BULL. BOT. SURV. INDIA
Vol. 4, Nos. 1-4 : pp. 105-112, 1962

THE BIOCLIMATES OF INDIA IN RELATION TO THE VEGETATIONAL CRITERIA

V. M. MEHER-HOMJI
Institut Francais, Pondiche'ry

ABSTRACTS

The purpose of a climatic classification is to characterise the climatic regions in terms of meteorological elements like temperature and precipitation which are the most decisive factors in determining the landscape of the earth. The plant-climate relation is so close that it is possible to differentiate the types of climates such as equatorial, tropical, mediterranean, with their different shades such as humid, sub-humid, arid using the characters of the plant-cover. In a physical classification of the climate, an arid or a humid region is defined on the basis of annual precipitation, the number of dry days or dry months in the year or by means of several climatic formulae.

In the present work emphasis is laid on the term "bioclimate". It is defined as the climate in relation to the life and is expressed by an index of aridity-humidity. This index is proposed on the basis of combining three essential ecological factors viz. temperature, precipitation and dry period. Correlations are obtained between the above index of aridity-humidity and four distinct criteria of the plant-kingdom : (1) Floristic criteria, (2) Vegetational criteria, (3) Morpho-ecological criteria and (4) Agronomic criteria.

I—GENERAL INTRODUCTION ON PLANT-CLIMATE RELATIONS

The purpose of a climatic classification is to characterise the climatic regions in terms of meteorological elements like temperature and precipitations which are the most decisive in determining the landscape of the earth. The plant-climate relation is so close that it is possible to differentiate the types of climates such as equatorial, tropical, mediterranean, temperate, polar with their different shades such as perhumid, humid, sub-humid, semi-arid, arid, hyperarid using the characters of the plant cover. For example, in a physical classification of climate, an arid or a humid climate is defined on the basis of the annual precipitation, or the number of dry months and dry days in the year or by means of several climatic formulae proposed by different workers. Using certain criteria of the plant-kingdom it is also possible to distinguish different types of climates. These criteria may be placed under four divisions.

(1) The floristic criteria
(2) The vegetational criteria
(3) The morpho-ecological criteria
(4) The agronomic criteria

Let us take up the first:

(1) **The floristic criterion :** The fact that there are certain species if not genera and families peculiar and restricted to the arid or the humid regions makes it possible to individualise these regions on a floristic basis. The recognition of floral elements such as Saharo-Sindian implies arid conditions, Sudano-Deccanian semi-arid conditions and Malayan humid conditions. The relative percentages of different floral elements in the flora of a given region could also reflect the climatic conditions. For example, the Indo-Malayan floral element is concentrated in the perennial humid regions as in the Upper Assam Valley, Khasia mountains, Brahmaputra Valley, Malabar coast and Ceylon. The Saharo-Sindian (i.e. the North African-Indian Desert element) and the North African steppe element are mainly confined to the dry North-West India.

Saxton and Sedgwick (1918) have shown that in North Gujarat the plants of Perso-Arabian origin are the denizens of the sandy tract whereas the Indo-Malayan species are confined to the forest-system of Malwa.

(2) **The vegetational criterion :** Here distinction may be maintained between flora and vegetation. The flora of a region is an enumeration of all the species which grow there envisaged in a taxonomic or descriptive manner. The vegetation of a region is the plant cover which clothes it. It is formed of the species of the flora associated in diverse quantities and proportions to constitute the landscape ; some play a considerable role, the others are scattered and lost in the mass. Thurmann (1849) was one of the first to make this distinction between the flora and the vegetation. Whereas the floristic aspect is the result of the phylogenesis and of the historical vicissitudes of the globe, the vegetational aspect is above all the expression of the prevailing ecological conditions. Similar climates induce the emergence of similar kind of plant-structure, in the physiognomic sense, in widely separated parts of the world. The climate strikes at the structure of the vegetation whatever its floristic composition.

Based on physiognomy are recognised the types of vegetation such as the rain-forest, deciduous forest, thorn-forest, desert, steppe, savanna, tundra etc.

(3) **The morpho-ecological criterion:** It is manifested by the adaptations of the plants to the climates. For example, the percentage of the xerophytes tends to be the highest in dry regions and the least in perhumid. In the same way, the prevalence of certain types of growth-forms or life-forms is under the control of the climate as shown by Raunkiaer (1934). On the basis of his biological spectra he showed phanerophytic phyto-climate for the tropics, therophytic for the desert and hemicryptophytic in the greater part of the cold temperate zone.

Some Indian examples of the biological spectra are given in Table 1 and illustrated diagrammatically in Figs. 1 to 7. On eight axis are presented the percentages of the life-forms, Ph, N, Ch, H, G, HH, Th, and L. Fig. 1 shows the normal spectrum. The normal spectrum is defined theoretically as the spectrum given by the whole flora of the world. According to Raunkiaer the plant-climate of a region is characterised by the life-form or the life-forms, which in the biological spectrum of the region exceed the percentage of the same life-form in the normal spectrum.

In Figs. 2 and 3 the spectra of the Libya desert and Cyrenaica computed by Raunkiaer himself are given. These come out as therophytic with a very high percentage of therophytes: 40-50%. The spectrum of the Rajasthan Desert given by Das and Sarup (1951) shows a similar pattern.

TABLE 1

BIOLOGICAL SPECTRA OF SOME COUNTRIES

Region	Ph	N	Ch	H	G	HH	Th	L	P	E	Plant-climate
Normal spectrum	28	15	9	26	4	2	13	—	—	3	
Rajasthan Desert							**41**				Therophytic
Libyan Desert	12		21	20	5		**42**				,,
Cyrenaica	9		14	19	8		**50**				,,
Semi-arid parts of North-West India	11	12	**18**	10	5	3	**33**	6	—	—	Thero-chamaephytic
Semi-arid parts of the Deccan	15	15	**12**	11	6	4	**28**	7	1	—	,,
Poona region	22	**16**	**20**	4	1	2	26	7	—	—	Nanophanerophytic with predominance of chamaephytes.
Andhra region (Old Hyderabad State)	**33**	18	12	4	1	3	16	10	—	—	Phanerophytic

DIAGRAMMATIC REPRESENTATIONS OF BIOLOGICAL SPECTRA OF DIFFERENT COUNTRIES

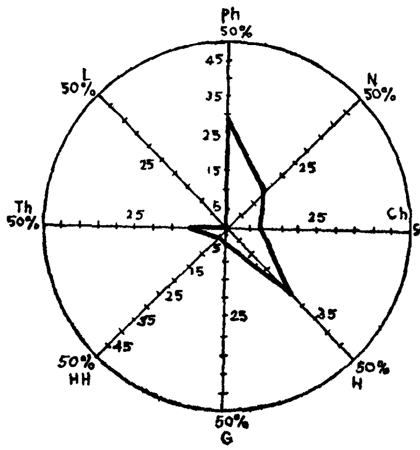


Fig. 1
Normal Spectrum
(Percentages of P and E being less than 1% in all countries, are omitted from the diagrams).

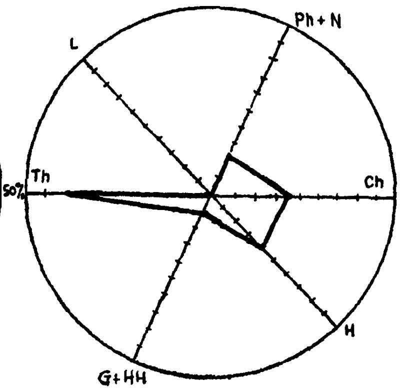


Fig. 2
Biological Spectrum
of
LIBYAN-DESERT
Plant-climate : Therophytic

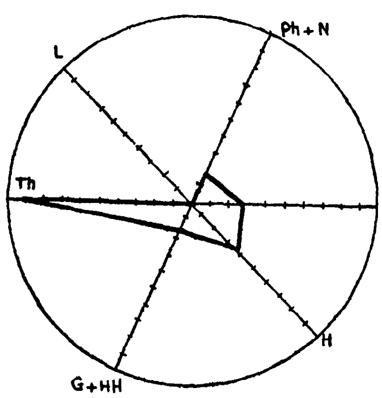


Fig. 3
Biological Spectrum
of
CYRENAICA
Plant-climate : Therophytic

The spectra of the semi-arid parts of the North-West India and of the semi-arid parts of the Deccan calculated by myself (1962) present a thero-chamaephytic climate. The region of Poona which has a dry period of seven to eight months shows a nanophanerophytic-chamaephytic climate according to Ferreira (1940) whereas the region of Andhra (Old Hyderabad State) with five to six months dry shows a phanerophytic climate.

(4) **The agronomic criterion:** From agronomic point of view an arid region may be defined as one where any type of cultivation is almost impossible without irrigation. In semi-arid regions only certain dry types of crops are possible and the crop production is very irregular, the occurrence of lean years or famine years being frequent. Further, grass constitutes an important resource in the semi-arid zones.

In India, crops like millets (*Pennisetum typhoides* Stapf. & Hubb. and *Sorghum vulgare* Pers.), groundnut and cotton are essentially the crops of the drier regions. On the other hand, paddy, sugarcane, tapioca, cardamom and coconut are crops of wetter regions. This may be seen in the vegetation map of Cape Comorin (Gaussen et al 1961). The west coast region with humid climate has the predominance of the wet crops in direct contrast with the dry crops of the eastern counterpart which is climatically less humid.

The comparison of the crop statistics of the dry districts with the moister districts gives interesting results as may be seen in Fig. 8-9. Two examples are given, one from Mysore State and the other from Madras. In the former, Bellary represents the dry district and South Kanara (i.e. Mangalore) the wet.

DIAGRAMMATIC REPRESENTATIONS OF BIOLOGICAL SPECTRA OF DIFFERENT COUNTRIES

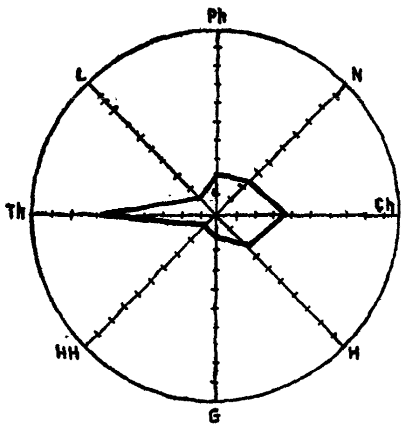


Fig. 4

Biological Spectrum of the semi-arid parts of N. W. INDIA.
Plant-climate : Thero-chamaephytic.

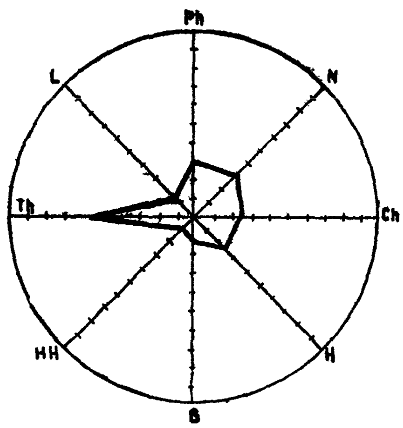


Fig. 5

Biological Spectrum of the semi-arid parts of the DECCAN.
Plant-climate : Thero-chamaephytic.

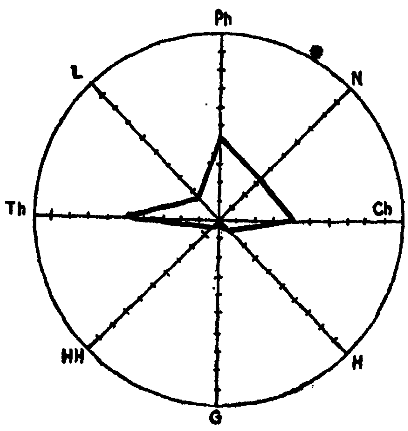


Fig. 6

Biological Spectrum of POONA region
Plant-climate : Nanophanerophytic-chamaephytic

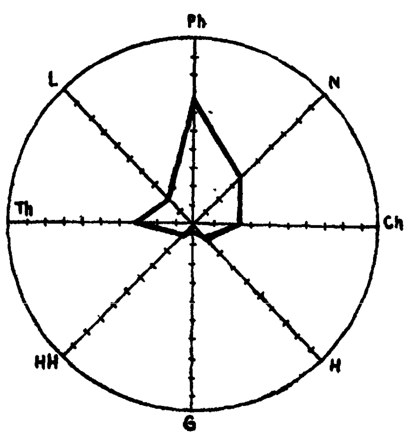


Fig. 7

Biological Spectrum of ANDHRA region
Plant-climate : Phanerophytic

In the latter, Coimbatore is an example of the dry district and Thanjavur (i.e. Tanjore) with plenty of irrigation facilities of the moist district. The statistics are taken from "Mysore State in Maps" (1958) and "Season and Crop report of Madras State" (1958).

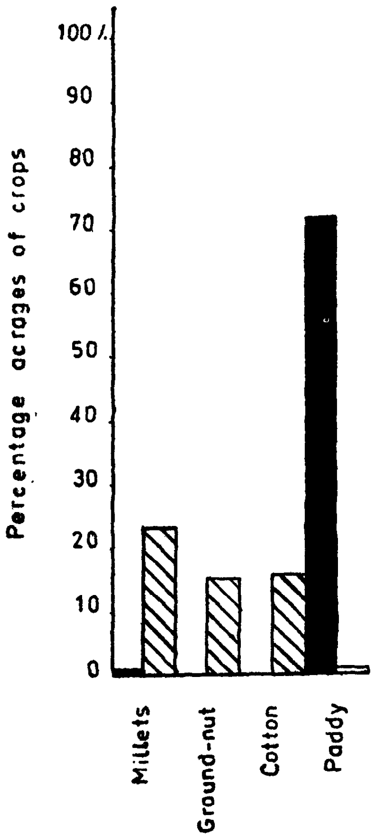


Fig. 8

Comparison of the crop statistics of dry district Bellary, and moist district South Canara.

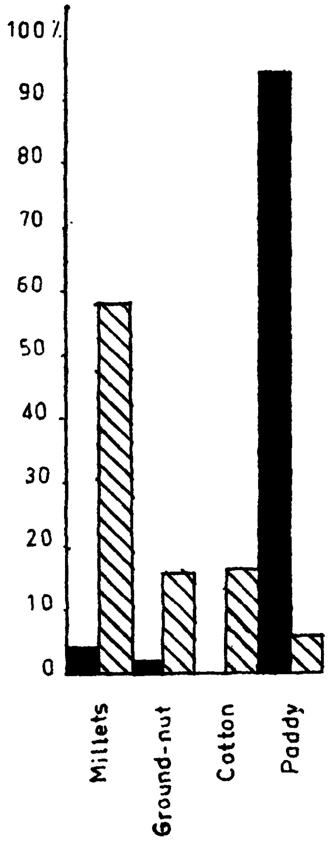


Fig. 9

Comparison of the crop statistics of dry district Coimbatore, and moist district Thanjavur (Tanjore)

South Canara Dist.
(Mangalore)
Annual rainfall—3290 mm.
Dry period—5 months

Bellary Dist.
Annual rainfall—509 mm.
Dry period—9 months

Thanjavur Dist.
Annual rain—1010 mm.
Dry period—6 months
Irrigation abundant

Coimbatore Dist.
Annual rain—590 mm.
Dry period—9 months

In these figures, crops are shown on the abscissa and the percentage acrages of these crops on the ordinates. The moist districts are shown in black, the dry districts by strokes. It will be seen from these diagrams that millets, ground-nut and cotton are the principal crops of dry districts whereas paddy of the moist.

II—WHAT IS A BIOCLIMATE ? ITS DEFINITION AND SIGNIFICANCE

One of the essential aims of applied climatology is to establish the analogous climates of the world. The first question which arises in this connection is to find a method to establish the analogous climates. The problem of defining different climatic regions of the world drew the attention of the geographers, climatologists and biologists from the beginning of the last century. These attempts may be divided into three categories :

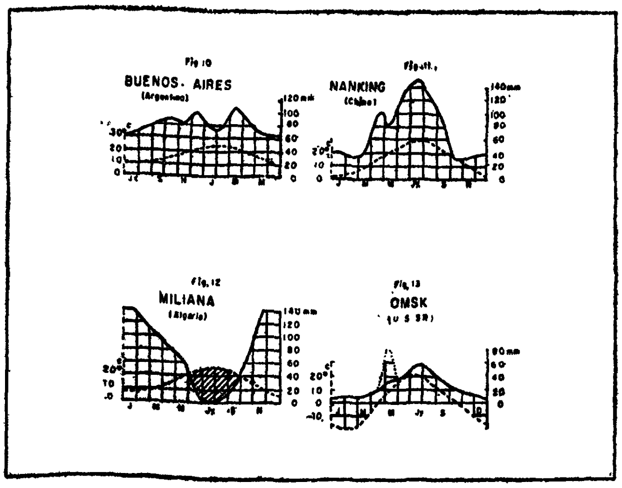
(1) The physical and meteorological methods by use of climatic formulae, indices and coefficents.

(2). The diagrammatic representation of the climate, examples of which are the hydrothermic figures of Raunkiaer, clima-diagram of Chaptal, agro-climate diagram of Azzi, hythergraph of

Taylor and ombrothermic diagram of Gaussen and Bagnouls (1953).

(3) The biological criteria to reflect the climatic analogies.

In physical classification of the climate, in general, a great importance is given to the mean annuals. Thus Buenos-Aires (Argentina), Nanking (China) and Miliana (Algeria) have almost the same mean annual temperature : 16°C, and the same total of annual precipitation, 950 mm. However, from point of view of natural vegetation Buenos-Aires possesses a Savanna, Nanking a temperate forest and Miliana a sclerophyllous forest. If we are to examine the ombrothermic diagrams of these three stations (Figs. 10, 11, 12) we note the differences in the rhythm of temperature and precipitation during the course of year for these three stations, which enable us to explain the diverse types of vegetation met with.



One more example which illustrates the defect of the use of the mean annuals is provided by the station of Omsk in Siberia. Here, the mean annual temperature is 0.8°C and the total of precipitation is 280 mm. These figures give an idea of a climate that is unfavourable to the vegetation and some authors have classed this station as arid. A study of the seasonal march of phenomena indicates that it is not so. The ombrothermic diagram of Omsk (Fig. 13) shows that after a cold period of almost six months lasting from Nov. to Apr., the growth of the vegetation is facilitated by an abrupt rise of temperature and by the water made available from the Spring thaw. With the result there are four months of favourable conditions for the plant-growth and consequently Omsk possesses a coniferous forest.

Therefore, a climatic classification which is based mostly on the mean annuals is not absolutely satisfactory in the domain of plant-geography. A bioclimatic classification based on the rhythm of temperature and precipitation in the course of year is much more reasonable. It should take into account the conditions favourable or unfavourable to the life : i.e. the wet and dry period or the warm and cold period. One may, therefore, define a bioclimate as the climate in relation to the life.

III—PROPOSAL OF A COMPLEX OF ARIDITY-HUMIDITY-FROST

Two principles may be employed in establishing the analogous bioclimates, firstly by comparison of the ombrothermic diagrams of Gaussen and Bagnouls (1953) and consequently by using the classification of "the biological climates" of the same authors (1957). Secondly, a more detailed analogy in the frame-work of the biological classification of the climates may be revealed by means of the ecological formulae proposed by Gaussen in 1954 and modified by us later in 1960. The elements considered for the ecological formulae are:

—— (t) Mean temperature of the coldest or of the hottest month of the year. Twelve classes are proposed ranging from t_1 to t_6. t_1 indicates the coldest condition, t_6 the hottest. $t_{\frac{1}{2}}$ indicates the intermediate condition between t_1 and t_2.

—— (S) Annual precipitation, in 12 classes. S_1 indicates very high precipitation : More than 3000 mm.; S_6 indicates very little precipitation: Less than 100 mm.

—— (X) The dry period expressed by number of dry months. A month is considered dry when its precipitation (expressed in mm.) is equal to or less than twice the mean temperature (in °C). X_1 means that one month is dry, X_6 indicates that 12 months are dry.

—— (g) The period of frost, in 12 modalities. A month with mean temperature less than -2°C is considered as a month of frost.

In the present work it is proposed that the last three factors : precipitation (S), dry period (X) and period of frost (g) may be combined to form a complex of aridity-humidity-frost (S+X+g). It may be mentioned that the factor of frost (g) which has great value in interpreting the climates of the world, has practically no importance in the tropics. It has been shown that the wetness of a place depends not only on the quantity of annual rainfall but also on the period of drought. For example, Bombay has an annual rainfall of 1800 mm. distributed over 5 months. It possesses a tropical deciduous forest. Ban Don (Thailand), Dalat (Viet-Nam) and Kindu (Congo) which receive the same quantity of rain in ten months have a luxuriant rain-forest. In this case the difference comes in on account of the longer dry period of Bombay. On the other hand, the vegetation types are different with the same period of drought but with different quantities of precipitation. Thus in Peninsular India where dry period lasts for seven to eight months, those parts of the Deccan which receive less than 750 mm. are clad with a thorn-forest, the west coast and the Western Ghats with more than 2500 mm. bear evergreen and semi-evergreen forests and the regions which receive intermediate quantities of rain have deciduous forests. (cf. Map of the bioclimates of S. E. Asia, Bagnouls and Meher-Homji, 1959).

Therefore, the factor of precipitation is combined with the factor of dry period. A place is as much dry as the value of the complex (S+X) is high. Thus for a desert station, as for example Jacobabad, the class of precipitation is S_6 (annual rainfall < 100 mm.) and the class of dry period is X_6 (12 months dry). Therefore, the complex (S+X) has the maximum value 12, $S_6+X_6=(S+X)_{12}$. A super-humid place on the contrary will have the value of the complex (S+X) very low. For example, for certain parts of South-West Ceylon, the class of precipitation is S_1 (annual rainfall > 3000 mm.) and that of the period of drought X_0 (no dry period). In this case the complex (S+X) has the minimum value of 1, $S_1+X_0=(S+X)_1$. Thus ranging from 1 to 12 in laps of ½ we have 24 classes of the complex of aridity-humidity. At one end of this scale the conditions are extremely wet, at the other end extremely arid.

IV—CORRELATIONS BETWEEN THE ECOLOGICAL FORMULAE AND THE VEGETATION TYPES

Finally, in order to verify the climatic analogies we must show a relationship between the climates and the vegetation types. The present author in 1960 established such a correlation between the vegetation-types of the Indian Sub-Continent as defined by Champion (1936) and the ecological formulae. In order to do this all the stations having the same type of vegetation were grouped together. Next we noted the ecological formulae of these stations and the frequency of occurrence of the vegetation type in each of these formulae. Thus for example, the type "Desert" in Table 2 presents the frequency 1/13 in the formula $t_{3/4}$ (S+X) 11 ½, that is to say, out of 13 stations having desert as vegetation, one station has the formula: $t_{3/4}$ (S+X) 11 ½. The frequency is 5/13 in the formula: t_4 (S+X) 11 ½ and so on.

TABLE 2

TYPE OF VEGETATION : DESERT AND ITS ECOLOGICAL FORMULAE

Station	Country	Ecological Formulae
1. Gilgit	Kashmir	$t_{3/4}\ (S+X)_{11\ 1/2}$
2. Dalbandin	West Pakistan	$t_{3/4}\ (S+X)_{12}$
3. Sriganganagar	India	$t_4\ (S+X)_{11}$
4. Khanpur	West Pakistan	$t_4\ (S+X)_{11\ 1/2}$
5. Bahawalpur	"	" "
6. Dera Ismail Khan	"	" "
7. Panjgur	"	" "
8. Sibi	"	" "
9. Jacobabad	"	$t_4\ (S+X)_{12}$
10. Pasni	"	$t_{4/5}\ (S+X)_{11}$
11. Las Bela	"	$t_{4/5}\ (S+X)_{11\ 1/2}$
12. Sukkur	"	$t_{4/5}\ (S+X)_{12}$
13. Ormara	"	$t_{4/5}\ (S+X)_{12}$

THE FREQUENCY OF OCCURRENCE OF THE TYPE "DESERT" IN DIFFERENT ECOLOGICAL FORMULAE

Ecological Formulae	Frequency	
$t_{3/4}\ (S+X)_{11\ 1/2}$	1/13	
$t_{3/4}\ (S+X)_{12}$	1/13	
$t_4\ (S+X)_{11}$	1/13	
$t_4\ (S+X)_{11\ 1/2}$	5/13	... H
$t_4\ (S+X)_{12}$	1/13	
$t_{4/5}\ (S+X)_{11}$	1/13	
$t_{4/5}\ (S+X)_{11\ 1/2}$	1/13	
$t_{4/5}\ (S+X)_{12}$	2/13	... MH

The formulae in which the frequencies are high, more than 3 are marked H, where the frequencies are moderately high (2 to 3), they are marked MH; where the frequency is one, it is considered as feeble.

As next step we have plotted on a graph the factor of temperature (t) on ordinates and the complex of aridity-humidity-frost on abscissa. (See Fig 14 of the Vegetation Type : Desert). The frequency corresponding to each formula is marked on the graph and the three types of limits of frequency are also distinguished.

Fig. 15 provides another example, that of the tropical dry deciduous forest with the three types of limits. If we are to place on such a graph the limit of high frequency of all the types of vegetation we note the distribution of these types in the frame-work of the ecological formulae (cf. Fig. 16). This graph thus shows the relationship between the vegetation types and the ecological factors.

Along the axis of temperature, from bottom to the top, we pass from the alpine, to the temperate, subtropical and tropical types. Along the axis of the complex of aridity-humidity-frost, from left to right, we move from the wettest type like the evergreen forest to the driest type, desert.

LITERATURE CITED

BAGNOULS, F. AND V. M. MEHER-HOMJI. Bioclimatic types of South-East Asia. *Trav. Sect. Sci. Tech. Inst. Francais*, Pondichéry t. I, fasc. 4, 1959.

CHAMPION, H. G. A preliminary survey of the forest types of India and Burma. *Ind. For. Rec.* (New Ser.) vol. I (1), 1936.

DAS, R. B. AND S. SARUP. The biological spectrum of Indian Desert flora. *Univ. Raj. Studies* Jodhpur. pp. 36-62, 1951.

FERREIRA, D. B. The vegetable life-forms of Cental and Southern Deccan in Peninsular India. *M. Sc. Thesis, Bombay Univ.* 1940.

GAUSSEN, H. Expression du milieu par des formules écologiques. Leur représentation cartographique. *Ann. Bot.* t. 31, fasc. 5-6, pp. 257-267, 1954.

—— AND F. BAGNOULS. Saison séche et régime xérothermique. *Documents pour les cartes des productions ve'ge'tales. Se'r. Gen.* t. III art. 8, 47 p., Toulouse. 1953.

——. Les climats biologiques et leurs classifications. *Ann. de Ge'ogr.* n° 355, pp. 193-220, 1957.

——, P. LEGRIS, M. VIART AND V. M, MEHER-HOMJI *et al.* International map of the vegetation and environmental conditions : Cape Comorin. *Trav. Sect. Sci. & Tech. Inst. Francais*, Pondichéry. 1961.

MEHER-HOMJI, V. M. Les bioclimats du sub-continent Indien et leurs types analogues dans le monde. *The'se. Sci., Toulouse.* (In Press). 1960.

—— Phytogeographical studies of the semi-arid regions of India. *A Thesis submitted to the Univ. of Bombay for the degree of Ph. D.* 1962.

RAUNKIAER, C. The life-forms of plants and statistical plant geography. *Oxford Univ. Press.* 1934.

SAXTON, W. T. AND L. J. SEDGWICK. Plants of Northern Gujarat *Rec. B.S.I.* Vol. 6 Calcutta. 1918.

THURMANN, J. Essai de phytostatique appliqué á la chaine de Jura. 2 vols. *Jent und. Gassmann, Bern.* 1849.

Fig. 14. DESERT

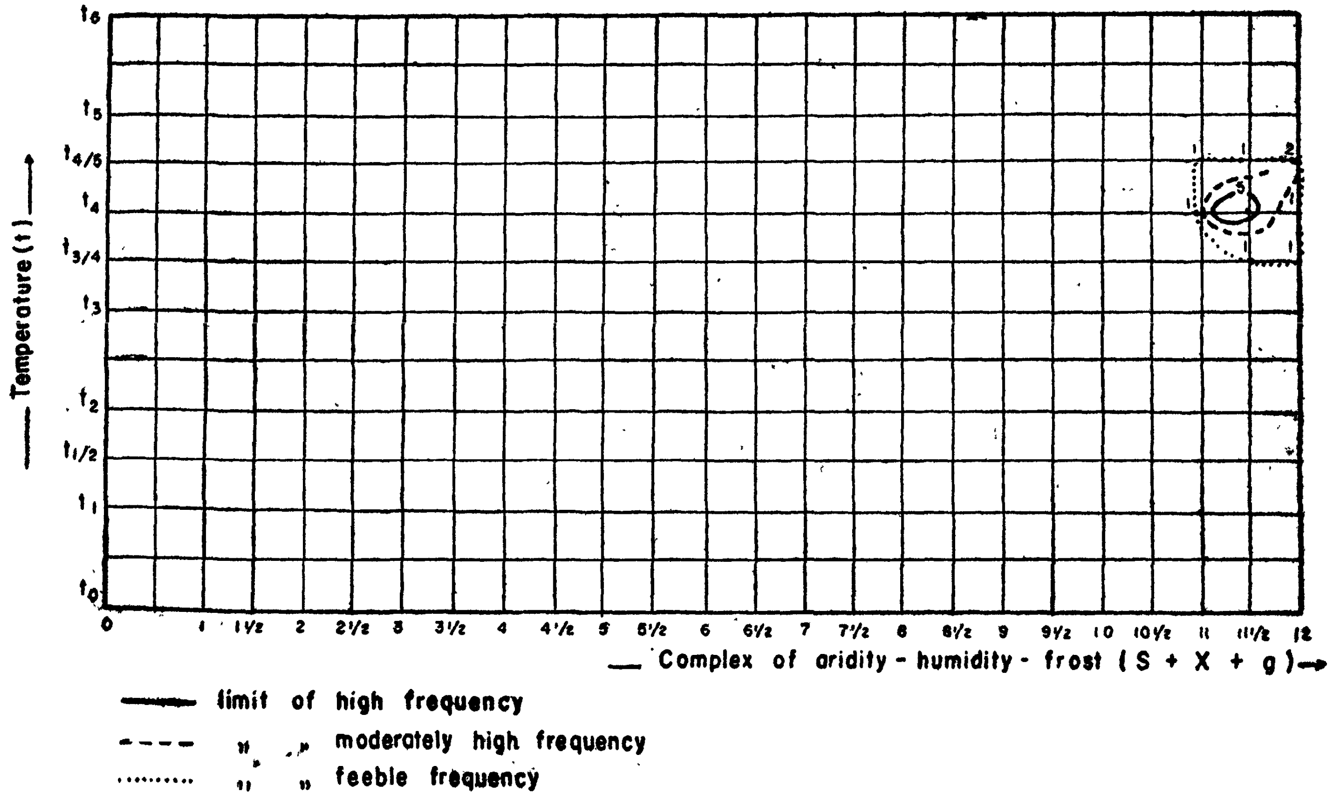
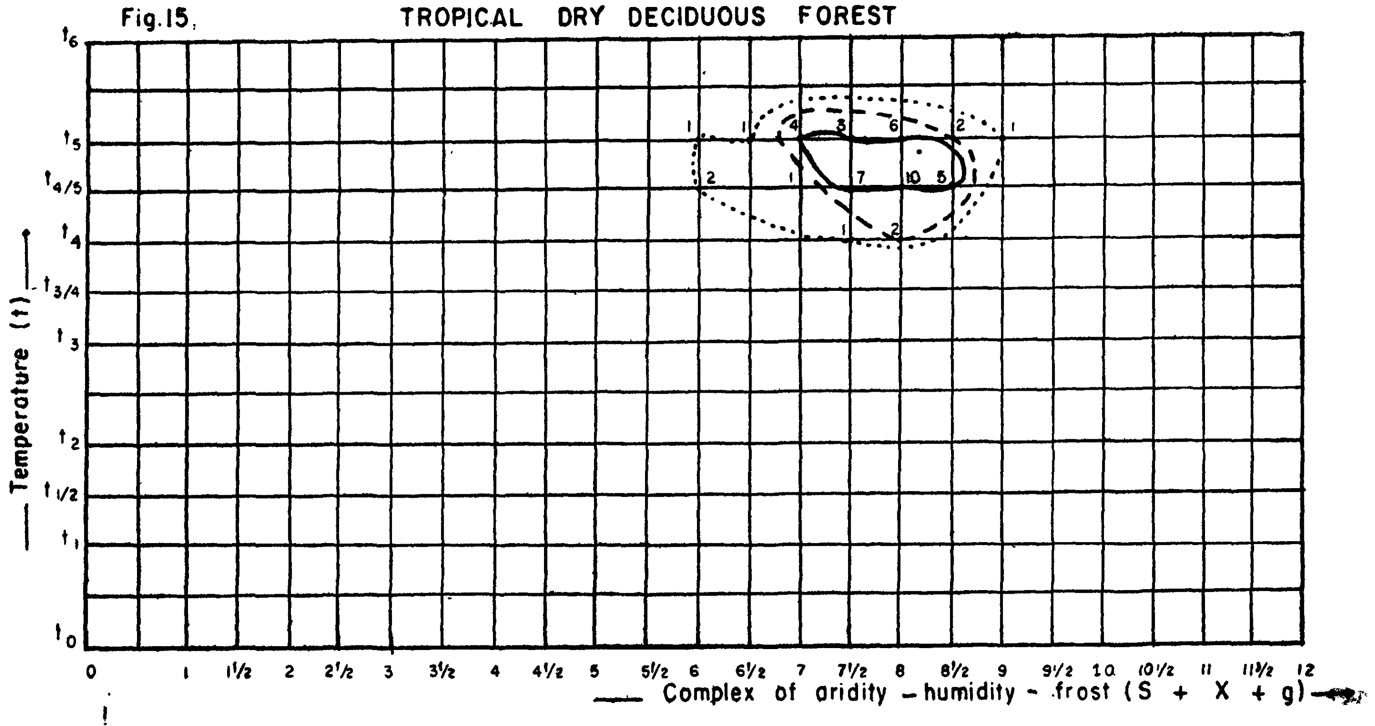


Fig. 15. TROPICAL DRY DECIDUOUS FOREST



—— limit of high frequency

– – – – " " moderately high frequency

.... " " feeble frequency

Fig. 16. THE LIMITS OF HIGH FREQUENCIES OF DIFFERENT TYPES OF VEGETATION.