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Agricultural Droughts and Crop Production in the Indian Arid Zone

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With 2 Figures

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Summary

Based on a rational approach, agricultural droughts were studied for the period 1901–75 for 5 selected regions in the Indian arid region using the *AE/PE* values during different phenophases. The productivity of pearlmillet and kharif pulses crops, the two major rainfed crops in this region, was assessed under different agricultural drought situations.

Zusammenfassung

Landwirtschaftliche Dürren und der Ernteertrag in der ariden Zone Indiens

Es werden landwirtschaftliche Dürren in der Periode von 1901 bis 1975 in fünf ausgewählten Gebieten der ariden Zone Indiens mit Verwendung von *AE/PE*-Werten in verschiedenen Pflanzenentwicklungsphasen untersucht. Die Produktivität von Hülsenfrüchten und Hirse, das sind die stärker vom Regen abhängigen Früchte in dieser Region, wird für verschiedene landwirtschaftliche Dürregrade geschätzt.

1. Introduction

For assessing the crop production potential of a region, a knowledge of the frequency and intensity of agricultural droughts is of paramount importance. Such knowledge also helps in suggesting any suitable amendments in the cropping patterns. The agricultural droughts can be better classified on the basis of crop water requirement rather than any other climatic parameter. Sastri et al. [5] proposed a new method of agricultural drought classification based on the minimal required value of *AE/PE* during the growing season for obtaining average yield.

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It is, however, well known that the intensity of drought depends upon the phenological stage of crop growth during which water stress occurred, as the water requirement varies during different phenophases of crop growth. Hence, the agricultural drought intensity can be well assessed if water stress during different growth stages is evaluated based on the moisture requirements in those periods.

In the arid region of Rajasthan rainfall is restricted to the southwest monsoon (July to September) and the earlier studies [6] revealed that the crop growing season varies from 100 days in the east to hardly 60 days in the west. Also, the time of onset of monsoon has a profound influence on the length of the growing season and thereby on the cropping pattern. Pearl millet with a duration of 90–100 days and kharif pulses with a duration of 70–80 days are the two major rainfed crops in this region.

In the present paper, an attempt has been made to assess the productivity potentials of pearl millet and kharif pulses based on rational approach for classification of agricultural droughts.

2. Materials and Methodology

Ramana Rao et al. [4] classified the agricultural droughts based on values of *AE/PE* during different stages of crop growth and the same methodology is used with slight modifications.

The potential evapotranspiration values were computed using Penman's [3] equation. The actual evapotranspiration values were arrived at from the water balance computations using the book-keeping procedure of Thornthwaite and Mather [7]. The agricultural droughts have been classified on the basis of *AE/PE* values during different phenophases of growth as follows

AE/PE (%) during different phenophases	Drought intensity	Code Seedling (S)	Vegetative (V)	Reproductive (R)
76 to 100	No drought	S_0	V_0	R_0
51 to 75	Mild drought	S_1	V_1	R_1
26 to 50	Moderate drought	S_2	V_2	R_2
25 or less	Severe drought	S_3	V_3	R_3

Depending upon the values of *AE/PE* during different phenophases, the drought code varies as S_0, V_1, R_2, S_1, V_2, R_3, etc. depending upon the drought situation.

This is generalized classification with no specification of any crop. At this stage, the crop factor can be introduced and the drought code in three

syllables can be unified into a single drought code applicable to one particular crop for a specific region.

Hence the drought code is specified for pearl millet crop which is the major rainfed crop in the Indian arid zone. The average growing season of pearl millet crop is about 14 weeks. The duration of different phenophases of pearl millet crop in this region is as follows: Seedling (S) 3 weeks, Vegetative (V) 4 weeks, Reproductive (R) 4 weeks, Maturity (M) 3 weeks.

As the water stress during maturity stage does not have much influence compared to water stress during other three stages, the maturity stage is eliminated and the three syllable agricultural drought code can be unified into a single code as per the following assumptions:

i) The agricultural drought situation for pearl millet crop is severe (A_3) when both vegetative (V) and reproductive (R) stages experience severe drought with any combination of S_0, S_1, S_2 or S_3 as the water requirement during seedling stage is usually less. In these circumstances even the natural grasses too suffer from drought conditions.

ii) The agricultural drought situation for pearl millet is moderate (A_2) when vegetative (V) and reproductive (R) stages experience one moderate and one severe drought each with any combination of S_0, S_1, S_2 or S_3. During this situation short duration crops like pulses also suffer from drought.

iii) The pearl millet crop escapes drought situation (A_0) even when mild drought prevails in one or two growth stages with no drought condition in the third stage.

iv) The rest of the situations result in mild drought (A_1) for pearl millet and short duration crops like pulses escape from drought in these circumstances.

The weekly water balances were computed for the period 1901–75 for 5 representative stations in the Indian arid region viz., Sikar, Jodhpur, Nagaur, Barmer and Jaisalmer, and the agricultural droughts were classified accordingly for all the years. The crop yields of pearl millet and kharif pulses were obtained from the Statistical Abstracts of Rajasthan State (1) which are available for the period 1955–75.

The normal onset of monsoon in this region is during 27th week (2–8 July). The commencement of growing season was considered early, normal to late as was suggested by Krishnan et al. [2]:

Early	during 26th week or early
Normal	27th to 29th week
Late	during 30th week or later

3. Results and Discussion

The *AE/PE* values during different phenophases of pearl millet crop averaged for the period 1901–75 for the 5 stations are given in Table 1.

Table 1. *Average Values of AE/PE During Different Phenophases of Pearl Millet Crop*

Station	Average values of *AE/PE* during seedling phase	vegetative phase	reproductive phase
Sikar	69	61	56
Jodhpur	60	44	44
Nagaur	51	36	32
Barmer	51	39	27
Jaisalmer	21	16	9

Table 2. *Percentage Probabilities of Various Intensities of Drought for Pearl Millet*

Station	Percentage probability of no drought (A_0)	mild drought (A_1)	moderate drought (A_2)	severe drought (A_3)
Sikar	31	44	3	22
Jodhpur	16	28	16	40
Nagaur	7	43	11	39
Barmer	7	46	7	40
Jaisalmer	1	11	9	79

It is obvious that higher values of *AE/PE* during different phenophases occur in higher rainfall region and vice versa. The average pattern of *AE/PE* during early, normal and late commencements of growing season in respect of 5 stations is shown in Fig. 1.

A comparison of Table 1 and Fig. 1 indicates that the pearl millet crop escapes drought under both early and normal commencements of growing season with respect to the average *AE/PE* values for obtaining the normal yield of crop. However, late commencement of growing season results in water stress during reproductive and maturity stages of crop growth.

The average agricultural drought situation, based on Table 1, indicates mild to moderate drought conditions in all the regions except in Jaisalmer, which experiences severe drought conditions.

But the normal yields of pearl millet in these regions are quite low ranging from 2.9 quintal/ha in Sikar to 1.1 quintal/ha at Jaisalmer. Under these low yield conditions, the production potential in these regions can never be assessed with respect to the average pattern. Instead, it gives an appropriate picture if the production potentials under drought free conditions (A_0) are assessed which result in maximum yield production.

The percentage probabilities of occurrence of no drought, mild, moderate and severe droughts of pearl millet crop for the 5 selected stations are shown in Table 2.

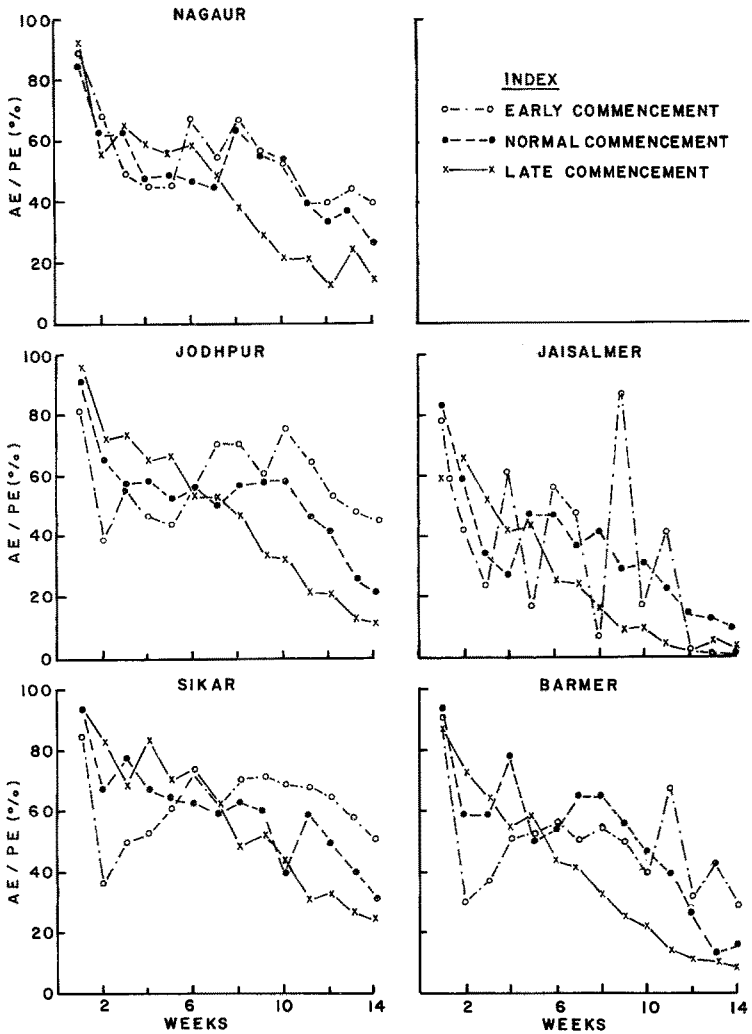

Fig. 1. The average pattern of *AE/PE* during early, normal and late commencements of growing season

If A_0 and A_1 conditions are considered as favourable for pearl millet production and A_2 and A_3 conditions taken together as unfavourable when compared to average conditions, the probability of favourable conditions are high for Sikar (75%) followed by Barmer (53%). In Jodhpur region the probability of unfavourable conditions is more (56%) and it is very high in case of Jaisalmer (88%). In Nagaur, it is even with 50 percent probability each.

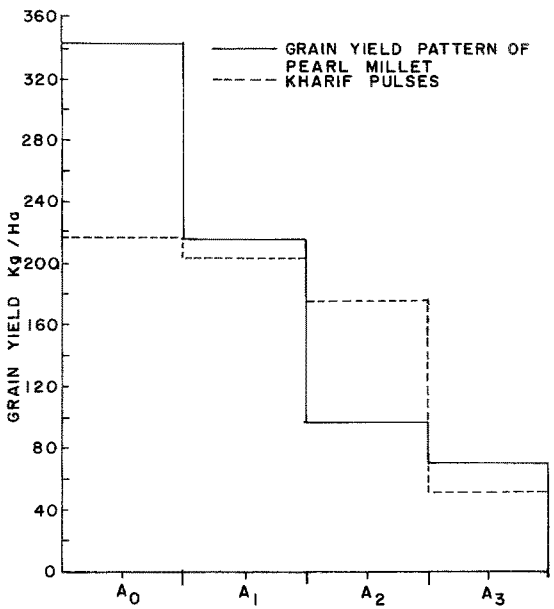

Fig. 2. Grain yield pattern of *pearl millet* and *kharif pulses* during different intensities of drought in Western Rajasthan

Under these drought conditions the production of the two major rainfed crops viz., pearl millet and kharif pulses was studied as shown in Fig. 2. It can be seen that except under moderate drought conditions, the yield level of pearl millet was always higher than that of kharif pulses. Moreover, it can be seen from Table 2 that the probability of occurrence of moderate drought conditions is very less in all these 5 regions, thus showing better performance of pearl millet compared to kharif pulses.

5. Conclusion

Thus the agricultural drought classification suggested in this paper can rationally be applied to any region and to any crop with a modification of the assumptions as suitable to that particular crop in that particular region. This rational classification can better be utilized in assessing the production potentials of various crops in a given region which can ultimately be used for suggesting any amendments in cropping patterns.

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