Mausam, (1984), 35, 3, 291-294

551.578.1 : 551.586

An agroclimatic approach to the assessment of tropical droughts

H. S. RAM MOHAN, MARIA JULIET STANISLAUS and P. VALSALA
Department of Marine Sciences, University of Cochin, Cochin

सार — पुराने जमाने से ही मानव के लिए सूखे की समस्या एक गंभीर समस्या रही है और आज भी ये प्रकृति का बड़े पैमाने पर एक भयानक परिघटना के समक्ष मनुष्य की विवशता को उजागर कर देते हैं। मौसम विज्ञानी के लिए सूखा, समय की एक विस्तृत अवधि के लिए अनावृष्टि की स्थिति है जिसके दौरान सामान्यतया कुछ वर्षण हो सकता है। यह उस क्षेत्र की भौगोलिक स्थिति और उस वर्ष की मानसून ऋतु पर निर्भर है। कृषि विज्ञानी के लिए सूखा, फसलों के लिए नमी का उपलब्धता में कमी है जबकि जलविज्ञानी की दृष्टि में यह पृष्ठ और उप-पृष्ठ के जलस्तर में अवदाब या धारा प्रवाह में कमी के लिए उत्तरदायी है।

सूखे से संबंधित साहित्य में दी गई अधिकांश धारणाएं और परिभाषाएं ऐसी तकनीकों पर आधारित है जिनमें या तो भौतिक आधार की कमी है या फिर आनुभाविक आधार की। फिर भी थोर्नथ्वइते ने सर्वप्रथम सुझाव दिया था कि जल की उपलब्धता या उसका कमी पर हमेशा उस क्षेत्र की जल की आवश्यकता के संदर्भ में विचार किया जाना चाहिए। साथ ही, सूखे का तर्कसंगत दृष्टि से समझने के लिए मृदा नमी की महत्वपूर्ण भूमिका पर भी विचार करना चाहिए।

इस शोध पत्र में जल संतुलन की प्रक्रियाओं से ज्ञात किए गए नमी पर्याप्तता सूचकांक (I_{ma}) को कृषि एवं पारिस्थितिकी दृष्टि से सूखे का वर्गीकरण करने के लिए उपयोग किया गया है। भारत के अर्ध शुष्क क्षेत्रों से कुछ चुने हुए स्टेशनों के सूखे का विश्लेषण किया गया है।

अलग-अलग भीषणता वाले सूखे के वर्षों की जानकारी देने से ज्यादा महत्वपूर्ण बात यह है कि सूखे के दौरों की अवधि का ठीक-ठीक आकलन किया जाए। इसीलिए सूखे के चुनिंदा दौरों का नमी पर्याप्तता मासिक सूचकांकों और जलवायु के अनुसार सामान्य नमी के अन्तर तथा उस माह के सूचकांक के मानक विचलन अनुपातों का आरेख बनाकर, उसका बारीकी से विश्लेषण किया गया है। यह तकनीक कृषि एवं परिस्थितिकी अन्वेषणों में काफी उपयोगी सिद्ध हुई है, क्योंकि इसमें उस क्षेत्र में अपनाई गई फसलों की सहन-शीलता तथा सूखा प्रतिरोध के लिए उपयुक्त महत्व दिया गया है। यह इस तथ्य को भी उजागर करता है कि वर्ष की विविध ऋतुओं में और फसल की बढ़वार के विभिन्न चरणों में जल की कमी की उसी राशि से नमी प्रतिबल में परिवर्तन होता रहता है। उष्ण कटिबंधीय क्षेत्र में इसका विशेष महत्व है क्योंकि वहां नमी एक ऐसा कारण है जो पेड़ पौधों की बढ़वार संभावित स्तरों तक होने में अड़चन पैदा करता है।

ABSTRACT. Droughts have been a matter of serious concern to man since ancient times, and even today they are an outstanding example of man's helplessness before nature's large-scale and formidable phenomena. To the meteorologist, drought is a rainless situation for an extended period of time during which some precipitation should have been normally received depending upon the geographical location of the region and season of the year. To the agriculturist, drought is a shortage of moisture availability for his crops while the hydrologist views it as being responsible for depression of surface and sub-surface water levels or decrease of stream flow.

Most of the concepts and definitions suggested in literature are based on techniques which either lack physical basis or are empirical. However, Thornthwaite for the first time suggested that water availability or its deficiency should always be considered in relation to the water need of the region taking into consideration the important role of soil moisture, for a rational understanding of droughts.

In this paper, the index of moisture adequacy (I_{ma}) derived from water balance procedures, has been employed to categorize droughts from the agricultural and ecological point of view. Droughts of selected stations in the semi-arid zone of India have been analyzed.

However, more important than the delineation of drought years of various severities, is the assessment of the exact duration of drought spells. Selected drought spells were, therefore, analyzed critically by plotting the ratio of the departures of monthly indices of moisture adequacy (I_{ma}) from the climatic normal, to the standard deviation of (I_{ma}) for that month. This technique is found to be of great value in agricultural and ecological investigations as due weightage is given to the drought resistance and tolerance of crops which are adapted to the region. It also highlights the fact that the same amount of water deficiency during the various seasons of the year and at different stages of crop growth causes varying moisture stress. This is of special interest in tropical regions where it is the moisture factor that inhibits the growth of vegetation to its potential levels.

1. Introduction

It is now a well established fact that the Indian economy is controlled to a great extent by the nature and distribution of rainfall that the country receives. An year with normal or above normal rainfall leads to all round prosperity and progress of the country. On

the other hand, the failure of the monsoons in a particular year or even a few weeks delay in their onset could cause widespread droughts leading to catastrophic consequences and large scale human misery. Historical evidences show that droughts and resultant famine conditions have been one of the most serious of natural hazards to man since ancient times in our country. Against this background of utter dependence on weather and climate for our progress and development, it is imperative that the droughts of our region are studied in the greatest detail possible.

Though droughts have been defined variously, they are generally understood as periods of dryness due to lack of rain. The concept of drought varies from place to place depending upon the normal climatic conditions, available water resources, agricultural practices and various economic activities of the region. A detailed description of definitions of droughts has been given by Subrahmanyam (1967). To the meteorologist drought is a rainless situation for an extended period during which some precipitation should have been normally received depending on the geographical location of the place and season of the year while to the agriculturist drought is a shortage of moisture availability for his crops.

From the above considerations, drought is seen to be a relative rather than an absolute condition. Further, since neither the beginning nor the end of droughts are normally recognizable, their assessment is based on the actual experience of its effects on surface run off, soil moisture and ground water levels.

Most of the concepts and definitions suggested in literature are based on techniques which either lack physical basis or are emperical. A clearer understanding and better appreciation of the problem of droughts and aridity became possible after Thornthwaite (1947) laid the basis for the water balance methods and suggested that drought cannot be defined in terms of rainfall shortage alone, since this does not take into account either the water need of the region or the important role of soil moisture on which the plants depend for their existence.

2. Materials and methods

In India, the water balance approach for the studies of aridity and droughts was first applied by Subrahmanyam (1958). He and his co-workers Subrahmanyam and Subramaniam (1964, 1965), Subrahmanyam and Sastri (1969) and Ram Mohan (1978) used the departures of Aridity Index (I_a) of Thornthwaite (1948) from the median value to categorize droughts.

A more useful parameter to study droughts from the agroclimatic point of view is the Index of Moisture Adequacy (I_{ma}) derived from water balance procedures. This index, first put forth by Subrahmanyam *et al.* (1963) with a view to study the cropping patterns in India, is defined as the percentage ratio of the actual evapotranspiration to the potential evapotranspiration on an annual basis. A value of 100% would mean that the moisture status is at the optimum level and agricultural operations can be carried out without any supplemental irrigation. High values of the index denote fairly sufficient quantities of water for use by the soil and plants for evapotranspiration. Some supplemental irrigation would help the actual evapotranspiration reach potential levels. Low values would indicate large moisture stress on the plants whose growth is inhibited resulting in low yields. Irrigation is then absolutely essential if crops are to survive under these conditions.

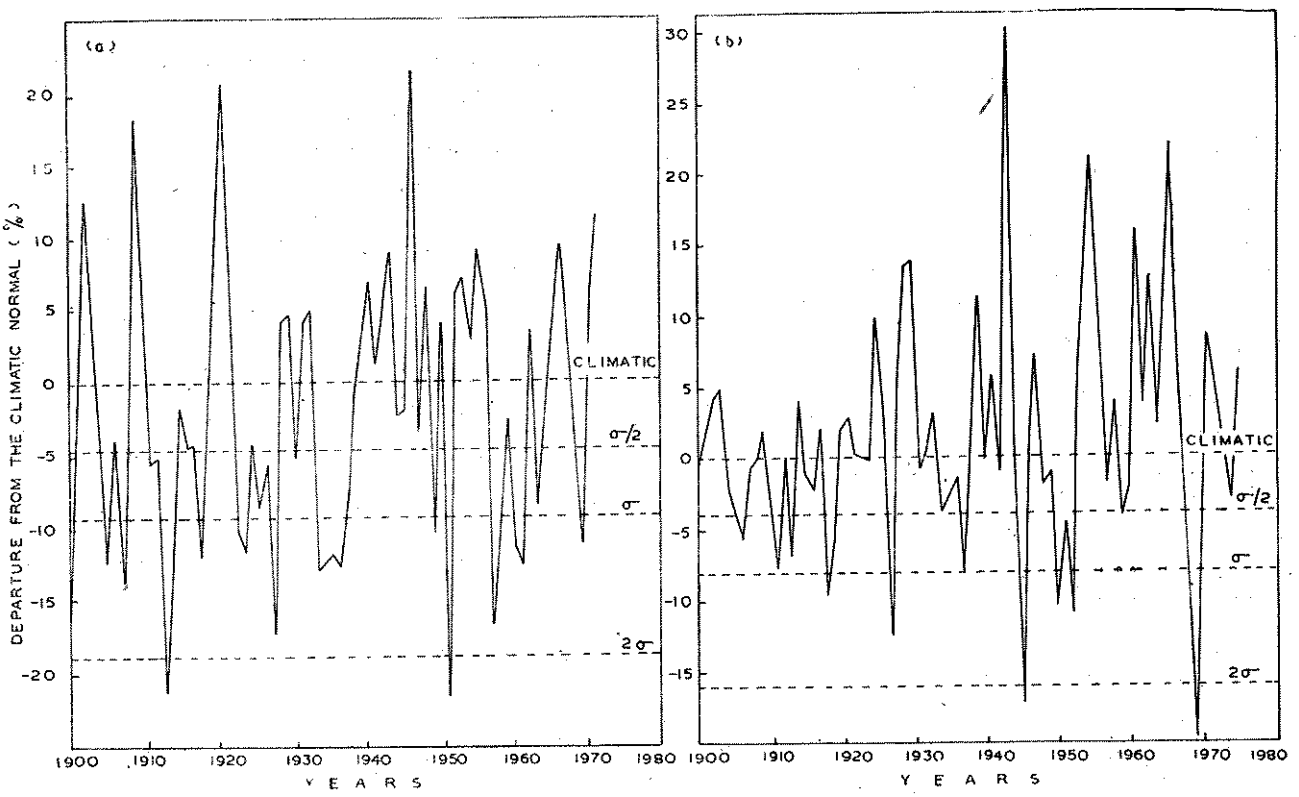
TABLE 1
Drought years at Madurai and Cuddalore

Station	Total frequency	Disastrous	Severe	Large	Moderate
Madurai	42	(2) 1913, 1952	(17) 1905, 1907, 1914, 1918, 1923, 1924, 1928, 1934, 1935, 1936, 1937, 1950, 1958, 1959, 1961, 1962, 1970	(9) 1908, 1911, 1912, 1926, 1927, 1931, 1938, 1964, 1969.	(14) 1901, 1904, 1906, 1915, 1916, 1917, 1918, 1925, 1939, 1945, 1946, 1948, 1960, 1965
Cuddalore	38	(2) 1945, 1969	(5) 1918, 1927, 1937, 1950, 1952	(7) 1906, 1911, 1913, 1919, 1951, 1959, 1968	(24) 1904, 1905, 1907, 1908, 1910, 1912, 1915, 1916, 1923, 1924, 1931, 1934, 1935, 1936, 1938, 1940, 1942, 1948, 1949, 1957. 1960, 1970, 1973, 1974

In this paper, the yearly water balances of two representative stations in Peninsular India — Madurai (Semiarid climate) and Cuddalore (Dry sub-humid climate) have been worked out for a period of 75 years (1901-1975) using the book-keeping procedure outlined by Thornthwaite and Mather (1955). The indices of moisture adequacy have been calculated on an annual basis. Percentage departures of I_{ma} from the climatic normal have been plotted (Figs. 1a and 1b). Categorization of droughts has been done as shown below employing the standard deviation (σ) as the basis of reference when the departures have been negative :

Negative departure of I_{ma} from normal	*Drought intensity*
Less than $\frac{1}{2}\sigma$	Moderate
Between $\frac{1}{2}\sigma$ and σ	Large
Between σ and 2σ	Severe
Above 2σ	Disastrous

During the period of study, Madurai experienced a total of 42 drought years while Cuddalore experienced 38 years of drought of various categories (Table 1). At both the stations droughts of disastrous nature occurred twice in 1913 and 1952 at Madurai and in 1945 and 1969 at Cuddalore.



(a) Madurai (b) Cuddalore

Figs. 1 (a&b). Yearly march of index of moisture adequacy

Madurai experienced more severe droughts than large or moderate ones while Cuddalore experienced more moderate droughts than of other categories.

However, more important than the delineation of drought years of various severities, is the knowledge of exact duration of drought spells. The study of the duration of droughts is of great practical importance in agriculture and hydrology.

3. Results and discussion

Droughts usually result from the cumulative effect of a set of weather sequences developing over an extended period of time. Thus, droughts may be either prolonged or shortlived depending upon the nature and duration of the water deficiency responsible for it. The severity of droughts depends upon the degree and duration of moisture deficiency. Therefore, the drought spells in disastrous drought years have been selected for detailed study of their durations and severities on a monthly basis. The ratios of the departures of the monthly I_{ma} values from their climatic normals to the standard deviations of the corresponding months were plotted (Fig. 2). Months with negative values indicate a drought spell while the magnitude of the negative departure from the normal is an assessment of its severity. This technique takes into consideration the fact that the same amount of water deficiency during the various seasons of the year cause varying moisture stress. This aspect is of importance in agricultural investigation as due weightage is given to the drought resistance and tolerance of crops which are adapted to climatic conditions of the region.

At Madurai the 1913 disastrous drought spell is actually found to extend from November 1912 to June 1914, during which its intensity is found to be maximum during the post monsoon months of September and November 1913; the dry spell of 1952 is found to have begun in September 1951 and continued upto March 1953 being most severe in November 1952.

Unlike at Madurai, the duration, of drought spell at Cuddalore is limited to the year itself in 1945. The spell has maximum severity in February. During the period from March to May, the station is free from the dry spell. However, dryness prevails again from May to November. The other disastrous drought spell extends from September 1968 to November 1969. During this period the driest months were February and October of 1969.

This approach highlights the fact that droughts have an origin, intensification and decay. Such an analysis is of great value in agroclimatic and ecological investigations as the exact duration and severity can be delineated. Such a study on shorter term basis, weekly for instance, would help locate the exact beginning and cessation of droughts. This would be of use in scheduling supplemental irrigation to mitigate the severity of dryness at the appropriate stages of crop growth. This

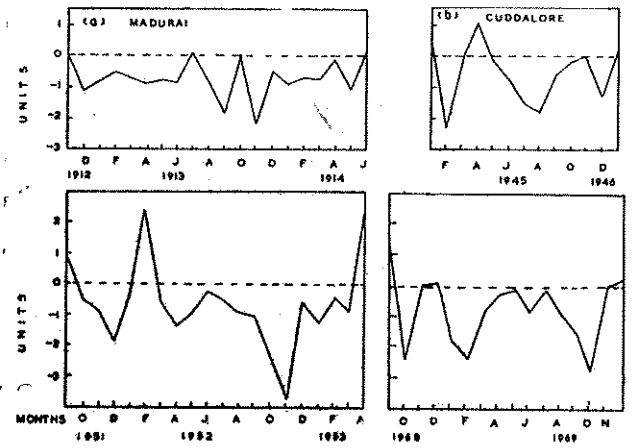


Fig. 2. Analysis of drought spells on a monthly basis

is of special interest in tropical regions, where it is the moisture factor that inhibits the full growth of vegetation to its potential levels, the thermal factor being more than adequate to support the most luxuriant type of vegetation.

Acknowledgement

The authors wish to thank Prof. V. P. Subrahmanyam, Department of Meteorology and Oceanography, Andhra University, Waltair for his encouragement and valuable suggestions.

References

Ram Mohan, H. S., 1978, A study on the water balance and drought climatology of Tamil Nadu, Unpublished Ph.D. Thesis submitted to Andhra University.

Subrahmanyam, V. P., 1958, Droughts and aridity in India—A climatic study, Proc. Symp. on Met. & Hydrol. aspects of Floods & Droughts in India, New Delhi, 171-177.

Subrahmanyam, V. P., 1967, Incidence and spread of continental drought, WMO/IHD Rep. No. 2, 1-52.

Subrahmanyam, V. P. and Sastry, C. V. S., 1969, Some aspects of drought climatology of the dry subhumid zones of south India, *J. met. Soc. Japan*, **47**, 239-244.

Subrahmanyam, V. P., Subba Rao, B., Subramaniam, A. R., 1963, Moisture adequacy in relation to some crops in India. International Union of Geodesy and Geophysics, Berkely Symposium, pp. 462-467.

Subrahmanyam, V. P. and Subramaniam, A. R., 1964, Application of water balance concepts for a climatic study of drought in South India, *Indian J. Met. Geophys.*, **15**, 393-402.

Subrahmanyam, V. P. and Subramaniam, A. R., 1965, Some characteristics and frequencies of occurrence of droughts in the dry climatic zones of India, *Bull. Inter. Assoc. Sci. Hydrol.* Xe *Annee.*, **3**, 31-37.

Thornthwaite, C. W., 1947, Climate and moisture conservation, *Annals of the Assn. of Amer. Geogr.*, **37**, 87-100.

Thornthwaite, C. W., 1948, An approach toward a rational classification of climate, *Geogr. Rev.*, **38**, 55-94.

Thornthwaite, C. W. and Mather, J. R., 1955, *The water balance*, Publ. in Clim. Drexel Inst. Tech., **8**, 104.