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Incidence of Drought in Relation to Rainfed Rice Production: an Analysis

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Abstract

The distribution of rainfall during a season is more important than its amount. It is therefore, the progressive balance between the receipt and expenditure of the moisture during the growing season, which creates favourable or unfavourable conditions for successful crop production. Several research workers have attempted to study the various aspects of drought on this basis. Their studies have not taken into account the crop yields in determining the agricultural drought. In this paper, the data on rainfall (1945 to 1993) and yield of a crop like rainfed rice in Midnapore district of West Bengal (India) have been analyzed for determining drought threshold value and characterizing agricultural drought. An amount of 20 mm rainfall for two consecutive weeks was identified as drought threshold value in the test location. During drought period, high negative correlation between grain yield and maximum rainfall was observed. The recurrence of drought in relation to rainfed rice has also been studied.

1. Introduction

Indian economy has for many years been agriculture in nature. Among the weather components, rainfall has been regarded as the principal factor which influences the crop production. The vast areas of land depends on rainwater for agricultural operation i.e. rainfed in nature. The amount and distribution of rainfall in rainfed areas make the country surplus or deficit in regard to agricultural production. In West Bengal also, crop production is affected largely by the fluctuation of rainfall in monsoon season. It is known that water requirement differs at different phases of crop growth. The occurrence of inadequate and ill-distributed rainfall and the resulting crop failure at a particular place and time in relation to a given crop provide the concept of crop-specific drought or agricultural drought.

In the past a number of studies were conducted by several workers on modeling of occurrence of rainfall and also to predict the length of dry and wet spells (Sahoo et al., 2008; Singh et al., 2006; Raha et al., 2010; Seetharam, 2010). However, very little attention was paid to the study the effect of varying duration of drought on crop production. Barger and Thom (1949) developed methods for characterizing drought intensity of varying duration during the crop growing period. Kar (2002) performed rainfall variability and probability analysis for studying water harvesting potentials and crop diversification. Studies were also conducted to evaluate various aspects of future projections of precipitation (Revadekar et al., 2011) and drought indicators (Steinemann et al., 2006) for prediction of assured rainfall in different seasons for crop growth.

In present paper, an attempt has been made for obtaining the minimum rainfall amounts for rainfed rice (*Aman*) crop for different durations below which a drought is said to exist in respect of Midnapore district of West Bengal, India. The relative occurrence of drought for the district has also been discussed.

2. Materials and Methods

The weekly rainfall data of Midnapore station (IMD recommended) for 49 years (1945 to 1993) collected from IMD, Pune were used in this study. The yield data for the above 49 years of rainfed rice (*Aman*) crop, collected from Statistical Abstract, Govt. of West Bengal, were also used for the study.

As a first step to carry out the analysis of the study, the standard yield of rainfed rice was worked out. Simple average of 49 years of yield data could not be the standard yield because the high yielding variety of rice crop was introduced in 1974-75

in Midnapore district. Thus, instead of taking the average of all, two averages, first one by averaging the yield values from 1945 to 1975 and second by averaging the rest of the years, were worked out.

A standard meteorological week system was adopted in tabulating total rainfall of consecutive week (n), i.e. from 26th week to 41st standard week. Rainfall for each standard 'm' th week with $26 \leq m \leq 41$ were prepared. From these weekly rainfalls, n-week rainfall totals for $2 \leq n \leq 14$ beginning during the m-th week were tabulated for each year. These totals give the total amount of rainfall received during any given number of consecutive weeks beginning with the crop growing season. Corresponding to each consecutive week, the smallest n-week total from amongest those relating to different values of m were obtained for each year. For instance if n=9, we would have 8 rainfall totals from which the minimum could be chosen for each year.

3. Results and Discussion

3.1. Determination of drought thresholds

For determining the drought thresholds, i.e., the minimum amount of rainfall below which a drought may exist, the deviation from rainfed rice yield was plotted against the minimum rainfall values for the corresponding week (n, $2 \leq n \leq 14$) for each year as in Figure 1 and 2 with n=2 and 10, respectively. Each point in the Figure 1 (or 2) represents a year. Out of all the 49 points (years), some of the points (year) have negative deviation from the standard yield while others have positive deviations. The point beyond which increasing rainfall becomes relatively ineffective in determining yield should be such that at least half of the yields are above the standard yield line. In Figure 1, 20 mm can be taken as the threshold value below which drought existed. This criterion is, therefore, adopted for fixing the threshold value of drought, i.e. that amount of n-week rainfall total beyond which progressively at least half of the points lie above the line of standard yield. In this manner, the drought threshold for all n was determined.

It is apparent that drought thresholds increase with n. Then thresholds with n were fitted for curve estimation of three types (e.g. linear, quadratic and cubic). The best fitted curve is quadratic as the regression coefficients (b_1 and b_2) are significant with highly significant R^2 value (Table 2). Thus, corresponding to each value of n, the rainfall values were read which provide the estimates of drought base values.

The amount of deficit in rainfall for n-week from the base value would constitute a measure of drought intensity with n- week duration. If the n-week rainfall is higher than the base value corresponding to n, the rainfall is not considered as deficient. It is quite likely that a number of deficits, each for different duration, may be recorded during a dry year. Shorter periods would often be contained within longer periods of droughts. The greatest single deficit, regardless of the duration involved, is taken to be the measure of drought intensity for that season.

3.2. Correlation of rainfall deficit with rice yield

In order to test the accuracy of the drought base values in depressing the crop yields for the district, the correlation between the maximum rainfall deficiency and the yield for each year was worked out. This correlation was compared with the corresponding correlation worked out by including the years in which no rainfall deficit was noticed.

Correlation coefficient (-0.46) value was highly significant in drought years signifies crop failure in response to rainfall deficits. However, successful crop yield is not only depends on sufficient rainfall. Therefore, the correlation coefficient (-0.19) for all years was not significant.

3.3. Probability of occurrence of drought

The drought base values obtained in Table 1 pre-estimates the minimum amount of rainfall required for crop growth during a given number of consecutiWve weeks in a particular place/zone. As such, corresponding to each value of 'n', the observed rainfall total of 'n' week in a given year, if found below the corresponding drought base value, will indicate the

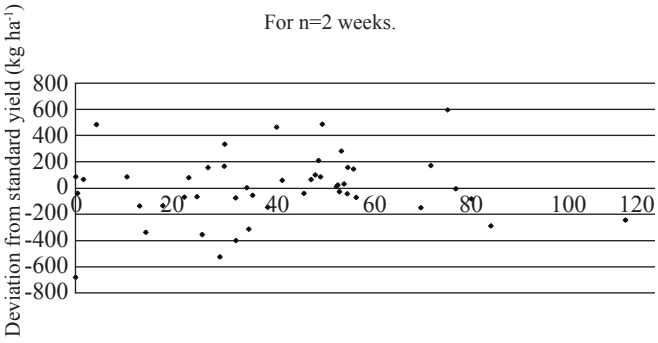

Figure 1: Deviation from standard yield under different rainfall regime (n=2 weeks)

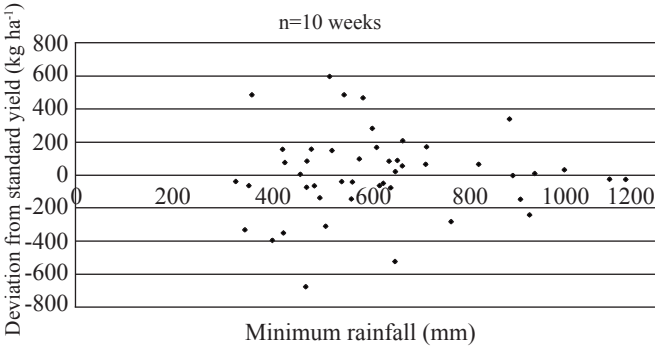

Figure 2: Deviation from standard yield under different rainfall regime (n=10 weeks)

existence of a crop specific drought. The relative frequency of such cases have been determined over a long period of time would, therefore, provide an estimate of the probability of the occurrence of crop specific drought. Since the period of n-weeks can begin with any week 'm', where $26 \leq m \leq 41$, such probabilities for droughts of varying durations can be computed for each value of 'm' during the crop season. For the sake of illustration, however, we have determined certain values of 'n' e.g. 4, 5, 6, 7 and 8 with m=26, 28 and 32. These are presented in Table 3.

Table 1: 'n'-week drought threshold and base values (mm)

n	Threshold value	Base value		
		Quadratic	Linear	Cubic
2	20	7.53	23.79	27.14
3	50	54.61	38.96	54.61
4	110	104.55	101.70	93.85
5	150	157.33	164.45	143.07
6	210	212.96	227.20	200.48
7	260	271.45	289.95	264.30
8	325	332.76	352.69	332.76
9	355	396.93	415.44	404.07
10	485	463.95	478.19	476.43
11	590	533.82	540.93	548.09
12	620	606.53	603.68	617.23
13	675	682.09	666.43	682.09
14	735	760.49	729.18	740.88

Table 2: Curvilinear equation fitted to drought threshold data

Type	R^2	Regression equation	t value		
			b_1	b_2	b_3
Linear	0.99	$Y=-149.29+62.75x$	27.07		
Quadratic	0.99	$Y=-78.11+39.97x+1.42x^2$	4.228	2.46	
Cubic	0.98	$Y=14.62-9.66x+8.55x^2-0.30x^3$	0.34	2.18	1.83

Table 3: Probability of occurrence of drought of different weeks

n	m=26	m=28	m=32
4	0.06	0.10	0.18
5	0.06	0.08	0.20
6	0.08	0.06	0.12
7	0.08	0.06	0
8	0.08	0.06	0

It was observed that for n=4 and 5, the probabilities consistently increasing as the week (m) increases from 26 to 32 th week. Highest values observed for 32 th week with n=4 and 5. These probability values (0.18 and 0.20) indicate that 4 weeks and 5 weeks duration drought may come once in 5 years at 32 th week.

4. Conclusion

The occurrence of rainfall below the predicted drought threshold which gives rise to drought conditions can be used to determine the probability estimates of the occurrence of drought of varying durations and accordingly agronomic manipulations can be done to avoid yield loss in rainfed rice.

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