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A study on the occurrence of drought at Hebbal

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ABSTRACT. Rainfall data of seventy-one years of Agricultural Research Station, Hebbal, Bangalore have been made use to study the rainfall distribution and occurrence of drought. Out of several classifications and groupings of rainfall, "decile" grouping found to be the best for any analysis. The percentage of rainy days, number of dry spells during the cropping season and coefficient of variability in the amount of rainfall were found to be the important factors affecting the severity of drought. Using these factors along with crop-soil-water relationships a tentative definition of drought for south eastern parts of Mysore State has been drawn.

1. Introduction

The rainfall distribution has been studied by several workers with more than one objective. Predicting the occurrence of drought based on the analysis of rainfall is one of the major objectives in these studies.

The quantity and distribution of rainfall of any place depends upon its geographical position. It has been pointed out by Hiatt and Schlomer (1955) that places near sea shore, usually receive good rainfall associated with good distribution.

Tannehill (1955) reviewing the work on the cyclic nature of rainfall, classified the studies into two groups. First group was to identify a cycle based on the data for a very long number of years. He pointed out that in similar studies Edward Brukner of Vienna identified a thirtyfive years cycle in the rainfall distribution of Europe, based on the severity of winters. The second group of studies confined to a few years data and in these, the larger changes were explained by relating them to some physical factors. Of the several factors responsible for the changes in precipitation, variation in solar radiation is of more importance as it is supposed to follow a definite cycle.

In order to interpret the rainfall data, Cocheme and Frequin (1967) grouped the years into quintiles; and fitted a theoretical frequency distribution. Gibbs and Mahar (1967) have used "Decile" groupings for rainfall studies and have drawn the maps of Australia, depicting the zones of drought.

Studies on the rainfall pattern poses a special problem as, it is non-continuous both with respect to time and space. Glover and Robinson (1953) opined that the rainfall data could be used without transformation for most of the studies. Manning (1950) on the other hand has suggested the transformation of the raw data.

In order to study the frequency of occurrence of drought and its severity, the rainfall data of the Agricultural Research Station, Hebbal was used. It was also intended to specify the factors that contribute to the severity of drought and to define a drought year based on the observations made.

2. Material and methods

Agricultural Research Station, Hebbal, Bangalore is situated at Lat. 13°7′ N, Long. 74°37′E and at an elevation of 899 m above mean sea level. The mean temperature during the year varies from 19·0°C during winter season to 27·0°C during hot weather season.

The annual rainfall (mean annual 828 mm) is received in two distinct monsoons, that is, southwest monsoon (June to September) and northeast monsoon (October and November). Daily rainfall data of the station from 1897 have been utilized.

In order to classify the years into bad and good years in terms of total rainfall and distribution, three systems were followed. In the first, the data were classified into three groups using mean and standard deviation. In doing so it was observed that there were only 8 years of below one standard deviation. From practical experience, it was observed that there were many more number of drought years. Therefore, in the second, the data was

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TABLE 1

Types of rainfall classifications

(A) Five groupings using mean, 0·5 S.D. and 1 S.D.

	Rainfall range (mm)				
	Less than (mean—S.D.) <558	(Mean—σ) to (Mean—0·5σ) 559-653	(Mean—0·5σ) to (Mean + 0·5σ) 654-843	(Mean + 0·5σ) to (Mean + σ) 844-938	Greater than (Mean + S.D.) >939
No. of years	8	17	24	6	16
Probability of occurrence (%)	11·3	23·9	33·8	8·6	22·5
Mean C. V.	148	140	140	131	123

(B) "Decile" grouping

	Rainfall range (mm)								
	401-484 (Severe drought)	485-567 (Drought)	568-650 (Moderate drought)	651-733	734-899	900-982	983-1065	1066-1148	>1149
No. of years	5	7	12	14	15	9	5	3	1
Probability of occurrence (percentage)	7·1	9·9	16·9	19·7	21·1	12·7	7·1	4·2	1·4
Mean C. V.	148	148	138	139	137	129	128	106	122

Mean for cropping season 748 mm, Standard deviation 190

further sub-divided into five groups, using mean and 0·5 standard deviation. In the third system nine groupings were made. In all these cases the probability of occurrence of rainfall in each group was computed.

In order to study the severity of drought and to find the important parameters for the same, the coefficient of variability for weekly rainfall during cropping season was worked out. The cropping season at Hebbal is considered from 19th to 48th "standard weeks" (7 May to 2 Dec) of the year (total 30 weeks). 90 per cent of the annual rainfall is received during this period alone. In addition, number of dry spells of more than 8 days duration and percentage of number of rainy days to total days in cropping season were studied.

3. Results and discussion

(a) *Studies on the cyclic pattern of annual rainfall*

In order to study whether a cyclic pattern in the rainfall could be traced, 5-year averages were examined. The same is presented in Fig. 1. The figure reveals no cyclic trend upto 1927. A cycle of ten years of below average and five years of above average can be traced after 1927, and three such cycles could be seen. The latest peak was in 1958 to 1962, which is being followed by five years of below average rainfall. If the cycle continues, the average rainfall of next five years can be expected to be below normal. The figure further indicates that the rainfall upto 1922 was above the general mean of 71 years data. Separate means were worked out for the first 25 years (upto 1922) and for the remaining period. It was observed that the mean for the first 25 years was 67 mm; more than the mean for the next 45 years (1923-67). Tannehill (1947) stated that large scale denudation of forests may affect the amount of precipitation in a locality. The denudation of forests to meet the demands of increasing population and industrial development may be one of the causes for reduction in average rainfall since 1922. However, there is no data available regarding the denudation of forests around Bangalore.

(b) *Classification of years on the basis of quantity of rainfall and probability of occurrence of drought year*

In order to identify drought years of varying degrees, the individual years data was subjected to 3 types of groupings. In this, as pointed out earlier,

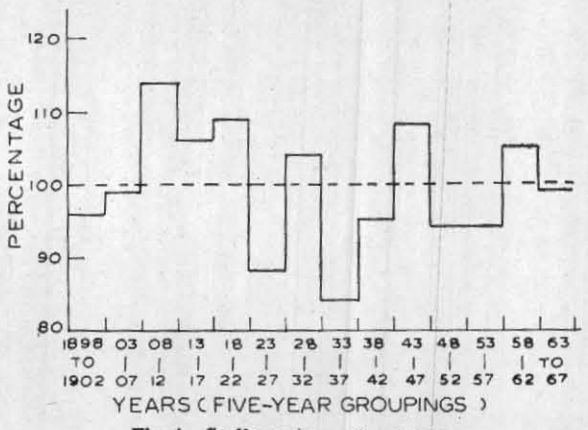

Fig. 1. Cyclic nature of rainfall

the rainfall received during the cropping season, from May to November end alone was taken up, as this bears more relationship to crop growth, and further nearly 90 per cent of the annual rainfall is concentrated during these periods.

According to mean *plus* or *minus* 0·5 standard deviation grouping, there were 17 years in mean *minus* 0·5 standard deviation, thus bringing 25 years in below normal range. This is presented in Table 1(A). Following Gibbs and Mahar (1967) the range of variation was divided into ten, and the number of years coming under each group was worked out. The decile groups 5 and 6 were pooled together to represent normal rainfall range, leaving nine groups of which four are below normal and four are above normal rainfall range. This type of classification was better than the previous one (*viz.*, Mean$\pm$0·5 S.D. and 1·0 S.D.), in that it not only brought the same number of years under below normal rainfall years, but it clearly classified them into three groups of varying degrees of drought (Table 1). The first decile group, the years that received less than 484 mm of rainfall have been classified as 'severe' drought years, the years which come under' decile' group two (rainfall between 485-567 mm) as drought years and the years that come under decile group three (rainfall between 568-650 mm) as 'moderate drought' and the years that come under decile group four, as just below average rainfall years. The two groups of drought, *viz.*, 'Severe drought' and 'drought' falls in the general limit suggested by Kanitkar (1960) except for the fact that rainfall received during cropping season alone has been considered here, instead of in the whole year. This modification has been introduced here, because, rainfall received during winter and summer in these localities is of little use to the main crop as the soils are coarse and have poor water holding capacity, unlike in black soil of Deccan plateau, based on which conditions Kanitkar (1960) have drawn his definition. Further the third decile grouping with upper limit 650 mm, have been named here as 'moderate drought' mainly because of soil conditions, and also due to cropping pattern. Landsberg (1958) has pointed out both soil and plant have to be considered for defining drought. The major crop *Ragi* (*Eleusine Coracona*) is of 100 to 140 days duration and the water requirement is 500 to 510 mm (Raheja 1961; Baliga and Sridharan 1968). Giving provision for moisture loss through soil drainage and run-off, it may become difficult to get a normal crop even with 650 mm. So based on the quantity alone, years with rainfall less than 650 mm during cropping season could be classified as 'drought years of varying degrees'.

The relative frequencies of occurrence of drought of different degrees was also worked out and given in the same table in the third row.

(c) *Studies on distribution of rainfall*

Hitherto only the quantitative aspect of rainfall was considered without any reference to qualitative aspect. The distribution of a known quantity of rainfall is as important as the quantity. Baliga and Sridharan (1968) have mentioned the water requirement of *Ragi* at different phases of growth. Moisture stress at any phase, particularly critical stages like tillering and grain-filling, will effect the yield. Therefore the study of nature of distribution of rainfall during good, average and bad years is of importance. Accordingly the coefficient of variability of weekly rainfalls in each year was worked out. The coefficient of variability values varied from 92 to 219 per cent. These coefficient of variability values were also grouped according to decile group classification. Using the lower value in the grouped 4-7 decile range the chances of getting good distribution in the group decile range of rainfall has been worked out and presented in Table 3.

TABLE 2

Classification of years according to decile values of coefficient of variability of rainfall

Coefficient of variability (ranges)	No. of years
Decile range 1-3	
<134	35
Decile range 4-7	
134-186	34
Decile range 8-10	
>187	2

TABLE 3

Relationship between the rainfall amount and its distribution

Rainfall (mm) (According to decile value of rainfall)	No. of years	Percentage of years with good* distribution
	Decile range 1-3	
401-650	24	37·5
	Decile range 4-7	
651-982	38	52·6
	Decile range 8-10	
983-1149	9	66·7

*Coefficient of variability $\leq$ 134 has been considered as good distribution

TABLE 4

Values of parameter for drought years (deciles I and II)

Year	Rainfall (mm)	No. of dry spells (>8 days duration)	Percentage of rainy days to the total No. of days of the season	C.V. of weekly rainfall
1934	401	4	10	179
1908	409	4	19	99
1937	425	10	15	131
1965	441	9	12	166
1907	442	9	15	167
1957	508	5	21	158
1967	521	7	17	143
1945	525	8	17	145
1929	560	5	19	137
1920	561	8	21	113
1914	563	8	20	175
1913	567	7	18	167

Mean coefficient of variability values for the different rainfall decile groups are presented in Table 1 (B). The C. V. values for the years receiving normal rainfall was found to be 137 per cent (mean of 5th and 6th deciles) which nearly coincides with the lower value of 4-7 decile group of coefficient of variability and this value was found to increase as the rainfall reduced and *vice-versa*; indicating that good rainfall is usually associated with good distribution and *vice-versa*.

(d) *Definition of drought*

Many attempts have been made to define drought. Gibbs and Mahar (1967) have mentioned that the amount of a rainfall is the best indicator of drought. Landsberg (1958) stated that drought is not a physical but a biological phenomenon and should therefore be defined separately for each plant species and soil environment. Thronthwaite (1947) and Subramanyam and Subramaniam (1964) have also opined that any definition of drought should consider the type of crop and its water requirement and soil condition.

Other definitions by Henry (1906), British Rainfall Organisation (1936) confined only to a shorter periods than the year and they considered only one factor, *i.e.*, amount of precipitation. Such definition where only one factor for smaller periods was considered would not be of much use as such small droughts may not effect the crop to a large extent, especially the millets, which are noted for their drought tolerance and usually recovers from short spells of drought.

The concepts of drought by Kanitkar (1960) and Ramdas (1950) though covers the entire year, do not take into consideration the distribution of rainfall, soil condition and crops. Further in these definitions, the factors affecting the severity of drought have also not been taken into consideration.

In order to identify and study the parameters affecting drought the rainfall of twelve years, out of 71 years which have received very low rainfall (less than 568 mm) coming under decile groups of one and two, were subjected to detailed studies. For these years the percentage of rainy days to the total number of days during the cropping season, number of dry spells of more than 8 days duration were worked out and the data is presented along with respective coefficient of variability values in Table 4. Here rainy day is considered as the day receiving a rainfall of 2·5 mm or more and duration of 8 or more days with *nil* rainfall was considered as dry spell, as the soils (red

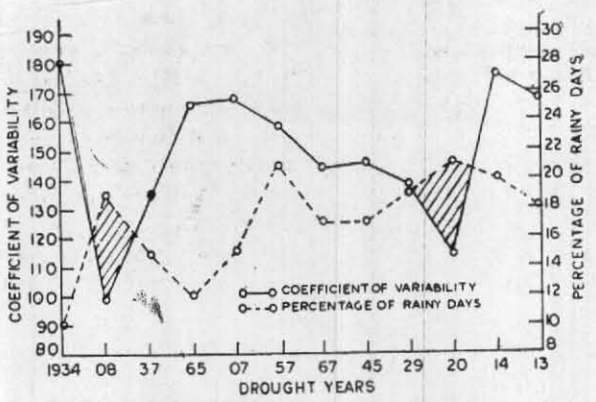

Fig. 2. Percentage of rainy days *versus* coefficient of variability

loams) around Bangalore completely lose their moisture in 6 to 7 days.

The percentage of rainy days and number of dry spells stress mostly on qualitative aspects of rainfall distribution. The percentage of rainy days give a rough indication of rainfall distribution during the cropping season as spread of these days within the season is not taken into consideration. On the other hand, the number of dry spells of more than 8 days duration also indicate a rough picture of rainfall distribution without mentioning the prolongivity of these spells. Hence, along with these two factors the coefficient of variability which measures the quantitative aspect of the dispersion, has also been taken into consideration. Using these factors a graph has been drawn for the twelve years (Fig. 2). In all the years excepting 1908 and 1920 the higher coefficient of variability is associated with low percentage of rainy days to varying degrees. But in 1908 and 1920 low variability is associated with higher percentage of rainy days indicating better distribution of the limited quantity of rainfall received. Under such circumstances the effect of drought may entirely depend on the quantum of rainfall.

As can be seen from the above, any definition of drought has limited scope in respect of space, although the parameters characterising the drought remain the same. The value of these parameters changes in different agro-climatic zones. Taking into consideration the water requirements of finger millet or *Ragi* (*Eleusine Coracona*) and the water holding capacity of these soils and using the parameters like quantity of rainfall, percentage of rainy days, number of dry spells and coefficient of variability, here, an attempt has been made to draw a definition for south-eastern parts of Mysore State where soil conditions and rainfall distribution are almost similar.

A "drought year" is one in which the rainfall during the cropping season falls in the lower two decile ranges (567 mm which coincides with rainfall less by 30 per cent of the normal) which is concentrated in short periods (rainy days less than 20 per cent) intermingled with more than 7 dry spells of more than 8 days duration and associated with bad distribution (C. V. values more than 137 per cent). The severe drought experienced in 1965 (by crop failure) agrees well with this classification. Due to want of data the intensities of drought in other years could not be compared.

The probability of occurrence of drought of severe nature at Hebbal conditions is in trough period of the cycle only (Fig. 1) and it is (9 out of 71 years) about 12 per cent.

4. Summary and conclusions

The rainfall of the Agricultural Research Station, Hebbal was studied to interpret the occurrence of drought.

A cycle has been traced in the annual rainfall of the locality. Five years of above average rainfall was followed by ten years of below average rainfall from 1927 onwards. Of the three types of groupings, 'decile' system of classification appears to be the best. Rainfall above normal was found to be associated with better distribution than below normal rainfall.

Some important parameters affecting the severity drought were identified. Using these parameters, an attempt has been made to define drought for this agro-climatic region.

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REFERENCES

Anonymous	1936	*British Rainfall*, British Rainfall Organisation, Air Ministry Met. Office, London.
Cocheme, J. and Fraquin, P.	1967	*An Agroclimatology Survey of a Semiarid Area in Africa South of Sahara*, WMO, No. 210, T. P. 110, Tech. Note 86, pp. 21-40.
Gibbs, W. J. and Mahar, J. V.	1967	*Rainfall Deciles as Drought Indicators*. Bull No. 48, Bureau Met. Melbourne.
Glover, J. and Robinson, P.	1953	*J. Agric. Sci.*, **43**, 3, 275-280.
Henry, A. J.*	1906	*U. S. Weath. Rev.*, Bull. Q. (W. B. No. 361), 51-58.
Hiatt, W. E. and Schlomer, R. W.	1955	*Water*, Year Book of Agriculture, USDA, Washington, 78-84.
Kanitkar, N. V.	1960	*Dry Farming in India*, ICAR, New Delhi, Second Ed. 1960, 53.
Landsberg, H. E.*	1958	*Physical Climatology*, Gray Printing Co., Second Ed. 247.
Manning, H. L.	1950	*J. Agric. Sci.*, **40**, 1 & 2, 169-176.
Raheja, P. C.	1961	*Water Requirements of Indian Field Crops*, Indian Council of Agric. Res., New Delhi (Publ.), 6.
Ramdas, L. A.	1950	*Indian J. Met. Geophys.*, **1**, 4, pp. 262-274.
Subrahamanyam, V. P. and Subramaniam, A. R.	1964	*Ibid.*, **15**, 3, pp. 393-402.
Surendranath, Baliga, B. V. and Sridharan, P. C.	1968	*Mysore J. Agric. Sci.*, **2**, 3, 170-181.
Tannehill, I. R.	1947	*Drought—its causes and effects*, Princeton Univ. Press, 178.
	1954	*Water*, Year Book of Agriculture, USDA, Washington, 84-90.
Thronthwaite, C. W.*	1947	*Ann. Ass. Amer. Geogr.*, **37**, 2, 87-100.

*Original not seen