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Meteorological aspects of arid and semi-arid regions of India with special reference to Thar desert

A. CHOWDHURY, A. K. BANERJEE and (KM.) S. S. GOKHALE

Meteorological Office, Pune

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ABSTRACT. In this review paper general climatological features of rainfall including rainy days maximum and minimum temperatures, annual evaporation, droughts and floods, thunderstorms, hailstorms and duststorms, and the water balance aspects, namely, water surplus and water deficit, over arid and semi-arid regions of the country have been discussed. A review has also been made of the studies on climatic fluctuations over this area. It has been observed that the climatic elements do not exhibit presence of any regular pattern. It was, therefore, concluded that there is no reason to believe that the Rajasthan desert is accentuating or spreading.

1. Introduction

The arid and semi-arid areas of India have been defined from different angles by various scientific disciplines on the basis of emphasis they have laid on some or a group of parameters selected for their study. As a result, no uniform procedure has been evolved to delineate the arid and semi-arid tracts in India. However, from the meteorological point of view and for the purpose of this review, all those areas getting normal rainfall less than 40 cm annually have been defined as arid and those receiving rainfall between 40 to 100 cm annually, as semi-arid regions or the dry land farming areas of the country. In Ladakh and parts of Jammu & Kashmir also, the rainfall is between 40-100 cm. But because of low rate of evapotranspiration, the effective rainfall is more. As such, this area is not considered as semi-arid region. Accordingly, both the arid and semi-arid tracts stretch from Punjab and Haryana in the north to interior Tamil Nadu in the south and covers over 60 per cent of the total area of the country (Fig. 1).

2. General climatology

The predominant features of the climate over the areas are low and uncertain rainfall, general dryness with hot summer and excessive rate of evaporation and evapotranspiration. These together with lack of adequate irrigation facilities make agriculture in the area, a hazardous and risky vocation.

2.1. *Rainfall*

The principal rainy season is the southwest monsoon (June to September). It accounts for 80 to 90 per cent of the annual rainfall over the area. Over Gujarat (including Saurashtra & Kutch) and adjoining areas of Rajasthan and Madhya Pradesh, the season accounts for more than 90 per cent of the annual rainfall, while in Saurashtra & Kutch and north Gujarat, the percentage is even more than 95.

The distribution of the rainfall varies widely from one part of the region to another and also from year to year and even month to month within the season. Yearly variation stems principally from the vagaries of the monsoon. Early arrival and early withdrawal of the monsoon restricts the duration of the rainy season. Late arrival followed by early withdrawal sets in another constraint. Wide variations occur in frequency, duration and pattern of movement of tropical systems from Bay of Bengal during the monsoon season. The floods and droughts in the season are largely determined by the occurrence or otherwise of these systems and the tracts they follow.

In the annual rainfall pattern (Fig. 2), the 40 cm isohyetal line runs from Mandvi, Pali and Pilani and Hissar in northwest India. West of this line, rainfall decreases rapidly to less than 20 cm on western districts (Jaiselmer, Bikaner, Phalodi etc) of Rajasthan. The Peninsula south of 20° N gets less than 75 cm of rain.

During southwest monsoon the regions of scanty rainfall of northwest India are subjected to high variability of 60 per cent or more (*vide* Fig. 3). In the lee of Western Ghats and over Gujarat, east Rajasthan and adjoining areas, the

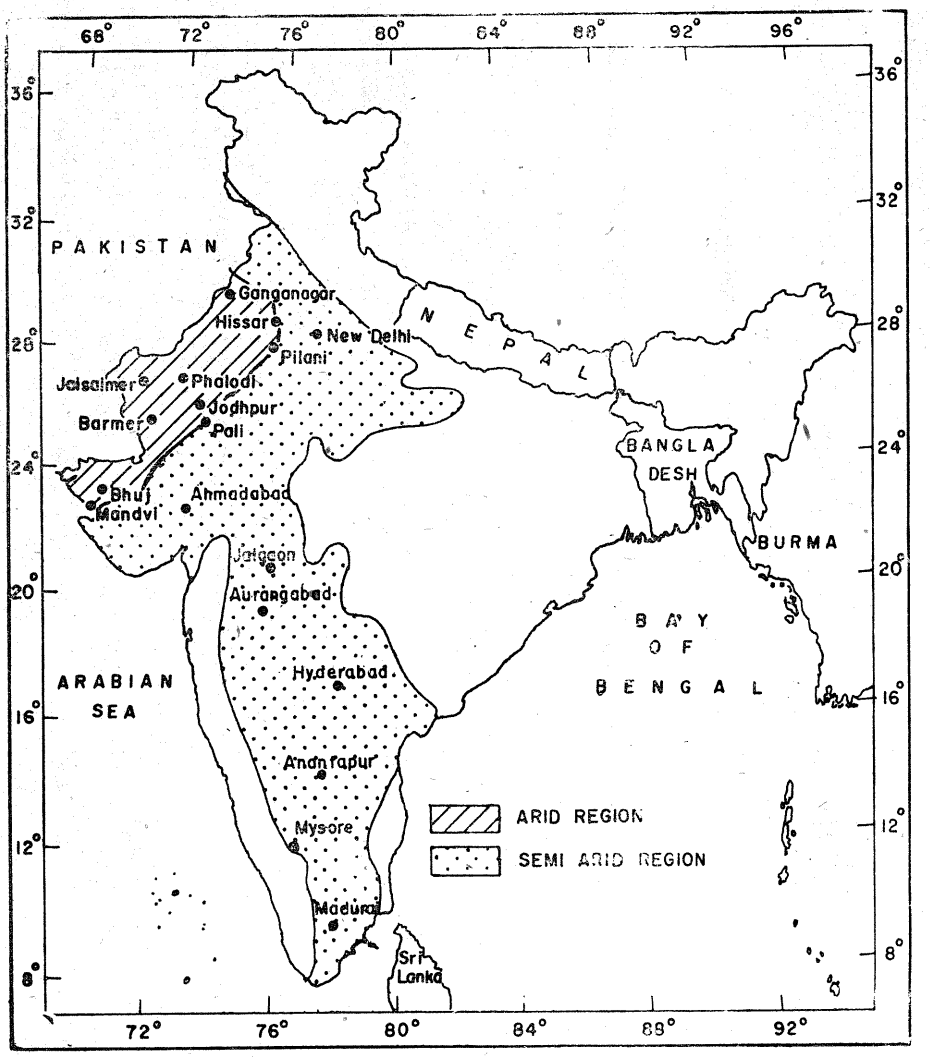

Fig. 1. Arid and semi arid areas

variability varies between 30 and 40 per cent. South Peninsula suffers from the largest variation of 40 to 100 per cent. However, during northeast monsoon season, interior areas of southern extremity of the Peninsula experience somewhat less variable rainfall (less than 40 per cent). Even on a month to month basis, the variability is large over northwest India and the Peninsular semi-arid tracts. Variability assumes very large values (300 to 400 per cent) when rainfall over short periods, *i.e.,* weeks are considered. This brings out the great uncertainty and precariousness of even the meagre rainfall. In fact, over western parts of west Rajasthan some rain can be expected in only three weeks even in the rainy season.

The annual number of rainy days (rainfall equal to or more than 2.5 mm per day) are less than 20 over west Rajasthan and Kutch; in the case of Thar desert (*i.e.,* Jaiselmer district) they are even less than 10. There is a progressive increase in the number outward of the desert, and in the interior of the Peninsula they exceed 40.

2.2. *Evaporation*

Based on data for 5 years or more for a network of about 80 stations equipped with pan evaporimeter, evaporation in India has been analysed by Rao *et al.* (1972) and depicted in Fig. 4. The analysis revealed that highest evaporation of 16 to 17 mm per day are recorded in north Maharashtra, southwest Madhya Pradesh and Rajasthan during May.

On an annual basis, areas of maximum evaporation (exceeding 300 cm) are located over Gujarat and adjoining southwest Rajasthan, north Madhya Maharashtra and adjoining parts of Marathwada and Telangana and the extreme south Peninsula. A core of 350 cm evaporation is located around Ahmedabad and Jalgaon. Over

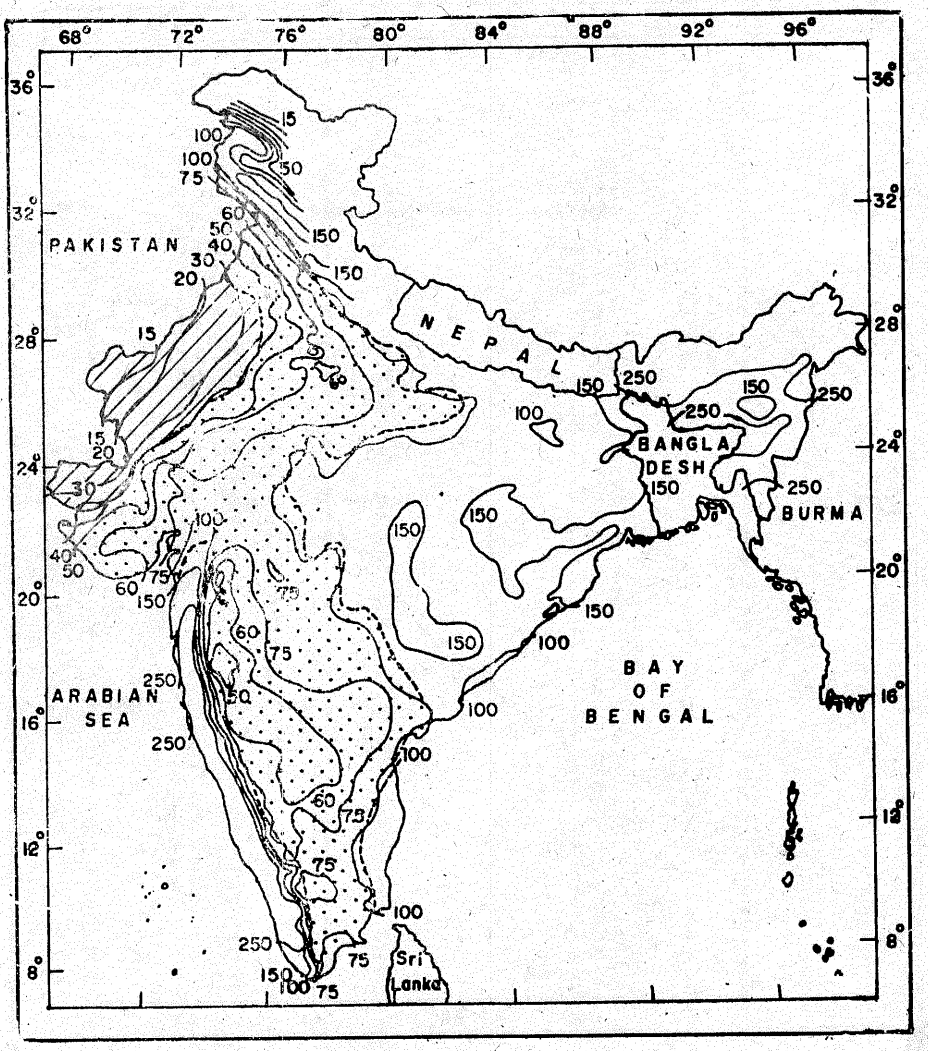

Fig. 2. Annual rainfall (cm)

the remaining portion of the arid and semi-arid regions, evaporation is in the range of 250-300 cm.

2.3. *Temperature*

Like other arid regions of the globe, the arid zone of India is characterised by high extremes of temperatures. December and January are the coldest months while highest temperatures are attained during May (India met. Dep. 1971).

During winter the night temperature over Rajasthan, Punjab and Haryana range between 5° and 10° C and there is a gradual increase southwards reaching 15° to 20° C in the interior Peninsula. The temperature in many places in northwestern parts falls below freezing point on few days.

Day temperature during summer is 40° to 45 ° C generally in both arid and semi-arid regions. However, at individual stations in Rajasthan, Gujarat, Punjab and Haryana, the day temperatures on some days reach 45° to 50° C. Temperatures exceeding 50° C have also been recorded. Owing to dryness of the atmosphere, the change of temperature from day to night is sudden, large and rather trying. May month is characterised by highest temperature, lowest rainfall and maximum radiation.

2.4. *Droughts*

Defining droughts as annual rainfall deficiency exceeding 25 per cent of the normal, an analysis has been made of drought prone areas of the country based on rainfall data from 1901 to 1960 (India met. Dep. 1971). For this purpose, the areas where drought occurred in 20 per cent of the years were considered as 'drought areas' and those where such ocasions exceeded 40 per cent as chronically 'drought prone areas'. The

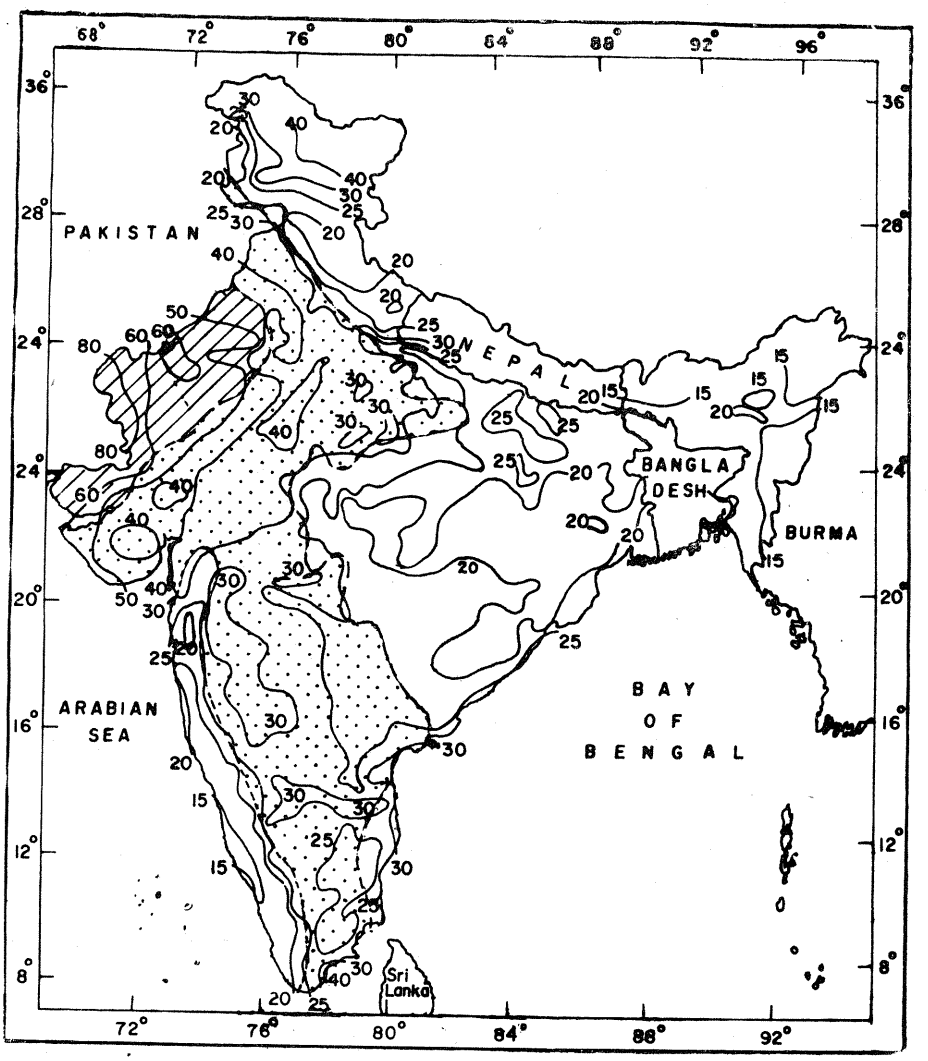

Fig. 3. Coefficient of variation of annual rainfall (%)

following results emerged from the study:

(a) *Drought areas*

(*i*) Saurashtra & Kutch, Gujarat, Rajasthan and adjoining areas of Punjab Haryana, west Madhya Pradesh and north Maharashtra.

(*ii*) Madhya Maharashtra and portion of interior Karnataka and Rayalaseema.

(b) *Chronically drought prone areas*

Western parts of west Rajasthan and Kutch.

2.5. *Floods*

Narmada, Tapti, Godavari and *Krishna* are the major river systems flowing across the semi-arid regions, whereas through the arid region no major river flows. Consequently the arid regions generally are free from flooding during rainy season. However, when monsoon disturbances reach east Rajasthan or Gujarat, localised floods occur over these areas. Floods also occur sometimes in Peninsular rivers in association with the movement of monsoon depressions. The frequency and duration of such floods are, however, small.

2.6. *Thunderstorms, hailstorms and duststorms*

Thunderstorms occur mostly during pre-monsoon months (March-May) and to a lesser extent during monsoon. In south, they are more common during the northeast monsoon season (October-December). However, hailstorms and dust-storms occur only during pre-monsoon and early parts of monsoon (India met. Dep. 1966).

In the Thar desert, particularly in its core, thunderstorms are conspicuous by their absence. The annual frequency of thunderstorms at Jaiselmer is zero. In about 10 days, they occur in a year at Phalodi and Bikaner, and about 25 days at Jodhpur. There is an increase in its incidence towards east and north. Over east Rajasthan and

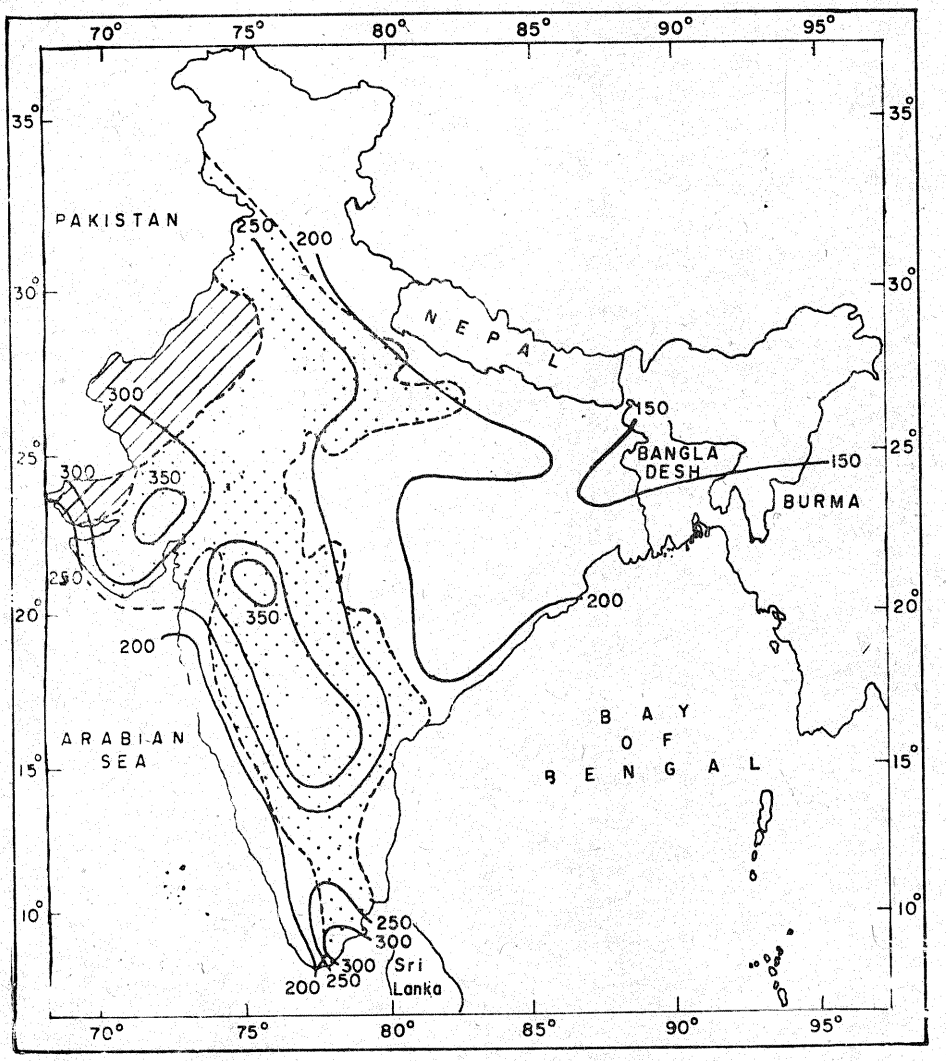

Fig. 4. Annual evaporation (cm)

adjoining Madhya Pradesh, thunderstorm frequency is about 30. Over arid regions of Kutch and coastal Saurashtra, the occurrence is less than 10 days. Over Gujarat region the frequency, however, is slightly more (10 to 15 days) while over the Peninsula it is 15 to 25 days and over interior Tamil Nadu even more.

Incidence of hailstorm, as in case of thunderstorm, is a rare phenomenon in the core of Thar desert, the annual frequency being zero at Jaiselmer. Similarly over Gujarat and Saurashtra & Kutch, the incidence is rare. The frequency increases eastwards and southeastwards of the desert core, and over Barmer, Phalodi, Jodhpur and Ganganagar they occur once in 3 or 4 years. Over Bikaner, as also over east Rajasthan and the neighbouring areas of Punjab and Haryana the frequency is slightly more, *i.e.*, about once in a year. Over the rest of the semi-arid regions they are infrequent and occur once in 4 or 5 years.

In sharp contrast to the incidence of thunderstorms and hailstorms, duststorms are more frequent in west Rajasthan. The annual frequency is the highest, *i.e.*, 17 days at Ganganagar. It decreases rapidly outwards, being 10 days at Amritsar, 8 days each at Bikaner and Delhi, 7 days each at Ferozpur and Karnal, 6 days each at Jodhpur and Jaipur, and 5 days at Phalodi. In only 2 or 3 days in a year, it may be expected at Jaiselmer and Barmer. Over Gujarat they are practically absent. In the remaining parts of the semi-arid regions they are less frequent.

2.7. *Water balance aspects*

Employing Penman's formula for computing potential evapotranspiration, normal monthly and annual values of potential evapotranspiration have been computed and analysed. The study reveals that the annual potential evapotranspiration ranges between 140 and 180 cm over most parts of the country, and is highest over extreme

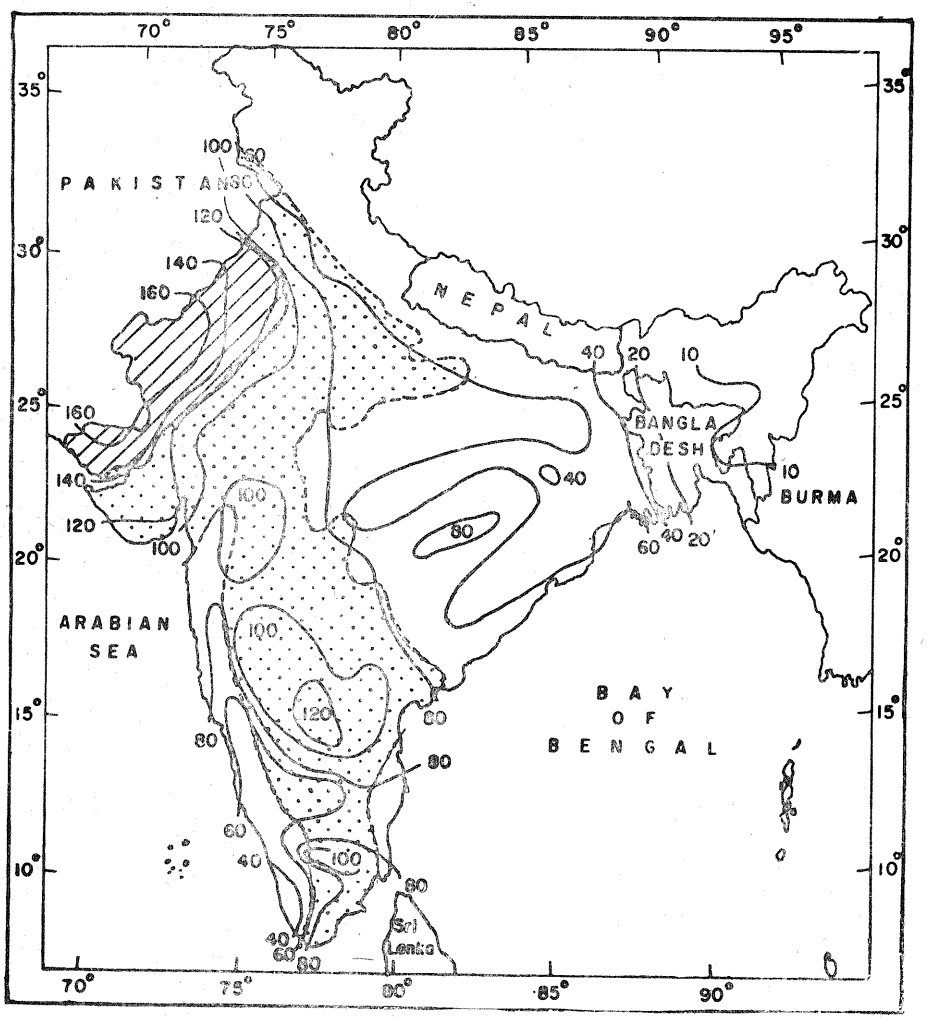

Fig. 5. Annual water deficit (cm)

west Rajasthan (in Jaiselmer district), where it is about 200 cm. Parts of Karnataka, Andhra Pradesh and Tamil Nadu also show values exceeding 180 cm.

The difference between potential evapotranspiration and actual evapotranspiration is the water deficit while that between precipitation and actual evapotranspiration is the water surplus. Making use of Thornthwaite's water budget technique actual evapotranspiration and, therefore, water surplus and water deficit have been calculated. Though the computations have been done on monthly basis, values have been obtained for year as a whole.

Water surplus

In the arid and semi-arid regions, there is no area where water surplus on annual basis is seen.

Water deficit

The annual water deficit exceeds 160 cm in west Rajasthan gradually decreasing eastwards and southwards (Fig. 5). In the Peninsula, regions where water deficit exceed 100 cm are:

(*i*) Northern parts of Karnataka and adjoining Rayalaseema and Telangana.

(*ii*) Interior parts of Maharashtra.

(*iii*) Interior and south coastal areas of Tamil Nadu.

3. Climate fluctuations

In different parts of the globe, rainfall during past decade has been abnormally low and questions are being raised with justifiable alarmness, if the climate is changing its accustomed pattern. In India too in recent past, there have been years (*e.g.*,1965-1966 and 1972) when large part of the country experienced deficient to scanty rainfall resulting in large scale crop failures and famine conditions. In fact, in India drought has been a recurrent feature in the last century, and extensive drought had occurred in 1877, 1899 and 1918 resulting in disastrous

famines. Government was baffled by the bewildering frequency with which drought and famine were occurring after 1860 and asked India Meteorological Department to prepare a report dealing with the problem from purely meteorological angle, whether changes in climate are taking place, particularly over northwest India. Walker (1919) based on study of rainfall from 1841 to 1908 concluded that there was no proof to suggest any permanent climatic change over large part of northwest India, although there has been a tendency for the rainfall :

(a) to increase to a maximum between 1892 and 1894 and

(b) to sink to a minimum in 1899 and to improve slowly thereafter.

He attributed the deficiency in rainfall to abnormal movement of atmospheric systems.

A systematic study of climatic changes in India began in early fifties. For this purpose, various statistical methods were employed.

Utilising 60 to 70 years data, meteorological conditions were examined in relation to the extension of Rajasthan desert by Pramanik *et al.* (1952). They found no appreciable upward or downward trend in the yearly rainfall values or in the five or ten yearly moving means for most of the stations. In fact, Jodhpur, Kota, Barmer, Agra and Nimach showed a definite tendency for increase in rainfall. From this, they concluded that there was no accentuation of desert conditions. Similar conclusions were arrived at by Desai (1952) from a polynomial analysis of monsoon rainfall of Gujarat. Pramanik and Jagannathan (1952) found in general, no tendency for increase or decrease of annual rainfall of selected stations in Deccan.

Pramanik and Jagannathan (1953) examined over 60 years of rainfall data for over 100 stations and found:

(*i*) no significant short period cyclic movement;

(*ii*) the distribution of rainfall particularly in arid and semi-arid regions of northwest India and semi-arid regions of Deccan showed a general tendency for deficient rainfall to be more frequent;

(*iii*) examination of decadal averages or polynomial analysis showed absence of general tendency for increase or decrease.

Pramanik and Jagannathan (1954) analysing temperatures (maximum and minimum) of 30 observatories over India and Pakistan for more than 50 years found in general no tendency for a systematic increase or decrease in temperature at most of the places, but at some of the stations variations of oscillating nature (of period 8 to 12 years) were observed. On analysis of pressure data of 25 stations Jagannathan and Pramanik (1955) found a general tendency for the pressure to decrease over major part of the country. This was confirmed by analysis of decadal averages.

Rao and Jagannathan (1963) examined two sets of data, *viz.*, district normal rainfall upto 1920 and 1940, and stationwise 1901 to 1930 and 1901 to 1950 normals. This was done for Rajasthan and Gujarat stations. They found little difference between the two sets of normals. Thus, they concluded that no significant changes have occurred in the rainfall in Rajasthan or Gujarat during the period under study. They found year to year variations were random. Examination of sub-divisional rainfall for east Rajasthan, west Rajasthan and Gujarat also corroborated these results. The frequency distribution was found to be not statistically different from normal.

Jagannathan and Parthasarathy (1973) studied rainfall data for over 70 years for 40 stations, and found that in the desert area of Rajasthan (Jodhpur, Jaiselmer and Jaipur) no trend, persistence or cycles except at Jodhpur, where a cycle of 8 to 12.5 years was significant.

Trend and periodicities in rainfall on meteorological sub-divisionwise were also examined by Parthasarathy and Dhar (1974). Their results revealed a positive trend from western to the central parts of Peninsula between 12° to 25° N as also over Punjab and Himachal Pradesh. A significant increase (4 to 19 per cent) of mean per 30 years period, in the mean annual rainfall was also noticed in many sub-divisions. A significant cycle of 8 to 12 years range in and around arid and semi-arid regions of Rajasthan, central parts of India and extreme south Peninsula was seen.

From a study of fluctuations of monsoon rainfall over Rajasthan and associated sunspot cycles, Bhalme (1975) confirmed that the rainfall assumes different pattern during different sunspot epochs. During sunspot maximum, he found that the 'breaks' are more frequent and that the frequency of the depressions is less and tracts shorter.

A decreasing trend from 1890-1905, more marked over northwest India was observed from an analysis of 100 years of rainfall by Banerjee and Raman (1976). After this period, the rainfall was mainly oscillatory in character.

4. Conclusion

From the above study, it is evident that there is no tendency for rainfall or other meteorological factors to systematically increase or decrease in the Thar desert or semi-arid regions of the country. There appears no reason to believe that the conditions in Thar desert are accentuating or the desert is expanding. It is also clear that the apprehensions expressed by Winstanely (1973) based on the analysis of data of only two Indian stations (namely, Jodhpur and Bikaner) about southward extension of Rajasthan desert, are not supported by the results of the above studies.

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