A STUDY OF ARIDITY AND ITS FLUCTUATIONS OVER ANDHRA PRADESH

by P. RAKHECHA *and* O. N. DHAR, *Indian Institute of Tropical Meteorology, Poona-5*

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The annual aridity indices values obtained from water balance considerations for a group of 9 representative observatories over Andhra Pradesh have been analysed by standard statistical methods, in order to find out trends, if any. It has been found apart from the oscillatory character, in the central part of the state comprising Hanamkonda, Nellore and Kurnool stations, the aridity index which is an index of drought has significant decreasing tendency, suggesting that the rainfall is controlling the aridity. However, in other parts of the state the aridity has no significant increasing or decreasing tendency, suggesting that aridity does not appear to be significantly influenced by rainfall alone. Possibly the soil moisture determines the aridity in these areas in which case the conservation of soil moisture may assume considerable importance in this part.

INTRODUCTION

For delineation and scientific study of droughts aridity index (I_a) of Thornthwaite based on water balance considerations serves as a useful parameter (Subrahmanyam 1964). Aridity index is defined as the ratio of water deficiency to water need over a region. Since water deficiency, which is the primary cause of droughts, is incorporated in this definition, the aridity index can be employed as a rational parameter for the quantitative analysis of droughts.

The aridity index is obtained indirectly from rainfall values and therefore, it seems reasonable for us to expect the aridity index to vary with rainfall. Pant (1958) has studied the rainfall variations in Andhra Pradesh and found a significant increasing trend in the annual rainfall of Masulipatnam and Kakinada while a significant decreasing trend was found at Visakhapatnam. It may be of interest to see to what extent the trend in rainfall is related to the trend in aridity index. For this purpose nine representative observatory stations were studied. The results are discussed here.

CONCEPT OF ARIDITY

Aridity is characterised by sparse and highly variable precipitation and normally associated with high rate of evaporation. Thornthwaite (1948) introduced the concept of potential evapotranspiration to denote the water need. Precipitation is compared with potential evapotranspiration which is a measure of water requirements on a monthly basis to determine periods and quantities of water surplus and water defiicit. The water deficiency represents the amount by which the precipitation fails to meet the demands of potential evapotranspiration after all the soil moisture has been used up. Deficiency may be offset if there is sufficient soil moisture to supplement precipitation. If the amount of soil moisture is absent aridity results. The

aridity index is the ratio of annual moisture deficiency to the annual water need expressed as percentage and is mathematically shown as:—

$$A.I = \frac{d}{N} \qquad \ldots (1)$$

where $A.I$ = aridity index, d is the moisture deficiency, and N is the moisture need.

The aridity index delineates areas of different grades of aridity and is useful in planning the development of the area.

Data and Method Used

Data of mean monthly meteorological elements published in the '*India Weather Reviews*' for nine representative observatory stations of Andhra Pradesh (shown in Fig. 1) extending over a period of 70 years (1901–70) were utilised. For each station the monthly and annual water need values for the individual years were computed by the Thornthwaite's formula (1948). By following the book-keeping procedure of Thornthwaite the yearly water balance (surplus and deficiency) was calculated. From the annual water deficiency values, thus obtained, the annual aridity indices were worked out by using the Eq. (1).

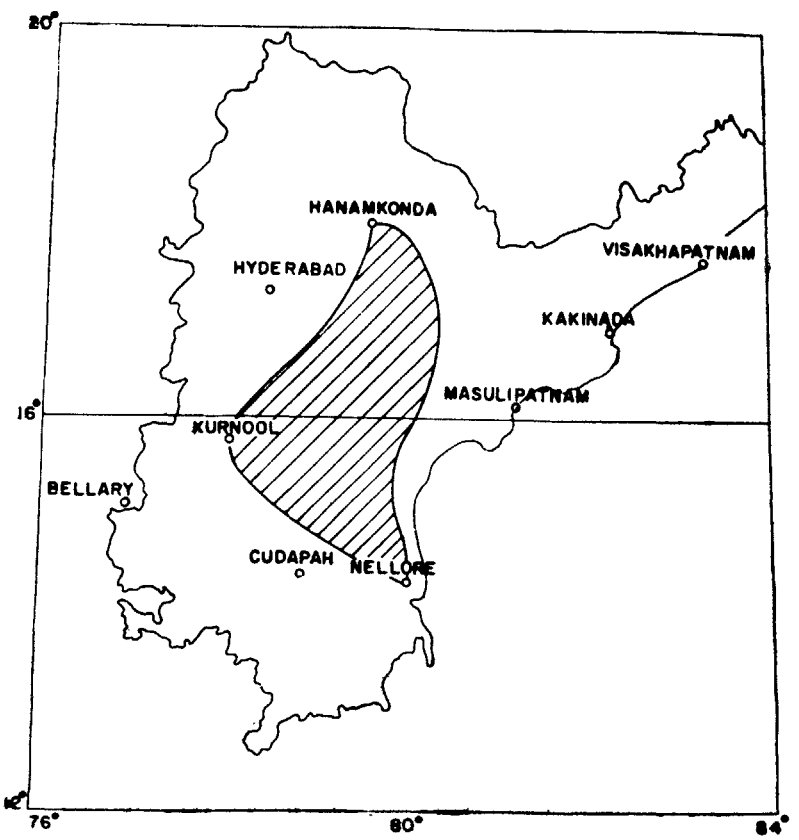

Fig. 1. Map of Andhra Pradesh showing significant trend in aridity,

Distribution and Variability of Aridity Indices

The mean value of aridity indices, their standard deviation and coefficient of variability with respect to each station are given in Table I.

Table I

Mean aridity index and its variability

Name of stations	Mean aridity index	Standard deviation	Coefficient of Variability (%)
Bellary	69.2	8.5	12.3
Cuddapah	60.2	9.9	16.4
Hanamkonda	50.9	9.5	18.7
Hyderabad	53.7	8.0	14.9
Kakinada	46.0	8.8	19.1
Kurnool	64.1	7.9	12.3
Masulipatnam	46.6	8.3	17.8
Nellore	59.1	6.8	11.5
Visakhapatnam	50.8	9.0	17.7

It is seen from Table I that the mean aridity index is low at the coastal stations and increase gradually inland being the highest at Bellary station. The coefficient of variability of aridity index varies from 12 to 19 per cent over this region. The coefficient of variability is the highest over Northeast Andhra Pradesh and the lowest in the southwest.

The annual aridity indices of all stations are shown in Fig. 2. An examination of this figure does not indicate any clue as to possible trend in the annual aridity indices. They however reveal certain variations but it is not clear whether these variations are purely random or they have any trend or short period cycles.

Variation in Mean Values

In order to get a rough idea of the trend, the annual series of aridity indices were arranged according to years and then divided into two halves. Decade means were also determined for the entire series together with their means of each half of the series. This statistics gives an idea of the trend in the series in the successive decades. The values are given in Table II.

Moving Averages (Low-pass Filter)

In order to understand the nature of trend, the series were subjected to moving average filter. This has the advantage of smoothing out the year to year fluctuations and also to supress the high frequency oscillations. Mathematically we may express such filter by the equation.

$$\bar{x}_t = \sum_{-n}^{n} w_i \, x_t + i \qquad \ldots (2)$$

in which $\bar{x}_t$ is the filtered value of the series corresponding to the t^{th} term thereof, and w_i is the weight by which the value of the series i units removed from t is

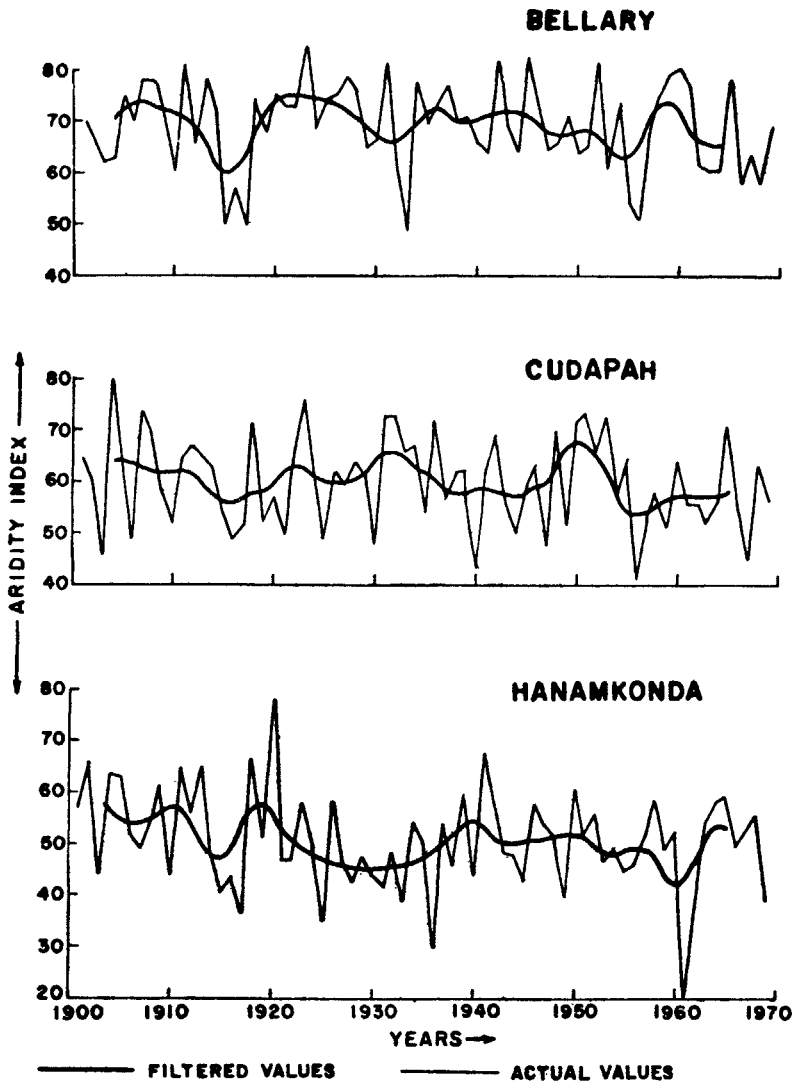

FIG. 2 (a)—Fluctuations of aridity indices.

multiplied. The weights used in Eq. (2) were the nine ordinates of the Gaussian probability curve (0.01, 0.05, 0.12, 0.20, 0.24, 0.20, 0.12, 0.05, 0.01). The filtered series are shown in Figs. 2. This figure reveals the gradual variation of the moving averages superposed on rapid fluctuations of the annual indices.

From Figs. 2 it is also observed that the filtered curves show oscillatory tendencies indicating that the series consists of oscillations whose periods are more than 10 years. Apart from the oscillatory tendencies it has been seen that so far as individual

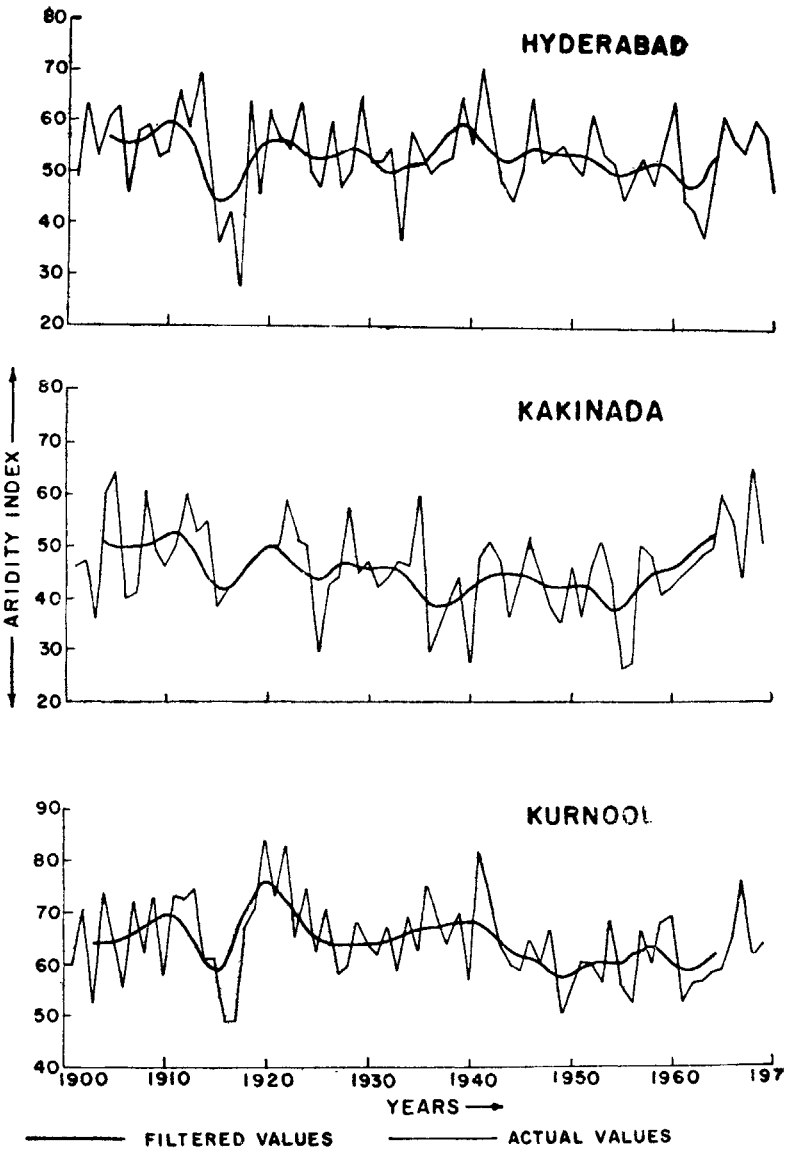

FIG. 2 (b) Fluctuations of aridity indices.

stations are concerned, in the case of Bellary, Cudapah, Hyderabad, Visakhapatnam and Masulipatnam the annual aridity curves show decreasing tendency upto 1915. This is then followed by an increasing trend up to 1920 and thereafter either there is no tendency or the curves show slight decreasing tendency in aridity. In the case of remaining stations viz., Hanamkonda, Kurnool and Kakinada there is a decreasing tendency in aridity. However, Kakinada shows an increasing trend from 1950 onwards while Nellore has shown a decreasing tendency from 1934 onwards.

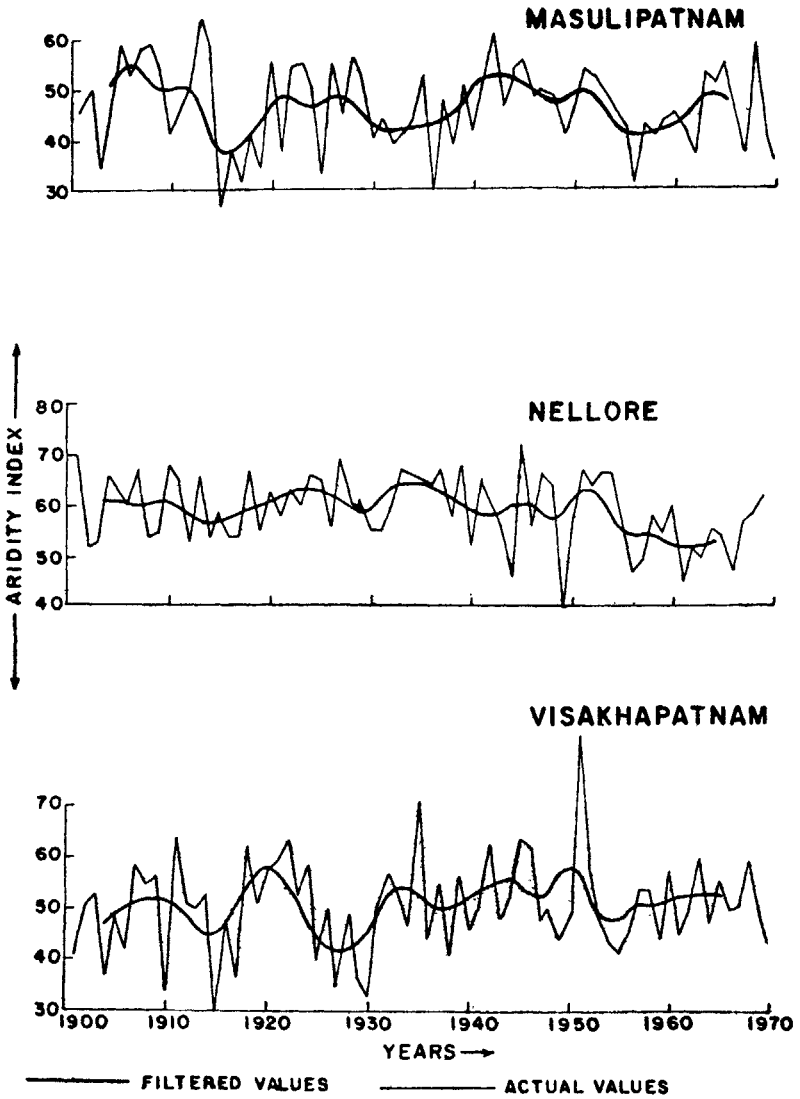

FIG. 2 (c) Fluctuations of aridity indices.

LINEAR TRENDS

The above methods of analyses suggest a trend in the annual aridity indices of some of the stations. To confirm this, the annual values of aridity indices with respect to each station were analysed by the method of least squares. Assuming,

$$I_a = a + bt \qquad \ldots (3)$$

where I_a is the annual mean of aridity index, t is the time (unit one year) and a and b are constants. If b in Eq. (3) is positive then the local aridity index at the station

TABLE II

Decade-wise averages of aridity indices

Name of station	Mean of 1st half	Mean of 2nd half	Decades Means 1	2	3	4	5	6	7
Bellary	70.3	68.6	69.7	67.1	73.6	69.6	69.8	69.0	65.0
Cuddapah	61.5	58.9	62.2	59.5	60.2	62.7	60.1	60.0	56.5
Hanamkonda	52.0	49.8	55.4	55.1	47.7	47.1	52.8	50.5	47.4
Hyderabad	53.8	53.5	55.8	52.5	54.6	53.1	55.1	53.4	51.5
Kakinada	49.3	44.1	49.2	47.4	47.0	41.4	44.7	41.8	51.0
Kurnool	65.7	62.5	64.1	66.2	68.0	65.0	63.2	61.5	60.6
Masulipatnam	46.9	46.3	49.8	44.7	47.8	43.0	50.0	45.2	45.6
Nellore	60.5	57.6	60.6	58.7	61.3	62.0	58.1	59.0	53.2
Visakhapatnam	49.6	51.9	47.5	50.5	47.7	52.2	52.8	53.5	51.3

TABLE III

Trends in aridity

Name of station	Constant (a)	Constant (b) per cent per year	Equation of line fitted
Bellary	70.8	—0.05	$I_a = 70.8 - 0.05\ t$
Cuddapah	62.8	—0.07	$I_a = 62.8 - 0.07\ t$
Hanamkonda	54.3	—0.10	$I_a = 54.3 - 0.10\ t$
Hyderabad	55.0	—0.04	$I_a = 55.0 - 0.04\ t$
Kakinada	47.4	—0.04	$I_a = 47.4 - 0.04\ t$
Kurnool	67.3	—0.09	$I_a = 67.3 - 0.09\ t$
Masulipatnam	48.0	—0.04	$I_a = 48.0 - 0.04\ t$
Nellore	62.1	—0.09	$I_a = 62.1 - 0.09\ t$
Visakhapatnam	48.6	+0.06	$I_a = 48.6 + 0.06\ t$

has a tendency to increase, and if b is negative, then the aridity index tends to decrease. The results are shown in Table III.

Table III shows that the observed aridity indices have a decreasing tendency at all stations except that at Visakhapatnam. Pant (1958) has shown that there is an increasing trend in the annual rainfall of Masulipatnam and Kakinada but decreasing trend in that of Visakhapatnam station.

The student's 't' test of significance has been applied and the regression coefficients have been found significant only with respect to Hanamkonda, Nellore and Kurnool while at other stations they have been found to be insignificant which suggests that there is no linear trend at these stations.

From the above it is evident that rainfall is a decisive factor in the incidence of aridity in the central parts of Andhra Pradesh represented by Hanamkonda, Kurnool and Nellore (*vide* Fig. 1). The aridity in the rest of the state does not seem to be significantly influenced by rainfall.

Conclusions

This study shows that in the central parts of Andhra Pradesh the aridity which is an index of drought is significantly influenced by rainfall. In other parts of the state the aridity does not appear to be significantly influenced by the rainfall alone. Possibly, the soil moisture determines the aridity in these areas in which case the conservation of soil moisture may assume considerable importance in these parts.

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