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Pattern of rainfall variability over dry farming zone of India and its agricultural implications

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सार – इस शोध–पत्र में वर्षा के लिए उपयुक्त मानदंडों का उपयोग करते हुए फसल बोने के लिए उपयुक्त मानसून वर्षा के प्रारंभ, कृषि संबंधी बिंदुओं को ध्यान में रखते हुए वर्षा ऋतु का समापन और वर्षा के चरम मानों का पता लगाया गया और इनके स्थानिक वितरणों का अध्ययन किया गया। संभावित प्रवृत्तियों की जाँच करने के लिए समय के साथ प्रत्येक प्राचल के सहसंबंधों का आकलन किया गया। वर्षा के कुल दिनों और समय के साथ मौसमी (मानसून) वर्षा के मध्य संबंधों का पता लगाने का प्रयास किया गया और इस पर विचार विमर्श किया गया। वर्षाधीन खेती के क्षेत्र (डी.एफ.आर.) में वर्षा के पैटर्न में सामंजस्य स्थापित करने के लिए क्षेत्र के विभिन्न उप–प्रदेशों से एक सूचकांक तैयार किया गया है। यह पता लगाने के लिए दशकीय विश्लेषण भी किए गए कि क्या एक दशक में हुई माध्य वर्षा के आँकड़ें अन्य दशकों के आँकड़ों से भिन्न थे।

ABSTRACT. Using suitable rainfall criteria, beginning of monsoon rains suitable for crop sowing, cessation of rainy season from agricultural point of view and the peak values of the rainfall, have been determined and their spatial distribution studied. Correlations of each of these parameters with time were computed to examine the possible trends. Association between number of rainy days and seasonal (monsoon) rainfall with time have also been attempted and discussed. With a view to determine coherence in rainfall pattern in the dry farming region (DFR), an index has been devised from its different sub-regions of the zone. Decadal analysis has also been done to see whether mean rainfall in a decade statistically differed from those in other decades.

Key words – Rainfall variability, Dry farming zone, India, Agriculture.

1. Introduction

Nearly one third of India's land area receives annual rainfall between 400 and 1000 mm. This is called the dry farming region (DFR) and stretches from Punjab to Tamil Nadu. Agriculturally, this is the area where crop production often is dependent on rainfall and is low as it lacks adequate irrigation facilities. Instability in agriculture production in India is mostly due to wide-fluctuations of the crop produced in this region. Though this vast stretch of land has medium to deep soils, it is the low quantum of rainfall and its high variability, which makes agricultural operation a hazardous task.

Unfortunately, this region does not seem to have attracted the attention of agricultural scientists/ agrometeorologists, it deserves. Sarkar and Biswas (1978, 1988) analysed probabilistic rainfall in the region. Water requirements of maize crop in this region have been determined from lysimetric studies by Das and Ballal (1994). The present study is designed to find out patterns of rainfall fluctuations at selected districts within the region, using suitable criteria for crop onset and retreat rainfall. The peak rainfall during the season, the number of rainy days etc. have also been determined and their characteristics evaluated. An index has been developed, based on seasonal rainfall data, to evaluate spatial coherence in rainfall incidence in the region.

2. Materials and methodology

The study utilises weekly, seasonal and annual rainfall data from 1901 to 1990 in respect of 50 districts in the dry farming region (Fig. 1). The weekly analysis stretches rainfall between the last week of May to the end of October. Onset and retreat of rainfall from agricultural point of view and the highest weekly rainfall between these two epochs, called "Peak rainfall", have been determined for each year. In this study, crop onset rainfall *i.e.*, the onset week of the agricultural season is defined as the week receiving rainfall 25% or more than that in the preceding week provided the weekly rainfall amount is more than 10 mm (Adejuwon *et al*. 1989). Similarly, the retreat rainfall week is defined as the week receiving rainfall 25% or less than that in the preceding week provided the weekly rainfall amount is less than 10 mm but greater than zero. Peak rainfall is defined as the highest rainfall in a week between the onset and retreat

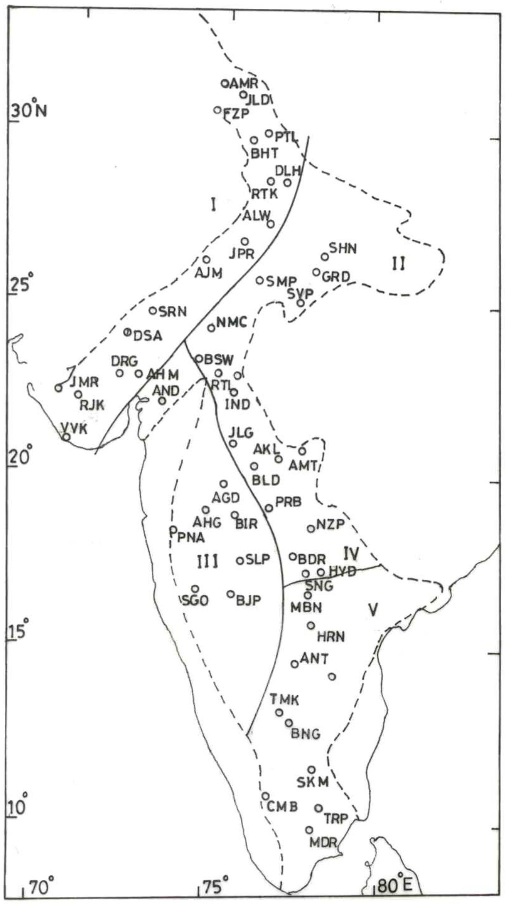

Fig. 1. Network of stations used in dry farming zone and sub-zones

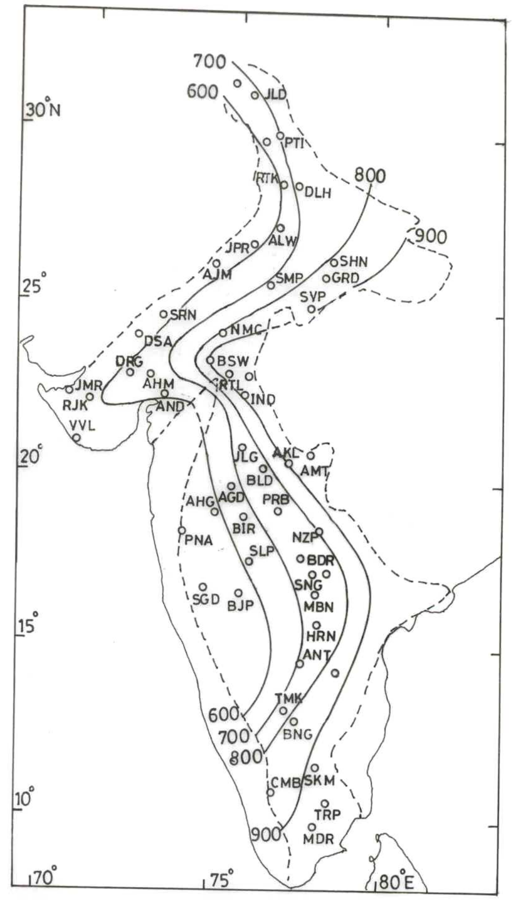

Fig. 2. Mean annual rainfall (mm) in DFR zone

weeks. On the other hand the seasonal rainfall is defined as the total rainfall between 1 June to 30 September, which constitute the monsoon season.

With a view to find a systematic increase or decrease in above rainfall parameters, linear correlations of each of these with time, have been computed. This has also been done for rainfall per rainy day. The 90 years data provided a fairly long series, to examine if (*i*) rainfall pattern at any location is under going secular variations, and (*ii*) how does the rainfall at a station differs from nearby stations. For these purposes, the data series has been divided into periods consisting of 10 years *i.e.*, 1901-1910, 1911-1920,………. , 1981-1990. They were then used to compute Students ' *t* ' statistic as

$$t = (\bar{x}_1 - \bar{x}_2) \,/\, [\,(n_1\sigma_1^2 + n_2\,\sigma_2^2)\,/\,(n_1 + n_2 - 2)\,(1/n_1 + 1/n_2)\,]^{1/2} \qquad (1)$$

where, x_1 and x_2 are the two sets of rainfall series and $\bar{x}_1$ and $\bar{x}_2$ the means of the two sets, σ_1 and σ_2 the corresponding standard deviations, n_1 and n_2 the number of respective observations. In this mode of analysis $n_1 = n_2 = 10$ and thus decadal rainfall for the each of decades 1901-10, 1911-20, …….., 1981-90 has been compared with one another for the same station.

DFR was divided into five different zones (Fig. 1) based mainly on soil characteristics, thus,

Zone I - Sandy soil

Zone II - Alluvial soil

Zone III - Black soil

Zone IV - Black and red sandy soils

Zone V - Red sandy soil

An attempt was also made to quantify coherence in the rainfall characteristics within each zone. The

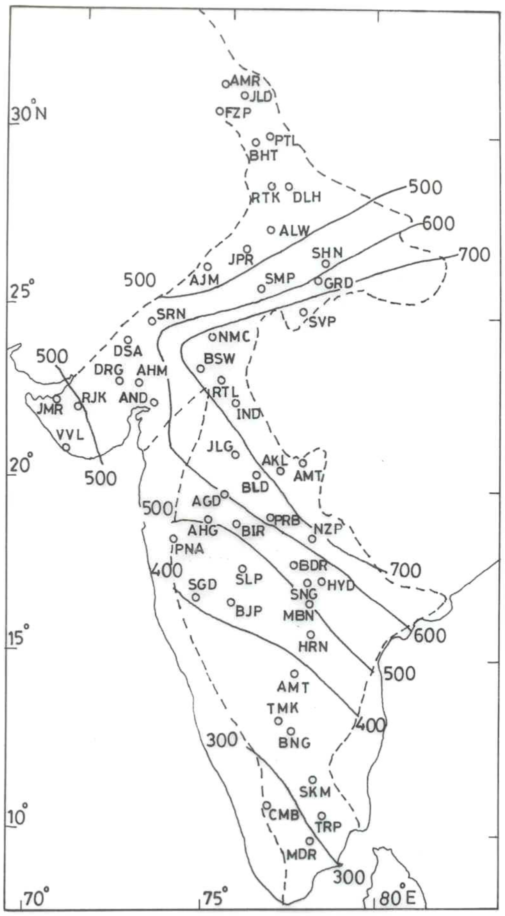

Fig. 3. Mean crop seasonal rainfall (mm)

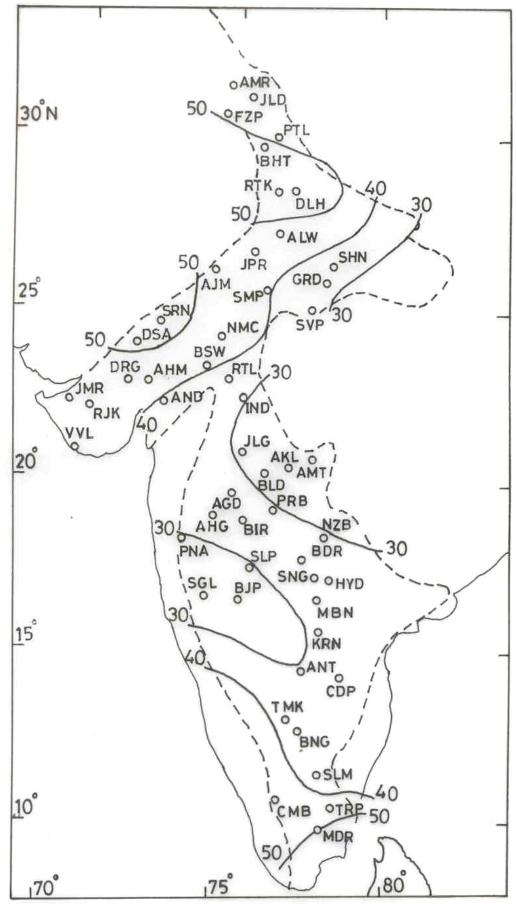

Fig. 4. Variability of crop seasonal R/F

coherency factor 'S' was computed as described in the following method.

If 'I' is the number of the stations in a zone, and x_i is the rainfall at the i^{th} station within it, then

$$R_j = I^{-1} \sum x_i \qquad (2)$$

Where as 'R_j' is the normalised departure of seasonal rainfall for each year for each zone.

R_j has been determined for each of the five zones demarcated in the study for each year.

Here j = 5, the number of zones within DFR.

Next for DFR as a whole we determine R_z using Eqn. (2) where, in this case I would represent the total number of stations in the DFR. 'R_z' is the normalised departure of seasonal rainfall for each year for whole DFR. Based on 'n' years of data let the mean of R_z be $\overline{R}_z$.

The sum of departure of R_j for any year from $\overline{R}_z$ is determined as,

$$Aj = \sum_{i=1}^{n} \left(R_j\right)_i - \overline{R}_z \qquad (3)$$

Then the coherency factor

$$S = \left[\sum_{j=1}^{5} \left(A_j\right)^2 / 5\right]^{1/2} \qquad (4)$$

This is rainfall index for coherence for DFR as whole.

3. Results and discussion

3.1. *Rainfalls analysis*

Based on 90 year's data, the mean annual rainfall for DFR is shown in Fig. 2. It can be seen that the rainfall is

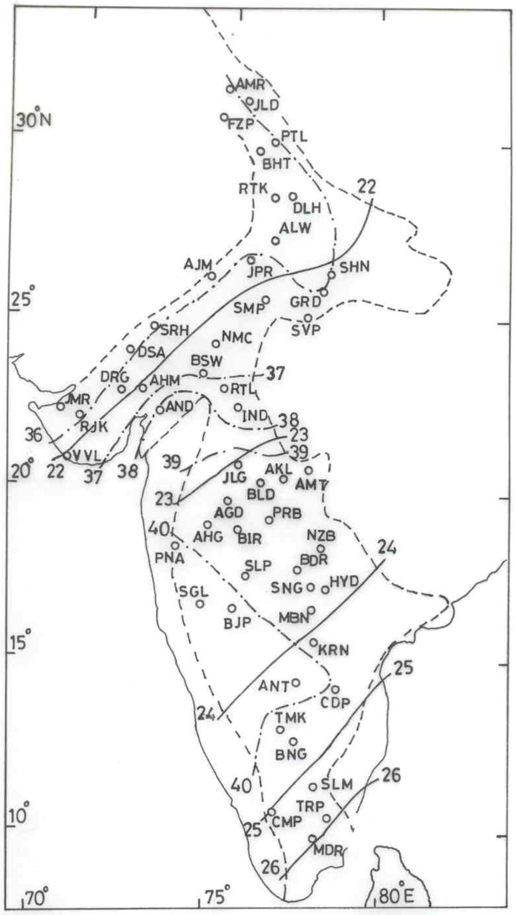

Fig. 5. Crop mean onset week (—) and retreat week (–·–·–)

600 mm or less over extreme west Rajasthan, Madhya Maharashtra and North Interior Karnataka. Though the DFR as a whole receives 400-1000 mm of rainfall annually there are wide variations within the zone. This is particularly the case when we consider rainfall in the crop growth period. The crop season rainfall is less than 300 mm in the extreme southern peninsula (Fig. 3). Incidently this region is also characterised by high rainfall variability of more than 50% in kharif season (Fig. 4). Another region of variability of this magnitude is in Punjab - Haryana and central Rajasthan, which, however receives rainfall in the range of 400 to 500 mm. But in other areas, the rainfall is 500-700 mm with a comparative low component in variability. Considering an average of 14 cropping weeks and assuming 5 mm as evapotranspiration loss per day, these are the areas which seem to be highly vulnerable. In contrast, the eastern periphery of the zone from Telangana to NE Madhya Pradesh seems to receive rainfall, which meets ET demands to a very large extent.

The crop seasonal rainfall is characterised by high variability as mentioned above. Over parts in north and extreme south the variability is more than 50% as may be seen in Fig. 4. In the north-west parts of DFR, the variability exceed 40%. A small pocket in west Vidharbha and adjoining areas as well as parts of north western Karnataka the rainfall shows least variability about 30%. Fig. 4 shows that the variability ranges from 30% to 50% over entire dry farming region.

The crop onset rainfall (Fig. 5) over interior Maharashtra and adjoining Telangana region of DFR could be as early as 24^{th} week (11^{th} to 17^{th} June). North and south of this zone, the onset of crop seasonal rainfall is delayed particularly in the interior Tamil Nadu where it could be as late as 26^{th} week (25^{th} June to 1^{st} July). The retreat of crop seasonal rainfall (Fig. 5) is earliest *i.e.* 36^{th} week (3^{rd} to 9^{th} September) over DFR in the NW, while the same is delayed southwards. Over the Peninsula the retreat of rainfall gets delayed. In Rayalaseema, it is 39^{th} week (*i.e.* 24^{th} to 30^{th} September), while it is as late as 40^{th} week (*i.e.* 1^{st} to 7^{th} October) over Tamil Nadu. The cause of the prolonged crop season over these areas is perhaps the passages of low latitude easterlies, which brings copious rains in the south Peninsula. Rainfall peaks are noticed around 30-31^{st} week (late July to early August) north of 20° N when the monsoon axis is in its normal position or south of it. The peak weekly rainfall often exceeds 200 mm, declining southwards. Moreover there appears a bi-modal tendency in weekly rainfall over DFR during the crop season with a serious consequence on agriculture in the zone.

Even today there is no universally acknowledged criteria for the start and end of crop season. Thus, there is no accepted measure of the length of the crop growth season (Hutchinson 1985). In the present analysis, arbitrary values for their two epochs of the growth cycle have been chosen as described above. Analysis of crop season i.e., number of weeks from onset to retreat, revealed that over extreme NW parts of DFR and in interior Tamil Nadu, the crop period is of 12 to 14 weeks duration (Fig. 6). In the interior Peninsula the crop duration is comparatively large and could be 15 weeks or even more. Analysis of yearly variations in length of crop season revealed that the crop season virtually remains unaltered. This is also, confirmed from the correlation analysis when we find the association with time was very weak and insignificant.

3.2. *Correlation analysis*

The large sample of data was used in this paper to find if the rainfall in any location in the DFR exhibit any regular pattern. For this purpose, time was used as an independent dummy variable while the rainfall characteristics mentioned above were considered as dependent variable. It was found that the correlations for a

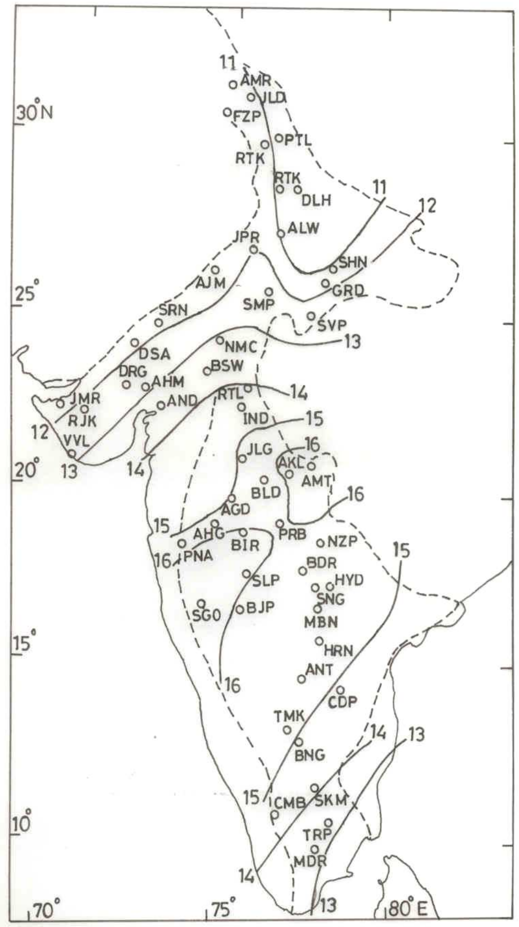

Fig. 6. Mean duration (weeks) of crop season

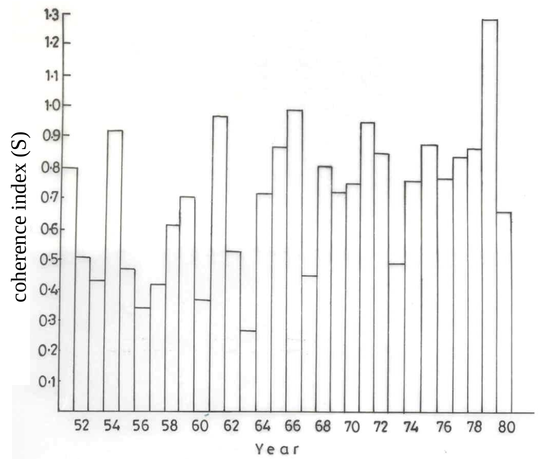

Fig. 7. Yearly variation of coherence index (S)

good number of stations were rather low *i.e.* less than 0.40 and among those cases where they were statistically significant, the low values of correlation precluded their potential use for forecasting purpose. Thus, the climate over DFR does not seem to be undergoing any systematic climatic shift.

As is natural to expect, crop seasonal rainfall *i.e.*, rainfall from onset to retreat, bear a very high and significant correlation with seasonal (June to September) rainfall for all stations. The peak rainfall and the crop seasonal rainfall also had positive and large (generally more than 0.60) co-relations. Similarly, the crop season rainfall and the weeks of retreating phase were positively associated for all stations. In other words, the later the retreating week, the more will be crop seasonal rainfall.

Also, the number of rainy days (*i.e.* rainfall more than 2.5 mm per day) and crop seasonal rainfall were found significantly correlated, the coefficients often exceeding 0.90. This means the larger the number of rainy days; the larger is the likely crop season rainfall were also separately correlated with time. The correlations between week of onset and crop season rainfall were found low and insignificant.

3.3. *Decadal analysis*

Analysis of rainfall at the same location for two different non-overlapping periods using Eqn. (1) do furnish some information on possible climate change. Study of mean rainfall in the same district in two different decades brought out some interesting results. By and large, it was seen that the rainfall in first decade (*i.e.* 1901-1910) is significantly different from the rainfall till 1951-1960 decade. Rainfall in 1971-1980 decades also showed significant difference with 1941-1950 and 1951-1960 decades.

3.4. *Spatial coherence in rainfall anomalies*

As may be seen above, a notable characteristics of DFR is its remarkable extent in space, which nearly covers one third of India's area. Naturally, one is tempted to assure that rainfall in such an extensive tract is far from coherence in characteristics. The coherence pattern in the crop season rainfall characteristics within the DFR has been computed using Eqn. (4). For the entire DFR, for the period 1901-90, the value of spatial coherence S is found to be 0.412. A low value in the coherence index S would indicate that rainfall in the zones is coherent with that of the DFR within which they are geographically located. Ideally, a value of zero would suggest a perfect coherency. A high value of 20 would mean utter lack of coherency in the rainfall. For the 30 years period *i.e.* 1951- 80, the yearly variation in *S* is shown in Fig. 7 by histograms. This period was choosen as it witnessed a large number of drought for many areas in the country. Yearly variability in the values of S is clearly reflected in the figure. However, it may be noted the values rarely exceed 1.0 .

3.5. *Agricultural implications*

Agriculture in the northern part of DFR depends heavily on southwest monsoon rainfall while the eastern Peninsula depends upon northeast monsoon**.** Uneven distribution of rainfall during the crop season and deficiency in seasonal rainfall amounts always lead to severe drought and decrease in the production as it happened in the well known drought years in 1972, 1979, 1982, 1987 etc., (Bhalme *et al*., 1982, Bhalme and Jadhav, 1983). A low rainfall area may be located along the southern part of the dry farming tract where mean crop seasonal rainfall is confined to 300 mm to 400 mm (Fig. 3). It is difficult to raise kharif crop in this area, but prospects of rabi crops are good. With the progress of the monsoon, the main rainfall belt shifts towards north and it is found to be located in the areas comprising of southeast Gujrat, adjoining parts of Madhya Pradesh and Maharashtra where crop seasonal rainfall exceeds 700 mm. The kharif crop potential in this area seems to be very good. This is also in conformity with the identification of broad crop prospects by Sarkar *et al*., (1982) in different areas of the dry farming tract of India. It is likely that the kharif crop in Maharashtra and Gujrat may suffer water stress conditions during the 2^{nd} half of August to early September when the monsoon activity remains lowest. There is need to introduce varieties which could resist water stress in such conditions. Water management methods to utilise every drop of water for agriculture and allied applications should be practiced to enhance crop yields in these dry farming tracts of the country.

It is found that seasonal rainfall bears a high correlation with each of the other elements *viz*. crop season rainfall, number of rainy days etc. However when these parameters were correlated with time, the correlations were found small and insignificant. Absence of significant correlations between crop seasonal rainfall, week of onset retreat of rainfall and number of rainy days with time, thus indicate that rainfall and its associated parameters have been fluctuating each year within the normally accepted ranges. Any abnormal behaviour in these factors in any year as a result, need not be a cause of concern. The existing cropping pattern in the DFR zone, therefore, does not call for any immediate major changes. However, detailed analysis of crop season rainfall and other parameters would be needed for contingent planning to deal with any abnormality but not for changing cropping pattern. Since moisture availability to plants from soil determines its growth and yield, what is needed is to have a better soil-water-management system to take care of possible moisture stress during crucial crop growth stages particularly during anthesis and flowering stages.

4 Conclusions

(*i*) The crop seasonal rainfall variability is around 40% over most parts of dry farming region. It exceeds 50% around north-west part of DFR and is less than 30% over a small pocket in east Vidarbha and adjoining districts of Marathwada and Telangana.

(*ii*) Crop seasonal rainfall bear positive correlation with both peak rainfall and weeks of the retreating phase and has potential use in agriculture from forecasting point of view.

(*iii*) The rainfall in DFR is largely coherent. Decadal analysis indicated that the rainfall in most of districts during 1971-90 is significantly different from that in two decades between 1941-60. However, it does not indicate that this is a result of climatic change.

(*iv*) No persistent large scale changes in rainfall and its associated parameters has been observed. For changing the cropping pattern the detail analysis is needed for drawing any contingent plans.

References

Adejuwon, J. O., Balogun, E. E. and Adejuwon, S. A., 1989, "On the annual and seasonal patterns of rainfall fluctuations in sub-Saharan west Africa", *J. Climatal*., **9**, 839-898.

Bhalme, H. N., Mooley, D. A. and Jadhav, S. K., 1982, "Fluctuations in the drought/flood area over India and relationship with the southern oscillation", *Mon. Weath. Rev*., **3**, 86-94.

Bhalme, H. N. and Jadhav, S. K., 1983, "Major quasi-periodic fluctuations in the drought indices", *Arch. Met. Geoph. Biocl. Ser. B*., **32**, 309-317.

Das, H. P. and Ballal, A. S., 1994, "The evapotranspirative demand and water use efficiency of maize crop (*zea mays* L.) in the semi - arid tract of India", *Mausam*, **45**, 337-346.

Hutchinson, P., 1985, "Rainfall analysis of the Sahelian drought in the Gambia", *J. Climatol*., **5**, 665- 672.

Sarkar, R. P. and Biswas, B. C., 1978, "Agricultural Meteorology in India a status report. Proceedings Agroclimatological research needs of semi-arid tropics", ICRISAT, Hyderabad, India, 37-46.

Sarkar, R. P., Biswas, B. C. and Khambete, N. N., 1982. "Probability analysis of short period rainfall in dry farming tract in India, *Mausam*, **33**, 3, 269-284.

Sarkar, R. P. and Biswas, B. C., 1988. "A new approach to agroclimatic classification to find out crop potential", *Mausam*, **39**, 343-358.