh *et al.*, 2013). Several workers have done meteorological drought analyses based on rainfall data (Dhar *et al.*, 1979; Ray *et al.*, 1987; Kumar and Kumar, 1989; Dabral, 1996; Shrivastava *et al.*, 2008; Marathe *et al.*, 2001; Tiwari *et al.*, 2007; Ray *et al.*, 2012b; Ray *et al.*, 2013c; Ray *et al.*, 2013d). Sharma *et al.* (1979, 1987a. and 1987b) 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. Assessment of meteorological drought for, Meghalaya is needs of hour to quantify the extent and pattern on the production and productivity in rice based faming in Williamnagar region. In the present paper an attempt has been made to study the frequency of drought occurrence at Williamnagar, East Garo Hills district of Western Meghalaya based on rainfall deficiency.

MATERIALS AND METHOD

The study place, Williamnagar is located at 89^0 to 91^0 East Longitudes and 25^o to 26^o North Latitude with an altitude of less than 300 m above mean sea level. The behavioral pattern of rainfall with reference to the amount of rainfall and number of rainy days at Williamnagar were analysed using probabilistic approach from historic daily rainfall records (1998-2009). The probability 'p' (probability) of the weekly rainfall normal value was calculated using Weibull's formula (Eq. 1).

$$p = \frac{m}{n+1} \qquad \text{[Eq. 1]}$$

where

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

The monthly rainfall, seasonal rainfall (*i.e.* June to September-monsoon; October to December-post monsoon; and January to May-pre monsoon) and yearly rainfall were analysed. The average monthly, seasonal and yearly rainfall values were worked out. The variation of rainfall for each month, season and year from the mean was determined and the mean 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 (Dhar *et al.*, 1979). 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).

$$D_i = \left(\frac{P_i - \text{m}}{\text{m}}\right) \times 100 \qquad \text{[Eq. 2]}$$

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 table1. The percentage of deviation (D_i) is then used to categorise the drought.

Table1: Drought codification 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

The quantum of rainfall to be received at different probability was calculated and analysed. It may be noted that, with increase in probability level the amount of rainfall is reducing. The weekly extreme and normal rainfall with their standard deviation (SD), coefficient of variation (CV) and percentage of contribution was evaluated and presented in table 2. It may be noted that the standard meteorological weeks (SMW) 1st, 2nd, 48th, 50th and 52nd don't receive any rainfall/sometimes a meagre amount of rainfall. During the rainy period i.e. from 23rd to 39th SMW the CV value was almost below

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

Standard Meteorological Week (SWM)	Extreme Value		Normal (mm)	Standard Deviation (mm)	Coefficient of Variation (%)	Percentage of Contribution (%)
	Minimum (mm)	Maximum (mm)				
1.	0	0	0	0.0	-	0
2.	0	3.0	0.3	0.9	346.41	0.01
3.	0	36.0	3.9	10.6	270.30	0.12
4.	0	10.0	2.1	3.9	185.86	0.06
5.	0	4.0	0.3	1.2	346.41	0.01
6.	0	22.0	4.0	7.9	196.28	0.12
7.	0	5.0	0.8	1.6	204.81	0.02
8.	0	71.0	11.5	21.2	184.65	0.35
9.	0	58.0	9.3	18.0	192.66	0.29
10.	0	60.0	12.2	19.6	161.11	0.38
11.	0	33.0	9.8	13.0	133.72	0.30
12.	0	70.0	17.9	25.3	141.32	0.55
13.	0	181.1	43.7	54.5	124.75	1.35
14.	0	90.4	38.6	34.8	90.31	1.19
15.	0	72.1	36.2	28.1	77.73	1.11
16.	0	239.0	84.7	83.9	99.02	2.61
17.	0	289.0	98.3	91.6	93.13	3.03
18.	0	337.0	115.1	87.3	75.84	3.55
19.	3.0	104.0	54.7	29.2	53.45	1.69
20.	18.0	183.0	72.4	57.0	78.73	2.23
21.	4.0	213.0	86.7	74.7	86.14	2.67
22.	0.0	490.0	134.3	141.3	105.26	4.14
23.	10.0	382.1	139.5	106.3	76.17	4.30
24.	16.0	435.0	160.8	127.4	79.21	4.96
25.	66.0	381.7	165.4	83.9	50.74	5.10
26.	13.1	298.0	100.5	81.0	80.59	3.10
27.	16.0	378.1	138.5	108.2	78.13	4.27
28.	32.9	642.7	186.8	168.0	89.92	5.76
29.	7.5	333.0	161.5	104.2	64.56	4.97
30.	34.0	631.0	157.4	171.4	108.90	4.85
31.	10.0	396.0	132.9	125.8	94.63	4.10
32.	11.1	223.7	76.9	62.7	81.51	2.37
33.	5.0	849.0	197.8	264.6	133.75	6.09
34.	18.1	312.0	116.8	91.6	78.38	3.60
35.	6.0	202.1	74.7	57.1	76.44	2.30
36.	10.0	582.4	125.6	156.5	124.60	3.87
37.	2.1	89.0	36.8	32.2	87.52	1.13
38.	1.0	274.0	80.8	85.6	105.93	2.49
39.	0	329.0	57.3	89.7	156.72	1.76
40.	0	384.0	94.5	112.4	118.92	2.91
41.	0	293.0	88.5	96.9	109.57	2.73
42.	0	152.0	38.6	53.7	139.00	1.19
43.	0	211.1	44.2	69.7	157.71	1.36
44.	0	13.0	1.1	3.8	346.41	0.03
45.	0	82.0	9.4	23.5	249.44	0.29
46.	0	139.0	19.3	43.3	224.04	0.60
47.	0	30.0	2.5	8.7	346.41	0.08
48.	0	0	0.0	0.0	0.00	0.00
49.	0	4.0	0.3	1.2	346.41	0.01
50.	0	0.0	0.0	0.0	0.00	0.00
51.	0	7.3	0.6	2.1	346.41	0.02
52.	0	2.0	0.2	0.6	346.41	0.01

100% except in some case it was more. The 28th SMW received the maximum amount of rainfall with 186.8 mm, for which the extreme value was 642.7 mm. The average rainfall recedes during 37th, 38th and 39th SMW. The recorded drought week was more than five (5) for the 31st, 36th and 37th SMW during the rainy period (Table 3).

The coefficient of variation is more than 100% for the month of January, February, November and December for both rainfall and rainy days. Standard deviation was maximum for the month of August and minimum for the month of December. The highest normal rainfall of 730.7 mm was observed in the month of July and the lowest 1.1 mm occurred in the month of December. The average monthly rainfall of the place is 240.45, 611.44, 1068.47, 1116.58, 729.12, 626.41 and 295.31 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 1116.58 mm and the minimum average rainfall is received during the month of November to a tune of 19.91 mm. The frequency of drought was observed to be the highest at a magnitude of 10 times in 12 years in December; while it is 8, 7, 6 and 4 times in 12 years during January, November, February and March month, respectively. It indicates that, there is a need for assured irrigation in the above months.

For this station the monsoon period contributed around 75% of rainfall, with only 1% during post-monsoon and 24% as pre-monsoon shower. So 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 quantum of runoff is anticipated during rainy seasons. No drought was observed during monsoon, pre-monsoon and post monsoon period. The yearly intensity of drought for Williamnagar, Meghalaya is presented in table 4. An increasing trend of annual rainfall was noticed for the station. The average annual rainfall of Williamnagar is 3,246 mm with a maximum of 4,231 mm corresponding to the year 2000 and a minimum of 2,108.7 mm corresponding to the year 2006. The years are codified according to IMD specification as described in the table 1. It is found from the Table 4 that, there was no severe drought occurrence. However, there was a moderate drought occurrence in the year 2006.

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
23 (4th to 10th June)	139.51	69.76	3	4.05
24 (11th to 17th June)	160.85	80.42	3	4.05
25 (18th to 24th June)	165.43	82.71	1	1.35
26 (25th to 1st July)	100.51	50.25	4	5.41
27 (2ndto 8th July)	138.47	69.24	4	5.41
28 (9th to 15th July)	186.83	93.42	5	6.76
29 (16th to 22nd July)	161.46	80.73	3	4.05
30 (23rd to 29th July)	157.39	78.70	5	6.76
31(30th to 5th August)	132.92	66.46	6	8.11
32 (6th to12th August)	76.95	38.47	4	5.41
33 (13th to 19th August)	197.80	98.90	5	6.76
34 (20th to 26th August)	116.81	58.41	5	6.76
35 (27th to 2nd September)	74.66	37.33	3	4.05
36 (3rd to 9th September)	125.57	62.79	6	8.11
37 (10th to 16th September)	36.81	18.40	7	9.46
38 (17th to 23rd September)	80.80	40.40	5	6.76
39 (24th to 30th September)	57.26	28.63	5	6.76

Table 4: Yearly intensity of drought

Year	Annual rainfall (mm)	Mean Rainfall (mm)	% deviation	Category	Intensity of Drought
1998	2510	3245.85	-22.67	M_1	Mild drought
1999	2708	3245.85	-16.57	M_1	Mild drought
2000	4231	3245.85	30.35	M_0	No drought
2001	2918	3245.85	-10.10	M_1	Mild drought
2002	3892	3245.85	19.91	M_o	No drought
2003	2876	3245.85	-11.39	M_1	Mild drought
2004	3838.4	3245.85	18.26	M_0	No drought
2005	3607.67	3245.85	11.15	M_0	No drought
2006	2108.68	3245.85	-35.03	M_2	Moderate drought
2007	3845.51	3245.85	18.47	M_o	No drought
2008	3120.97	3245.85	-3.85	M_1	Mild drought
2009	3293.97	3245.85	1.48	M_o	No drought

CONCLUSION

The drought analysis of Williamnagar was made according to deficiency of rainfall shows that out of twelve years there was no severe drought occurrence in this region. However, for the year 2006 there was moderate drought occurrence. For growing rain-fed rice during monsoon farmers of this region may depend on monsoon as there was hardly any drought occurrence. Since the post monsoon seasonal rainfall is very less, for growing winter season crops arrangement may be done for assured irrigation with proper rainwater harvesting methods.

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