WATER RESOURCES OF INDIA IN THE FORM OF RAINFALL

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An account is given of the rainfall of India, including its distribution in space and time, the areas of low rainfall and rainfall variability. Evaporation, potential evapotranspiration and the moisture status of the various parts of the country are also dealt with. The importance of conserving the abundant rain waters, utilizing the same during lean periods and adopting the cropping patterns to suit the climatic conditions of arid and semi-arid zones is stressed.

INTRODUCTION

Water is necessary for the sustenance of all forms of life on the earth. Man requires water for drinking, bathing, cooking, growing food, generating power, swimming, fishing, cooling buildings, fighting fires, flushing away wastes and for sailing. Sometimes and in some places there is too much water. Often there is too little.

Ninty seven per cent of the water resources of the earth are in the seas. Only the remaining 3 per cent is fresh water. Nearly three quarters of even this 3 per cent is in the form of permanent ice fields over the polar regions and on mountain tops. A large percentage of the remaining water is stored underground. It is estimated that at any one time the lakes and the rivers of the world hold only 1/3 of 1 per cent of the earth's fresh water and the atmosphere only a tenth of this percentage.

Although the atmosphere contains only a very small portion of the earth's water at any instant, the atmosphere transports tremendous volume of water over a period of time because of its constant motion. Thus the southwest monsoon precipitates over India 2400 cubic kilometres (2400000 million cubic metres) of water during the four months of the monsoon season. All the water that replenishes our lakes, rivers and wells must pass through the atmosphere. The atmosphere therefore ultimately controls the water that flows through the rivers of the world or which lie as ground water deep below. The atmospheric events which control these often take place far away from the wells or river courses where the influence is felt. The unusually low level of water in the Bhakra reservoir in the river Sutlej this year, which led to a widespread power shortage crisis in the Punjab and Haryana is recent memory. The reason for this lay in the decrease of snowfall and hence snowmelt in far away Manasarovar areas and neighbourhood.

Thus rainfall and snowfall are of paramount importance in mobilisation of water resources for the benefit of man.

RAINFALL OF INDIA

The average annual rainfall in the plains of India has been estimated as about 105 cm. Very few countries in the world can boast of an average rainfall of this magnitude. The corresponding figure for the U.S.A. is about 75 cm., for Canada

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60 cm., Australia 35 cm., Africa 30 cm. and Europe 65 cm. Fig. 1 shows the distribution of annual rainfall in India and Table I shows the annual rainfall of India in the various meteorological sub-divisions of the country and its seasonal distribution. The striking features of the rainfall distribution are the very heavy rainfall of over 400 cm. over the southern slopes of the Khasi Hills, the Brahmaputra Valley and the western ghats, heavy rainfall amounting to over 200 cm. over the whole of Assam and the west coast of the Peninsula and the low rainfall of less than 40 cm. over West Rajasthan with portions of it receiving less than 20 cm. On the east of the western ghats, there is a big patch extending north to south which receives less than 60 cm. The coastal strip on the east extending from the Madras coast to the head of the Bay of Bengal and prectically the whole of Bihar, Orissa and Madhya Pradesh receive more than 100 cm.

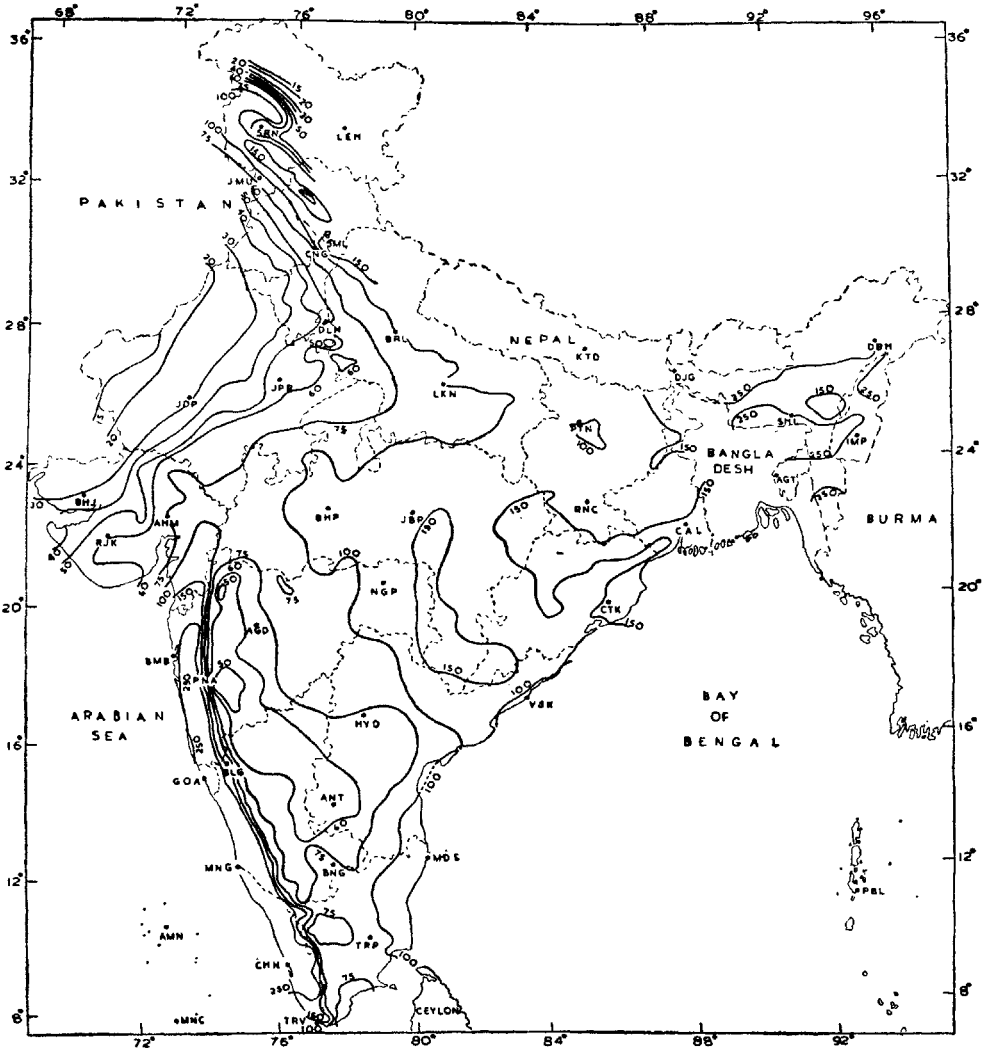

FIG. 1. Annual Rainfall of India.

TABLE I

Rainfall of India

Name of the Sub-Division	Annual Rainfall (mm)	Rainfall as percentage of annual			
		Jan. & Feb.	Mar. & May	Jun. to Sep.	Oct. to Dec.
Bay Islands	2994.5	2.7	15.0	59.3	23.0
Assam (including Manipur and Tripura)	2516.4	2.3	25.1	65.3	7.3
Sub-Himalayan West Bengal	3126.2	1.0	15.4	78.0	5.6
Gangetic West Bengal	1435.3	2.7	12.4	75.6	9.3
Orissa	1482.2	2.7	8.6	76.7	12.0
Bihar Plateau	1372.0	3.9	6.5	82.0	7.6
Bihar Plains	1202.9	2.9	6.1	85.0	6.0
Uttar Pradesh, East	1007.7	3.4	3.0	88.2	5.6
Uttar Pradesh, West	964.2	5.1	3.9	87.0	4.0
Punjab (including Delhi)	624.7	8.6	7.2	80.0	4.2
Jammu & Kashmir	994.6	19.2	24.0	47.5	9.3
Rajasthan, East	704.1	2.1	2.3	92.5	3.0
Rajasthan, West	311.1	3.6	4.9	89.1	2.4
Madhya Pradesh, West	1044.9	2.2	2.0	90.7	5.1
Madhya Pradesh, East	1401.7	3.1	3.5	87.7	5.7
Gujarat Region	976.5	0.4	1.0	95.2	3.2
Saurashtra & Kutch	482.6	0.9	2.1	93.1	3.8
Konkan	2872.0	0.1	1.2	93.9	4.8
Madhya Maharashtra	920.7	0.8	4.1	83.6	11.5
Marathwada	773.6	1.5	4.0	83.3	11.0
Vidarbha	1099.6	2.9	3.1	87.0	7.0
Coastal Andhra Pradesh	1008.3	2.3	8.8	56.6	32.3
Telengana	926.5	2.1	6.1	81.7	10.0
Rayalaseema	677.8	2.2	11.3	54.4	32.0
Tamil Nadu	1008.1	5.3	14.6	33.0	47.1
Coastal Mysore	3264.8	0.1	4.4	87.7	7.8
Interior Mysore, North	675.0	0.9	12.7	65.2	21.2
Interior Mysore, South	1244.9	0.8	13.0	67.6	18.5
Kerala	2996.1	1.2	13.5	66.9	18.3
Arabian Sea Islands	1572.4	2.8	13.0	62.3	21.4

The rainfall is not at all distributed uniformly over the year; more than 75 per cent of the annual rainfall is received during the southwest monsoon season over practically the whole country excepting Assam, Jammu and Kashmir and the south Peninsula. In the Madras State, 47 per cent of the annual rainfall is received during the post-monsoon season. In Jammu and Kashmir, about 20 per cent is received during January and February, and another 25 per cent during March to May. There is a wide variation in the distribution even of the seasonal rainfall in the different parts of the country For example, during the southwest monsoon, the west coast of the Peninsula receives more than 250 cm. while West Rajasthan receives less than a tenth of this quantity.

The broad area-wise distribution of rainfall in India is given below :

Rainfall Amount	*Area Percentage*
0 — 75 cm	30
75 — 125 cm	42
125 — 200 cm	20
Above 200 cm	8

The annual rainfall is less than 75 cm. in the following meterological sub- divisions:

Punjab (including Delhi and Haryana)	63 cm
Rajasthan East	70 cm
Rajasthan West	31 cm
Saurashtra and Kutch	48 cm
Rayalaseema	68 cm
Interior Mysore North	68 cm

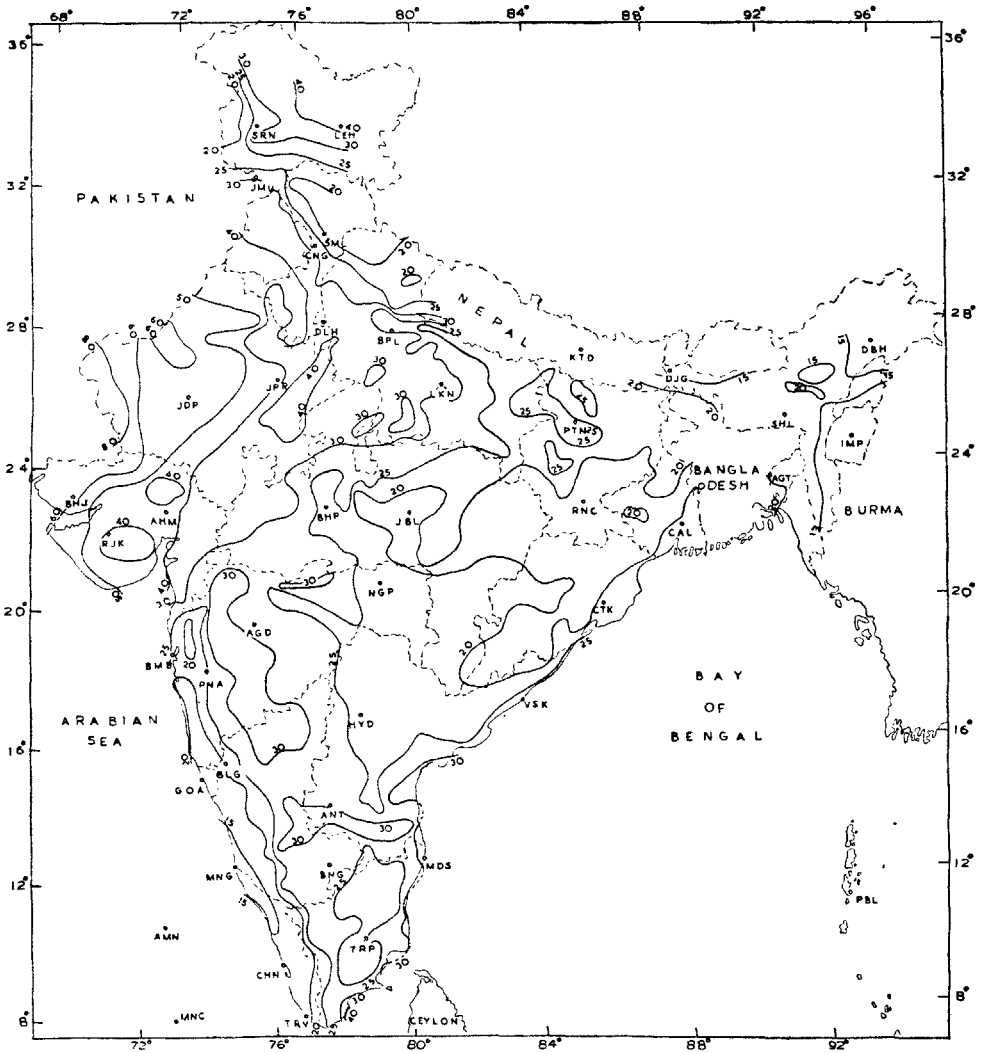

FIG. 2. Coefficient of variation of annual rainfall.

TABLE II

Variability of rainfall (percentage)

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
West Rajasthan	223	152	157	170	182	96	59	76	146	253	333	180
East Rajasthan	107	152	162	231	138	92	38	50	78	150	145	171
Rayalaseema	207	241	221	81	61	41	52	63	45	56	83	172
Madhya Maharashtra	215	175	144	71	76	33	30	37	39	61	101	200

RAINFALL VARIABILITY

It is well known that rainfall is very much variable both in space and time. When we consider periods less than a season, say, a day, the rainfall distribution over the country bears no semblance to the normal seasonal distribution.

No two years have exactly the same rainfall. Some years stand out as phenomenal years when the rainfall was very much in excess and some others when the rainfall was much in defect. The worst famine year on record viz., 1899 and the year of very heavy rainfall viz., 1917 are well known. The drought years of 1965 and 1966 fresh in our memory.

The variability of rainfall is shown in Fig. 2. The variability exceeds 30 per cent over large areas of the country and is over 40 to 50 per cent in parts of Saurashtra, Kutch and Rajasthan. In some of the interior districts in these areas as also in the Deccan plateau, the variability is as high as 100 per cent or more and these are particularly liable to very heavy rainfall in some years and very scanty rainfall in others. The variability is least over the northeastern parts of India and the southwestern coast of the Peninsula, being only 15–20 per cent, indicating very high reliability of rainfall over these areas. As a rule, areas which have the lower rainfalls are also those in which rainfall is most irregular.

The variability of the monthly rainfall in the arid and semi-arid sub-divisions of India are given in Table II.

The performance of the monsoon varies from year to year in respect of the following : (*a*) the timing of the onset or the commencement of the rainy season in different parts of the country, (*b*) the pattern of distribution of rainfall including the timing and duration of breaks in the monsoon, (*c*) the timing of withdrawal of the monsoon from different parts of the country and (*d*) total rainfall of the season.

HEAVIEST RAINFALL IN A DAY

Large tracts of India are liable to receive excessive rainfall in heavy downpours caused by cyclonic storms and depressions. Locally heavy falls caused by depressions vary from 7 to 20 cm. extending over several districts. Falls to the extent of 25 to 35 cm. in a day have been recorded especially in the neighbourhood of hills and on the coast near the central regions of storms. Heavy falls exceeding 25 cm. in a day are not uncommon even in Gujarat and Rajasthan. Dwaraka in Saurashtra with an annual average rainfall of 32 cm. has received about this amount in a day in November 1951. Dharampur in Surat district had recorded 100 cm. on

2nd July, 1941. This is the heaviest 24 hour rainfall in any of the plain stations in India. Generally rainfall of 75 cm. and over in a day is confined to a very small area in the Khasi and Jaintia Hills in Assam, the head of the Gulf of Cambay around Surat district and the Bhagamandla area in Coorg. The record 24 hour rainfall for India is maintained by Cherrapunji in Khasi Hills with 103.3 cm.

Evaporation

Apart from rainfall, what is most important to know is how much of it is lost as a result of evaporation. Figure 3 shows the mean annual evaporation in different parts of India based on observations recorded with mesh-covered U.S.A. standard open pan evaporimeters. The high evaporation exceeding 250 cm. over Rajasthan, Saurashtra-Kutch, Interior Maharashtra, Rayalaseema and parts of North Interior Mysore may be readily seen from the figure. Over some parts of India pan evaporation exceeds 325 cm. or even 350 cm.

A more important parameter from the point of view of agriculture is evapotranspiration, which is the combined loss of water from the soil and crops under field conditions. Such data are generally meagre all over the world and India is no exception.

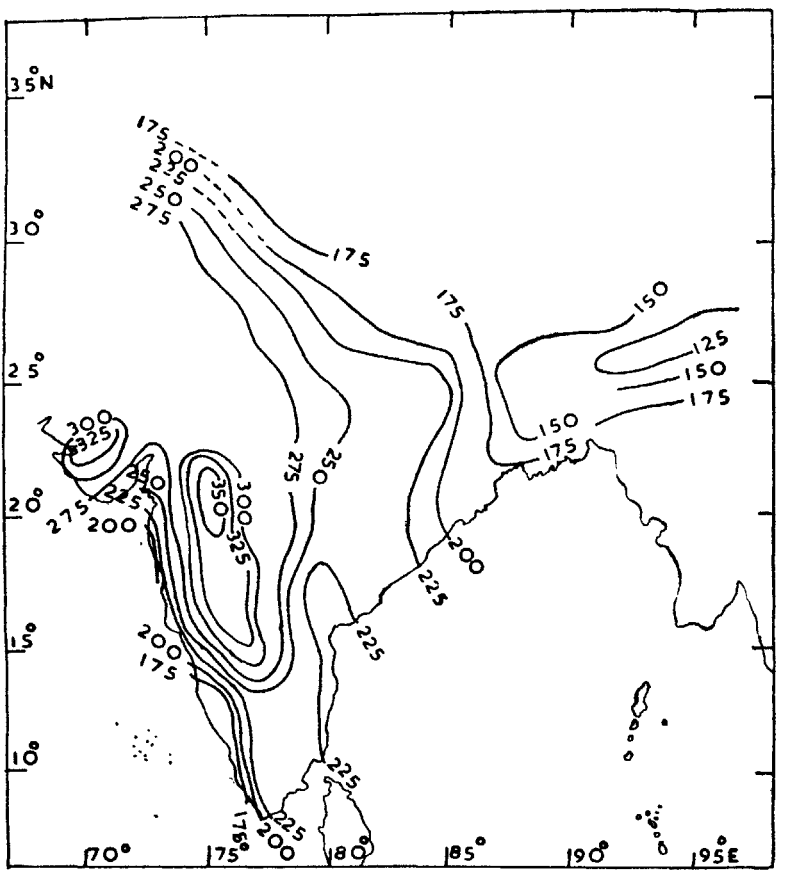

Fig. 3. Annual evaporation

However, it is proposed to measure evapotranspiration at a network of 9 principal centres and 26 auxiliary centres at important agricultural research stations under the Fourth Plan. These will provide very important data for the study of the water balance of the areas concerned and for planning cropping patterns.

However some, approximate values of potential evapotranspiration can be computed on the basis of the well-known Penman's formula making use of available meteorological parameters. Isopleths of annual values together with the highest and lowest mean monthly values of potential evapotranspiration are shown in Figs. 4, 5 and 6. These are based on data of about 300 stations in and near India.

Potential evapotranspiration ranges between 140 and 180 cm. over most of the country and is highest over extreme west Rajasthan in the Jaisalmer area. Values exceeding 180 cm. are also seen in parts of Mysore, Andhra Pradesh and Tamil Nadu.

Moisture Status

The ratios of precipitation (P) to potential evapotranspiration (PE) provides a simple method of estimating the moisture status of a place. If the ratio is less than unity it would mean that the moisture content of soil in a place is not sufficient to cope with the needs of evapotranspiration; if the ratio is greater than unity the availability of soil moisture is greater. $\frac{P}{PE}$ ratio has been computed for each month or the year for about 300 stations. These are plotted on maps and isolines drawn for the ratios of 1.0, 0.50, 0.25, and 0.10. The isolines demarcate humid

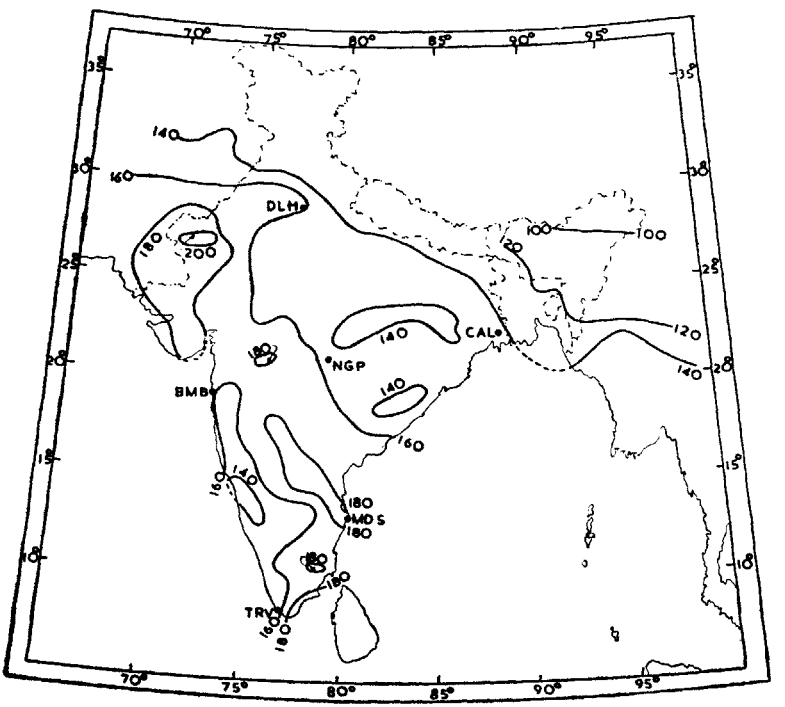

Fig. 4. Annual potential evapotranspiration.

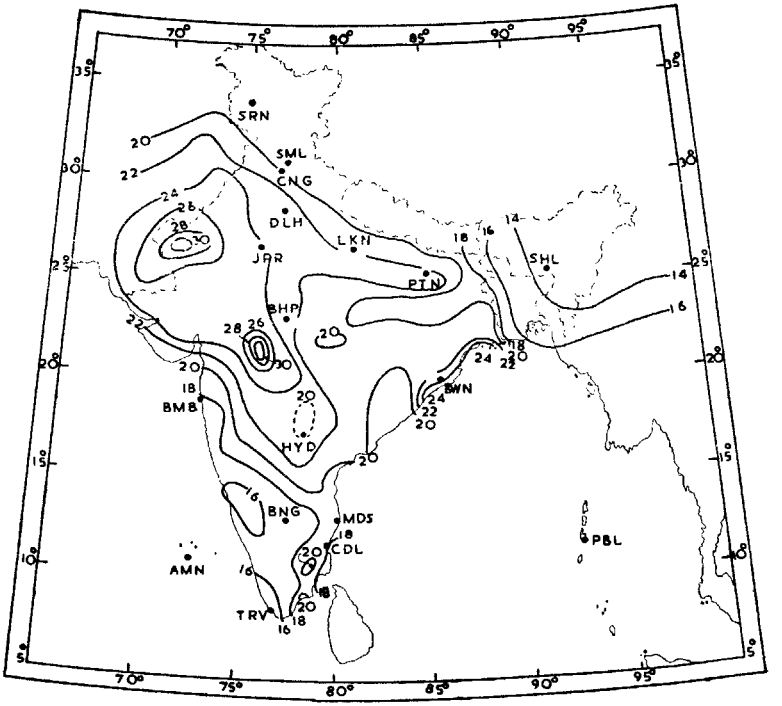

FIG. 5. Highest mean monthly potential evapotranspiration.

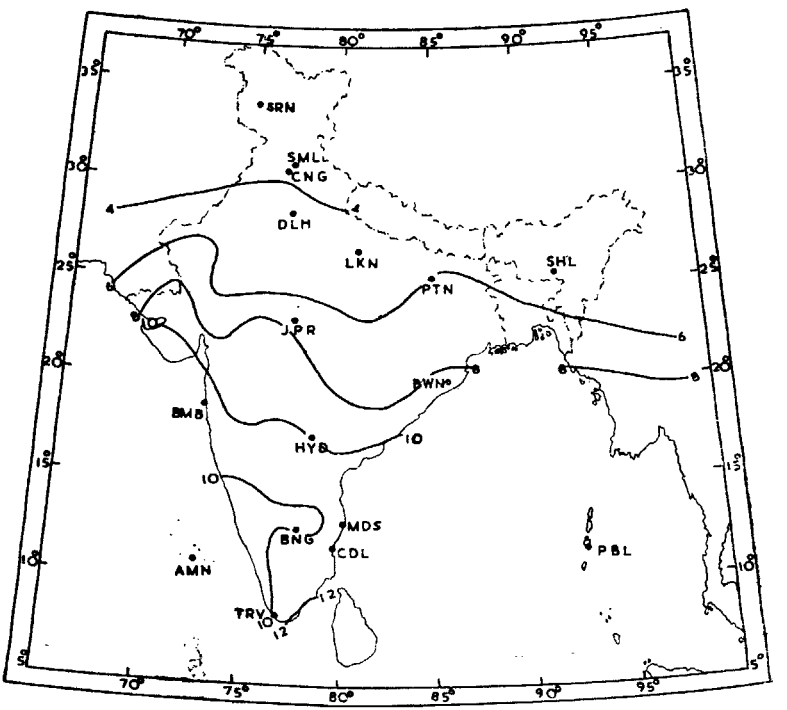

FIG. 6. Lowest mean monthly potential evapotranspiration.

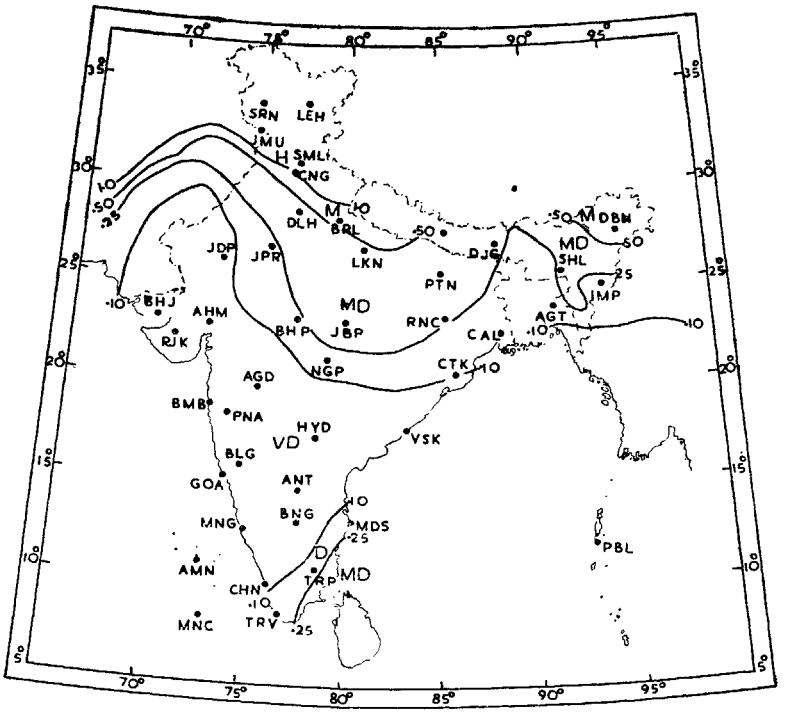

FIG. 7. Ratio of precipitation to potential evapotranspiration (January).

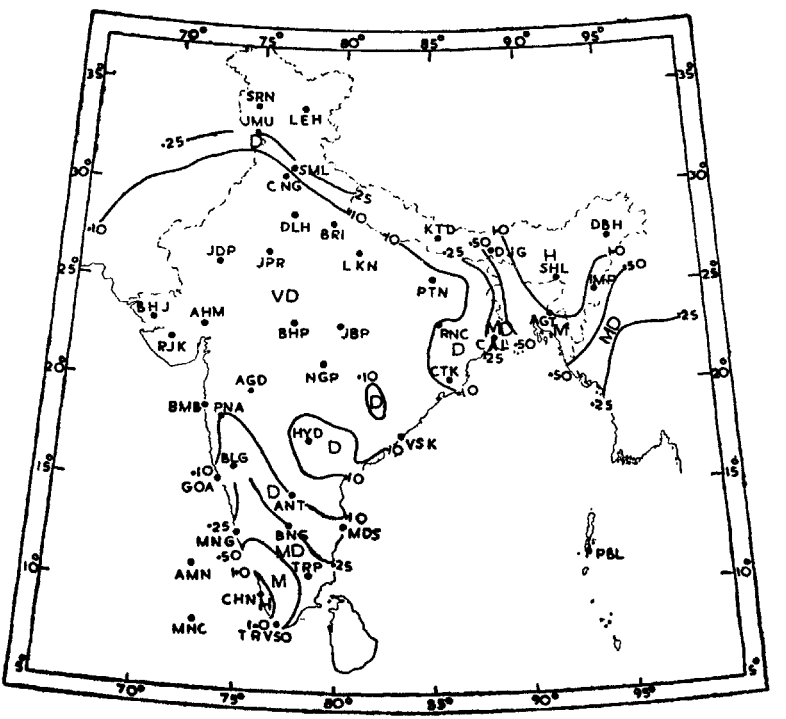

FIG. 8. Ratio of precipitation to potential evapotranspiration (April).

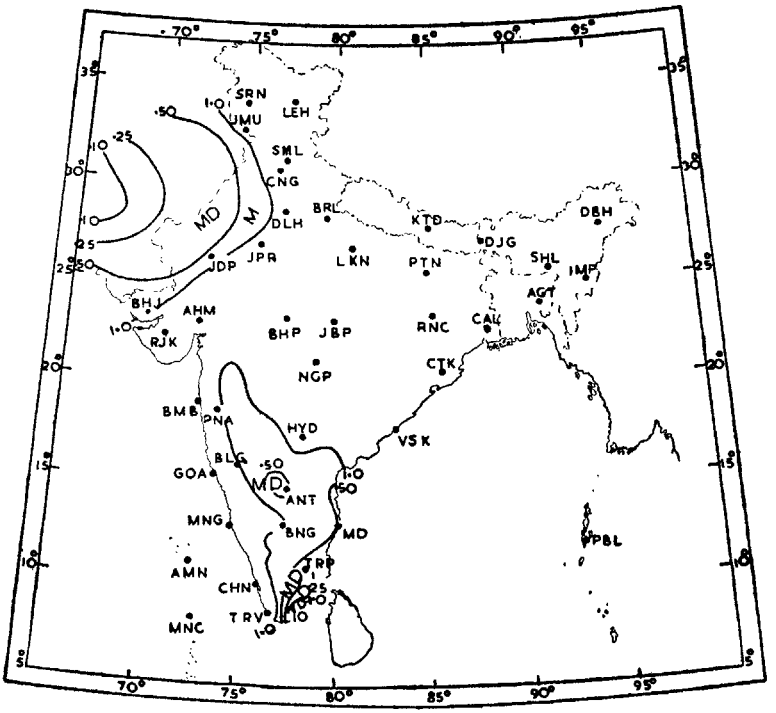

FIG. 9. Ratio of precipitation to potential evapotranspiration (July).

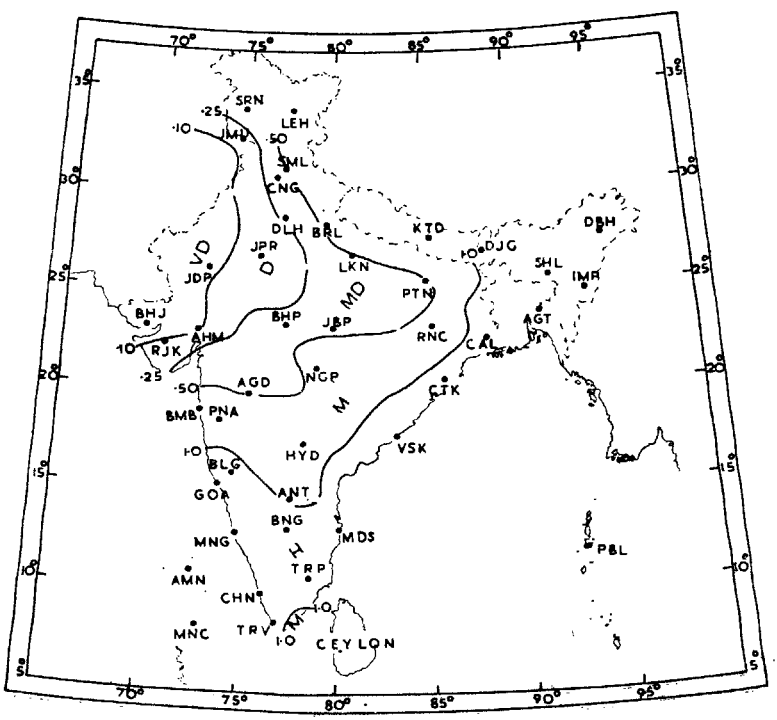

FIG. 10. Ratio of precipitation to potential evapotranspiration (October).

(>1.0), moist (1.0—.50), moderately dry (0.50—0.25) dry (0.25—0.10) and very dry (<.10) conditions.

Maps for representative months January, April, July and October are given in Figs. 7, 8, 9 and 10. The main features are :

January—Under the influence of western disturbances moist conditions prevail over a belt extending from the Punjab to the northern parts of west Uttar Pradesh. Further north, over the western Himalayas and the adjoining areas, humid conditions prevail. The rest of the country is generally dry.

April—With the commencement of the season of thunderstorm activity, moist/humid conditions prevail over *(i)* Kerala and adjoining areas, *(ii)* Assam and northeastern parts of the country. Rest of the country, barring Kashmir and adjoining northern areas, is generally dry.

July—Dry and very dry areas are confined to portions of south Tamil Nadu.

October—Dry areas in Tamil Nadu have disappeared. In the north, dry or very dry conditions prevail mainly over Gujarat and Rajasthan.

Conclusion

India is fortunate in having been blessed with an abundance of rainfall. However, this is not uniformly distributed over the year. We have, therefore, to conserve the water that falls as rain during the monsoon and utilize the same during the lean periods. We have also to adopt cropping patterns to suit the climatic conditions of the arid and semi-arid zones.

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