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Research Article

CROP PLANNING TO COMBAT CLIMATE CHANGE THROUGH RAINFALL ANALYSIS

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Abstract-The weekly rainfall data of about 22 years (1993-2014) for the Satna district of Madhya Pradesh were analyzed to determine rainfall deficit or surplus for evaluating a strategy for contingency crop planning and water management practices to promote crop production in rain fed areas. The study showed that there were about 8 drought years when the rainfall was found deficit by more than 25 % during the period of 1993 to 2014 in Satna. The worst was experienced in the year 1993 that received 53.58% of the normal rainfall. It was interesting to observe a definite trend in drought periods, showing seven year interval between two successive drought years during the period under study. The month of April, May, November and December were found to be the most drought prone. All the three drought indices identified Satna as the drought prone area. The study also revealed that last week of June will be the best time for sowing kharif crops in the district for better crop germination, establishment and to combat drought. The early maturing rice varieties *'Vandana' 'Kalinga''JR-201*', '*Danteshwari*','*Samlesheari*' '*NDR-97*', and '*Sahbhagi*' and soybean varieties '*JS-95-60*' and '*JS-93-05*' may be grown in deep soils under the undulating terrain of the district. Crops like sorghum, maize, sesame, blackgram, greengram and vegetables (coriander, radish, spinach, cauliflower, tomato, chillies, cowpea, and okra), may be grown under rain fed conditions in well drained shallow soils of the undulating terrain and second crop is not possible because of short LGP. Clay soils with impeded drainage may be used under paddy varieties *'Pusa-1509'*. '*Pusa Sughandh-3*' '*Pusa Sughandh-5*' '*Pusa Sughandh-4*' '*Pusa Sughandh-2*''*MR-219'* and *'WGL-32100'* maturing with in the 120-130 days duration. Whereas, in clay soils, medium duration paddy varieties maturing within 100-120 days duration *'IR-36', 'IR-64'*, *'Sonam'* '*Pant Dhan -10*', *Pant Dhan-12*', '*JR-353*''*JR-503'* and '*MTU-1010*' can be grown.

Keywords- Climate change; Drought; Length of growing period (LGP); Rainfall; Crop and Varietal selection.

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Introduction

Drought is a major constraint to rain-fed crop production. The frequency of climatic risks in agriculture production in the last few years has increased on account of rain, drought, frost variability and change due to EL NINO and LA NINO effects. The climatic change principal evidence has been change in temperatures resulting in heat strokes and frost, erratic rainfall pattern, sunshine hours, humidity, smog, fog and increase in the frequency and severity of different climatic rick like droughts, floods and cyclones, those are causing huge losses in agricultural production and the livestock population. Occurrences of dry spell during the crop growing season particularly during critical crop growth period is one of the important phenomenon of erratic monsoon. Drought occurs in different parts of India for centuries, but not so frequently, but in the recent past the frequency has been increased. Out of 329 m ha geographical area of India, 108 m ha is severely affected by drought, which includes 39 % of cultivable land and it has been estimated that about 263 m population live in drought prone districts [3]. As per [9] a month in which actual rainfall is less than or equal to 50 % of the average defined as drought month. According to the India Meteorological Department [7], a station is considered as drought –hit if it receives total rainfall less than 75 % of the normal rainfall. Various workers [6,7,12] have worked on the assessment of the drought using the rainfall data of various stations over different parts of India. The Indian rainfall distribution is uneven and varies considerably from not only the region to region but also considered season to season and year to year [5]. Under rain-fed conditions, the period of water available for plant growth is of vital importance for crop planning. Therefore, the concept of length of growing period plays a significant role for rain-fed crop planning [1] By using short duration varieties during *kharif* crops mature before the depletion of soil moisture [10]. In the Satna district of Madhya Pradesh, farming is mostly rain-fed. The agro-ecological condition of the district affects rain fed production system. In dry season most of the rain fed agriculture experiences moisture shortage and farmers find it difficult to grow crops successfully. A vast tract remains uncultivated during *kharif* as well as during *Rabi* season due to lack of irrigation. Drought analysis at the Satna district of Madhya Predesh has not been attempted earlier. Therefore, an investigation on drought analysis using the rainfall data of district Satna of Madhya Pradesh was undertaken to identify the duration of moisture available for crops in rain-fed situation and selection of such crops and varieties whose growth maturity period appropriately matches with the length of growing period (LGP).

Materials and Methods

Satna district forms a part of the Kaymore Plateau and Satpura Hill agro ecological region of Madhya Pradesh- situated between 23^0 58' to 25^0 12' N latitude and 80^0 20' to 81^0 23' E longitude and represents semi arid climate. The monthly and weekly rainfall data of the district were obtained from the meteorological observatory of Krishi Vigyan Kendra, Satna established under the for the period of 1993 to 2014 and analyzed for drought proneness. The criteria

used by [9] were used for investigating the drought. Any year receiving rainfall less than or equal to X - SD of the annual rainfall is a drought year. Whereas, any year receiving rainfall more than or equal to the X + SD of the average annual rainfall is termed as an abnormal or wet year and the year receiving rainfall in the range of X ± SD is a normal year. Where, X is the mean and SD is the standard deviation. The month receiving less than 50 %, more than 200 % and between 50-200 % of the average monthly rainfall is termed as drought, abnormal or wet and normal month, respectively.

Droughts are characterized by their intensity, duration and frequency which form the basis in the planning of management strategies to drought. Drought intensity refers to magnitude to which actual precipitation are lesser than a mean value. Here, the period in which deficit of precipitation recorded is indicated by drought duration which followed by normal rainfall or periods of no deficit. The criteria suggested by IMD to define the intensity of drought are used.

Departure of actual rainfall from normal (%)	Drought Intensity	Code
0.0 or above	No drought	M_0
0.0 to - 25.0	Mild drought	M_1
-25.1 to -50.0	Moderate drought	M_2
-50.1 to – 75.0	Severe drought	M_3
> -75.1	Extreme drought	M_4

As per the IMD if the annual rainfall is less than 75 % of normal in 20 % or more of the years examined is defined as a drought prone area. IMD adopted coefficient of variation (CV) of rainfall as normal practice, if annual CV is 30 % or more, the rainfall is said to be erratic and the area is classified as drought prone. Irrigation Commission (1972) observed that an area, having annual rainfall less than 750 mm, would not be able to sustain a stable crop. Thus, any area satisfying these criteria will be considered as drought prone. The degree of consistency between two drought indices is evaluated by finding out whether the station is identified either as drought prone or non drought prone by both the indicators.

Results and Discussion

Annual rainfall

The annual rainfall in Satna from 1993 to 2014 is shown in [Table-1]. The results showed that the average annual rainfall in Satna is 947.41 mm with a standard deviation of 304.57 mm. Therefore, any year in which rainfall received less than or equal to 642.84 mm would be the indicate as drought year. Thus, there were 3 drought years *viz.* 1993, 2000, 2007, during 1993 to 2014 [Table-2]. The worst drought was experienced in 1993 and 2000 due to 46.52 % and 36.35 % deficit of the average annual rainfall and the year 2007 was the least severe among the three drought years. It was further observed that 2 drought years (event) occurred in the last decade. It was interesting to observe a definite trend in drought periods, showing seven year interval between two successive drought years during the period under study. The year 2014 again showing deficit recording deficit rainfall of 27.46 % of the average rainfall.

Table-1 *Annual rainfall and departure of rainfall from mean at district Satna during 1993 to 2014.*

Year	Rainfall (mm)	Deviation from mean	% Deviation
1993	506.7	-440.71	-46.52
1994	1582.8	635.39	67.07
1995	862.5	-84.91	-8.96
1996	903.77	-43.64	-4.61
1997	737.2	-210.21	-22.19
1998	1050.8	103.39	10.91
1999	880.3	-67.11	-7.08
2000	603.05	-344.36	-36.35
2001	1201.8	254.39	26.85
2002	776.48	-170.93	-18.04
2003	1298.66	351.25	37.07
2004	824.5	-122.91	-12.97
2005	1003.75	56.34	5.95
2006	809.9	-137.51	-14.51
2007	635.2	-312.21	-32.95
2008	751.8	-195.61	-20.65
2009	786.6	-160.81	-16.97
2010	928.2	-19.21	-2.03
2011	908.75	-38.66	-4.08
2012	1409.45	462.04	48.77
2013	1693.5	746.09	78.75
2014	687.29	-260.12	-27.46
	947.41		

S.D – 304.57, C.V. – 32.15

Table-2 *Characteristics of drought years at Satna during 1993 to 2014*

Drought years	Yearly rainfall (mm)	Average annual rainfall (%)	Time interval between drought (years)	No. of drought months in the drought year
1993	506.7	46.52		07
2000	603.05	36.35	7	08
2007	635.20	32.95	7	09

The year receiving the annual rainfall equal to or greater than 1251.98 mm would be the normal or wet year. Thus 4 years *viz.* 1994, 2003, 2012 and 2013 were observed as wet years. Results revealed that district Satna received 178.75 % of average annual rainfall in 2013 and was the most abnormal or wet year [Table-1]. The year receiving the rainfall in the range of 642.84 mm 1251.98 mm would be the normal year. Therefore, there were 15 normal years during 1993 to 2014 in Satna.

Intensity of drought

The intensity of drought was categorized as M_0 to M_4 based on the deviation of rainfall from normal rainfall i.e.1077.7 mm. Seven drought events of category M_2 and Nine drought events of category M_1 and one drought event of category M3 were observed over Satna during 1993 to 2014 [Table-3]. Only five years 1994, 2001 and 2003, 2012 and 2013 were observed with normal rainfall during the period under study.

Seasonal and monthly rainfall

The analysis of mean seasonal rainfall [Table-4] revealed that the amount of rainfall received in *kharif* season (June to September) was 863.02 mm. Rainfall in *rabi* season (October to February) was 68.18 mm and the summer season (march to May) 16.25 mm. The season coefficient of variation revealed the lowest variability (C.V. 4.79 %) in *kharif* season indicated that rainfall is reliable as compared to *rabi* and summer seasons. The numbers of rainy days 33.79, 2.47 and 0.47 were observed in *kharif* season followed by *rabi* and summer season, respectively.

The results of monthly rainfall showed that the maximum rainfall of 301.44 mm received in July followed by August (273.35 mm) and recorded almost negligible rainfall in the months of April to May. However, a sharp decline in rainfall was observed after September. The coefficient of variation due to monthly rainfall ranged from 14.54 to 21.31 %. The most dependable month in respect of C.V. values are June to September whereas the C.V. for March to May and October to December were recorded much higher.

The monthly rainfall data over the years [Table-4] revealed that the month of May witnessed the highest number of drought events (19) *i.e.* 86.36 % of the 22 rainfall events followed by the months of April, November and December (18 drought events). Minimum numbers, i.e. Only two drought event were observed in the month of July. There were three drought events in the months of August. Drought events during the months of October to February (post monsoon and winter season) were quite high, i.e. more than 50 % of the 22 rainfall events of individual months. The frequency of drought was also associated with the type of soil e.g. in light soil it was higher whereas in a heavy soil minimum number of frequency was observed. Thus, the months of pre-monsoon, post monsoon and winter seasons were more likely to be drought hit than the monsoon seasons because the rainfall received during the monsoon season was 91.08%, whereas during pre and the post monsoon season only 1.7% and 7.19%, respectively. The 90.91 % of the rainfall events during the month of July and 81.82 % of the rainfall events of August were found to be normal. In September about 77.27 % of the total rainfall events were normal. The normal rainfall events during the months of July to September were quite high and more than the events of post monsoon and winter seasons.

Table-3 *Annual drought analysis based on rainfall of district Satna (1993 – 2014).*

Year	Rainfall	Departure of rainfall from normal	% Departure	Drought Intensity (Code)
1993	506.7	(-) 571.00	(-) 52.98	Severe drought (M3)
1994	**1582.8**	505.10	46.87	No Drought (M0)
1995	862.5	(-) 215.20	(-) 19.97	Mild Drought (M1)
1996	903.77	(-) 173.93	(-) 16.14	Mild Drought (M1)
1997	737.2	(-) 340.50	(-) 31.60	Moderate Drought (M2)
1998	1050.8	(-) 26.90	(-) 2.50	Mild Drought (M1)
1999	880.3	(-) 197.40	(-) 18.32	Mild Drought (M1)
2000	603.05	(-) 474.65	(-) 44.04	Moderate Drought (M2)
2001	1201.8	124.10	11.52	No Drought (M0)
2002	776.48	(-) 301.22	(-) 27.95	Moderate Drought (M2)
2003	**1298.66**	220.96	20.50	No Drought (M0)
2004	824.5	(-) 253.20	(-) 23.49	Mild Drought (M1)
2005	1003.75	(-) 73.95	(-) 6.86	Mild Drought (M1)
2006	809.9	(-) 267.80	(-) 24.85	Mild Drought (M1)
2007	635.2	(-) 442.50	(-) 41.06	Moderate Drought (M2)
2008	751.8	(-) 325.90	(-) 30.24	Moderate Drought (M2)
2009	786.6	(-) 291.10	(-) 27.01	Moderate Drought (M2)
2010	928.2	(-) 149.50	(-) 13.87	Mild Drought (M1)
2011	908.75	(-) 168.95	(-) 15.68	Mild Drought (M1)
2012	**1409.45**	331.75	30.78	No Drought (M0)
2013	**1693.5**	615.80	57.14	No Drought (M0)
2014	687.29	(-) 390.41	(-) 36.23	Moderate Drought (M2)

Table-4 *Average monthly rainfall, rainy days and monthly drought events during 1993 to 2014 at Satna.*

Month	Average rainfall (mm)	CV (%)	Rainy days	No. of monthly drought events	Percentage of events		
					Drought	Normal	Abnormal
January	12.05	21.05	0.47	12	54.55	27.27	18.18
February	12.14	21.05	0.33	14	63.64	18.18	18.18
March	12.54	21.04	0.13	17	77.27	4.55	18.18
April	3.08	21.25	0.20	18	81.82	4.55	13.64
May	0.64	21.31	0.07	19	86.36	4.55	9.09
June	155.44	17.82	4.13	9	40.91	36.36	22.73
July	301.44	14.54	12.33	2	9.09	90.91	0.00
August	273.35	15.17	11.13	3	13.64	81.82	4.55
September	132.79	18.33	6.20	4	18.18	77.27	4.55
October	40.78	20.40	1.33	12	54.55	27.27	18.18
November	2.62	21.26	0.27	18	81.82	0.00	18.18
December	0.59	21.31	0.07	18	81.82	9.09	9.09
Seasonal							
Summer	16.25	61.01	0.40	54	81.82	4.55	13.64
Kharif	863.02	4.79	33.79	18	20.45	71.59	7.95
Rabi	68.18	44.62	2.47	74	67.27	16.36	16.36
Total	**947.45**		**36.66**				

Thus, the detailed analysis of rainfall data of Satna district revealed that 36.36 % of the total years had annual rainfall less than 75 % of the normal since 1993. And therefore, district Satna is drought prone as per IMD criteria according to which any area receiving annual rainfall less than 75 % of normal in 20 % or more of the years examined will be identified as drought prone. The coefficient of variation (CV) of rainfall was also found to be more than 30 % (32.15%), which again satisfies the criteria of IMD, according to which, if annual CV is 30 % or more, the rainfall is said to be erratic and the area is classified as drought prone. Similarly, in five years, annual rainfall was found to be less than 750 mm which satisfy the criteria of Irrigation Commission (1972), according to which any area having

annual rainfall less than 750 mm, would not be able to sustain a stable crop and will be considered as drought prone. Thus, all the drought indices identified Satna as drought prone.

Length of growing period (LGP) and crop planning

The weekly rainfall data showed that the length of growing period for the clay soils, heavy soil of the district will be the 4th week of June to the last week of October which is about 120-130 days. The growing period for shallow soils (less than 50 cm) on undulating terrain will not go beyond the 1st week of October (90-100 days) because of its poor water retention capacity less stored soil moisture. Even for the deep soil (more than 100 cm) in the undulating regions, there is shortening of growing periods ending in the 2nd week of October because of faster depletion of moisture due to slopping terrain results in poor vegetation and hence faster depletion of soil moisture was observed.

Kharif crops require 40 to 50 mm of first rain water within a span of 3 days for germination and thereafter 40 to 50 days to sustain the crop under medium and heavy textural soils [11]. The present study also revealed that the 40 to 50 mm rainfall will be available from the 4th week of June which is an appropriate time (moist period) for crop germination and establishment. The short duration varieties of early maturing rice paddy varieties '*JR-201*','*Danteshwari*', '*NDR-97*' and '*Sahbhagi*' and soybean varieties '*JS-9305*', '*JS-95-60*' may be grown in deep soils under the undulating terrain of the district. Medium duration paddy rice varieties (120-140 days) would not be an appropriate for undulating terrain because of the short duration of moisture availability (90-100 days) and crops are likely to suffer from water stress during the most critical crop growth stages i.e. reproductive and grain filling maturity stages. Under rain-fed conditions, the onset and withdrawal of monsoon along with soil type are the important determining factor in crop planning [4]. Crop like sorghum, maize, sesame, blackgram, green gram and vegetables (coriander, radish, spinach, cauliflower, tomato, chilies, coupe, okra, and cucurbits) may be grown under rain fed conditions in well drained shallow soils of the undulating terrain and second crop is not possible because of short LGP. Clay soils with impeded drainage may be used under for rice paddy varieties *'Pusa -1509', 'Pusa Sughandh-3*' and '*Pusa Sughandh-5*'' *'MR-219'* and *'WGL-32100'* maturing within the 120-130 days duration. Whereas, in clay soils, medium duration paddy varieties maturing within 100-120 days duration '*Pant Dhan -10*', '*Pant Dhan-12*', '*JR-353*' and '*MTU-1010*' *'IR-36'* and *'IR-64'*can be grown. Chand *et al.,* (2011) [2] also advocated the selection of crops and varieties in *kharif* season on the basis of length of growing period and soil type.

Thus, it can be concluded that there were about six drought years during the period of 1993 to 2014 in Satna. The worst was experienced in the year 1993 that received 53.58 % of the average rainfall. Further, It was interesting to observe a definite trend in drought periods, showing seven year interval between two successive drought years during the period under study. The month of April, May, November and December were found to be the most drought prone. All the three drought indices identified Satna as the drought prone area. There is a need to replace rice varieties '*IR-64*' and '*IR-36*' (maturing in 115-120 days) with short duration and drought tolerant rice and soybean varieties early maturing rice varieties '*JR-201*', '*NDR-97*' and '*Sahbhagi*'; soybean varieties '*JS-335*' and '*NRC-37*' with '*JS-93-05*' and '*JS-95-60*'; long duration pigeon pea varieties with short duration and frost escaping varieties 'PUSA 2002' '*ICPL-88039*', '*TJT-501*' and '*TT-401*' in rain fed and drought prone areas. These varieties will tolerate a dry spell of 15-20 days (rice-Sahbhagi) and 12-15 days (soybean- NR-7) occurs during the monsoon season, especially during the month of August and September during crop growing season escape terminal drought because of early maturity. Some of the others short duration crops and varieties *viz.* sesame-JTS-8, JTS-21, black gram-IPU-94-1, PU-31, green gram-PDM-139, Meha, PM-5 and cowpea-Kashi Kanchan needs to be promoted in drought prone areas. Further, there is a need to organize awareness camps on climate literacy in grass root level mass scale and educate the farmers on drought management techniques to minimize consequences or ill effects of drought on crop production and making agriculture more profitable and sustainable in the changing scenario.

Conflict of Interest: None declared

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