e-planet **14** (1): 76-82 (June 2016)

A study on drought assessment and its impact on rice cropping system in Keonjhar district, Odisha

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Date of receipt : 19. 02. 2016 Date of acceptance: 24. 06. 2016

ABSTRACT

Knowledge about the amount of rainfall and its distribution and the occurrence of drought during its growth period are the prerequisite to adopt any cropping system at a particular region especially for rain fed crops. Therefore, a study was carried out to learn about the drought pattern and its impact on rice mono-cropping system in Keonjhar district of Odisha. The rainfall analysis was done based on the last 15 years (2001-2015) daily rainfall data to study monthly, seasonal and yearly drought of Keonjhar district based on the Indian Meteorological Department (IMD) protocols. The average annual rainfall of Keonjhar is 1064 mm with 59 numbers of rainy days. During the fifteen years period, no extreme and moderate drought years were experienced, but there were 4 mild (2001, 2003, 2005 and 2010) and 5 moderate (2002, 2004, 2006, 2007 and 2009) drought years. The frequency of drought month recorded for the January, February, March, November and December was 10, 7, 10, 9 and 11, respectively out of 15 years of record. This study revealed that the farmers of this region may depend on monsoon for growing rain-fed rice, as there was hardly any drought occurrence during the monsoon season. However, there is fair chance of occurrence of moderate drought during November to March due to scanty post-monsoon rainfall, hence growing of winter rice may needs assured irrigation.

Keywords: Climate change, drought year, meteorological drought, rainfall analysis, rain fed rice

INTRODUCTION

Odisha comes under humid subtropical climatic zone with average annual rainfall varying from 150 to 400 cm and has mainly rice based cropping system. Paddy being the major cereal crop during *Kharif* season, rain-fed rice cultivation is mostly practiced in Keonjhar district. Rainfall plays a pivotal role in agricultural production (Singh *et al*., 2008). Rainfall also determines the potential of any region in terms of crops to be grown in farming systems to be adopted, the nature and sequence of farming operations to be followed to achieve higher agricultural productivity as well (Singh and Dhillon, 1994). In rain-fed agriculture, the total amount of rainfall as well as its distribution affects the plant growth (Suresh *et al*., 1992). The mean global temperatures are expected to rise over the next few decades, leading to increased evaporation rates (European Environment Agency, 2004) and causing a concern in the rain fed areas. Drought is one of the major environmental stresses limiting to rain-fed agriculture system (Singh and Kumar, 2009). Out of 143 mha of India's cultivable land, 80 mha is rainfed supporting 40% human and 60% livestock population (Jat *et al*., 2013). Drought

significantly constrains rice production in India. Of the roughly 40 million hectares of harvested rice area, only about 60 percent is irrigated (AIREA, 2015), leaving the rest precariously dependent upon rainfall, and hence susceptible to drought. (Arora *et al*., 2015). About 70% of upland rice area in India are drought prone (Singh, 2002). 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). Rainfall availability is not well assured at all the place and time. More than 60% of the cultivable rice area in India is rainfed. Rainfed agriculture still remains a voracious water user (Bhelawe *et al*., 2015). Hence, its major share has to be met from rainfall available in less than four months (Ray *et al*., 2012). Around 75% of the annual rainfall is occurring during June to September spread over 120 rainy days. Extreme conditions of rainfall are also observed in certain years and as such no general method for the drought prediction is available (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 distribution characteristics of the rainfall (Jakhar *et al*., 2011; Ray *et al*., 2013), maximum probable rainfall (Ray *et al*., 2012), contingency crop planning (Sharma *et al*., 1987), trend in rainfall and impact of drought on livelihood (Singh *et al*., 2013). Several workers have done meteorological drought analysis based on rainfall data (Dhar *et al*., 1979; Shrivastava *et al*., 2008; Marathe *et al*., 2001; Tiwari *et al*., 2007; Asati., 2012 and Bhelawe et al., 2015). Sharma *et al.* (1979 and 1987) 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 one which receives 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. Assessment of meteorological drought in Keonjhar district of Odisha is necessary to quantify the extent and pattern on the production and productivity in rice based faming. In the present paper, an attempt has been made to study the frequency of drought occurrence in Keonjhar district of Odisha, on the basis of rainfall deficiency.

MATERIALS AND METHODS

Covering an area of 8240 km^2, Keonjhar district lies between 21°1' N and 22°10' N latitude and 85°11' E to 86°22' E longitude. The behavioural pattern of rainfall with reference to the amount of rainfall and number of rainy days at Keonjhar were analysed using probabilistic approach from trend of daily rainfall records from 2001 to 2015. The probability 'p' (probability) of the weekly rainfall normal value was calculated using Weibull's formula

$$p = \frac{m}{n+1}$$

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 (i) drought months (ii) drought seasons and (iii) drought year were determined using the following definition viz. (i) if the actual rainfall is less than 50% of the average monthly rainfall (Sharma *et al*., 1979), (ii) if the annual rainfall is deficient by more than twice the mean deviation of the season (Marathe *et al*., 2001) and (iii) 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 drought year (Dhar *et al*., 1979) respectively. 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 equation:

$$Di = \left(\frac{Pi - \mu}{\mu} \right) \times 100$$

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 (in 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.

RESULTS AND DISCUSSION

At different probability level, the amount of rainfall that would be received was calculated and analysed. It was observed that with the 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 1. It may be noted that the standard meteorological weeks (SMW) 1st, 3rd, 4th, 6th, 47th, and 52nd did not receive any rainfall or sometimes received a meagre amount of rainfall. During the rainy period i.e. from 23rd to 39th SMW, the CV value was almost below 200%, except in some cases, it was more. The 28th SMW received the maximum amount of rainfall with 49.63 mm, for which the extreme value was 290.7 mm. The average rainfall recedes during 42nd, and 43rd SMW. The recorded drought week was more than five for the 25th, 26th, 27th, 29th, 32nd, 35th, 36th, 39th SMW during the rainy period (Table 2).

The coefficient of variation for rainfall is more than 100% for the month of January, February, March, November and December. Standard deviation was maximum for the month of September and minimum for the month of December. The highest normal rainfall of 210.41 mm was observed in the month of August and the lowest 4.64 mm occurred in the month of December. The average monthly rainfall of the study site is 30.58, 42.94, 129.16, 192.84, 210.41, 161.99 and 100.90 mm for the month of April, May, June, July, August, September and October, respectively (Table 3). The maximum average rainfall was received during the month of August to a tune of 239.7 mm and the minimum average rainfall is received during the month of December to a tune of 3.0 mm. The frequency of drought was observed to be the highest at a magnitude of 11 times in 15 years in December; while it is 10 times in 15 years during January and March and 7 and 9 times during February and November months respectively (Table 4). It indicates that, there is a need for assured irrigation in the above months.

The monsoon period contributed about 76% of rainfall, with only 11% during post-monsoon and 13% as pre-monsoon shower for Keonjhar district (Fig 1). The post-monsoon seasonal rainfall is very less, for growing winter season crops, hence further arrangement may be made for assured irrigation with proper rainwater harvesting methods. No drought was observed during the monsoon, 3 times in pre-monsoon and 4 times drought was observed in post monsoon period. The yearly intensity of drought for Keonjhar, Odisha is presented in Table 5. An increasing trend of annual rainfall was noticed for the station. The average annual rainfall of Keonjhar is 1,063.61 mm with a maximum of 1,859 mm corresponding to the year 2011 and a minimum of 590.9 mm corresponding to the year 2007(Table 5). The years are codified according to IMD specifications as described in the Table 6. It is found from the Fig 2 that, there was no severe or extreme drought occurrence. However, 4 mild drought years (2001, 2003, 2005 and 2010) and 5 moderate drought years (2002, 2004, 2006, 2007 and 2009) were observed during the course of study.

CONCLUSION

The drought analysis of Keonjhar district based on the deficiency of rainfall shows that out of fifteen years, there was no severe drought occurrence in the region. However, there were 4 mild (2001, 2003, 2005 and 2010) and 5 moderate (2002, 2004, 2006, 2007 and 2009) drought years. The seasonal drought analysis shows the monsoon period contributed around 76% of rainfall, with only 11% during post-monsoon and 13% during pre-monsoon showers. Therefore, for growing winter season crops during post monsoon season, assured irrigation facilities need to be provided simultaneously with ample emphasis on rainwater harvesting during the monsoon season, as high quantum of runoff is anticipated during rainy seasons. The farmers of this region may depend on monsoon rains for growing rain-fed rice, as there was hardly any drought occurrence.

Table 1. Weekly extreme and normal rainfall, SD, CV and per centage 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	4.2	0.73	1.4	220.6	0.08
2.	0	77.3	3.21	19.9	331.8	0.34
3.	0	0	3.40	0.0	--	0.36
4.	0	4.2	0.30	1.3	210.2	0.03
5.	0	19.6	1.30	5.7	217.2	0.14
6.	0	3.7	0.57	1.0	288.1	0.06
7.	0	73.2	5.77	20.9	192.3	0.61
8.	0	41.9	2.49	10.8	363.8	0.26
9.	0	58	3.04	15.0	341.0	0.32
10.	0	25.7	3.98	11.0	175.7	0.42
11.	0	161.2	6.66	41.6	379.0	0.71
12.	0	91.6	5.70	23.4	303.7	0.60
13.	0	11.8	4.25	4.0	136.9	0.45
14.	0	36.4	6.18	11.3	127.0	0.66
15.	0	31.2	5.11	11.1	134.6	0.54
16.	0	66.4	12.58	18.4	141.7	1.33
17.	0	38.4	6.31	12.0	144.6	0.67
18.	0	25.7	7.12	10.6	153.3	0.75
19.	0	69	12.00	17.6	297.3	1.27
20.	0	111.3	11.05	30.7	173.1	1.17
21.	0	38.8	10.41	12.8	119.9	1.10
22.	0	63.5	7.97	16.7	175.1	0.84
23.	0	76.2	23.92	24.2	87.2	2.53
24.	0	126.4	44.45	42.4	88.9	4.71
25.	0	119.7	33.42	39.1	94.6	3.54
26.	0	187.5	27.89	47.6	146.3	2.96
27.	0	103.3	37.42	32.3	98.3	3.97
28.	0	134.6	43.37	45.5	96.5	4.60
29.	0	230.6	45.54	58.7	118.1	4.83
30.	0	191.7	50.98	50.1	84.5	5.40
31.	0.6	290.7	49.63	73.4	102.3	5.26
32.	0	188.8	52.85	56.5	97.0	5.60
33.	1.2	68.6	36.74	21.0	65.9	3.89
34.	0	157.3	48.70	49.5	84.4	5.16
35.	0	190.3	43.78	53.5	103.9	4.64
36.	6.2	200.6	38.76	53.8	100.7	4.11
37.	0	139.3	37.85	39.2	92.4	4.01
38.	1.4	306.9	48.20	74.0	138.9	5.11
39.	0	112.3	25.59	39.9	106.9	2.71
40.	0	139.6	30.66	38.3	135.6	3.25
41.	0	184.7	30.48	52.9	143.0	3.23
42.	0	76.9	21.56	28.0	146.7	2.29
43.	0	79	10.69	24.1	186.9	1.13
44.	0	113.7	16.87	30.8	187.2	1.79
45.	0	11.8	3.27	3.4	259.9	0.35
46.	0	22.4	10.51	6.2	273.5	1.11
47.	0	1.2	5.39	0.4	252.0	0.57
48.	0	11.6	0.46	3.0	387.3	0.05
49.	0	10.6	2.34	2.7	387.3	0.25
50.	0	7.6	0.92	2.0	325.4	0.10
51.	0	15.8	0.67	4.1	387.3	0.07
52.	0	1.4	0.59	1.3	297.7	0.06

Table 2. Weekly rainfall analysis for drought

Standard week		Average rainfall (mm)	Half of the average Rainfall (mm)	No of drought week
23	(4th to 10th June)	27.75	13.88	5
24	(11th to 17th June)	47.71	23.86	5
25	(18th to 24th June)	41.32	20.66	6
26	(25th to 1st July)	32.56	16.28	8
27	(2ndto 8th July)	32.80	16.40	6
28	(9th to 15th July)	47.15	23.58	5
29	(16th to 22nd July)	49.73	24.87	6
30	(23rd to 29th July)	59.36	29.68	4
31	(30th to 5th August)	71.69	35.85	5
32	(6th to12th August)	58.24	29.12	7
33	(13th to 19th August)	31.86	15.93	3
34	(20th to 26th August)	58.62	29.31	5
35	(27th to 2nd September)	51.46	25.73	6
36	(3rd to 9th September)	53.44	26.72	7
37	(10th to 16th September)	42.37	21.18	4
38	(17th to 23rd September)	53.29	26.65	4
39	(24th to 30th September)	37.37	18.68	6

Table 3. Monthly extreme and normal rainfall, SD, CV and per centage of contribution

Months	Extreme Value		Normal (mm)	Standard Deviation (mm)	Coefficient of Variation (%)	Percentage of Contribution (%)
	Minimum (mm)	Maximum (mm)				
Jan	0	94.7	8.52	24.0	266.6	0.90
Feb	0	46.3	10.04	22.1	147.2	1.06
Mar	0	167.6	22.76	48.3	149.9	2.41
Apr	0	89.2	30.58	25.9	66.2	3.24
May	0	138.3	42.94	41.1	95.0	4.55
Jun	39.6	320.7	129.16	100.6	67.2	13.68
Jul	32	495.9	192.84	135.7	65.0	20.43
Aug	53.8	506.3	210.41	122.9	51.3	22.29
Sep	26.4	723.5	161.99	161.7	78.8	17.16
Oct	0	296	100.90	88.1	81.9	10.69
Nov	0	48.2	29.08	15.5	142.6	3.08
Dec	0	20.2	4.64	6.7	223.6	0.49

Table 4. Analysis of monthly and seasonal rainfall for drought

Month/Season	Name of month / season	Average rainfall mm	Half of the average rainfall	No. Of drought month/season Year	Percentage of drought months
	January	9	4.5	10	67
	February	15	7.5	7	47
	March	32.2	16.1	10	67
	April	39.1	19.6	4	27
	May	43.3	21.6	5	33
	June	149.7	74.8	4	27
Month	July	208.9	104.4	5	33
	August	239.7	119.9	2	13
	September	205.3	102.7	2	13
	October	107.5	53.8	4	27
	November	10.8	5.4	9	60
	December	3.0	1.5	11	73
	Pre monsoon	138.65	69.33	3	20
Season	Monsoon	803.58	401.79	0	0
	Post monsoon	121.37	60.69	4	27

Table 5. Yearly intensity of drought

Year	Annual rainfall (mm)	Mean Rainfall (mm)	% deviation	Category	Intensity of drought
2001	840	1063.61	-21.02	M_1	Mild drought
2002	643	1063.61	-39.55	M_2	Moderate drought
2003	1041.6	1063.61	-2.07	M_1	Mild drought
2004	768	1063.61	-27.79	M_2	Moderate drought
2005	1040.6	1063.61	-2.16	M_1	Mild drought
2006	720.3	1063.61	-32.28	M_2	Moderate drought
2007	590.9	1063.61	-44.44	M_2	Moderate drought
2008	1174.3	1063.61	10.41	M_0	No drought
2009	663.2	1063.61	-37.65	M_2	Moderate drought
2010	1045.7	1063.61	-1.68	M_1	Mild drought
2011	1859.9	1063.61	74.87	M_0	No drought
2012	1147.6	1063.61	7.90	M_0	No drought
2013	1474.5	1063.61	38.63	M_0	No drought
2014	1760.61	1063.61	65.53	M_0	No drought
2015	1183.9	1063.61	11.31	M_0	No drought

Table 6. 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_0
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

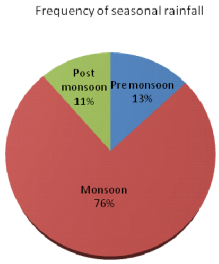

Fig. 1. Frequency of seasonal rainfall Keonjhar dist, Odisha

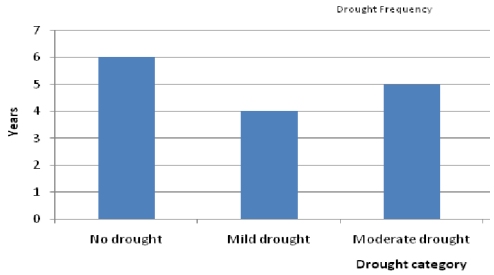

Fig. 2. Relative drought frequency in Keonjhar dist, Odisha

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