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DISTRIBUTION OF CROP YIELDS IN THE ARID REGIONS OF RAJASTHAN

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ABSTRACT

Randomness, normality and year to year fluctuations in the yields of pearl millet and kharif pulses in western Rajasthan were studied using non-parametric tests, co-efficient of variation and probability of the crop yields as the tools of analysis. The analysis showed random distribution of yields, non - normal distribution in more than 50 per cent of the cases, very high probability of low yields and increasing tendency of fluctuations.

INTRODUCTION

The crop yields in arid regions are not only characterised by low levels and high variability but also have successive recurrence (bunching). Bunching of low crop yields renders inventory and resource management difficult, Successive droughts cause a failure of the farmers' capacity for loss management and the risk adjustment mechanism becomes a negative sum game. Study of the distribution of crop yields is, thus, very important and the present investigations were carried out to examine the stochastic properties of randomness and normality for yields of pearl millet and kharif pulses, and to study the temporal fluctuations in crop yields in arid districts of western Rajasthan.

MATERIAL AND METHODS

The crop yield series for each of the 10 arid districts were analysed for bunchiness to find out whether such bunchiness had potential to reappear in total production at the regional level. Further, the aspect of frequency of occurrence of fluctuations in crop yields was studied by comparing coefficient of variation and skewedness during the time periods 1954-55 to 1969-70 (period I) and 1970-71 to 1977-78 (period II). The second period comprised years of special schemes for dryland agriculture such as All India Coordinated Research Project for Dryland Agriculture, Drought Prone Areas Programme etc. The results of earlier studies indicated that the crop yields did not incorporate significant trand and thus the need for netting it out and analysing the residuals did not arise (Nadakarni and Deshpande, 1980, Mruthyunjaya *et al.*, 1983).

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As a preliminary to the analysis of normality, each series was tested for randomness by methods of non-parametric tests requiring no previous knowledge of the distribution of the series. The three tests used were, Turning point test (Yule and Kendall, 1968), Runs test (Siegal, 1956) and Wallis-Moore phase length test (Day, 1965).

For testing normality of crop yields, test of skewedness (Snedecor and Cochran, 1967) and Geary's test of kurtosis (Day, 1965) were used in the study, taken from Critical values of coefficient of skewedness $\sqrt{b_1}$) for samples of small size were taken from table D. 25 (Zar 1974) and the crit cal values for testing the significance of coefficient of kurtosis (w') were obtained from linear interpolations from table 4 by Day (1965).

RESULTS AND DISCUSSION

Yule and Kendall (1968) turning point test for randomness in pearl millet and kharif pulse yield series indicated that, except in Bikaner for pearl millet, the actual number of turning points were within the range of two standard deviations from the mean number of turning points in all the arid districts combined. The Runs test for randomness in both the crops for all the districts combined indicated that the critical values ranging from 9 to 15 fell within the region of acceptance (7 and 19) of the alternate hypothesis of randomness. Wallis-Moore phase test for randomness also indicated that in pearl millet as well as in kharif pulses, the estimated values were within the critical points of 6.99 and 10.74 at 5 and 1 per cent, respectively. Thus, the results of all the three tests for randomness indicated random distribution of dryland crop yields (except for pearl millet in Bikaner district). Further, bunchiness at the regional level was not evident in case of both the groups of crops because of no bunchiness in individual districts.

Non-parametric tests do not always provide a definite indication of either randomnees or normality. For instance, Shiang *et al.* (1963) observed that for cotton yield series, Wallis-Moore test showed non-randomness at either of 1 or 5 per cent probability while Wald-Wolfwitz test established randomness at 5 per cent probability. In the present study, pearl millet yield series in Bikaner district showed bunchiness by Turning point test but the same turned out to be random by Runs test. To resolve the variance generated by using more than one test, visual inspection of scatter of residuals is often suggested (Mukherji and Vaidyanathan, 1980).

The results of the test for skewedness and kurtosis (Table 1) revealed that (1) the distribution of yields of both pearl millet and kharif pulses was non-normal (skewed, peaked or both) in more than 50 per cent of the cases. Further, it was revealed that the crop yield distributions were positively skewed and, in many cases, more peaked. Evidently, therefore, the probabilities of getting yields below average can be easily estimated only in less than 50 per cent of the cases. For the rest of the cases, compli-

cated distributions need to be fitted for characterising the probability properties. The magnitude of the yield deviations (obtained as the sum total of differences of the regional average with that at the district level) was also examined. Higher total absolute deviations for pearl millet resulted in skewed distribution at the regional level while lower absolute deviations for kharif pulses resulted in near-normal distribution at the regional level. There is greater risk in the production of crops as evident by greater probability of getting yields below average than getting yields above average. The high yield values in the series extending far above the mean, in some years, may more than offset lower values and thus provide the much needed cushion to dryland farmers to tide over bad years.

Table 1. Values of skewedness ceofficient (b_1) and standardised mean deviation coefficient (w^1) of the crop yields for arid districts in western Rajasthan

Cases	Pearl millet		Kharif pulses	
	b_1	w^1	b_1	w^1
Barmer	0.70 (+)	0.8109	2.01**(—)	0.7140**
Bikaner	0.35 (-)	0.8616	2.04**(—)	0.6872**
Jaisalmer	0.27 (+)	0.8 91**	0 99* (—)	0.7954
Churu	0.65 (—)	0.7958	0.15 (+)	0.8505
Jalore	1.85 **(—)	0.6505**	0 07 (+)	0 8557
Jodhpur	0.99 * (—)	0.7881	0.41 (+)	0,8886*
Nagaur	0.03 (+)	0.8854*	0.14 (+)	0.8457
Jhunjhunu	0.15 (+)	0.8405	1.67 (—)	0.6862
Pali	2 94 **(—)	0.6050**	0.20 (—)	0.8056
Sikar	0.63 (—)	0.7639	2.18**(—)	0.7218**
(Aggregate)	0.91* (—)	0.7519	0.49 (—)	0.7987

*Significant at 10% and **Significant at 2% probability. For b_1, the critical values (two tailed) for N-24 are 0.72 (10%) and 1.08 (2%). For w^1, the upper 5 and 1 per cent critical points are 0.8910 and lower 5 and 1 per cent critical points are 0.7353 and 0.7246, respectively; the expected value is 0.8063. Positive and negative signs denote nature of departure from the expected value.

Both randomness and normality of crop yields were apparently unaffected by the amount of rainfall. Contrary to the general belief, the number of significant cases of skewedness and kurtosis showed a tendency of increase with the increase in amount of annual rainfall received in these areas. For instance, 24 per cent of the crop yield observations in different crops showed significant skewedness in the districts (Barmer, Bikaner and Jaisalmer) receiving an annual rainfall of 300 mm or less while it was 30 per cent in the districts (Jhunjhunu, Pali and Sikar) receiving 400 mm or more of rainfall.

Deviations of crop yields from mean can be considered to be random and probabilities of consecutive years of low yields can be estimated easily if there are no cyclical or bunchy patterns in crop yields over large enough areas. The past variability of yields in each series was used to estimate the probabilities of getting yields 5% or 10%

below average for one, two and three years in a row, following Lutrell and Gilbert (1976). Such probabilities were worked out for pearl millet (Tabel 2) and pulses (Table 3) for only random and normal cases *vide* table 1. The variability of pearl millet yields in Barmer district (Table 2) for the years 1956-57 to 1979-80 indicated that the probability of getting yields 5% or more below the average in any one year was about 47%, for two years in a row 22% and for 3 consecutive years, about 11%. Boussard and Petit (1967) opined that risk could be neglected if its probability was small, say 5% or 1%. The risks of low yields observed in this study were much above these limits and hence cannot be overlooked. The numbers below each probability figure (Table 2) indicate the frequency with which various deviations from the mean occurred. For instance, pearl millet yields in Barmer district (Table 2) were 5% or below mean in 11 out of 24 years or in about 46% of the years. The frequencies

Table 2. Probabilities of getting yields of pearl millet 5% and 10% below average for one, two and thre years in a row for arid districts in Western Rajasthan.

Particulars		Districts			
		Barmer	Churu	Jhunjhunu	Sikar
5% below average:					
1 year	(Prob)[b]	0.4721	0.4641	0 4641	0 4522
	Freq.	11	11	9	12
		0 4583	0.4583	0.3750	0.5000
2 year	(Prob)[2]	0.2229	0.2154	0.2154	0.2045
	Freq	6[c]	8	2	8
		0.2609	0.3478	0.0870	0.3478
3 year	(Prob)[3]	0.1052	0.1000	0.1000	0.0925
	Freq.	0	0	3	0
		0	0	0.1364	0
10% below average:					
1 year	(Prob)	0.4443	0.4286	0.4247	0.4052
	Freq.	11	11	9	11
		0.4583	0.4583	0.3750	0.4583
2 year	(Prob)[2]	0.1974	0.1837	0.1804	0.1642
	Freq.	6	8	2	6
		0.2609	0.3478	0.0870	0.2609
3 year	(Prob)[3]	0.0877	0 0787	0.0766	0.0665
	Freq.	0	0	3	0
		0	0	0.1364	0

a. Yield series in this analysis are not skewed and average is simple arithmetic mean of 24 years.

b. The value of the normal deviate corresponding to the 5% and 10% below average yields and the probability of occurence of an yield less than or equal to them are obtained by referring normal probability integral table.

c. The frequency indicates that in the years (1956-57 to 1979-80) pearl millet yields in Barmer district were below average for 2 years in a row on 6 occasions. This frequency is expresed as a ratio by dividing 6 by 23, since there were only 23 possible combinations of two years in a row.

of actual occurrence of bad crop-yields provide a check on the randomness and symmetry of the crop yields series. If the frequencies diverge greatly from the probabilities calculated by using the normal distribution, the yield data would tend to be non-random, skewed or both. The frequencies were fairly close to the probabilities especially the probabilities of a crop in any one year or two years in a row.

Table 3. Probabilities of kharif pulse yields 5% and 10% below average for one, two and three years in a row for districts in Western Rajasthan. a

Particulars		Districts				
		Nagaur	Churu	Jalore	Pali	Western Rajasthan
5% below average						
1 year	(Prob)[b]	0.4522	0.4052	0.4721	0.4641	0.4483
	Freq.	9	11	10	11	10
		0.3750	0.4583	0.4167	0.4583	0.4167
2 year	(Prob)[2]	0.2045	0.1642	0.2229	0.2154	0.2010
	Freq.	2[c]	4	4	4	6
		0.0870	0.1739	0.1739	0.1739	0.2609
3 year	(Prob)[3]	0.0925	0.0665	0.1052	0.1000	0.0901
	Freq.	3	5	4	5	0
		0.1364	0.2273	0.1818	0.2273	0
10% below everage						
1 year	(Prob)[2]	0.4052	0.4090	0.4443	0.4286	0.3974
	Freq.	9	11	10	11	6
		0.3750	0.4583	0.4167	0.4583	0.2500
2 year	(Prob)[2]	0.1642	0.1673	0.1974	0.1837	0.1579
	Freq.	2	4	4	4	4
		0.0870	0.1739	0.1739	0 1739	0.1739
3 year	(Prob)[3]	0.0665	0.0684	0.0877	0.0787	0.0627
	Freq.	3	5	4	5	0
		0.1364	0.2273	0.1818	0.2273	3

c. The frequency indicates that in 24 ycars (1956-57 to 1970-80) kharif pulse yields in Nagaur district were below average for 2 years in a row on 2 occasions. This frepuency is expressed as a ratio by dividing 2 by 23, since there were only 23 possible combinations of two years in a row.

The temporal amplitudes of fluctuations in crop yields and methods to contain such fluctuations in arid areas from the core of analysis of yield distribution. A perusal of table 4 would indicate that relative variability (C.V.) at district as well as at the aggregate level of both the crop groups tended to increase in recent years (period II). Similarly, the departure from symmetry was more pronounced and widespread, particulary in pearl millet, during the period II. Obviously, crop yield fluctuations tended to increase over time, implying that the special schemes introduced during 1970's to develop arid dry farming regions have atleast not so far shown signs of stabilizing the crop yields.

Table 4. Fluctuation in crop yields in the Districts In Western Rajasthan during 1953-55 to 1969-70 (PI) and 1970-71 to 1977-78 (PII)

Districts	Pearl millet				Kharif pulses			
	P-I		P-II		P-I		P-II	
	C.V.	$/b_1$	C.V.	$/b_1$	C.V.	$/b_1$	C.V.	$/b_1$
Barmer	61	0.35	78	0.72	116	2.36	112	1.23
Bikaner	63	0.15	79	0.36	60	0.96	81	1.60
Nagaur	30	0.04	32	0.02	26	0.48	69	0.37
Churu	39	0.03	69	0.08	33	0.38	56	0.14
Jalore	65	0.36	82	1.55	59	0.21	88	0.50
Jhunjhunu	35	0.56	73	0.35	45	0.03	99	1.40
Sikar	39	0.94	45	0.34	80	2.32	82	0.75
Pali	38	0.13	93	1.93	38	0.55	85	0.60
Jaisalmer	84	0.07	95	0.45	—	—	—	—
Jodhpur	60	0.22	71	0.50	62	0.18	92	0.84
Western Rajasthan	35	0.33	59	0.72	21	0.38	56	0.27

C.V. means coefficient of variation expressed in percentage and b_1 means coefficient of skewness.

Under such increasing risk situation, investment in modern inputs may not be feasible and a break-through in crop production is difficult to achieve. Technological options in the form of soil moisture conservation measures, diversification of demand for coarse grains and inter-cropping with pulses are often suggested as corrective measures. A more pragmatic approach in land use logistics in such areas (particularly those receiving < 400 mm annual rainfall) would be to gradually dispense with crop production and shift to a kind of mixed farming with animal husbandry, grassland and pasture improvement, and tree crop production as the essential components.

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