Letters to the Editor

551.5 : 63

EVALUATION OF AGRICULTURAL DROUGHT FOR DRYLAND CROP

1. In the recent years with large scale utilization of water resources, there is a need for judicious use of water for proper agricultural managements and to minimise drought risk. Among the various soil tracts in India, dry farming region (DFR) face the greatest drought hazard and is characterised by low and uncertain crop yields. Dry farming region is defined as the region which gets annual rainfall between 40-100 cm.

For most of dryland crops, the yields are invariably dependent on residual soil moisture storage. Unfortunately reliable soil moisture data for a large network of stations is lacking in India. Because of difficulty in obtaining accurate field measurements, predictive methods for crop water requirements are normally used. Soil moisture budget helps to estimate the extent to which the water needs of crop is met at any stage of its growth and development.

Vagaries in south-west monsoon is a well recognised fact in India. This often creates an imbalance in the rainfall regimes across the country particularly the semi-arid tropical tracts (Kanitkar *et al*., 1968), which mostly constitute dry farming zone. The erratic rainfall during monsoon makes it difficult to predict the timings and intensity of stress experienced by crop or in other words, the agricultural drought during a crop season. Rainfall analysis in dry farming zone has attracted attention of Indian meteorologists only in recent years. Incidentally most of these studies were based on, probabilistic analysis using incomplete gamma distribution (Sarker *et al*., 1982). Das (2000) discussed about monitoring the incidence of large scale droughts in India with particular emphasis on indices for delineating meteorological and agricultural droughts.

In the present paper, water balance method is used to study variability in spatial distribution of various water balance parameters. An index called Moisture Deficit Index has also been developed from water balance to assess agricultural drought in the dry land farming zone of India.

2. In this study data of 20 well distributed stations in DFR zone of country has been availed. The list of stations along with their co-ordinates, soil types *etc*. is given in Table 1.The period of study is 40 years *i.e*. from 1951 to 1990. *Kharif* season is the major crop growth season in most parts of the DFR zone. As such, weekly rainfall data from 23rd to 42nd standard weeks (*i.e*. 4 June to 21 October) which covers nearly all major stages of development of *kharif* crops have been used. Based on the 40 years data, normal weekly rainfall and its variability have been computed. The study is confined to four major epochs, though in the development of drought index all weeks in the crop season have been considered. The epochs analysed are as below :

(*i*) Onset phase, 23rd -27th week.

(*ii*) Active monsoon phase, 29th -30th week.

(*iii*) Weak monsoon phase, 34th -37th week.

(*iv*) Retreating phase of monsoon, 38th -42nd week.

Water balance equation used in the study is given as

$$R = AET + \Delta\ SM + RO$$

Where, R = Precipitation, AET = Actual evapotranspiration, Δ SM = Change in soil moisture storage and RO = Surface run off or deep drainage.

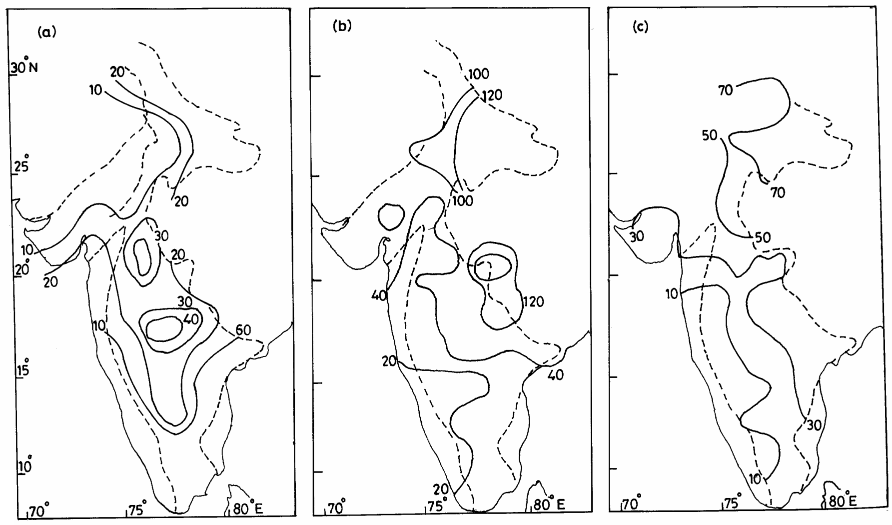
In the analysis Thornthwaite and Mather (1957) water balance technique has been used in computing various components of the budget. The Moisture Deficit Index (MDI) derived in the study is given by :

$$MDI = \frac{(AET - PET)}{PET} \times 100$$

Where, PET = Potential evapotranspiration.

Penman's modified method as formulated by Doorenbos and Pruitt (1979) has been used for computing the PET, MDI is calculated for crop period *i.e*. 23rd to 42nd week for all the stations.

3.1. Rainfall, its quantity and distribution is the most important factor for crop production in the DFR. Since most of the crops are rainfed, the optimum time of sowing, establishment and survival of crops depend to a large extend on the degree of fluctuations at the onset stage of monsoon and on duration and subsequent withdrawal of monsoon from the area. For some selected



Figs. 1(a-c). Normal weekly total rainfall (mm)

representative weeks the rainfall is described below. During the 25th standard week *i.e.* 3rd week of June [Fig. 1(a)] the monsoon is in onset phase in the DFR. In Madhya Pradesh and Vidarbha rainfall is of the order of 20-40 mm while in Punjab, Haryana, west Rajasthan and west Uttar Pradesh and the lee side of western Ghats, it is 10 mm or less. As the season progresses, the monsoon gets firmly established and by 30th week (23 July–29 July) [Fig. 1(b)] rainfall exceeds 100 mm in east Rajasthan and west Uttar Pradesh. Except in southern parts, rainfall by and large, is more than 10 mm during the week. Gradual decrease in rainfall occurs in the subsequent period and in the 35th week (27 August – 2 September) [Fig. 1(c)] rainfall is 30 mm or more over most of parts, with east Rajasthan and west Uttar Pradesh having 50–70 mm and in western peninsula rainfall is 10 mm or less. The CV is also large during this phase and is largest among the four phases, often exceeding 60%.

3.2. Soil moisture storage during a week denotes the availability of moisture to an actively growing crop. It is thus a more meaningful measure of crop growth and development, if combined suitably with other climatic parameters. Das *et al*. (1993) have convincingly demonstrated utility of soil moisture in assessing stress situation in sorghum grown in DFR.

The information on soil type, soil depth, field capacity *etc*. in respect of selected stations in DFR is given in Table 1. Characteristic feature of DFR is large variations in soil type and associated elements. The soil varies from deep black soil with soil depth exceeding 100 cm to red sandy and alkaline soil with depth of 30 mm. Consequently the water holding capacity also changes from 150 mm in west Rajasthan and Punjab and Rayalaseema to 300 mm in interior Maharashtra.

During 23rd week (3 June–10 June) soil moisture storage is very small in DFR due to the fact that during the period northward march of monsoon is just occurring. As the monsoon season progresses gets building up and by 30th week (23–29 July) the soil moisture exceeds 150 mm except areas south of 15° N where it is less than 50 mm and also Punjab and Haryana where soil retains less than 100 mm of moisture. During 35th week (27 August–2 September) there is further augmentation in soil moisture. Over most part it is greater than 200 mm but over Tamil Nadu and Rayalaseema it is nearly 100 mm. In the last phase, that is, during 24–30 September, though moisture depletion occurs to some extent, yet the soil retains quite a high amount of moisture in the range of 100-200 mm. The *rabi* crop in north India thrives only on this residual moisture. The soil moisture storage for some selected stations in DFR has been depicted in Table 2.

3.3. Evapotranspiration has a direct bearing on the crop growth hence the final yield. It also represents the availability of moisture to the growing crop. Because the onset, withdrawal and other phases of monsoon rains differ widely in the DFR zone, it does not seems feasible to describe the ET in the critical growth phases for each location; as such for representative weeks the actual ET distribution is depicted in Fig. 2 and described below. During 25th week (18 June–24 June) [Fig. 2(a)] in central

TABLE 1

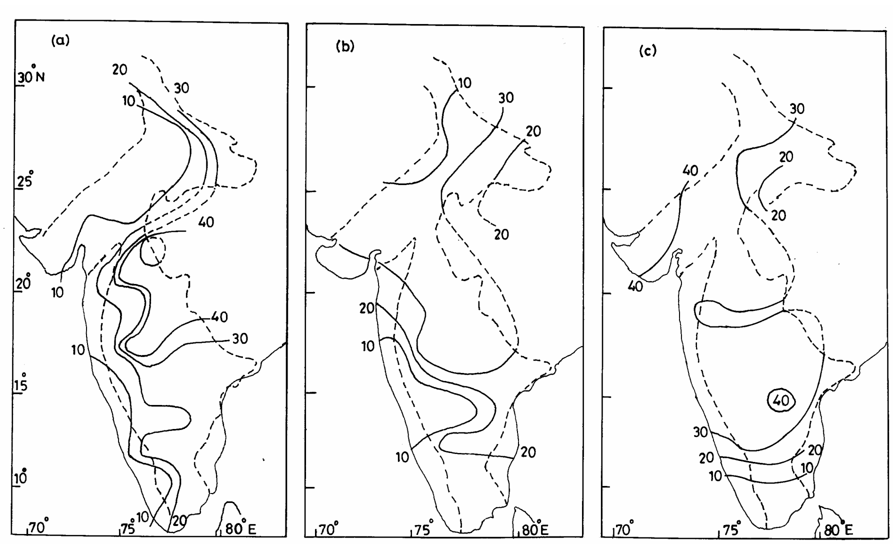
Coordinates, soil type, field capacity, soil depth and major crops

S. No.	Station	Latitude (°N)	Longitude (°E)	Soil type	Field capacity (mm)	Soil depth (cm)	Major crops
1.	Delhi	28° 41′	77° 13′	Alluvial	150	50	Maize/Wheat
2.	Alwar	27° 30′	76° 35′	Alluvial	150	50	Maize/Wheat
3.	Shivpuri	25° 20′	77° 39′	Medium black	300	130	Maize/Jowar
4.	Ajmer	26° 27′	74° 37′	Alluvial	150	50	Bajra/Wheat
5.	Jaipur	26° 49′	75° 48′	Alluvial	150	50	Bajra/Wheat
6.	Rajkot	22° 18′	70° 47′	Medium black	300	130	Bajra/Groundnut
7.	Ahmedabad	23° 04′	72° 38′	Alluvial	150	50	Maize/Wheat
8.	Banswara	23°33′	74° 27′	Mixed red & black	200	60	Soyabean/Wheat
9.	Bangalore	12° 57′	77° 38′	Red loamy	200	60	Sunflower/Ragi
10	Nizamabad	18° 30′	77° 50′	Medium black	300	60	Sorghum
11.	Anantapur	14°41′	77° 37′	Red sandy	150	60	Jowar/Maize
12.	Raichur	16° 12′	77° 21′	Deep black	300	130	Jowar/Maize
13.	Aurangabad	19° 53′	75° 20′	Shallow black	300	130	Sorghum
14.	Ahmednagar	19° 05′	74° 48′	Deep black	300	130	Maize/Jowar/Wheat
15.	Jalgaon	21° 03′	75° 34′	Deep black	300	130	Wheat/Jowar
16.	Parbhani	19° 16′	76° 46′	Deep black	300	130	Sorghum/Soyabean
17.	Sangli	16° 51′	74° 36′	Medium black	300	60	Pearl Millet/Jowar
18.	Solapur	17° 40′	75° 54′	Deep black	300	130	Pearl Millet/Jowar
19	Coimbatore	11° 00′	76° 58′	Mixed red & black	200	50	Sorghum/Cotton
20.	Amravati	21° 25′	77° 19′	Deep black	300	130	Wheat/Jowar

TABLE 2

Soil moisture amount in mm for some selected stations in dry farming zone. Depth of soil profiles has been taken as 1 metre

S. No.	Stations	Soil types	Soil moisture amount (mm) during		
			30th week	35th week	39th week
1.	Delhi	Alluvial	130.0	150.0	125.0
2.	Alwar	Alluvial	70.0	140.0	130.0
3.	Shivpuri	Medium black	275.0	300.0	275.0
4.	Ajmer	Grey brown	100.0	130.0	120.0
5.	Jaipur	Alluvial	150.0	150.0	120.0
6.	Rajkot	Medium black	150.0	210.0	240.0
7.	Ahmedabad	Grey brown	190.0	200.0	195.0
8.	Banswara	Mixed red and black	190.0	200.0	180.0
9.	Bangalore	Red loam	100.0	160.0	150.0
10.	Nizamabad	Medium black	180.0	260.0	198.2
11.	Anantpur	Red sandy loamy	50.0	100.0	150.0
12.	Raichur	Deep black	100.0	160.0	225.0
13.	Aurangabad	Shallow black	125.0	180.0	225.0
14.	Ahmednagar	Deep black	150.0	200.0	160.0
15.	Jalgaon	Deep black	125.0	225.0	240.0
16.	Parbhani	Deep black	175.0	275.0	300.0
17.	Sangli	Medium black	50.0	140.0	200.0
18.	Sholapur	Deep black	210.0	220.0	270.0
19.	Coimbatore	Mixed red and black	40.0	70.0	160.0
20.	Amravati	Deep black	190.0	300.0	290.0



Figs. 2(a-c). Actual evapotranspiration (mm)

part of India, AET is of the order of 40 mm. As the crop season advances area of 40 mm isohyte shifts from Madhya Pradesh and Vidarbha to Punjab, Haryana and NW Rajasthan with decrease in the AET in the peninsular India. During the 35th week (27 August–2 September) general decrease in AET continues [Fig. 2(b)]. In Punjab and Haryana, however, the evapotranspiration is maintained around 30–40 mm during the week. During 39th week (24 September–30 September), the last phase of monsoon, 40 mm isopleth shifts westwards from Punjab and Haryana and by and large AET is between 30-40 mm [Fig. 2(c)] over most areas.

3.4. Spatial variation in the accumulated moisture deficit index is given in Fig 3. The MDI accumulates to above 600 units in Punjab and Haryana during the crop season. In the peninsula the MDI is rather low and is generally 300 units or less. However, Rayalaseema region and interior Tamil Nadu of DFR the value of MDI is rather large and often exceeds 1000 units at isolated locations. Thus it is felt, crops in general in DFR do not seem to experience deficit throughout the growth season. This is more acute in some pockets in the peninsula.

A comparison has also been made of the MDI values between a pair of neighbouring stations having more or less similar soil and climatic characteristics. The following pairs were selected for this purpose :

(*i*) Alwar and Ajmer

(*ii*) Ahmedabad and Rajkot

(*iii*) Aurangabad and Ahmednagar

(*iv*) Anantpur and Coimbatore

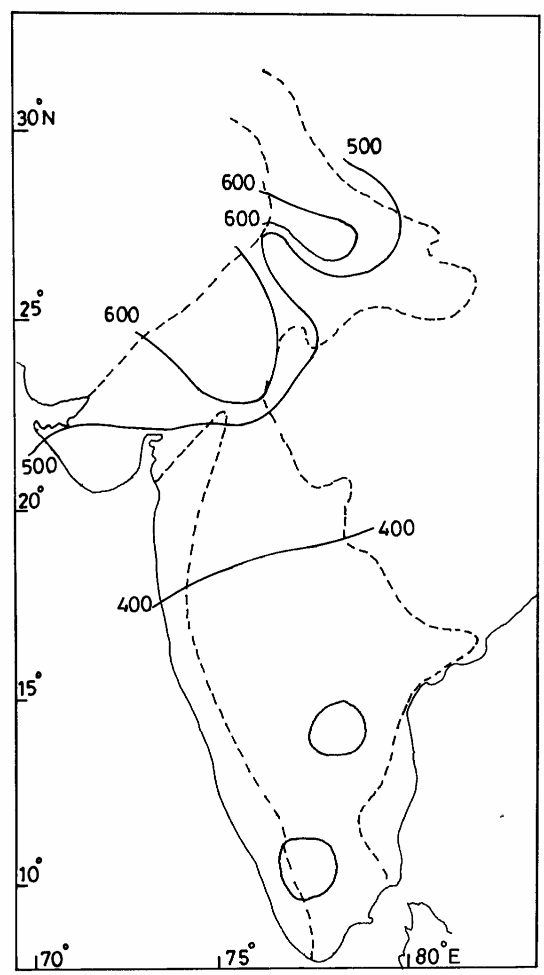
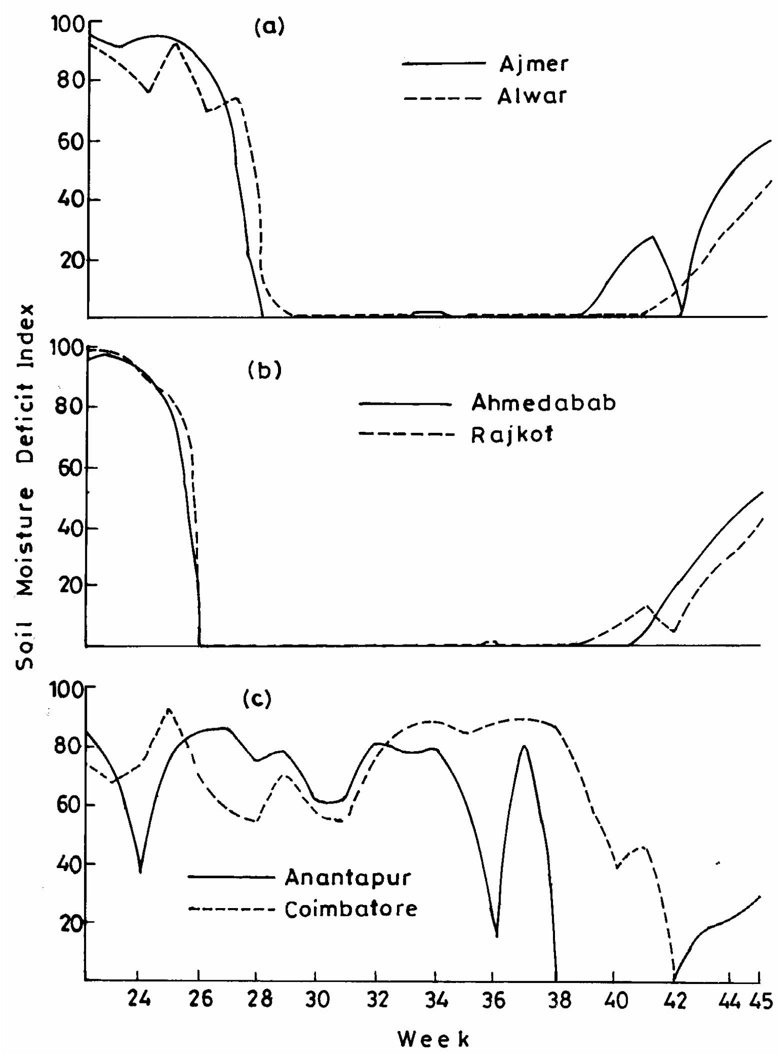


Fig. 3. Accumulated SMDI over India



Figs. 4(a-c). March of soil moisture deficit index

The total MDI units at Alwar *i.e.* 623 is nearly 100 units less than in Ajmer. Till 26th week MDI continues to rise in both locations, more steeply at Ajmer. Between 28th-38th week the MDI values at both locations are zero. But subsequently it rises, steeply more so at Ajmer [Fig. 4(a)]. When MDI values are compared between Ahmedabad and Rajkot MDI is found to exceed at the former location atleast by 200 units than the later for the season as a whole. Till 25th week the MDI does rise at both location but later till 41st week MDI becomes unimportant. Towards the end of vegetative growth phase of dry land crops MDI rises sharply, more so at Ahmedabad [Fig. 4(b)].

The annual accumulation of MDI at Coimbatore and Anantpur are 1441 and 1191 respectively. In other words, the *kharif* crops are subjected to greater stress at Coimbatore than at Anantpur. However as may be seen in Fig. 4(c), the fluctuations are more intense at Anantpur than at Coimbatore.

There is hardly much difference in the accumulated MDI values at Aurangabad and Ahmednagar, in both cases, it is about 400 units. The amplitude of weekly fluctuation of MDI at Ahmednagar (Fig. not shown) was found marginally more than at Aurangabad.

4. The following conclusions could be drawn from the study :

(*i*) During most parts of crop season the water transpired from the plant by a large lies between 30 - 40 mm per week.

(*ii*) The soil moisture generally exceeds 150 mm throughout the crop season in the northern and central part of DFR during *kharif* season.

(*iii*) The index evolved in the study is explained reasonably well. The moisture stress experienced by the crop and its accumulation could be used as a factor in determining the crop yield.

(*iv*) When drought conditions occurs during any phenological stages of the crop. The method described above can assist farmers to make critical management decisions.

References

Das, H. P., Kale, A. N. and Ponkshe, A. S., 1993, "Effect of soil moisture stress on growth and yield of dry land sorghum", *Mausam*, **44**, 3, 261-264.

Das, H. P., 2000, "Monitoring the incidence of large scale droughts in India", In : Donald A. Wilhite (Ed.), Drought A Global Assessment. Vol. I Rauteldge London and New York, 181-195.

Doorenboss, J. and Pruitt, N. O, 1975, "Guidelines for predicting crop weather requirements", F.A.O. Irrigation and Drainage Paper No. 24, F.A.O., Rome, p144.

Kanitkar, N. V., Sirur, S. S. and Gokhale, D. H., 1968, "Dry farming in India", New Delhi, India, Indian Council of Agricultural Research, p470.

Sarker, R. P. and Biswas, B. C., 1980, "Consultants Meeting on Climatic Classifications", ICRISAT, Hyderabad, 89-107.

Sarker, 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.

Thornthwaite, C. W. and Mather, J. R., 1957, "Publ. In Climatology", New Jersey, **10**, 185-311.

H. P. DAS
S. B. GAONKAR
E. I. FERNANDES
V. K. PANDEY

Agricultural Meteorological Division,
Meteorological Office, Pune-411 005, India
13 September 2000, Modified 8 February 2002