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Climatic types of India according to the rational classification of Thornthwaite

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ABSTRACT. Using the climatic data of about 250 stations, the climates of India and the neighbourhood are classified according to the 1948 scheme of Thornthwaite. The analysis seems to reveal certain features which no previous classification has shown. It is found that most sections of India are more arid than indicated by earlier schemes. The thermal efficiency regime of the country is more than adequate to support forest type of vegetation, limited in maintenance and growth only by the seasonal distribution of rainfall. It is felt that a natural vegetation map of the country is very essential for the validity of the scheme to be verified.

The real purpose of a climatic classification is to define the climatic types in statistical terms in which the climate, as a geographic factor, is to be regarded as having definite and uniform characteristics (Hare 1951). Since soil and climax vegetation are known to reflect faithfully the climatic features of most regions, modern systems of classification base their divisions on the characteristics of natural vegetation. Köppen was the first to give much thought to the classification of climates and his first paper dealing with his comprehensive scheme appeared in the year 1900. In a very interesting article on the problems in the classification of climates, Thornthwaite (1943) traced the historical development of the Köppen system and showed how it is not rational and why it cannot be applied to the study of regional climates.

For a detailed analysis of all the climatic types, it is highly necessary to investigate the hydrologic balance of the region under consideration. Since the moisture available to plants depends not only on the amount of rainfall but also on the evapotranspiration losses, the main problem here is one of obtaining an index of precipitation effectiveness. Precipitation can be measured fairly accurately by means of raingauges but, till today, there is no satisfactory means of measuring actual evapotranspiration for it depends not only on the meteorological characteristics of the overlying atmosphere but also on the amount of available moisture, apart from the fact that it is also influenced by the nature of the evaporating surface. In view of the various difficulties involved in the experimental measurement of actual evapotranspiration, Thornthwaite (1948) introduced the potential evapotranspiration which he defines as the total amount of water that would evaporate and transpire if it were always available for full use. From a series of field investigations, Thornthwaite showed that this potential evapotranspiration (abbreviated as P.E.) depends primarily on the climatic properties of the atmosphere and can, therefore, be determined much more easily than the actual evapotranspiration. There are not, however, many stations in the world today where measurements of P.E. are made and in view of the urgent need for such data in various other fields, attempts are, at present, being made to estimate this quantity by empirical methods. From a careful study of the water-balances of a number of irrigated valleys in the North American continent, Thornthwaite derived a mathematical expression for the computation of P.E. from a knowledge of the mean monthly temperature, provided the latitude of the place is known. The equation in its original form is not easy to use but with the help of the nomograms and tables devised by Thornthwaite himself, the P.E. can be computed without any difficulty.

Table 1 shows the data of temperature and precipitation for thirty selected stations in India and the vicinity, the computed climatic parameters for which are presented in other pages. In all, data for 250 stations in India, Pakistan, Burma and Ceylon supplied to the author by Dr. L.A. Ramdas, Deputy Director General of Observatories of the India Meteorological Department were used for this study. Most of the stations had a very good period of record of meteorological observations (more than 35 years) and those stations for which the period was felt to be inadequate were entirely deleted from computational work.

No attempt is here made to reproduce the computational procedure which was given in great detail in the above-referred paper of Thornthwaite. The computed values of mean monthly potential evapotranspiration for the 30 stations in the above table are presented in Table 2.

Knowing the P.E. (or water need) as computed above, it is easy to study the climatic characteristics of any region by comparing the same (P.E.) with precipitation. Thornthwaite evolved a simple book-keeping procedure for the determination of the numerical values of water surplus and water deficiency, where precipitation is treated as income and P.E. as outgo while the moisture stored in the soil is a sort of reserve capable of being drawn as long as it lasts. The maximum amount of this soil moisture available for the use of vegetation varies in different soils but it was shown that for most kinds of agricultural soils it is equivalent to about 10 centimetres of rainfall. Examples of this procedure as applied to Sukkur and Colombo are shown in Table 3.

Due to non-uniform distribution of precipitation through the year, a region may experience water deficiency in one season and a surplus in another. Taking these two moisture parameters into consideration, it is possible to define an index of precipitation effectiveness which, according to Thornthwaite, is

$$I_m = \frac{100\,s - 60\,d}{n}$$

where I_m = the moisture index

s = annual water surplus

d = annual water deficiency and

n = annual water need (or P.E.) all expressed in the same units

I_m thus is a ratio and is therefore non-dimensional. According to the above notation, positive values of I_m signify moist climates and negative values dry climates. A classification of climatic types based on moisture indices, as developed by Thornthwaite, is as follows:—

Moisture index	Climatic type	
100 and above	A	Perhumid
80 to 100	B_4	Humid
60 to 80	B_3	Humid
40 to 60	B_2	Humid
20 to 40	B_1	Humid
0 to 20	C_2	Moist subhumid
—20 to 0	C_1	Dry subhumid
—40 to —20	D	Semiarid
—60 to —40	E	Arid

The moisture index, as defined above, indicates only how wet or dry a given region is but cannot tell anything about the seasonal variation of effective moisture. This seasonal moisture variation is represented by the introduction of another symbol; s and s_2 are used to indicate respectively moderate and large variation of moisture when the dry season occurs in summer and w and w_2 are similarly used with the dry season occurring in winter. In those regions where precipitation is consistently above or below water need throughout the year, there is no water deficiency or surplus in any season and the symbols r and d are used to denote respectively no moisture deficiency in humid climates and no surplus in generally dry climates. The various climatic subtypes according to this system are given below.

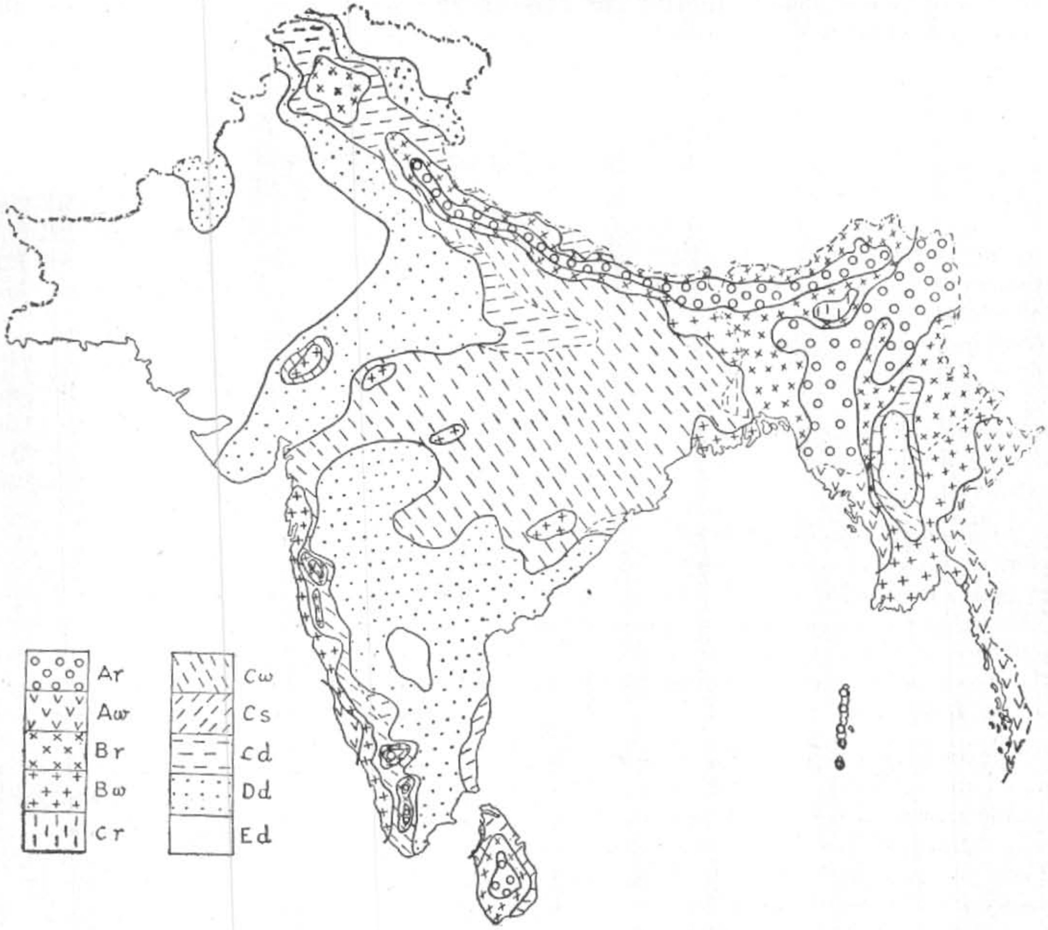

Fig. 1. Moisture regime of India and neighbourhood

Moist climates (A, B and C_2)

Little or no water deficiency	r
Moderate summer water deficiency	s
Moderate winter water deficiency	w
Large summer water deficiency	s_2
Large winter water deficiency	w_2

Dry climates (C_1, D and E)

Little or no water surplus	d
Moderate winter water surplus	s
Moderate summer water surplus	w
Large winter water surplus	s_2
Large summer water surplus	w_2

The computed values of water surplus, water deficiency and moisture index for the previous 30 stations are shown in Table 4 along with their climatic types and sub-types based on their moisture regimes.

Fig. 1 is the map of India and the neighbourhood showing the distribution of climatic types on the basis of moisture index and the seasonal variation of effective moisture. As mentioned earlier, the complete data for all the stations (about 250) in India, Pakistan, Burma and Ceylon were used in the preparation of this map and also the one shown in Fig. 2. To avoid much complication and to simplify the discussion, only the major climatic divisions are presented in the figure, *e.g.*, all the humid climates, irrespective of whether they are B_1, B_2, B_3, or B_4, are considered only as B climates. Similarly, both C_1 and C_2 are regarded as only the C climates, *i.e.*, the subhumid type. The symbolic data were plotted against the station locations on the map and isolines were drawn separating different climatic types according to the familiar method adopted in climatological work.

The figure shows an interesting pattern of the moisture regime. The whole of western India, including a part of the northwest, is completely arid; adjoining this is a belt of semiarid climates extending from the Punjab through the central parts to the southern tip of peninsular India, divided into a northern and southern belt by a strip of subhumid climates running east-west along the Vindhya region. To the immediate east of the Western Ghats is a very narrow region of subhumid climates, merging gradually into the humid and perhumid types westwards to the coast. An island of fairly humid climates in the northern semiarid belt is found in the Aravalli hills. To the east and northeast of this extensive dry belt lies a vast region of subhumid character joining the same climate of the Vindhya area. Further northeast are the humid and perhumid types in the Shillong plateau and the high mountains of Assam and Burma. Humid conditions also prevail in Nilgiri, Annamalai and Palni hills in south India and the central mountainous districts of Ceylon. In the northwestern coastal section of Ceylon is a small dry region, existing as an extension of the semiarid belt of south India. The Eastern Ghats too have humid climates capable of supporting forest type of vegetation.

In recent years, there has been much concern over the so-called "spreading of the Rajasthan desert". There is not enough climatological evidence to support this view, but the climatic analysis of the Indian subcontinent according to various investigators shows different eastward limits of this well-known desert region. Thornthwaite's new classification which has been developed on rational concepts depicts a picture which appears to be much closer to the actual conditions than shown by any other earlier scheme. Similarly, in south India, the existence of almost arid conditions in the Central Deccan is a feature which no previous climatic map, neither Köppen's nor Thornthwaite's first map (1933) has revealed.

India has a strong mal-distribution of rainfall through the year in the sense that most of the country receives tremendous amounts of precipitation during the monsoon season and the rest of the year is practically rainless. Accordingly, the region of humid climates in the southwestern section of India which receives all its precipitation water from the summer monsoon has got the subtype "w" indicating that it has moderate deficiency of water in the winter season. Similar is the case in the subhumid regions of central and eastern India in regard to their seasonal variation of moisture. The symbol "d" for the belt of arid and semiarid climates signifies that in no part of the year have they got any moisture surplus. Only in the northeastern section of the country is the subtype "r" found showing adequate moisture throughout the year. Certain high peaks in the Western Ghats and Nilgiris too have no moisture deficit in any season. Winter water surpluses in India are nowhere found except in a small portion of the southeastern coast of the peninsula and the northeastern part of Ceylon, which have a clear winter maximum of rainfall due to the predominant influence of the northeast monsoon. Thus, these regions, belonging as they are, to the dry subhumid type of climate have the symbol "s" in their climatic notation indicating moderate water surplus in this season. It is worthy of note that the subhumid climates are transitory between the humid climates on one side and arid types on the other and, therefore, are areas of critical water balance; measures for supplemental irrigation in them are highly desirable if not altogether indispensable.

The P. E., since it is derived from temperature and length of the day, is also an index of thermal efficiency, expressing plant growth and development in terms of water need. The climatic divisions based on thermal efficiency are analogous to those derived from moisture index and are represented by the following symbolic notation—

P.E. (*cm*)	*Climatic type*	
	C'_1	Microthermal
42·7		
	C'_2	
57·0		
	B'_1	Mesothermal
71·2		
	B'_2	
85·5		
	B'_3	
99·7		
	B'_4	
114·0		
	A'_1	Megathermal
128·2		
	A'_2	
142·5		
	A'_3	
156·7		
	A'_4	
171·0		
	A'_5	
185·2		
	A'_6	
199·5		
	A'_7	

In the equatorial regions, where the length of the day is the same throughout the year with uniform temperature, seasonal variation of P.E. is small or even negligible. There is strictly speaking, no summer in these regions and the total P.E. for any three months will constitute 25 per cent of the annual total. On the other hand, at the poles, the growing season for vegetation is only during the three summer months and the total P.E. for this period will therefore be 100 per cent of the total annual P.E. Thus, as one passes from the megathermal climates of the equatorial regions to the frost climates of the poles, the concentration of thermal efficiency (P.E.) in the summer quarter rises gradually from 25 per cent to 100 per cent. Based on this thermal efficiency accumulation, Thornthwaite subdivides the thermal regime of climates as shown below—

Summer concentration of thermal efficiency	Climatic subtype
%	
	b'_1
61·6	
	b'_2
56·3	
	b'_3
51·9	
	b'_4
48·0	
	a'_1
44·6	
	a'_2
41·6	
	a'_3
38·8	
	a'_4
36·3	
	a'_5
34·0	
	a'_6
31·9	
	a'_7
29·9	
	a'_8

Table 5 shows the various climatic types and subtypes of the 30 stations mentioned before, on the basis of their thermal efficiency regime.

Fig. 2 is the distribution of climatic types in India according to thermal efficiency. As, in the case of the moisture regime, here too the different subtypes are not discussed in this paper in order to omit complicated details. Investigations show that, as far as the broad classification of vegetation types is concerned, these subtypes, especially in the megathermal zone, are not too much of significance; their importance is only to the regional studies of climatic types in relation to plant and

Fig. 2. Temperature regime of India and neighbourhood

forest ecology. It is thus seen from the figure that almost the whole of India has megathermal climates and only in the high mountains of the eastern and northeastern sections of the country are the mesothermal types found. For the summer concentration subtype of climate, the whole of India has the symbol "a" signifying that not more than 48 per cent of the total annual thermal efficiency is accumulated during the summer season. Only in western India and the northwest are regions where summer concentration percentages upto 60 are found and are, therefore, classified as having the symbol "b".

Having thus dealt with the elements of climatic classification, it is easy to assign a formula to any given region for its climatic features. Thus, Bombay has the formula $B_1A'_4w_2a'_7$ meaning that it is (first) humid and (fourth) megathermal with a large winter water deficiency and having a temperature efficiency normal to the (seventh) megathermal type of climates. Cherrapunji's formula is $A\,B'_2r\,a'_4$ indicating that it has a perhumid (second) mesothermal climate with no water deficiency in any season and a thermal efficiency of the (fourth) megathermal climates. Madras, whose formula is $C_1A'_5s\,a'_6$

has a dry subhumid (fifth) megathermal type of climate with moderate summer deficiency of moisture and having a thermal efficiency normal to the (sixth) megathermal climates. Nellore, with the formula $DA'_5da'_7$ is semiarid and (fifth) megathermal with no water surplus in any season of the year and has a summer concentration of the (seventh) megathermal climates. In a similar manner for Sukkur the climatic formula is $EA'_3da'_2$ indicating that it has an arid (third) megathermal climate with no water surplus at all and a temperature efficiency of the (second) megathermal type of climates.

Thus, from the mean monthly temperature and precipitation, the climatic features of any place can be determined and a formula can be worked out, provided its latitude is known. It has been realised by all climatologists alike that the natural vegetation of any place reflects faithfully its climatic features. Unfortunately, we have till today no natural vegetation map of India in the real sense. The Champion map (1936) which is probably the only vegetation map of India available is not strictly a natural vegetation map but only a map of climatic types. Till such a map becomes available it is hard to ascertain the validity of one scheme or other of the existing climatic classifications.

It is, by no means, claimed that this system of classification is either final or entirely rational; it is only an *approach* toward a rational classification and can be further improved or modified. It is almost impossible to achieve this objective without extensive measured data of potential evapotranspiration or in other words, the water need in different parts of the world. With our present knowledge of the processes of evaporation and transpiration, it cannot be said with any degree of certainty whether empirical formulae could provide a substitute solution to this problem, in the absence of actual measured data. There is a strong feeling among many workers today that a single formula, however accurate it may be for a given region, will not be suitable for direct application to another region, even of the same country, without proper modification or alteration. This is one of the many problems of applied climatology requiring further and more intensive investigation. In the present paper, an attempt has been made to understand the various climatic types of India according to what is today considered to be most rational system of classification. Individual regions need a more detailed study and analysis of their climatic characteristics for an assessment of their potentialities for agricultural and other purposes.

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TABLE 1

Normal climatic data of temperature (°C) and precipitation (cm)

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Agra	T	16·1	18·3	24·4	30·6	34·4	34·4	30·6	29·4	29·4	26·7	21·7	16·7	26·1
	P	1·3	0·8	0·8	0·5	1·0	5·6	22·4	18·8	10·4	1·8	0·2	0·8	64·4
Allahabad	T	16·1	18·9	25·0	30·5	33·9	33·9	30·0	28·9	28·9	26·1	20·6	16·7	25·6
	P	1·5	1·3	0·8	0·2	0·8	11·4	29·0	28·2	15·2	5·6	0·5	0·5	95·0
Calcutta	T	19·4	20·7	26·7	30·0	30·0	29·4	28·9	28·3	28·3	26·7	22·8	18·9	26·1
	P	1·0	2·5	3·3	5·3	14·0	29·7	32·3	33·8	25·4	12·4	1·8	0·5	162·0
Chittagong	T	18·9	21·1	25·0	27·2	27·8	27·8	27·3	27·2	27·2	26·3	23·3	20·0	25·0
	P	0·8	2·5	6·6	14·1	24·1	52·8	56·9	49·0	30·2	17·5	4·8	1·8	261·0
Darjeeling	T	5·0	5·6	9·4	12·8	14·4	16·1	16·5	16·7	15·6	13·3	9·4	6·1	11·7
	P	1·5	2·8	4·3	11·3	21·8	58·9	79·1	62·7	46·0	14·2	0·8	0·5	303·9
Delhi	T	15·0	17·2	23·3	29·4	33·3	33·9	31·1	30·0	29·4	26·7	20·6	16·1	25·6
	P	2·5	2·0	1·0	0·8	1·5	8·1	19·6	19·0	11·7	1·0	0·2	1·3	68·7
Gauhati	T	17·2	18·3	22·2	24·4	26·7	28·3	28·9	28·9	28·3	26·1	21·7	17·2	23·9
	P	1·3	2·5	6·4	16·3	24·4	32·5	31·0	27·2	18·8	7·6	1·5	0·5	170·0
Jodhpur	T	17·2	18·9	25·0	30·6	33·9	34·4	31·7	29·4	29·4	27·8	23·3	18·9	26·7
	P	0·5	0·5	0·2	0·2	1·3	3·6	9·1	11·7	6·4	0·8	0·2	0·2	34·7
Karachi	T	18·3	20·0	23·3	26·1	28·9	30·0	28·9	27·8	27·2	26·7	22·8	19·4	25·0
	P	1·3	1·0	0·8	0·5	0·2	2·3	7·4	4·3	1·0	0·0	0·0	0·5	19·3
Lahore	T	12·2	14·4	20·0	26·1	31·1	33·3	32·2	30·6	29·4	25·0	18·3	13·3	23·9
	P	2·3	2·5	2·3	1·5	1·8	4·3	15·5	13·0	5·6	1·0	0·2	1·3	51·3
Lucknow	T	15·6	17·8	23·9	30·0	32·8	33·3	30·0	28·9	28·9	25·6	20·0	16·1	25·6
	P	2·0	1·8	0·8	0·8	2·5	11·7	29·0	27·7	18·8	3·6	0·5	0·8	100·0
Patna	T	16·7	18·9	25·0	30·0	31·7	31·1	29·4	28·9	29·2	26·9	21·9	17·2	22·8
	P	1·5	1·8	1·0	0·8	3·6	18·0	29·8	33·3	21·8	5·8	0·8	0·5	118·7
Peshawar	T	10·6	12·5	17·5	22·5	29·2	33·3	33·3	31·7	28·6	22·8	16·4	11·7	22·5
	P	4·0	3·0	4·8	4·0	2·0	0·8	3·3	5·1	2·0	0·5	1·3	1·3	32·1
Simla	T	5·3	5·6	9·4	14·4	18·6	19·7	18·4	17·8	16·9	14·2	10·6	6·9	13·1
	P	6·1	6·7	6·1	5·3	6·6	17·5	42·4	43·4	16·0	3·3	1·3	2·8	157·5
Srinagar	T	1·1	2·5	7·8	13·1	17·8	21·4	23·9	23·6	19·4	13·1	7·8	3·1	12·8
	P	7·4	7·1	9·1	9·4	6·1	3·6	5·8	6·1	3·8	3·0	1·0	3·3	65·7

T=Temperature in °C, P=Precipitation in centimetres

TABLE 1 *(contd)*

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Veraval	T	21·7	21·7	23·9	26·1	28·1	28·6	27·8	26·7	26·7	27·2	25·8	22·8	25·6
	P	0·0	0·2	0·2	0·0	0·8	13·5	20·6	13·0	6·7	2·0	0·5	0·2	57·7
Bangalore	T	22·4	22·7	25·2	27·1	26·7	24·2	23·1	23·1	23·2	22·9	21·4	20·1	25·0
	P	0·5	0·8	1·0	4·1	10·7	7·4	9·9	12·7	17·0	15·0	6·9	1·0	87·0
Bombay	T	24·2	24·4	27·2	28·6	30·0	28·9	27·5	26·7	27·5	28·1	26·3	25·3	27·1
	P	0·2	0·2	0·2	0·0	1·8	42·5	61·7	34·0	26·4	24·1	1·2	0·2	192·5
Cuttack	T	22·5	25·0	29·4	32·2	32·8	31·1	29·2	28·6	28·9	28·1	24·3	21·9	27·5
	P	0·8	2·3	5·2	3·0	9·4	26·2	31·0	34·3	25·6	14·5	3·8	0·5	153·9
Cuddapah	T	25·0	27·8	31·4	34·2	34·7	32·2	31·1	29·7	29·2	28·6	26·1	24·4	29·4
	P	1·0	0·2	0·5	1·5	3·8	7·6	10·4	13·2	15·2	12·4	8·9	0·8	75·5
Madras	T	24·4	25·3	26·9	29·7	31·9	31·9	30·6	29·7	29·4	28·1	23·3	24·7	28·3
	P	2·8	0·8	0·8	1·5	4·6	5·1	9·6	11·4	12·4	28·2	34·5	13·7	125·4
Mangalore	T	26·7	26·9	28·3	29·4	29·4	26·7	26·4	26·1	26·4	26·9	26·9	26·7	27·3
	P	0·2	0·2	0·5	3·8	15·8	94·2	98·8	59·7	26·7	20·8	7·4	1·3	329·4
Nagpur	T	21·1	23·6	28·1	32·5	35·3	31·7	27·5	29·3	27·5	23·3	22·5	20·8	24·2
	P	1·5	1·5	1·3	1·3	1·8	22·4	34·3	27·2	19·8	5·3	1·5	1·3	119·2
Poona	T	21·1	23·1	26·9	29·4	30·0	27·5	25·0	24·4	24·7	25·3	22·8	20·8	25·1
	P	0·2	0·2	0·2	1·5	2·8	11·4	16·8	9·1	13·5	8·9	2·8	0·5	67·9
Trivandrum	T	25·6	26·7	27·2	28·3	28·1	26·4	25·8	25·8	26·1	26·1	25·8	25·6	26·4
	P	1·8	1·5	3·8	11·4	21·3	34·0	18·8	10·4	10·4	26·9	16·8	6·1	163·2
Ootacamund	T	12·5	13·2	15·0	16·4	16·4	14·6	13·9	14·1	14·3	14·2	13·3	12·5	14·2
	P	3·3	1·3	3·3	7·7	16·0	16·7	21·2	14·5	14·8	20·3	16·1	4·4	139·6
Port Blair	T	25·5	25·6	26·4	27·7	27·2	26·5	26·4	26·2	25·8	26·1	25·9	25·7	26·3
	P	4·5	2·8	2·8	6·0	38·4	55·2	39·2	41·4	44·2	31·8	26·7	20·1	313·1
Rangoon	T	25·2	26·5	28·7	30·4	29·2	27·4	27·0	27·0	27·3	27·8	27·1	25·3	27·4
	P	0·3	0·6	0·8	5·0	30·8	48·1	58·0	52·9	39·3	18·1	6·8	1·1	261·8
Akyab	T	21·0	22·5	25·7	28·4	28·8	27·5	27·0	26·9	27·6	27·5	25·3	22·1	25·9
	P	0·2	0·4	1·0	5·0	39·1	115·1	139·9	113·4	57·7	28·6	13·0	1·9	515·3
Mandalay	T	20·2	22·8	27·4	31·4	31·2	29·8	29·6	29·1	28·8	27·4	24·1	20·3	26·8
	P	0·1	0·5	0·5	3·6	14·9	15·1	7·2	10·2	14·8	12·7	6·4	1·1	87·1

T=Temperature in °C, P=Precipitation in centimetres

TABLE 2

Mean monthly potential evapotranspiration in centimetres

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Agra	1·9	3·0	10·3	17·7	21·1	20·9	19·5	17·9	16·1	13·6	5·7	2·2	149·9
Allahabad	2·0	3·6	11·1	17·5	20·7	20·5	19·0	17·4	15·8	12·5	4·9	2·3	147·3
Calcutta	4·1	5·8	14·1	17·1	18·5	17·9	18·0	16·8	15·3	13·5	7·2	3·7	152·0
Chittagong	4·2	5·8	11·6	14·8	16·7	16·5	16·2	15·6	14·4	13·7	8·2	5·0	142·7
Darjeeling	1·6	1·8	4·0	6·0	7·4	8·5	9·1	8·7	7·2	5·7	3·5	2·0	65·5
Delhi	1·6	2·4	9·1	16·9	20·7	20·9	20·1	18·3	16·3	13·4	4·9	2·3	146·9
Gauhati	3·3	3·9	8·2	11·3	15·8	17·3	18·1	17·4	15·3	12·9	6·7	3·4	133·6
Jodhpur	1·3	1·8	10·3	17·5	20·7	20·9	20·0	17·7	16·1	14·5	7·3	3·3	151·4
Karachi	3·6	5·1	9·1	13·6	17·8	18·4	18·1	18·6	14·3	13·5	7·5	4·4	144·0
Lahore	1·1	1·7	5·9	13·2	20·1	21·3	21·0	19·0	16·3	11·4	3·8	1·4	136·2
Lucknow	2·0	2·6	9·9	17·3	20·4	20·4	19·1	17·5	15·8	12·2	4·6	2·2	144·0
Patna	2·4	3·6	11·6	17·2	19·7	19·4	18·5	17·4	16·0	13·8	6·4	2·6	148·6
Peshawar	0·9	1·4	4·3	9·5	18·8	21·4	21·7	19·8	15·7	8·8	3·0	1·2	126·5
Simla	1·4	1·4	3·4	6·4	9·9	10·7	9·9	9·0	7·5	5·7	3·5	1·9	70·7
Srinagar	0·0	0·8	2·1	5·0	8·9	11·8	14·2	13·1	8·7	4·5	1·7	0·4	71·2
Veraval	6·5	6·1	9·9	13·3	16·6	17·1	16·9	15·2	14·0	14·1	11·6	7·6	148·9
Bangalore	8·2	10·2	15·1	16·4	17·5	16·1	14·0	13·6	12·5	12·4	12·1	8·3	156·4
Bombay	9·0	9·0	14·6	16·1	18·3	17·1	16·4	15·1	14·7	14·9	12·2	12·0	169·4
Cuttack	6·1	9·7	16·8	18·3	19·9	18·8	17·9	17·0	15·8	14·9	8·7	5·1	169·0
Cuddapah	10·0	13·4	17·5	18·8	20·2	18·8	18·9	17·3	16·0	15·4	12·2	8·8	187·3
Madras	9·3	10·4	14·3	16·6	19·2	18·5	18·3	17·3	16·1	15·0	7·5	9·8	172·3
Mangalore	13·4	12·6	15·5	16·4	17·5	14·7	14·6	14·0	13·6	14·0	13·3	13·4	173·0
Nagpur	5·3	7·9	15·3	18·4	20·7	19·2	16·6	15·7	14·7	8·3	6·8	4·9	153·8
Poona	6·2	7·9	14·3	16·6	18·3	15·8	13·0	11·4	11·1	11·8	7·8	5·9	140·1
Trivandrum	12·5	12·6	14·5	15·5	15·9	14·0	13·4	13·3	13·6	13·6	12·3	12·4	163·6
Ootacamud	4·7	4·6	6·3	7·1	7·5	6·3	6·0	6·0	5·8	5·7	4·9	4·7	69·6
Port Blair	12·0	11·2	13·7	14·9	15·4	14·4	14·6	13·8	12·7	12·9	12·2	12·1	159·9
Rangoon	10·8	12·3	15·8	17·2	17·6	15·6	15·7	15·1	14·5	14·7	13·2	11·0	173·5
Akyab	5·7	6·9	12·7	15·9	17·4	16·0	15·8	15·4	14·8	14·4	11·1	6·8	152·9
Mandalay	4·4	6·8	14·7	17·9	19·3	18·0	18·3	17·3	15·7	14·3	8·7	4·5	159·9

TABLE 3

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
					SUKKUR (All values are in centimetres)								
P.E.	1·2	2·8	8·2	16·5	21·0	21·3	21·4	19·9	17·6	14·4	6·0	2·0	152·3
P	0·5	0·7	0·6	0·3	0·4	0·4	0·4	2·8	0·1	0·0	0·0	0·1	6·3
S.C.	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
S	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
A.E.	0·5	0·7	0·6	0·3	0·4	0·4	0·4	2·8	0·1	0·0	0·0	0·1	6·3
W.D.	0·7	2·1	7·6	16·2	20·6	20·9	21·0	17·1	17·5	14·4	6·0	1·9	146·0
W.S.	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
					COLOMBO (All values are in centimetres)								
P.E.	13·0	12·1	14·5	14·8	15·6	14·9	15·0	14·8	14·2	14·0	14·0	12·8	168·7
P	10·1	6·6	11·8	23·0	39·3	22·0	13·9	10·2	17·4	34·8	33·2	14·2	236·5
S.C.	—2·9	—5·5	—1·6	+8·2	+1·8	0·0	—1·1	—4·6	+3·2	+2·5	0·0	0·0	0·0
S	7·1	1·6	0 0	8·2	10·0	10·0	8·9	4·3	7·5	10·0	10·0	10·0	87·6
A.E.	13·0	12·1	13·4	14·8	15·6	14·9	15·0	14·8	14·2	14·0	13·0	12·8	167·6
W.D.	0·0	0·0	1·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	1·1
W.S.	0·0	0·0	0·0	0·0	21·9	7·1	0·0	0·0	0·0	18·3	20·2	1·4	68·9

NOTE: P.E.—Potential evapotranspiration, P—Precipitation, S.C.—Soil moisture storage-change, S—Soil moisture storage, A.E.—Actual evapotranspiration, W.D.—Water deficiency, W.S.—Water surplus

TABLE 4

Station	Annual water need (cm)	Annual water surplus (cm)	Annual water deficiency (cm)	Moisture index, I_m	Climatic type	Climtic subtype
Agra	149·9	0·0	85·5	— 34·2	D	d
Allahabad	147·3	10·8	63·1	— 18·4	C_1	d
Calcutta	152·0	53·2	33·2	+ 21·9	B_1	w
Chittagong	142·7	127·4	9·1	+ 84·4	B_4	r
Darjeeling	65·5	238·4	0·8	+364·0	A	r
Delhi	146·9	0·0	78·2	— 31·9	D	d
Gauhati	133·6	45·0	8·6	+ 29·7	B_1	r
Jodhpur	151·4	0·0	117·1	— 46·3	E	d
Karachi	144·0	0·0	118·7	— 51·5	E	d
Lahore	136·2	0·0	84·4	— 37·4	D	d
Lucknow	144·0	13·1	57·1	— 14·7	C_1	d
Patna	148·6	22·7	52·9	— 6·0	C_1	w
Peshawar	126·5	0·0	94·2	— 44·7	E	d
Simla	70·7	86·8	0·0	+123·0	A	r
Srinagar	71·2	18·5	23·5	+ 6·3	C_2	w
Veraval	148·9	0·0	91·4	— 36·8	D	d
Bangalore	156·4	0·0	69·4	— 26·6	D	d
Bombay	169·4	106·5	77·3	+ 35·6	B_1	w_2
Cuttack	169·0	37·6	52·7	+ 3·5	C_2	w
Cuddapah	187·3	0 0	111·8	— 35·8	D	d
Madras	172·3	34·1	80·9	— 8·4	C_1	s
Mangalore	173·0	219·3	62·9	+105·2	A	w_2
Nagpur	153·8	27·5	62·1	— 6·3	C_1	w
Poona	140·1	0·0	72·2	— 30·9	D	d
Trivandrum	163·6	32·5	32·9	+ 7·8	C_2	w
Ootacamund	69·6	70·0	0·0	+100·5	A	r
Port Blair	159·9	175·9	25·7	+103·5	A	r
Rangoon	173·5	174·0	55·7	+ 81·2	B_4	w
Akyab	152·9	391·9	29·5	+244·6	A	w
Mandalay	159·9	0·0	72·8	— 27·3	D	d

TABLE 5

Station	Annual P.E. (cm)	Climatic type	Summer concentration (%)	Climatic sub-type
Agra	149·9	A'_3	41·0	a'_3
Allahabad	147·3	A'_3	40·9	a'_3
Calcutta	152·0	A'_3	35·8	a'_5
Chittagong	142·7	A'_3	34·6	a'_5
Darjeeling	65·5	B'_1	40·3	a'_3
Delhi	146·9	A'_3	42·0	a'_2
Gauhati	133·6	A'_2	39·5	a'_3
Jodhpur	151·4	A'_3	40·6	a'_3
Karachi	144·0	A'_3	39·4	a'_3
Lahore	136·2	A'_2	45·8	a'_1
Lucknow	144·0	A'_3	41·6	a'_2
Patna	148·6	A'_3	38·8	a'_3
Peshawar	126·5	A'_1	39·7	a'_3
Simla	70·7	B'_1	43·2	a'_2
Srinagar	71·2	B'_1	55·3	b'_3
Veraval	148·9	A'_3	40·1	a'_3
Bangalore	156·4	A'_3	31·9	a'_7
Bombay	169·4	A'_4	30·4	a'_7
Cuttack	169·0	A'_4	33·7	a'_6
Cuddapah	187·3	A'_6	30·9	a'_7
Madras	172·3	A'_5	32·5	a'_6
Mangalore	173·0	A'_5	28·5	a'_8
Nagpur	153·8	A'_3	37·2	a'_4
Poona	140·1	A'_2	36·2	a'_5
Trivandrum	163·6	A'_4	28·1	a'_8
Ootacamund	69·6	B'_1	30·0	a'_7
Port Blair	159·9	A'_4	28·0	a'_9
Rangoon	173·5	A'_5	29·1	a'_8
Akyab	152·9	A'_3	32·4	a'_6
Mandalay	159·9	A'_4	34·8	a'_5