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THE VEGETATION MAPS

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F. BAGNOULS & V. M. MEHER-HOMJI
TYPES BIOCLIMATIQUES DU SUD-EST ASIATIQUE

IMPRIMERIE DE LA MISSION
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PREFATORY NOTE

This Publication is intended for the first results obtained by application to India and the neighbouring countries of H. GAUSSEN's and F. BAGNOUL's Principles of ecological and cartographical studies.

In the first instance it has been thought advisable to give the translation in extenso of a paper already published in French: "Les Cartes de végétation" by H. GAUSSEN (1).

The subject of the second article is a "Study of xerothermic indexes of India, Burma, Pakistan and Ceylon" carried out by compiling the data of 246 meteorological stations. A map of the variations of this factor in the studied area is given in appendix.

The third paper gives an idea of the information available in India and a broad outline of its utilization in view of the working out of the International Map of the Vegetation at one millionth scale.

Finally a study of bioclimatic types of South-East Asia aims at classifying the biologic climates of each area into the classification of the World climates, a first step towards a study of homologous climates. A map drawn according to these principles is joined along with typical ombrothermic diagrams of each climatic area or sub-area.

(1) Travaux de la Section Scientifique et Technique de l'Institut Français de PONDICHERY — Tome 1 — Fascicule 2 — 1957.
AVERTISSEMENT

Ce fascicule est consacré aux premiers résultats obtenus en appliquant à l'Inde et aux pays voisins les principes d'études écologiques et cartographiques préconisés par H. GAUSSEN et F. BAGNOULS.

Il nous a cependant paru nécessaire de donner en premier lieu la traduction in extenso d'un article déjà publié en français, "Les cartes de végétation" par H. GAUSSEN (1).

Le second article est une "Étude des indices xérothermiques de la région Inde, Birmanie, Pakistan et Ceylan", réalisée après dépouillement des statistiques de 246 stations météorologiques. Une carte des variations de ce facteur dans la région étudiée y est annexée.

Le troisième article fait le point de la documentation disponible en Inde et donne les grandes lignes de son utilisation pour l'établissement de la Carte du tapis végétal.

Enfin, une étude des types bioclimatiques du Sud-Est Asiatique propose un classement des climats biologiques de cette région dans le cadre de la classification des climats du monde, premier pas vers une étude des climats homologues. Une carte établie selon ces principes est jointe ainsi que les graphiques ombrothermiques types de chaque région ou sous-région climatique.

(1) Travaux de la Section Scientifique et Technique de l'Institut Français de PONDICHERY — Tome 1 — Fascicule 2 — 1957.
VARIATION

...
THE VEGETATION MAPS

By H. GAUSSEN, Professor, Toulouse University

At the outset, it is necessary to define the terms.

The vegetation cover more or less unbroken, which covers the earth might be represented by charts, but these charts can be envisaged in various ways.

— The vegetation cover is formed by plants of different species. The list of species which one finds at a place, in a district or country constitutes the "flora" of that place, of that district or of that country. If one draws a map showing the distribution of each species or of a group of species, that will be a floristic map. That map is not the object of this study.

— Another kind of map aims at studying the physiognomical units of vegetation. Here, there might be a desert where plants are rare and far off from each other; there, there might be a lawn of crowded grass serving as pasture ground. In another place again there might be an evergreen scrub with coriaceous leaves, yet elsewhere, there might be a forest of conifers or of broad leaved species. Each of this vegetation landscapes is a physiognomical unit which can be represented cartographically. By doing so, one draws a vegetation map. This type of map we shall study presently.

One may conceive it in various ways:

— A first conception may be only a reproduction of aerial photographs indicating forests, crops, lawns, etc. This kind of map is useful in its own way, which gives an idea of the actual state of the vegetation. But it is hardly more than a photograph. One can make it more scientific by indicating the particular type of forest or vegetation that is there. We may call this a physiognomical map of vegetation.
— A second conception which is a more useful one, would be to study how man utilizes for his own purpose the vegetation resources of the earth.

Here, we have to distinguish an irrigated crop from one which is not, to single out the crops in rotation with fallows, orchards, pasture lands, etc. This will be a **land use survey map**.

Both these kinds of maps represent the present state of vegetation, but that state varies from one year to another according to land utilization by men. For a map to be of economic interest — and it is due to this interest that one may incur expenditure on editing it — it will not suffice to state how man utilizes land in a given year. It would be much more interesting and useful to know how he could utilize it if he wanted to change it. The conservation of present state necessitates no research. But the improvement of production by bringing about a change requires intervention of scientific research if people want to obtain a favourable result without groping.

In the study of vegetation, it is therefore necessary to take into account what is the part of human action which would be changeable, and at the same time what are the factors which are constant and limit human fantasy. These constant factors are the conditions of climate and soil, which are called the conditions of the environment or ecological conditions.

I say that these conditions are constant. It is true generally, though man is not incapable of modifying them. Thus irrigation creates an oasis in the desert, the drainage transforms the marsh into a meadow or a field. But these are permanent modifications which are to be shown clearly on the map with a distinction between the conditions of environment resulting from natural conditions and those caused by human activity.

One may, therefore, conceive ecological maps of vegetation showing on one hand the actual plant ground cover and on the other the permanent ecological conditions.

This kind of map will be studied in the present paper.

**THE NOTION OF SCALE**

Speaking of maps, the first problem will be the choice of a scale. It is evident that the same detail cannot be represented at different scales. At 1/1 000, in a city, one can draw all the streets, at 1/100 000 one can only indicate the outline of the city and its most essential streets, at 1/1 000 000 only its outline can be indicated, provided the city is big enough.
All this is understandable.

Moreover, the agriculturist who wants to know of the conditions of vegetation in his land requires a chart with a cadastral scale (1/1000 or 1/5000). For knowing the conditions in a village a smaller scale would be necessary (1/10000, 1/20000). One who is interested in a small district might utilize a scale of 1/50000. One wishing to know the conditions prevailing in a province may utilise the 1/200000. The Agriculture Department of a State could have a general view with a scale of 1/1000000.

The selection of the scale thus depends on the purpose of the maps. It also depends on the extent of our knowledge of the country concerned. Evidently aerial photographs are possible in the same scale everywhere in the world. But to interpret them, it is necessary to know exactly the nature of the plant ground-cover. But one finds considerable differences in the documentation. Certain countries like those of the Western Europe have been studied with care for many centuries with a great density. So far as a country like France is concerned, it can be said that it has been divided into not less than hundred parts and, on each part, one or several volumes treating the flora or the vegetation are available, and that too is being constantly improved since nearly two centuries. Other countries like the United States of America are so vast that in spite of a very high scientific development, the number of the research workers and the duration of their researches bring forth to a knowledge, which is certainly ten times feeble than in Western Europe. So what to say about countries which are, for various reasons, scientifically underdeveloped.

The conclusion is that the scale will not be the same in the study of the country. How would it be possible to undertake the working out of a map of ecological conditions and of vegetation on a surface of, say, 10 Km2 if no information is available regarding geology, pedology, if there is no good topographical background to enable us to draw the map.

An aerial photography permits underdeveloped countries to have an immediate topographic representation, but there is not yet a mechanical process for establishing the geological age of a rock or for giving the name of a plant.

In conclusion a country like France can envisage maps at 1/10000 or 1/200000 or 1/1000000. For the United States of America maps at 1/200000 represent already a great difficulty; everywhere a map at 1/1000000 will be an extremely great contribution towards world knowledge. This scale is that of the World's International Map and it is with this map that we should start.
Therefore, I intend to study now the *International Ecological Map of the Vegetation Cover*.

**THE FACTS TO BE SHOWN**

We have said that the map should represent on the one hand the actual composition of the vegetation and on the other, the ecological conditions.

1. **ACTUAL VEGETATION**

A distinction between (a) the cultivated areas and (b) the uncultivated areas must be done.

a) **The cultivated areas**

The cultivated areas are left in white on the map. Their importance and their location can therefore be distinguished quite easily for they contrast with the coloured background. One difficulty however arises here concerning the temporary cultivation. In the underdeveloped agricultural economies or where the climate is not favourable, there is alternation of cultivation and fallow lands (shifting cultivation). While deciding that human activity is represented by white portions and horizontal lines, we will alternate horizontal white bands with bands representing the fallow vegetation. If the land is cultivated every alternate year, the two bands will have the same width. If the cultivation is done for one year in every three years, the band indicating the fallow will be twice as broad as the white one.

If the cultivation is permanent, i.e., orchards, vine, natural pasture lands, it is indicated by coloured symbols on the white background. These signs may have a statistical value, so a sign of vine represents 100 ha of vine-yards, a sign of Olive tree represent 1000 or 10,000 trees according to the size of the sign, etc. Thus a statistical knowledge of the permanent cultivation is given.

A statistical idea of the crops in rotation can be given on a map at 1/200,000. A scale of 1/1,000,000 would make it more difficult but it is nonetheless possible. It will however be easier to put a letter in black on the white background, which will refer to legend explaining the essential points about crops and agricultural practices.

b) **Uncultivated areas**

They are represented in colour. On a map at 1/1,000,000 scale, four types of vegetation landscapes: marshes, grasslands, scrubs and
forests may be represented. Obviously there are intermediate types between these fundamental ones.

— The marshes or swamps or fresh water or sea water might be shown on the background representing water by short and thick horizontal strokes. The fresh water is indicated in blue, the sea water in red, the peaty water in brown.

— The grasslands are indicated in light colour by a fine network of small dots. If any bushes are scattered throughout the grasslands they will be represented by big dots. If any trees are met with, they will be shown by very big dots, in full colour if trees are spontaneous and hollow if they have been planted.

— The scrubs are represented by more or less thick lines, according to the height and density of the small shrubby trees and bushes.

These vertical oblique or horizontal lines may be mixed in a great variety of networks. We shall see again this question in connection with colour study.

— Groups of trees may have the form of a closed stand — It is generally the case with forests —. If the forest is spontaneous a plain colour will be used. If the forest includes various fundamental species represented by different colours, alternating vertical bands, the thickness of which is proportional to the surface occupied by each species will be juxtaposed to show the forest.

If certain important species are introduced by man, they will be represented by horizontal bands showing the nature of the undergrowth between them, or cutting the vertical representation of other species.

If the forest is an open stand, some big dots will be scattered to represent the trees dominating the herbaceous or ligneous landscape. If they are palm trees, a different sign shall be used.

It happens that the undergrowth of a forest is more interesting than the upper storeys which are represented in plain colour. In this case, we can open some “windows” of geometric shape to distinguish them from natural glades.

The problem of the representation of forests is more complex in the case of tropical and equatorial forests which have rarely dominant species. Same process may be used as for the temperate forests, but in admitting that a colour does not represent a species but a group of species of similar ecological value.

However, in the case of forests as well as for other vegetation landscapes it is not necessary to complicate too much the map even if
the landscape is complex. It is enough to write a black figure on the surface concerned with reference to the index or the notice where explanation can be given in detail. One may even think of an important description with lists of plants and ecological study.

Finally by above fundamental graphic processes, and by quite a number of various other representative methods which may be extended ad infinitum, the vegetation landscapes may be shown, provided they have a sufficient extent to merit a representation on a map at one millionth scale.

But the distinction drawn between marshes, grasses, scrubs and forests is a simple statement of what is seen on the ground without intervening any other link that might exist between the various types. This, in short, is a simple botanical interpretation of aerial photographs. It is necessary to classify these landscapes, in view of drawing them close to each other in superior groups.

Here, two kinds of methods are possible: static classification and dynamic classification. It would be of interest to compare them.

c) Static interpretation

The plant groups, visible on the ground and represented according to their physiognomy, can be studied according to their floristic composition. This will bring out some units having almost the same floristic composition, and creates the notion of "Plant associations". Their study is this branch of science called "phytosociology". Having defined the associations by means of plants which are typical of each of them, we can compare these associations.

If we compare, for example, the various kinds of grasslands, we can state that some of them have floristic compositions which draw them close to each other. They have in common a good deal of plants, but the characteristics of association are different. These associations which are clearly allied can be classified in a superior group named alliance. By comparison of these alliances, we can classify them again into classes, orders, etc. . . .

For common plants to belong to two different groups, it is necessary that the environmental conditions are similar enough. A grassland, of herbaceous plants living in the open sun, will have common species with another grassland but will not have, or will have very few species common with a wood.
We can, therefore, imagine a hierarchy of plant communities according to this principle, based on the statistical study of their floristic composition.

d) Dynamic interpretation

A quite different conception is based upon the fact that the vegetation landscapes are largely the result of human activity. In a country like France, for example, the first men have found the land covered with forests. The vegetation was in equilibrium with the environmental conditions. Near the Mediterranean coast, forests of Green Oaks (1) were spread over; in the mountains were forests of Firs (2), and at higher level, forests of Larch trees (3), for example; along the stream banks Willows (4), Alders (5), and Poplars (6) formed valley forests.

Man has clear-felled forests, ploughed fields and left some fields in fallow. He has created pastures for his livestock; in short he has created a series of intermediate landscapes between barren lands and forests. But it has been noticed that if a barren soil is free from human activity and from his livestock, the land is gradually covered with vegetation, it becomes more and more bushy and passes through successive stages of grasses, scrubs, shrubby trees towards the forest state. These successive stages form a series; they constitute "series of vegetation".

If the barren land was on the coast of the Mediterranean Sea, the series will result in a wood of Green Oaks, it is named the Green Oak series. While admitting the successive stages it will be said that the series comprises: cv 0, cv 1, cv 2... cv 9, CV; cv 0 is the barren land and CV is the final term called "climax". If the barren soil is lying on shaded slopes of the hills, it will be covered with such successive vegetations as s 0,... s 4... s 9... and will reach the climax S which is a Fir forest.

In the "Fir series" the various stages follow each other and though very few species are in common between s 1 and S, they are relatives.

We may, therefore, think of classification in series which is called the dynamic classification. The fundamental units are the series CV, S, M, etc... and in each series lawns, scrubs and forests are found.

(1) Quercus ilex  (2) Abies pectinata
(3) Larix europea  (4) Salix caprea
(5) Alnus glutinosa  (6) Populus alba
I have taken France as an example where the climax are incontestably forests. It is not always like that. The conditions are not everywhere favourable to the growth of trees. In particular, in the countries very snowy or very cold with frozen soil, as well as in the very dry countries, it seems that the trees cannot live. The series are truncated in their arborescent forms. It may also happen that for reasons of geological history, the tree species able to colonize the soil have never come. In this case also, the series is represented only by its first stages, but it exists as well. It will be only more difficult to name it and instead of the name of a tree, the name of a bush or a shrubby tree or even that of grasses will be chosen.

All this does not bring any major difficulty.

e) Comparison between both these interpretations

Let us compare cv 2 with s 2 for example. They are grasslands and consist of herbaceous plants capable of enduring the sun. The grassland cv 2 must endure summer dryness, while s 2 should be able to bear cold and snow. There will be many different plants, but quite a good deal of them will be common.

In the static classification cv 2 and s 2 would be parts of the same order, for instance.

s 2 and S have almost no common plants. The herbaceous ones able to live in S, in a Fir forest, are different from those of s 2 capable to stand in the full sun. The static classification cannot class s 2 and S together, even in a grouping at a high order. But S is derived from s 2.

cv 2 and s 2 have some plants in common but are not related; s 2 and S have no common plants, but are related.

f) Selection of an interpretation

The static classification and the dynamic classification are both valid. Before selecting, it is necessary to examine which of these two is of more practical interest.

For they who utilize, it appears to me much more interesting to know what are the possibilities of transformation of an existing community rather than to know what are its floristic connections with another group. If we draw a map, it is to study how we could change the actual utilization into something better. The dynamic point of view appears then to be more profitable than any static classification. It is that which is adopted here.
A colour will be attributed to the "series". Each series will, therefore, have its own colour.

The dynamism of vegetation permits then to reach the notion of series.

The series materialize on the earth by means of notions of zones and stages of vegetation.

The zones of vegetation correspond to the geographical location of the series in flat open countries; on world scale they are placed on the earthly sphere like the spherical zones of the mathematicians. The cause is essentially climatic: the equatorial zone, tropical, desertic, hot temperate (1), cold temperate, eold.

There are also zones created by the decreasing action of a factor. The decreasing oceanic influence gives zonation roughly parallel to the coast. This is marked in Europe, from Norway to Portugal.

The stages of vegetation correspond to the zonation in altitude which is directly under the action of the progressive modification of the climate from the base to the top of mountains.

Zones or stages are designed by the essential vegetation type: stage of fir, zone of tundras. In Europe the mountains having humid summer (or ophrygorthere) have a nomenclature that has become classic:

Collinean stage (deciduous oaks), highlander (Beech (2), Fir), subalpine (Larch, Hook pine (3), Arole (4), alpide (without trees).

This classification cannot be extended elsewhere.

In brief 1°) The colour represents the "series", hence the genetic point of view.
2°) The way of marking the colour (plain colour, fine lines, fine dots, etc...) represents the actual stage in the series. If blue is the colour of the Beech series, the plain blue is the Beech forest, the thick squared blue represents the high brushwood which is on the way of being transformed into a Beech forest; a

(1) The authors in German often call "subtropical" the countries having Mediterranean climate. It seems to me that the desertic zone separates two worlds, floristically and climatically: the holarctic world (for the northern hemisphere) and the tropical world. Calling subtropical a climate and a flora, the holarctic affinities of which are certain, creates a confusion which can be avoided easily.

(2) Fagus silvatica.
(3) Pinus cembra.
(4) Pinus uncinata.
dark network of blue dots is a heath; a very light network of blue dots represents a grassland of the Beech series.

This map represents therefore the vegetation in its present state and gives indications on its possible transformation either by human effort or by man's leaving it to itself.

2.—ECOLOGICAL CONDITIONS

The ecological conditions will determine the choice of the colour. Instead of choosing the colour at random as it is done usually, the colour will have a signification. The main originality of the cartography proposed here lies in its rational use of the colour.

Firstly, it is necessary to specify which ecological conditions are concerned.

We have seen before that each series has its colour; it is a convention, for the ecological conditions of s 2, grassland of the Fir type, are not the same as that of S, Fir forest. It remains still that if s 2 is different from S, the reason is that S has been destroyed and that, at this particular place, the conditions are in favour of S.

So the ecology of a particular place is that of the vegetation climax in this place. Ecology is a complex thing: heat, dryness (or humidity) length of the dry period if there is any, light, regime of vegetation during the year, nature of soil, constitute the ecological conditions governing the type of vegetation. There are at least six fundamental conditions and others can be added: wind, snow, etc...

REPRESENTATION OF THE FACTORS

It is enticing to make a synthetic map by placing on the paper different maps one on top of the other representing each of these factors. This type of superposition has been done for a small surface at the scale of 1/200 000; it has given very interesting results (1926).

But here however, one great difficulty appears:

If in each point, the coloured representations of six or seven factors are placed one on top of the other, the result can be a nameless shade, illegible, even if the colours were chosen carefully.

To obtain a legible colour, we can represent certain factors by coloured signs and not by shades. This helps to reduce the number
of superpositions of shades. But it is difficult not to use shades to represent the 3 or 4 main factors. And 3 or 4 shades placed one upon the other give a colour still too complex. It is then necessary to reduce this number preserving at the same time the principle of superposition.

The application of the laws of maximum and minimum gives the solution: the representation of a factor in a point is useful only when the factor is locally important. An indispensable factor gains importance when it is next to its minimum: that is what is called the law of minimum (1947 b). For instance: an average humidity is of no interest: a great dryness is on the contrary very effective for limiting the agricultural possibilities and that of the natural vegetation. The average humidity will be represented by white, great dryness by a bright colour which will have a strong action on the resulting colour of the synthetic superposition.

The law of minimum is applicable only to the indispensable factors. All the factors are justiciable of the law of maximum. That is to say that they can have a strong influence if they are near their maximum. For instance the duration of the snowy cover (which is not indispensable to the vegetation) is of no great importance if it is at its minimum; it is on the contrary very effective if it is near its maximum.

Therefore there will be two types of factors:

1°) the indispensable factors, which will be given bright colour for the extreme values, average value being left in white. It will be convenient to choose colour ranges starting from white to dark shades and darker colours taken in the same half of the spectrum.

2°) the dispensable factors, have interest only for the maxima values, their weak values are left in white, strong values are of darker and darker colours taken in the same half of the spectrum.

In brief, all the factors can be considered as represented by a range going from white to a dark colour. White represents the unimportant values of the factor. While the indispensable factors have a double range, one going towards the minimum, the other towards the maximum.

These two ranges will be taken in the different two halves of the spectrum. The dispensable factors will be represented by a simple range going towards the maximum and taken in only one half of the spectrum or using colours of the same family: bistre, maroon, etc...

As it is hardly possible that in a particular place several factors are at their minimum or at their maximum, several colours of the superposition will be absent or light and the whole will be of well defined colour. Examples will be shown below.
The factors of compensation

It is the reaction of the plant to the factor and not the factor itself which interests us. The question must be viewed from the biological angle and not in the way of a climatologist who will admit with difficulty that a temperature data is used in the same way as a rainfall or a vapour pressure.

This notion compels us to admit the necessity of representing physiologically similar phenomena by similar shades. If a high temperature is indicated by orange or red, it will be possible to represent by almost similar colours the great dryness. The strong lights will require also use of colours of the same family as, physiologically, light can replace heat up to a certain point.

The regime of vegetation

One can try, on pluviosity maps, to indicate the pluviometrical regime on the representation of the annual average. It is obvious that annually 500 mm of water, distributed in 10 to 12 months, have not the same effects as if they fall in strong showers in two or three months.

Similar questions can be asked for vegetation. The forest with persistent leaves, with winter sleep, is different from the equatorial forest in constant activity, which is different from the forest subject to dry periods, itself different from the forest with deciduous leaves and long period of vegetation, and from the forest of deciduous leaves with short period of vegetation.

We must solve the cartographical problems arising from these distinctions. After having explained the question of environmental factors and of their synthesis, let us see how the map can be worked out.

A — ESSENTIAL FACTORS

After these few general notions let us study how we can select the factors to be represented. The knowledge in plant physiology shows that the factors of heat, dryness of the soil and of the air, duration of the dry season, light, rhythm of the seasons which determines the regime of vegetation, nature of substratum are important points. The graphical synthesis, an example of which I have given in 1926 apropos of the surroundings of Foix, has shown that the method enabled us up to a certain extent to measure the relative importance of certain factors.
Having acquired, after a long application, a certain sense of the suitable dosing of colours, the following chart can be proposed:

1°) Temperature
2°) Dryness
3°) Xerothermic factor
4°) Light factor
5°) Vegetative period
6°) Nature of the soil.

Other factors in maxima value can be added: for instance wind, snow, frost, salt carried by sea wind, etc. These factors will be considered only when it is necessary to introduce them because of a local maximum of their action. They will be studied later as complementary factors.

1°) Temperature

I do not think that it would be necessary to give too strict definitions of temperatures. We can only use the yearly average temperatures (1) which are a way not shaded enough for appreciating thermic climate. Our divisions make a synthesis and it is quite possible to interpret each composing factor of shadow and cold by colours of the black sector, and such factors as warmth, light, dryness by colours of the yellow or orange sector. It is not necessary to give

(1) It is, of course, the matter of true temperatures and not of temperatures "brought down" to sea level.

That will not satisfy those who worship the figures; but I believe that naturalists have often to shade ideas more than figures.

So, I propose a classification in six thermic types with a possibility to choose intermediate types.

\[
\begin{align*}
M & = \text{maximum temperature average} ; & m & = \text{minimum temperature average} . \\
t 1: & M < + 10^0 & m & < - 5^0 \\
t 2: & M > + 10^0 & m & < - 5^0 \\
t 3: & - 5^0 < m < + 10^0 & \text{Leningrad} & \text{Cold} & \text{light grey} \\
t 4: & - 10^0 < m < + 20^0 & \text{Paris} & \text{Cold temperate} & \text{white} \\
t 5: & m > 20^0 & \text{Lisbonne} & \text{Hot temperate} & \text{gold yellow} \\
t 6: & \text{yearly average} < 30^0 & \text{Libreville} & \text{Hot} & \text{orange brown} \\
t 7: & \text{yearly average} > 30^0 & \text{Djibouti} & \text{Very hot} & \text{orange red brown}
\end{align*}
\]
a definition of the terms: warm-temperate, warm; it is only necessary to remember all the climates of the world to locate each point satisfactorily.

2°) Dryness factor

While the yearly average temperature has a certain indicative value, specially in hot climates, the pluviometric conditions vary a great deal in the course of the year and the average is of little significance. It is necessary to interpret. Henceforth the use of the ombrothermic diagrams gives an idea of the way to consider the rainfall factor.

For instance, in a European temperate climate, the rainfall, though not excessive, is sufficient throughout the year, but if it falls either 800 mm or 700 mm it will not make much difference and a great variation will be shown by light shades of colour.

But in a monsoon country, what matters is not the average but the duration of the dry season separating two rainy seasons. I think that it is advantageous to draw the ombrothermic diagram and to leave aside what is more than one metre of water, for this water flows away and is of no interest for the vegetation. Then we calculate the yearly average thus obtained of which we will take account.

Though B gets less water than A, it is moister. This difference will appear when only the hachured part is taken into account.

The factor of dryness (or humidity) is indicated by the letter S. It is corrected by the xerothermic index and is interesting only because of its extreme values (law of minimum). So the proposed divisions are concerned mainly with the extremes.

Dryness and high temperature are often synonymous and the colours should be almost similar.
As it has been decided, the average values are represented by white; the minimum values by bright colour.

Here is the possible convention:

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<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>S1</td>
<td>P &gt; 2000 mm</td>
<td>Buitenzorg</td>
<td>Very wet</td>
<td>Dark violet</td>
</tr>
<tr>
<td>S2</td>
<td>2000 &gt; P &gt; 1500 mm</td>
<td>Tokyo</td>
<td>Wet</td>
<td>Dark blue</td>
</tr>
<tr>
<td>S3</td>
<td>1500 &gt; P &gt; 500 mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rainy days &gt; 100</td>
<td>Paris</td>
<td>Little wet</td>
<td>Light blue</td>
<td></td>
</tr>
<tr>
<td>S4</td>
<td>1500 &gt; P &gt; 500 mm</td>
<td>rainy days &lt; 100</td>
<td>Marseille</td>
<td>Little dry</td>
</tr>
<tr>
<td>S5</td>
<td>500 &gt; P &gt; 100 mm</td>
<td>Zaragoza</td>
<td>Dry</td>
<td>Sulphur-yellow</td>
</tr>
<tr>
<td>S6</td>
<td>P &lt; 100 mm</td>
<td>Bidon V Sahara</td>
<td>Very dry</td>
<td>Orange-yellow</td>
</tr>
</tbody>
</table>

P = yearly rainfall total

For dryness or humidity, only the yearly average rainfall must not be taken into account, it is often necessary to interpret the question of the humidity of the air. It may act as a factor of displacement. Thus in certain places, on the Atlantic shore in Morocco, the rainfall would, for instance, call for the use of the sulphur-yellow colour; but the atmospheric humidity coming from the Atlantic Ocean is of tremendous importance for the vegetation. Instead of making a special representation of this factor, it can be given a role of displacement. So instead of the sulphur-yellow colour we shall put a more humid division and we shall use white. After 30 kms from the coast we shall keep the colour corresponding to the official rainfall. Behind the Atlas Range, the air dryness may induce to indicate a more yellowish colour than the official figure of pluviosity would demand; such is the spirit in which the pluviosity chart is used. It is not falsifying it, but a shaded interpretation much nearer to the truth than the rigorous utilization of figures.

Let us not forget our aim: that is to represent the ecological conditions of vegetation by superposition of coloured maps; the aim is not to place some maps one upon the other by stiff rules.

3°) Xerothermic factor

The question here is to study the dry periods in the course of a year.

The regular regimes where each season provides the plants with sufficient heat and humidity are of no interest to us and do not deserve a special symbol.
But there are two types of regimes which need to be pointed out:

In one the dry season coincides with the lowest temperatures.

In the other, the dry season coincides with the highest temperatures.

I think that the simplest way is to count the dry days in the consecutive dry months. By convention — for a convention is necessary — a month is called dry when it falls:

- less than 10 mm of water with mean temperature $t < 10^\circ$;
- less than 25 mm $10^\circ < t < 20^\circ$;
- less than 50 mm $20^\circ < t < 30^\circ$;
- less than 75 mm $t > 30^\circ$.

This convention proposed in 1949 corresponds almost to the formula $P = 2T$ and we shall see while studying the climatic regime how useful is the graphic representation of this convention.

During the consecutive dry months so defined, the number $p$ of rainless days is counted. The foggy days and the dewy days are counted each for half a day and cut off from $p$.

The days when the relative humidity $H$ is superior to 40% are counted as fractions of dry days:

- if $40\% < H < 60\%$ we count $9/10$;
- if $60\% < H < 80\%$ we count $8/10$;
- if $80\% < H$ we count $7/10$.

The given number is cut off and we obtain a number $n$. According to the following ranges of values of $n$, we get the xerothemic index, name $x$:

- $x_1$: $1 < n < 40$ submediterranean climate chevrons 3 cm off
- $x_2$: $40 < n < 100$ eumediterranean mesomedit. chevrons 2 cm off
- $x_3$: $100 < n < 150$ thermomedit. chevrons 1 cm off
- $x_4$: $150 < n < 200$ xerothermmededit. triangles 1 cm off
- $x_5$: $200 < n < 300$ subdesertic climate full trian. 1 cm off
- $x_6$: $300 < n$ desertic climate 0.5 cm off

The maximum for $n$ is, of course, 365. The minimum 0 corresponds to the countries without dry season.
Chevrons and triangles are bright orange in colour.

4°) Light factor

Here it seems not necessary either to do many divisions or to use plain colours. It seemed that three divisions are sufficient.

L1 . weak light | fine network of grey dots
L2 . moderate light | white
L3 . bright light | fine network of pink dots

Pink is chosen for strong light because physiologically, light replaces well enough heat and an almost similar colour is imperative. Shadow puts in mind of cold, and dark colour seems suitable.

The problem of long days is temporarily solved by admitting a displacement towards bright light but a special and additional representation could be thought of for this feature.

5°) Vegetative period

If we consider the variations of climate on the surface of the Earth throughout the year, we can notice that they are of essential importance for the vegetative period.

In the North of the Tropic of Cancer, there is a cold winter and a warm summer; from North to South winter becomes shorter and milder, summer longer and warmer; but at least as far as insolation is concerned there is only one type: the sun is low on the horizon during the winter half and higher in the summer half of the year.

Between the tropics the sun reaches the zenith twice a year which doubles the moment of the maximum of insolation and heat; it creates, along with complex conditions of humidity, numerous variations of the season types.

In the South of the Capricorn the type of the northern countries is found but winter corresponds to summer and vice-versa.

The different vegetative periods, named V, can be classified in four main types as follows, with reference to the duration of active vegetation. (1)

(1) Some part of the study of the representation of this factor V was done with TROCHAIN’S collaboration while carrying on the preparation of the Senegal map at one millionth scale which will be published by TROCHAIN and ROBERTY.
V1 — Short growth period less than 6 months

The forests are evergreen (conifers of the cold countries), or deciduous. In general the forest is more or less sparse. The adopted representation consists in big dots. The dots are full if the trees remain evergreen, they are crossed, with a vaccinator’s lance with an oblique thin white line if trees are deciduous.

If there is no vegetation of trees, there can be a vegetation of bushes and representation will be of the same type with dots of small diameter.

If the vegetation is only frutescent, a fine network of thin lines will be used; if it is herbaceous, small dots will be suitable.

V2 — Mean growth period around 6 to 9 months

If the leaves are persistent as it is the case with forests of conifers in temperate or cold countries and with evergreen forests in mediterranean countries: plain colour.

If the leaves are deciduous, as in the case of temperate cold countries, the plain colour will be striped with white fine oblique strokes done on the zinc-block with a vaccinator’s lance.

The bush type is represented by a thick lines network.
The frutescent type by close network of thinner lines.
The herbaceous type by close dots.

V2/3 — Sub-equatorial countries

There are two humid periods separated from each other by a short dry period, then by a really dry season giving rise to partial leaves falling. It is then a deciduous forest but with long vegetative period.

The signs of V 2 and V 3 may be alternated.

V3 — Continuous growth

The equatorial or sub-equatorial forests belong to this type. There may be a mixture of deciduous and evergreen species, trembled interrupted indigo vertical strokes will be put. If the forest is evergreen, trembled indigo strokes can be used upon the plain colour. When there is no forest but shrubby trees or grasses, the normal sign with trembled indigo strokes will be used.
6") Soil factor

The soil factor may at times be included in the previous factors. Thus an impermeable soil in a humid country means a more lasting humidity. One may indicate it by shifting, of one class, the representation of rainfall towards the stronger humidity. In this case the soil is not represented by any special sign: in the biological formula the sixth place will be occupied by a round O. (1) But sometimes the soil has such an importance that it is necessary to give it a particular graphical representation.

Let us see how some kinds of representations can be imagined.

A Fresh water: The aquatic plants of fresh water are represented by short thick horizontal strokes if the aquatic life is permanent. For temporary water stretches a white thick stroke will alternate with a blue thick stroke.

T Peaty or acid water will require dark bistre colour.

M Sea, salted water. The same convention will be used with red colour. If the representation of any details is necessary, some symbols can be added to these strokes.

The brackish water vegetation will be represented by a mixture of blue and red strokes and their relative frequency can be adjusted according to the environment being nearer to fresh water than to salted water.

H Humid soil: a humid soil is represented by checks, a very humid soil will be marked with blue crosses. A soil with water table of small depth is represented by thin horizontal blue dashes.

S Salted soil: salted soil will be marked by red crosses.

Sm Brackish soil: a brackish soil will be represented by a mixture of red and blue crosses.

T Acid peaty soils are indicated by dark bistre crosses; alkaline peaty soils by orange crosses.

Hu If the humus is acid, the humic soils of this type are considered as peaty. If the humus is mild, light bistre crosses will be put.

Ca If the soil is calcareous yellow crosses will be used. A sandy soil will be represented by thin yellow dots if it is not salted; if salted by thin red dots, Σ and Σ separate the sandy soils from the finely sandy soil.

Ar Clay soil: inverted violet L will be used.

(1) cf. infra: Ecological formula.
ArL. Lateritic clay: unite the sign of clay and that of laterite.

L. Laterite: the sign L in violet is used.

These general conventions do not prevent modifications of details according to the local conditions if the scale allows them.

B. COMPLEMENTARY FACTORS

The six factors already studied are the most important and must be taken into account everywhere.

In certain places, factors near their maximum can acquire a local importance justifying their representation. It will be rarely the case in a map at 1/1 000 000 scale.

— Wind for instance, with a certain frequency and a certain violence can prevent an arborescent vegetation in climates which could allow trees.

Its drying and mechanical action will be indicated with orange lozenge-shaped signs.

— The duration of snow-covering shortens the period of plant growth and prevents the arborescent vegetation. It can be precised: use grey triangles when it will last more than 9 months, denser for 10 months.

— Frost, even when it is not very strong, is sufficient in certain countries to eliminate a lot of sensible species. In some "freezing hollows" frost goes on for such a long period of the year that it prevents certain types of vegetation. This quantity is difficult to measure. One may leave it to the appreciation of the cartographer and use grey crescent signs.

— Salty sprays are injurious at a certain distance from the sea according to the places; one can tighten more or less red strokes in chevron.

ECONOMIC INTEREST OF THE METHOD

With the six main factors and occasionally complementary factors, admitting also that certain factors may be represented by a modification of the value of another, we have a scale which can be used for the whole world.

Synthetic biology is thus summed up by a "formula" which includes the value affecting each factor.
Here a remark is necessary:

It may happen that two combinations of elementary colours give resulting colours being identical or almost analogous.

It is not at all a defect of the method. I would rather say that it is one of its advantages: as the choice of the colours has been made with logical principles based on the physiology of the plants if two resulting colours are analogous, it is because the environments are physiologically analogous. This statement is of a very great practical interest. To find the same colour in India and in Congo means that the plants of these two places, though of different names and even different on account of the detail of their biology, are interchangeable. One can understand the economic interest of the question for cultivation and afforestation.

It can be noticed that it is not always necessary to judge at glance the identity of colours: two colours are identical if the formulae which produce them are identical. It will be easy to find a great number of identical formulae if a detailed catalogue is made with the world groups. There will be no difficulty: due to the undeniable plasticity of the plants, identical formulae correspond to interchangeable groups and, no doubt, interchangeable crops.

Two colours are identical or almost identical if the formulae which produce them, though different, have two similar resultants by effect of compensation. It can be analysed, if need be, by the study of formulae, but will appear essentially by the vision of the synthetic colour. From the technical point of view this vision will be possible by the use of coloured glasses superposed in front of a projector, the synthesis appearing on the screen with a purity impossible to realize with pencils or inks.

Once the list of the countries is set up where the same colour is existing, the whole list of cultivated or spontaneous plants found therein would be that of the plants able to grow in each of them. The enormous economic interest of such a documentation is obvious.

It would evolve the study of plants which nobody thought of using: it would help one to avoid trials of plants whose success is doubtful. The difference of hemisphere which can be a source of difficulties must be taken into account. Our conclusions valid in the same hemisphere are not necessarily so in both.

A biological spectrum of each plant can be set up by making a list of the different formulae which enable it to live. So the range of colours which suits it can be obtained and thus its aptitudes can be materialized.

F. IV 4.
The economic interest of the method is obvious. Its climatological interest is of no less importance. A climatological map of the world can be based on it, in neglecting the non-climatic factors of the synthesis.

**Ecological formulae**

The synthesis of the above environmental factors can be defined by a kind of formula.

Let us give an example. In the scales from $t_1$ to $t_6$ for the temperatures, from $S_1$ to $S_6$ for the dryness, from $x_1$ to $x_6$ for the xerothermic factor, from $L_1$ to $L_3$ for light, from $V_1$ to $V_3$ for the vegetative period, with a dozen of different types for the soil, we obtain the formula suitable for the conditions of growth of Zenn Oak (Quercus mirbeckii) in Kroumiry (North of Tunisia):

$$t_{3/4} \ S_{2/3} \ x_4 \ L_2 \ V_2 \ 0$$

That means:

- temperature between $t_3$ (white) and $t_4$ (gold yellow)
- dryness between $S_2$ (dark blue) and $S_3$ (light blue)
- xerothermic index $x_4$ (scarce orange chevrons)
- light $L_2$ (white)
- vegetative period $V_2$ (plain colour with thin oblique white strokes)
- soil 0 indifferent.

The resulting colour will be: a bright green with thin white strokes and scarce orange chevrons.

In conclusion, such are the processes by means of which can be given information, as complete as the scale allows, regarding:

- Cultivation and agricultural statistics
- Actual vegetation with outline of the physiognomic units: forests, grasslands... etc...
- Series of vegetation and stage of the series, which each element of the landscape represents.
- Ecology of the environment at the stage of the climax vegetation by rational use of colours.
THE INSET MAPS

But the map gives much more information by the use of smaller scale maps which are placed outside of the frame.

1°) Hypsometric inset map. The interest of this diagram is obvious. Though the map includes level curves, they are hardly readable because of the superposition of colours. It is however useful to compare vegetation and altitude.

2°) Geological inset map. For the utilization of the soil for cultivation, pedology is more useful than geology. But in many countries edaphic knowledge is insufficient and the geological map is the only valuable document. If it was conceived to show the facies more than the geological age, it would be more interesting. To distinguish what is calcareous, sandy, eruptive etc... would be precious.

3°) Pedological inset map. More one knows of the soil of a country more one finds that a pedological map at one 2,500,000th scale does not mean much. Still it is interesting to compare it with the geological diagram. The colours employed give an idea of the genesis of the soil. Their use is reasoned: two fundamental types of parent rock can be distinguished: calcareous to which corresponds a yellow background, silicious to which corresponds white. The leaching is indicated in blue which gives green colour on calcareous soils and blue on silicious soil. Evaporation is indicated in red, which gives orange on yellow, red on white. A maroon colour can be used for the peaty soils.

4°) Botanical inset map. The question here is to represent the vegetation as it would be if man disappeared for about hundred years, what I have named "plesioclimax". This diagram is very useful because it gives a general view of the natural conditions. Moreover it enables us to know in each cultivated part, left in white on the map, the "series" for which the cultivated ground is a lack of series. The colours are naturally the same as on the principal map.

5°) Agricultural inset map. Its aim is to separate at the first glance the non cultivated areas from the cultivated areas and to determine the relative importance of the crops. The process consisting of putting a broad vertical band for the first crop in the statistics, a narrow band for the second, and oblique dash for the third, has the advantage of making the agricultural regions appear much better than the simple reading of statistics.
6°) Pluviothermic inset map. A map of the yearly average rainfall, and yearly average isotherms, can be enriched with indications on the xerothermic index and if necessary ombrothermics diagrams. The colours are always chosen in range according to the rainbow; the blue half of the spectrum is wet, the red half is dry.

7°) Agricultural adversities inset map. It is useful to give indications on winds, hailstorms, floods etc... These adversities vary with the maps.

CONCLUSION

After this report, we can be alive to the importance of information accumulated in the map and the joined inset maps.

Such a map at one millionth scale, if completed in every country, would be an extremely precious document. It is not an unattainable project. Thanks to aerial photographs, the outline of the vegetation unities can be traced everywhere in the world. A party of botanists can then correctly prepare the representation. Of course a mere first edition cannot be perfect. As in the case of a geological map, this map also will achieve perfection gradually, but its very first edition itself will render great service.

While concluding, we may as well refer to these services.

— The botanists are naturally the first to be interested in a map like this, which enables them to have a general view of the vegetation types of large regions.

— On a map at 1/1 000 000 scale, the agriculturist will of course not have a detailed knowledge of his lands, but studying the map and the botanical inset map he may acquire a knowledge of the general conditions. He will know in which series lay his lands and also to what extent he can vary his crops.

Personalities responsible for the agricultural politics of a region or a country will find in such a map, in a tangible way, essentials of statistical and cartographical documentation which they must constantly take into account.

— The forester who is particularly interested in the possibilities of afforesting uncultivated lands will be guided by the notion of zone or that of vegetation stage.

— The climatologist will see the obvious relation between the vegetation type and the climate and will devote his attention to vegetation to get an idea of the climate of a place where no meteorological data are available.
— Town-planner who wants to set up a factory, hygienist who wants to build a sanatorium, will get from the map valuable information, since the vegetation is the best synthesis of the climatic conditions.

— The Engineer will determine easily what should be the salient features of an irrigation planning or a drainage scheme.

— The engineer laying out roads will make them pass where the soil is not clayey and the vegetation map will indicate in a useful way the regions to avoid.

— The military officer wishing to conceal his troops or material would be interested to know where he could find evergreen forests. The vegetation would guide him properly as regards the passage possibilities of his tanks.

— Even the political opinion which is influenced by the environment could have a good deal to do with the vegetation.

So to prepare Ecological Map of the Vegetation Cover at one millonth scale, would be a great and prolific undertaking. It is to be hoped that each country, after the topographical and geological maps, undertakes this botanical map so important for science and for the economic development.
STUDY OF XEROTHERMIC INDEXES IN INDIA, BURMA, PAKISTAN AND CEYLON

by P. LEGRIS and M. VIART
Institut Français
Pondichéry

We have seen in the last article that among the main ecological factors playing a part in repartition of the vegetation there are, at first, heat, dryness and xerothermic factor.

The computation of this last factor will be developed below. It takes a great importance in the study of the climates having a well marked dry season. It enables their differentiation and comparison.

The problem will be treated in two steps:
1° Determination of the dry season
2° Determination of the xerothermic index.

DETERMINATION OF THE DRY SEASON

Let us remind Prof. GAUSSEN’s definition of a “dry month” (1):

A dry month is a month during which it falls:

— less than 10 mm with a mean temperature below 10° C
— less than 50 mm with a mean temperature between 20 and 30° C
— less than 25 mm with a mean temperature between 0 and 20° C
— less than 75 mm with a mean temperature above 30° C

(1) cf. page 170
"This discontinuous definition may be expressed continuously "with a curve if we point out that it can be approximately, but "very simply, said: a month is dry when the total monthly rainfall "expressed into millimeters is equal to, or less than, the double value "of the mean monthly temperature expressed into centigrade degrees:

\[ P \leq 2T \]

"With the help of this relation we can draw the ombrothermic "diagram as follows:

"On the same graphic are quoted:

"— in abscissa: the months

"— in ordinates: on the right side, the scale of precipitations "and on the left, temperature scale which is double of the precipitation "scale".

"The precipitation curve is drawn in full line, the temperature "curve in broken line.

"When both curves are intersecting, the temperature curve "passing above the other during the dry months, the "crossing area” "between the two curves measures importance of the dry season: in "duration (difference of abscissa) and in intensity (crossing area)." (1)

"On this graph, “crossing areas” correspond to the periods "when \[ P \leq 2T \]. If several “crossing areas” are found, that means "the year has several dry seasons.

"This might seem an arbitrary convention; however it is good, "for the results of its application are good. The idea is not absolutely "new. Köppen admitted, considering the mean annual values, \[ P = 2T \] "as a limit between the steppic vegetation and the ligneous vegetation. "But the steppic vegetation corresponds to the “dry” areas. As well,

\[ P \text{ Scaetta chooses as a limit } = 1.66. \text{ Let us take } T = 25^\circ \text{ for } T + 10 \]

"instance, we obtain \[ P = 58.10 \text{ instead of } P = 50 \text{ with our method;} "if \[ T = 30^\circ \], the result is \[ P = 66.40 \text{ instead of } P = 60. \text{ We are} "expecting more than him”. (2)

The dry season, whole of consecutive dry months, is shown clearly by the ombrothermic diagrams.

(1) F. BAGNOULS and H. GAUSSEN (1953) Saison sèche et Indice Xérothermique.
(2) H. GAUSSEN (1954) La Carte du tapis végétal.
**STATION COONOOR**

- **Longitude**: 76° 46'E
- **Latitude**: 11° 21'N
- **Altitude**: 1,746 m

**Indice xérothermique**

- Nombre d'années d'observation: 10
- Observ. ramenées à la période: 1931-1940

---

**Figure 1**: FAC SIMILE of card used for computation of xerothermic index at the French Institute of Pondicherry.
**STATION NEW-DELHI**

*Indice xérothermique*

<table>
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<tr>
<th>Nombre d'années d'observation</th>
<th>59</th>
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<tbody>
<tr>
<td>Observ. ramenées à la période</td>
<td>1881-1940</td>
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**Longitude**: 77°12' E

**Latitude**: 28°35' N

**Altitude**: 217 m

---

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<tr>
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<tbody>
<tr>
<td>J</td>
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</tr>
<tr>
<td>F</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td></td>
</tr>
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<tr>
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<tr>
<td>N</td>
<td></td>
</tr>
<tr>
<td>D</td>
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**Fig. 2: Fac simile of card used for computation of xerothermic index**
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<th>Février</th>
<th>Mars</th>
<th>Avril</th>
<th>Mai</th>
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<th>Novembre</th>
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<tr>
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<td>29,0</td>
<td>29,1</td>
<td>29,4</td>
<td>29,3</td>
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<td>Nb de journées de pluie</td>
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<td>9/10</td>
<td>10/10</td>
<td>10/10</td>
<td>10/10</td>
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<td>43</td>
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<tr>
<td>H</td>
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<td>10/10</td>
<td>10/10</td>
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</table>

**Calcul de n**

\[
\text{Coefficient de hygrométrie} = 24,7 \\
\text{Correction} = \frac{2,0 + 1}{2} = 24,7 \\
\]

**Fig. 3:** Computation of number of physiologically dry days
<table>
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<td>16.7</td>
<td>20.8</td>
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</table>

Fig.1: Fao Simile of card used for computation of xerothermic index
For instance at New Delhi the dry season lasts from October to May (fig. 2). The "crossing area" of the two curves shows a great intensity of the dryness in March, April and May, a less important dryness in November-December and much attenuated in January-February.

Out of the 660 mm of rainfall, recorded during a mean year at New Delhi, 563 mm are concentrated in a four months period from June to September, and fall in heavy showers. A great part cannot be retained in the soil and is lost for the vegetation.

During this dry season, with little precipitation, evaporation and transpiration, that vary roughly like temperature, are very important. Therefore the water balance is unfavorable to vegetation during the eight biologically dry months in a mean year at New Delhi: the temperature curve is above the rainfall curve.

This conclusion is not obvious if we consider only the total annual rainfall and mean annual temperature. The ombrothermic diagram that shows simultaneously variations of both these factors throughout the year brings out their monthly relative importance. (1)

We shall see further that the xerothermic index allows more precision regarding the intensity of the dryness during the dry season.

Let us see now the diagram of Coonoor (fig. 1) station on the Eastern side of Nilghiri hills. We can recognize the influence of this situation on the rainfall distribution, type of curve frequently found in the South-East of the peninsula, i.e. little rainfall during spring and much in autumn respectively due to the establishing and retreating south-west monsoon. But at Coonoor the total rainfall is more important than in the stations of the plain and temperature is lower. The two curves do not cross; there is no dry month. The vegetation is of an evergreen type.

Another extreme case is the station of Khanpur in a desertic country (fig. 4). The temperature curve remains above this of precipitation. The increase of rainfall during July and August cannot be a compensation to the evaporation which also increases with the summer temperature. Then every month is biologically dry.

(1) The temperature should increase from January upto July, following the ascending course of the Sun which reaches its highest point on the 21st of June. But due to the monsoon (refreshing effect of rain and decrease of insolation) the temperature reduces from the beginning of June. These features are also obvious on the ombrothermic diagram.

F. IV 5.
DETERMINATION OF XEROTHERMIC INDEX

Let us study now the dry periods during the year.
During consecutive dry months, as they have been defined above, all days are not biologically dry. Income of water may exist in the form of rain, dew, condensation of atmospheric humidity in the superficial layers of soil. As well evaporation is reduced if mist remains during a part of the day.

Taking account of these facts, the xerothermic index allows the appreciation of the intensity of the biologic drought.

The principle of its calculation has been explained above (p. 169). Let us summarize it practically:

Number of rainy days, \( R \), is substracted from the number of days of each dry month:

\[
\text{nbr of days in the month} - R = p.
\]

Among these \( p \) days without rain, \( D \) days received traces of rain, \( F \) days were misty. Each of them is considered as half a dry day and substracted from \( p \). (1).

The number of days without any precipitation is:

\[
p - \frac{D + F}{2}
\]

During that time the relative humidity, \( H \), might have been more or less important. The days with \( H \) less than 40% are taken as dry (10/10). In other cases, we adopt the following convention:

Days are counted as (2):

- 9/10 of a dry day when \( H \) is comprised between 40% and 60%
- 8/10 of a dry day when \( H \) is comprised between 60% and 80%
- 7/10 of a dry day when \( H \) is more than 80%

Therefore the figure \( n \) which is the equivalent of physiologically dry days of a given month, is obtained by application of the following formula:

\[
n = \frac{8}{10} \left( p - \frac{D + F}{2} \right)
\]

(1) Number of dewy days are not given in the climatological tables. But these tables give number of days with traces of rain (between 0.2 mm and 2 mm). These days are taken as half dry day.

(2) As the daily values of \( H \) are rarely given in the meteorological documentation, the mean monthly relative humidity, given by statistics, can be used.
(8/10 for instance if the mean monthly relative humidity is between 60% and 80%).

The sum of these monthly values gives for each station the number of the physiologically dry days throughout the year; it enables the comparison and a classification of stations.

An example of calculation of \( n \) is given for New Delhi (fig. 3) where the dry season extends from October to May. During this period the number of physiologically dry days is 218.

Same calculation gives \( n = 316 \) at Khanpur where the aridity is very much marked if compared to the maximum possible value of \( n \) which is, obviously, 365. We can see from the climatological card of the station that, though if falls 113 mm of rain in July and August, the relative humidity remains very low (51 and 54%).

At Coonoor there is no dry season and \( n = 0 \). The relative humidity remain high throughout the year.

Similar climatological index cards have been established for 246 stations of India, Burma, Pakistan and Ceylon. The value of \( n \) computed for all these stations are recorded in the joined table column n° 4.

— Column n° 5 gives the number of dry months in the year.

— Column n° 6 precises the name of the dry months (1 for January and 12 for December).

Some stations have two distinct dry periods; example Hambantota in February (2) and June-July-August (6 to 8).

Total of precipitation during the dry period (col. 7) is an interesting indication to be compared to the annual precipitations (col. 8).

— Same remark on the mean monthly temperature of the dryest month (col. 9) compared to the mean annual temperature (col. 10).

— Column 11 records the mean relative humidity during the dry months, and column 12 the mean annual saturation deficit.
In this table the stations are classified in the order of increasing values of \( n \). They are only compared from the point of view of duration and intensity of their dry period. This factor plays a part in the repartition of the vegetation types and becomes the limiting factor when nearing its high values.

It is interesting to compare for instance two stations of Bombay State submitted to the same type of rainfall repartition with six consecutive dry months from December to May. The total annual rainfall may be as different as Mahabaleshwar: 6635 mm, and Miraj: 652 mm. The intensity of dryness is similar in both cases \( n = 155 \), as well as the relative humidity of the dryest month: 41%; the mean annual temperature being close: 20 and 25° C.

The vegetation is not so luxuriant at Mahabaleshwar that it could have been expected from the mere consideration of annual rainfall and temperature.

In order to simplify the classification of stations, and allow the cartographic representation of the factor dryness, the values of \( n \) are drawn together into six classes, as defined above (1): from \( x 1 \) to \( x 6 \).

The limits of the classes (for instance: class \( x 5 \) including the values of \( n \) between 200 and 300) have been chosen by Gaussen and Bagnouls, after comparative studies of climates in the world. These six classes are quite satisfactory for the classification at the world scale.

For more detailed studies it is practical to adopt intermediary classes.

As an example of such possible convention for a regional study, the following scale has been used on the map of xerothermic index at about 1/10 000 000 scale illustrating this article:

\[
\begin{align*}
\times 1 & \quad 1 < n < 40 \\
\times 2 & \quad 40 < n < 100 \\
\times 3 & \quad 100 < n < 150 \\
\times 4 & \quad 150 < n < 200 \\
\times 4/5 & \quad 200 < n < 250 \\
\times 5 & \quad 250 < n < 300 \\
\times 6 & \quad 300 < n \\
\times 0 & \quad \text{is taken for stations without dry month and } n = 0.
\end{align*}
\]

(1) page 170
Some precisions on the origin of meteorological datas on which our calculations are based may be found in appendix.

THE CASE OF SECONDARY STATIONS

When undertaking a more accurate study of a country, the density of meteorological stations of prime order (giving temperature, relative humidity, etc...) becomes unsufficient for a satisfactory account of local climates. We have to use the datas given by "Memoirs of the Indian Meteorological Department" (Vol. XXVII, Part. V) giving for a great number of secondary stations the mean monthly rainfall and the number of rainy days. Datas given by small forest stations located near the forest areas are also of great interest.

From these figures we can draw the annual curves of precipitations for each secondary or forest station. These curves are compared to those of neighbouring primary stations. After this comparison may be drawn the limits of regions of same climatic type.

Taking account of the topographical location of the stations, it is then possible to get an idea of the number of dry days in each secondary station:

First case

When a secondary station is roughly at the same altitude as a neighbouring primary station (1) we may think that the variation of the mean temperature is similar in both the stations. Then we can draw on the index card of the secondary station the probable curve of variations of its mean monthly temperature by using the figures of the neighbouring primary station. We obtain a valid ombrothermic diagram, the "crossing area" of which determine the number of dry months. Taking account of the number of rainy days given by the tables and a mean value of relative humidity by comparison with the primary station, we can compute an estimated number of physiologically dry days in this station and then its xerothermic index.

Second case

When a station is situated at an altitude comprised between the altitudes of two neighbouring primary stations we have to compute the temperature gradient valid for this region. This gradient (diminution of temperature for an increase of hundred meters in altitude), is obtained from the difference of mean monthly temperatures of the two primary stations, and the difference of their altitudes.

(1) When the altitude of the station is not given in the tables, it is easy to know it from the survey map at one inch to one mile scale.
An example is given below of the gradient between Colombo (altitude of the observatory: 6 meters) and Nuwara Eliya (altitude of the observatory: 1,876 meters).

<table>
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<th>Mean monthly temperatures °C</th>
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<tbody>
<tr>
<td></td>
<td>J</td>
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<tr>
<td>Colombo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>26.2</td>
</tr>
<tr>
<td>Nuwara Eliya</td>
<td>14.1</td>
</tr>
<tr>
<td>Difference</td>
<td>12.1</td>
</tr>
<tr>
<td>Monthly Gradient</td>
<td>0.65</td>
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</tbody>
</table>

The temperature gradient between these two stations is roughly equal to 0.6 throughout the year. Same computation has been made for hill stations of South India (Western Ghats) and have given similar results (1)

When knowing the altitude of the secondary station and the temperature gradient valid in the region we can obtain a probable curve of the variations of the mean monthly temperature taking the nearest of the two stations as a base for this calculation. Having an approximate ombrothermic diagram, same considerations as in the first case, give us the number of dry months and xerothermic index value.

**CONCLUSION**

It has been shown how the value of xerothermic index have been completed for India and neighbouring countries.

However we want to draw the attention on three important points:

1°) the xerothermic index has no absolute value in itself. It must be considered as practical means of comparison of meteorological stations from the point of view of the length and intensity of their dry periods.

(1) In an article published in 1876 in the "Indian Meteorological Memoirs" (Vol. I — part. VI — pp 378-419) S. A. HILL gives the elements of calculation of the temperature gradient in the North Western Himalaya. His results are slightly lower and varies with the seasons. Variation is much smaller in the Southern part of India and Ceylon due to low latitudes.
2°) The computation is based on meteorological datas recorded by observatories which cannot give an account of the actual conditions of environment in which are growing the plants: they are different in the grasslands and under the forests; the thermic amplitude measured in open is different from that measured in the observatories.

Therefore it is useless to seek for too much precision in the calculation, as the available datas are themselves average values.

3°) "The xerothermic index is only one factor of the climate "and, in a climatic synthesis, it cannot be dissociated of the other "important factors".

"It has not much interest when its value is low, but characterizes "clearly a climate when it reaches high values. It shows the features "of the climate with much emphasis than the mere consideration of "temperature and precipitations".

"This index will be often very useful to show differences between "similar climates and to precise the secondary sub-types of climate in "the same climatic region". (1)

APPENDIX

Data for the calculation of Xerothermic Index are taken out of the Climatological Tables published in 1953 by the Government of India, giving the results of observations covering a maximum period of consecutive 60 years. These data were completed, regarding Ceylon with figures from Climatological Tables published in 1954 by the Ceylon Government.

1° Temperature

Tables give two figures for the temperature: the first one is the monthly average of maximum temperatures recorded daily, the second one is the monthly average of daily minimum temperatures. The temperature used is the average of these two figures.

It is slightly different from the average of temperature noted at 8 hrs I.S.T. and 5 hrs I.S.T. (2).

It is also best, for it includes the maximum and minimum values of this factor.

(1) F. BAGNOULS et GAUSSE (1933): Saison sèche et Indice Xérothermique
(2) I.S.T. means Indian Standard Time (8 hrs I.S.T. = 0230 hrs G.M.T.)
For more detailed studies it would be better to set out on the diagrams the curves of maxima and minima to follow variations of the thermic amplitude during the year.

These extreme values have an importance in the extra-tropical or mountain climates (laws of maximum and minimum).

2° Relative humidity

Figure of relative humidity is the mean of daily observation done at 8 hrs I.S.T. and at 17 hrs I.S.T. (1)

3° Rain

Tables give the mean monthly totals of daily measures during 50 or 60 years.

4° Number of rainy days

According to the tables “a rainy day is defined as one in which 10 cents or more of rain is recorded”, i.e. about 2 mm. Figures given are monthly averages of observations during a period of 50 to 60 years.

5° Number of days with rain traces

Under the heading: “Atmospheric Phenomenae” tables give the monthly average of rainy days in which 0.01 inches or more of rain are recorded, about more than 0.2 mm (2). The number of days with rain traces is equal to the difference between this number and the last one. Are considered, in fact, as rain traces, rainfalls below 2 mm and above 0.2 mm.

6° Number of misty days

This number is the monthly average extending on 5 to 10 years.

---

(1) Observations a 8 hrs I.S.T. were done during many years (50 to 60) and those at 17 hrs I.S.T. were done during five years (1936 - 1940).

(2) These observations were done only during 5 to 10 years.
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<th>Number of dry days</th>
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<th>Number</th>
<th>Name</th>
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<th>Air temperature</th>
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<tr>
<td>RAJ</td>
<td>Jodhpur</td>
<td>224 m</td>
<td>262</td>
<td>9</td>
<td>10 to 6</td>
<td>76 m/m</td>
<td>34°C</td>
<td>34 m/m</td>
<td>16 %</td>
<td></td>
</tr>
<tr>
<td>W-P</td>
<td>Khushab</td>
<td>186 m</td>
<td>266</td>
<td>10</td>
<td>9 to 6</td>
<td>197 m/m</td>
<td>35°C</td>
<td>35 m/m</td>
<td>25 %</td>
<td></td>
</tr>
<tr>
<td>RAJ</td>
<td>Barmer</td>
<td>194 m</td>
<td>268</td>
<td>10</td>
<td>9 to 6</td>
<td>84 m/m</td>
<td>34°C</td>
<td>34 m/m</td>
<td>27 %</td>
<td></td>
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<tr>
<td>BOM</td>
<td>Bhuj</td>
<td>104 m</td>
<td>273</td>
<td>10</td>
<td>9 to 6</td>
<td>111 m/m</td>
<td>31°C</td>
<td>31 m/m</td>
<td>26 %</td>
<td></td>
</tr>
<tr>
<td>W-P</td>
<td>Montgomery</td>
<td>170 m</td>
<td>274</td>
<td>11</td>
<td>9 to 7</td>
<td>181 m/m</td>
<td>35°C</td>
<td>35 m/m</td>
<td>25 %</td>
<td></td>
</tr>
<tr>
<td>RAJ</td>
<td>Bikaner</td>
<td>224 m</td>
<td>276</td>
<td>10</td>
<td>9 to 6</td>
<td>115 m/m</td>
<td>35°C</td>
<td>35 m/m</td>
<td>27 %</td>
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</tr>
<tr>
<td>IRA</td>
<td>Zahidan</td>
<td>1800 m</td>
<td>277</td>
<td>11</td>
<td>2 to 12</td>
<td>45 m/m</td>
<td>27°C</td>
<td>27 m/m</td>
<td>17 %</td>
<td></td>
</tr>
<tr>
<td>RAJ</td>
<td>Sriganganagar</td>
<td>177 m</td>
<td>280</td>
<td>11</td>
<td>7 to 5</td>
<td>183 m/m</td>
<td>34°C</td>
<td>34 m/m</td>
<td>25 %</td>
<td></td>
</tr>
<tr>
<td>J-K</td>
<td>Gilgit *</td>
<td>1491 m</td>
<td>281</td>
<td>12</td>
<td>1 to 12</td>
<td>132 m/m</td>
<td>29°C</td>
<td>29 m/m</td>
<td>17 %</td>
<td></td>
</tr>
<tr>
<td>IRA</td>
<td>Charbar</td>
<td>7 m</td>
<td>281</td>
<td>12</td>
<td>1 to 12</td>
<td>100 m/m</td>
<td>27°C</td>
<td>27 m/m</td>
<td>17 %</td>
<td></td>
</tr>
<tr>
<td>W-P</td>
<td>Badin</td>
<td>9 m</td>
<td>283</td>
<td>11</td>
<td>8 to 6</td>
<td>130 m/m</td>
<td>33°C</td>
<td>33 m/m</td>
<td>26 %</td>
<td></td>
</tr>
<tr>
<td>W-P</td>
<td>Las Bela</td>
<td>89 m</td>
<td>286</td>
<td>11</td>
<td>8 to 6</td>
<td>146 m/m</td>
<td>34°C</td>
<td>34 m/m</td>
<td>26 %</td>
<td></td>
</tr>
<tr>
<td>W-P</td>
<td>Dalbandin</td>
<td>849 m</td>
<td>290</td>
<td>10</td>
<td>3 to 12</td>
<td>45 m/m</td>
<td>33°C</td>
<td>33 m/m</td>
<td>26 %</td>
<td></td>
</tr>
<tr>
<td>W-P</td>
<td>Sukkur *</td>
<td>67 m</td>
<td>294</td>
<td>12</td>
<td>1 to 12</td>
<td>86 m/m</td>
<td>36°C</td>
<td>36 m/m</td>
<td>27 %</td>
<td></td>
</tr>
<tr>
<td>W-P</td>
<td>Hyderabad</td>
<td>29 m</td>
<td>296</td>
<td>11</td>
<td>8 to 6</td>
<td>105 m/m</td>
<td>34°C</td>
<td>34 m/m</td>
<td>26 %</td>
<td></td>
</tr>
<tr>
<td>W-P</td>
<td>Dera-Ismail Khan</td>
<td>173 m</td>
<td>300</td>
<td>12</td>
<td>1 to 12</td>
<td>231 m/m</td>
<td>35°C</td>
<td>35 m/m</td>
<td>24 %</td>
<td></td>
</tr>
<tr>
<td>W-P</td>
<td>Panjgur</td>
<td>969 m</td>
<td>305</td>
<td>11</td>
<td>2 to 12</td>
<td>101 m/m</td>
<td>32°C</td>
<td>32 m/m</td>
<td>22 %</td>
<td></td>
</tr>
<tr>
<td>W-P</td>
<td>Multan</td>
<td>128 m</td>
<td>314</td>
<td>12</td>
<td>1 to 12</td>
<td>179 m/m</td>
<td>35°C</td>
<td>35 m/m</td>
<td>25 %</td>
<td></td>
</tr>
<tr>
<td>W-P</td>
<td>Khanpur</td>
<td>90 m</td>
<td>316</td>
<td>12</td>
<td>1 to 12</td>
<td>164 m/m</td>
<td>36°C</td>
<td>36 m/m</td>
<td>26 %</td>
<td></td>
</tr>
<tr>
<td>W-P</td>
<td>Bahawalpur</td>
<td>107 m</td>
<td>317</td>
<td>12</td>
<td>1 to 12</td>
<td>143 m/m</td>
<td>35°C</td>
<td>35 m/m</td>
<td>25 %</td>
<td></td>
</tr>
<tr>
<td>W-P</td>
<td>Sibi *</td>
<td>134 m</td>
<td>318</td>
<td>12</td>
<td>1 to 12</td>
<td>117 m/m</td>
<td>38°C</td>
<td>39 m/m</td>
<td>27 %</td>
<td></td>
</tr>
<tr>
<td>W-P</td>
<td>Noakhundi</td>
<td>679 m</td>
<td>320</td>
<td>12</td>
<td>1 to 12</td>
<td>27 m/m</td>
<td>36°C</td>
<td>36 m/m</td>
<td>24 %</td>
<td></td>
</tr>
<tr>
<td>W-P</td>
<td>Jacobabad</td>
<td>56 m</td>
<td>327</td>
<td>12</td>
<td>1 to 12</td>
<td>91 m/m</td>
<td>37°C</td>
<td>37 m/m</td>
<td>27 %</td>
<td></td>
</tr>
</tbody>
</table>

**N. B.:**

1°) In the stations marked with an asterisk * the meteorological observations were only taken at 8 hrs. I. S. T.

2°) In the stations marked with two asterisks **, during the dry period, a part of drought is due to freezing.

3°) The meaning of the abbreviations used for the names of States is the following:

- **AFG**: Afghanistan
- **A-I**: Adaman Islands
- **A-P**: Andhra Pradesh
- **ASS**: Assam
- **BIH**: Bihar
- **BOM**: Bombay State
- **BUR**: Burma
- **CEY**: Ceylon
- **DEL**: Delhi
- **E-P**: East Pakistan
- **GOA**: Goa
- **H-P**: Himachal Pradesh
- **IRA**: Iran
- **KER**: Kerala
- **J-K**: Jammu-Kashmir
- **MDM**: Madras State
- **M-P**: Madhya Pradesh
- **MYS**: Mysore State
- **NEP**: Nepal
- **ORI**: Orissa
- **PUN**: Punjab
- **RAJ**: Rajasthan
- **TIB**: Tibet
- **U-P**: Uttar Pradesh
- **W-B**: West Bengal
- **W-P**: West Pakistan
DOCUMENTATION and METHOD
PROPOSED FOR VEGETATION MAPPING AT
ONE MILLIONTH SCALE
in INDIA and CEYLON

by P. LEGRIS and M. VIART
Institut Français
Pondichéry

The Scientific and Technical Section of the French Institute has completed the first sheet of the International Map of the Vegetation covering the South of India and the North of Ceylon at one millionth scale.

It seemed to us of some interest to give an idea of the method followed till now in carrying out this work, method which is liable to improvement when, with the help of experience, a better use of the documentation will be possible.

Such a map, being a synthesis of the maximum of information, is also an useful inventory, bringing up the economical interest of the various regions. It underlines the main features of their actual exploitation and shows the way of their improvement in the frame of a general planning.

THE FACTS TO BE SHOWN

The facts to be shown are on the one hand of biological order: climate, soil, natural vegetation; on the other hand of the economical order i.e. exploitation of these conditions by man (crop, irrigation, forest clearing, grazing).

The representation of the whole on a single document shows more clearly than a number of description and statistics, the relations between environment and biotic factors.

F. IV 6.
Let us have a brief review of the information made available to us for the analysis of the various factors of this complex.

1. Climate

The method followed in the climate analysis has been explained above with the help of numerical examples (1).

The geographical density of the meteorological stations, both principal and secondary, is generally sufficient for a climatic study at one millionth scale.

However these stations are very much scattered in the hilly regions where the natural vegetation shows the maximum of variation. Extrapolation becomes necessary from some well known stations, taking account of the variation of the different factors with altitude, exposure, direction of the rainy winds etc...

The study shows that the zonation of the vegetation in altitude remains more or less constant in the same region. For instance limits between different types of forests are found at similar altitudes on the same side of Western Ghats. These altitudes correspond themselves to variation in the mean temperature and mostly night temperature evolving more abundant condensations at upper altitude than at lower altitude.

Once the analysis of climatic factors has been done for some well known stations, the results may be extended to the whole stage which is covered with the same type of vegetation. We are entitled to do so, for, at last, the vegetation is the integrator of the environmental conditions and in the same region, the same type of forest reveals analogous or identical ecological conditions.

2. Soil

The soil factor does not play a great part in the repartition of broad types of vegetation when studied at one millionth scale.

While being studied at such a scale, the repartition of the main vegetation types is the result of interference of main climatic factors. Only some special soils (laterite, salted soils, marshes, salted muds

(1) cf. Study of xerothermic indexes of India, Burma, Pakistan, and Ceylon, page 191
of mangroves, etc...), have an important action by increasing either conditions of dryness or of humidity; they can also eliminate some non tolerant species. In that case we represent the action of these factors by special symbols (1), or by shifting, of one class more, the value of the affected main climatic factor.

The information regarding the soil distribution in India is, chiefly, the following:

— **Soil Map of India** published by the Indian Agricultural Research Institute; its scale is so small that it is difficult to get an accurate idea of the distribution of the main types of soils;

— **Soil Map of India** joined to the National Atlas of India at 1/5 000 000 scale published in 1957 is more useful.

The study of those maps can be perfected by examination of other maps published by the Agriculture Departments of States of India and by compilation of a number of papers written by Research Workers and giving some detailed studies of composition and structure of certain types of soil.

But, it is necessary to check up all these data while making prospection on the field:

— the nature of the soil is observed and recorded in the botanical "relevé" of the surveyed place;

— the repartition of the main types of soil is given by the Agricultural Officers in charge of the studied division;

— the working-plans give also some very useful information regarding the soils of the forest divisions.

So far as the soils of Ceylon are concerned, we found sufficient information in a paper published in 1955 by A.W.R. JOACHIM with a joined map. (2).

The result of this compilation and of these studies is synthetized and allows us to prepare the pedological inset map at 1/5 000 000 scale which will be joined to the main map, as it has been above precised (3).

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(1) cf. page 173
(2) Cf: The soils of Ceylon by A.W.R. JOACHIM — *Tropical Agriculturist* Vol. CXXI, No. 3, July to September 1955,
(3) cf. page 177
3. The Vegetation

As a first step, an inventory of the actual vegetation is to be undertaken.

Literature giving description of vegetation types is, doubtless, rather important. However it is worth to note that it includes a great proportion of purely floristic studies giving only a secondary importance to the definition of vegetation types. Some of them are pointing out only the presence of such and such species in the surveyed area without giving the least idea of their repartition in connection with altitude, soil... etc...

But the forest working-plans furnish information more suitable to our purpose. Each of them publishes a description of forests in a given division and an appreciation of the economic value of series under management.

On the other hand, though most of the authors refer to Champion's classification, the precisions about the physiognomy of forests are not always sufficient and some confusions may arise. So, it happens that the same type of forest can receive different names according to the different authors. Likewise the same name can designate two different types of forest formation.

Moreover, a part of forests is not submitted to the control of Forest Department. They are private forests and revenue lands which may cover very large areas in the humid part of Kerala and Mysore States, for example. Most of them are over-exploited or are already clearfelled or under clearfelling for cultivation. The study of their composition must be done, for they are not described in the forest working-plans.

Therefore, a prospection of the natural vegetation is absolutely necessary. Firstly, a general survey of the area to be mapped is worked out; so we can get a general view of the main types of forests and of their repartition. After that, a detailed prospection of the forests can be made in close contact with Forest Officers.

During this prospection a special attention is given to the physiognomy of stands, relative proportion of different storeys, percentage of cover of soil. Profiles of vegetation make easier comparison of types of forests.

At the same time, the limits of forests and their location on survey maps are checked up. This work is necessary, specially in the case of private forests. As mentioned above a great deal of them are often completely clearfelled and transformed into fields or estates. Some of them which are still shown on survey maps have totally disappeared.
It is obvious that aerial photographs would be very useful and would enable us to precise the location of these forests without groping. The photographic coverage of Ceylon was made recently and the Forest Department is now finishing to compile the aerial photographs in view of mapping the forest areas. Such a work is very useful for our purpose. But, in India, aerial photographs are not available, except in some parts, close to an irrigation scheme for example.

Therefore, we are obliged to survey the limits of those private forests by ourselves. Generally we roughly indicate them on survey maps at one inch to one mile by linking them up with some topographical landmarks, i.e. roads, ridges of mountains, rivers, etc... After reduction at one millionth scale we can get a sufficient precision.

So, we obtain the maximum possible of information regarding the composition of forests and their location. At this stage of the work we are in possession of the physiognomic description of natural vegetation and of its floristic composition.

As a second step, we try to group these various “relevés” with their profiles, into series of vegetation. We are guided by study of the ecological conditions. If, in a given region where environment is similar, the types A, B, C, D are found, it is legitimate to suppose that A, B, C, D belong to the same series of vegetation. The comparison of the floristic “relevés” enables us to class them the ones in relation to the others, for example in the order of increasing degradation.

In fact, it seems to us that in India, the influence of biotic factors plays the most important part in the regressive evolution of the forests. So the elimination of some species at the benefice of non-grazed species is the result of the over-grazing which often occurs in the plains and low hills. The frequency of the fires maintains the vegetation in a degraded stage. The practice of shifting cultivation can also damage the forests. Therefore it is necessary to have a comprehensive knowledge of all these causes of degradation for being able to understand the evolution of the natural vegetation. That is why an enquiry must be made on the occasion of prospections on the field.

Since a very long time, these biotic factors have played an extremely prominent part in India, this part is increasing rapidly in the present time with that of demographic pressure and the lack of new lands for agriculture. Though they are not present in the ecological formula because they require a special study, (1) the biotic factors are not negligible and we have to take account of them for understanding the series of vegetation.

(1) cf. page 176
4. Agriculture

The available documentation concerning agriculture is chiefly composed of statistics which give the total area covered by each crop generally district wise. Those statistics are published by the State Governments. Maps giving the location of crops at sufficient scale are rare except in the case of Ceylon where a very good “Land Utilization” map at one inch to four miles is available.

Statistics give also the percentages of cultivated areas, forest areas, fallow-lands, uncultivated areas... etc... Such an information is very useful, for it gives an idea of the land use in each district. These percentages will be marked on the map by means of conventional letters at different sizes. They are computed according to the district area, which is itself given in the legend of the map.

We can notice that in certain irrigated zones, there often may be two crops in a year. On the other hand, generally no land is specially assigned to grazing. The livestock, so abundant in India, grazes principally on the fallow lands and on the forests. Very few forests are completely closed to grazing.

The location of various crops is given by the Agriculture Officers in charge of taluks or development blocks. They have a good knowledge of the land utilization in their division and are able to show the limits of areas covered by the various crops on our quarter inch working maps. These investigations are made during the field work by our Research Officers who follow a questionary, a fac simile of which is given in appendix.

So we obtain all the possible information regarding location and importance of various crops. They are recorded on the map by the use of symbols for the main crops or group of crops of the same type: for instance, the various millets are drawn together under a symbol. Each of these symbols represents ten thousand hectares of this crop and is about located at the barycenter of the area concerned. The grouping of these symbols gives a rather good idea of crops cultivated in the various regions.

5. Irrigation

With the help of irrigation, man can change the conditions of environment. The results of his direct action is not only to allow the culture of irrigated crops, i.e. rice, sugar cane... etc... but also to change the vegetation landscape. Therefore it is necessary to represent irrigation on our map. This feature is shown by means of blue colour.
The types of sources of irrigation are: wells, tanks, dams and canals. On a map at one millionth scale, it is quite impossible to give a representation of the wells. But, the location of tanks can be marked on such a map by blue dots, the density of which can give an idea of importance of irrigated area. Those tanks are generally very old; some of them were built many centuries ago. They are shown on the survey maps even if they have not been recently published.

But, so far as the irrigation schemes are concerned which are often new projects, some difficulties arise. They are not represented on the survey maps; therefore it is necessary to obtain certain precisions regarding the laying out of canals which determine the location and the importance of areas irrigated by them.

It is obvious that such irrigation systems continuously working have a deep influence on character and ecology of a region. It is only to cross the boundary of an irrigated area to find the change between the semi-arid region with rainfed crops and xerophile vegetation under scattered palmyra trees (Borassus flabellifer) and the intensively cultivated area with crowded coconut trees (Cocos nucifera). This change appears clearly on the synthetic map by means of the accumulation of symbols and colours separately analysed on the working maps.

THE CARTOGRAPHICAL SYNTHESIS

1. Topographical maps

While carrying on these studies, we must always keep in mind that all the noticed facts are to be represented as exactly as possible on a map. That is why it is necessary to possess sets of topographical maps at various scales so that the least detail gathered on the field may be transferred on a map at suitable scale.

In India and Ceylon, survey maps at one inch to one mile (about 1/63 350) and at one inch to four miles (about 1/253 400) are available. They are our basic working maps and are precise enough for our purpose which is a representation at one millionth scale.

Sometimes some changes may be stated since the date of publication. It is chiefly the case of limits of forests and of irrigation schemes, as it was above written. But this defect is very small considering the good deal of information given by them.

The “Touring officers maps” edited recently in India by State Governments at one inch to four miles are more schematic from topographical point of view but they give generally actual forests limits and some irrigation systems.
The Forest Department has two kinds of maps in appendix to the working-plans: they are key maps at one inch to one mile which assemble the different working circles and stock maps at larger scale or management maps of each circle. Those maps are obviously very useful for they precise the limits of forests, the location of various types and also of plantations.

The back-ground on which is transfered all the information after reduction at suitable scale is the International Aeronauteal Map at one millionth scale.

2. Method

Three phases must be considered:

1°) Preparation of working maps: From the available documentation, some working maps are sketched according to the type of information they are intended for (1):

— administrative divisions.
— maps of forest boundaries (Reserve forests and Private forests)
— agricultural maps
— irrigation maps
— distribution of palmyra trees
— distribution of coconut trees

Those maps are generally made at one inch to one mile or one inch to four miles scales:

2°) Field work: All the facts noticed on the field are precised and located on the working maps. Complementary information, like lists of species, profiles of vegetation, agricultural practices, rotation of crops... etc... are recorded on tour reports with reference to working maps.

3°) The Cartographical synthesis properly so called brings together all the possible information gathered during the field work and from the working maps. It is made at one inch to four miles in taking account with details of the topographical features. Imprecisions in the documentation collected at one inch to one mile will be reduced and corrected when possible during this synthesis at one inch to four miles.

(1) Such a list is not limiting.
That is from this basic map that the definitive sketch map at one millionth scale is drawn. It is obvious that such a method enables us to get a sufficient precision. The impression of the coloured map deals with technical problems which are out of the frame of this article.

CONCLUSION

We tried to explain briefly the method which has been followed till now for collection of available documentation and its use for establishment of the International Map of the Vegetation.

It seems evident that realization of such a map within reasonable time and with sufficient precision could be only the result of a team work of a good deal of research workers and technical services putting in common their experience and their documentation. It would be too long to give a complete list of scientists who have collaborated to this scheme, sometimes unknown to them. But we are pleased to state the cooperation of such services as Forest Departments, Botanical Survey, Agriculture Department, Public Works Department. The indispensable documentation was also supplied by Survey of India, Survey of Ceylon, Geological Survey, Indian Society of Soil Science... etc...

It is possible to hope that the shortly expected publication of the first sheet of Southern India will raise interest for these ecological and economical improvement studies.
We are interested in the following information:

1. What are the main crops in the taluk?

2. Their distribution if possible with rough delimitation on the maps which will be supplied by us:

3. What is the source of water for the main crops, i.e. rainfed, tanks, wells, canals?

4. Any rotation with the main crop?

5. If so, nature of rotation:

6. Is the main crop the same every year or does it change according to the available water after rainy season?

7. Are there unarable land and, if so, their location?

8. Are there fallow lands and, if so, their location?

9. Nature of the soil in the various parts with location of main types:

10. Latest statistical figures may be given for the various crops:

11. Location of tea, coffee, sugar-cane, etc ...

12. Location of irrigated areas by canals.

We would be highly obliged if all the demonstrators of taluks or development-blocks can help us to give the above information on our maps at one inch to one mile.

The Director.
TYPES BIOCLIMATIQUES DU SUD-EST ASIATIQUE

par F. BAGNOULS et V. M. MEHER HOMJI
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Au 4ème Congrès forestier international de Dehra-Dun en 1954, GAUSSEN exposant ses idées sur une nouvelle méthode de classification des bioclimats, a insisté sur l'idée que, en climatologie, la répartition des températures et des précipitations pendant l'année a bien plus d'importance que leur moyenne annuelle. À l'échelle mondiale les moyennes annuelles ont une importance secondaire et les formules climatiques qui les utilisent ne sont applicables que dans une seule région climatique. Dans une région la formule donne plus d'importance à un facteur principal et si en changeant de région le facteur principal change, la formule n'est plus valable. Il en découle la nécessité de définir autrement que par des formules les régions climatiques. Partant de ce point de vue GAUSSEN (1955 b) développa la classification des climats biologiques. En 1957 la méthode fut appliquée à l'étude du bioclimat (BAGNOULS et GAUSSEN 1957).

Cette classification est basée sur le "rythme" de la température et des précipitations au cours de l'année. Elle tient compte essentiellement des états favorables ou défavorables à la végétation, c'est-à-dire les périodes chaudes, les périodes froides, les périodes sèches, les périodes humides.

Donnons la définition de certains termes :

CONVENTIONS ET DÉFINITIONS

Mois chaud : Un mois où la température moyenne est supérieure à 20° C. Il n'y a pas de risque de gel pendant les mois chauds. Ce risque est très faible si la température moyenne du mois se situe entre 15° et 20° C. Il existe pour les températures inférieures à 15° C.
Période chaude : La suite successive des mois chauds.

Mois froid : Un mois où la température moyenne est inférieure à 0° C. Pendant le gel les précipitations n’ont pas d’utilité directe pour la plante donc un mois froid a le même effet sur la végétation qu’un mois sec.

Période froide : La suite successive des mois froids.

Mois sec : Un mois où le total des précipitations exprimé en millimètres est égal ou inférieur au double de la température moyenne exprimée en degrés centigrades : \( P < 2T \).

Cette relation a été établie en considérant les travaux d’écologie végétale faits par de nombreux auteurs dans les différentes parties du monde où se manifeste une période sèche.

Période sèche : La suite successive des mois secs.

Diagramme ombrothermique : Sur un même graphique on porte : en abscisses les mois de l’année, en ordonnées à droite l’échelle des précipitations en mm, à gauche les températures en degrés centigrades à une échelle double de celle des précipitations. Sur nos diagrammes la courbe des précipitations est en trait plein, celle des températures en tireté. Lorsque la courbe des précipitations \( (\text{ombrique}) \) (1) passe sous la courbe des températures \( (\text{thermique}) \) on a \( P < 2T \). La surface de croisement indique la durée et, dans une certaine mesure, l’intensité de la période sèche. Un tel graphique est appelé diagramme ombrothermique.

Afin de rendre ces diagrammes comparables entre eux, la même longueur a été prise pour représenter un mois, 10° C et 20 mm de précipitation.

Sur la base de ces conventions et définitions il est possible de définir douze régions climatiques.

**DOCUMENTATION EMPLOYEE**

Les documents météorologiques pour les deux cent douze stations de l’Inde, Pakistan, Birmanie et Ceylan proviennent des “Climatological tables of Observatories in India”.


(1) du grec ombros = pluie
Ceux concernant l'Iran sont empruntés à Baghéri et Bagnoûls (1956).

Les stations météorologiques sont bien réparties sur la péninsule indienne et les pays voisins, mais pour les régions de l'Himalaya et de la Birmanie, nous n'avons que des stations rares et éloignées les unes des autres.

**LA CLASSIFICATION**

Résumons la classification bioclimatique qui est essentiellement basée sur les diagrammes ombrothermiques. D’après les courbes de température on distingue trois types principaux. Ce sont :

I. — Climats chauds et tempérés chauds. La courbe thermique est toujours positive.

II. — Climats froids et tempérés froids. La courbe thermique est négative à certains moments de l’année.

III. — Climat glacial. La courbe thermique est toujours négative.

Dans les régions climatiques, nous distinguons plusieurs modalités qui permettent de caractériser les sous-régions climatiques. D’après :

— la durée et l’intensité de la période sèche ;
— la durée et l’intensité de la période froide ;
— des valeurs caractéristiques de la température ;
— le régime de la température
— le régime des précipitations.
Régions et sous-régions climatiques

1. *Climats chauds et tempérés chauds*: La courbe thermique est toujours positive.

<table>
<thead>
<tr>
<th>REGION</th>
<th>SOUS-REGION</th>
<th>MODALITE</th>
<th>DENOMINATION ABREUGEE</th>
<th>NOMBRE DE MOIS SECS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>vrai désert à tendance méditerranéenne à tendance tropicale caractère atténué</td>
<td>La pluie peut ne pas tomber tous les ans Pluie pendant les jours courts Pluie pendant les jours longs Pluies sans rythme saisonnier</td>
<td>1 a 1 b 1 c 1 d</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>à tendance méditerranéenne à tendance tropicale caractère atténué</td>
<td>Jours longs secs Jours courts secs Sans rythme saisonnier</td>
<td>2 a 2 b 2 c</td>
<td>9 à 11</td>
</tr>
<tr>
<td>3</td>
<td>xérothermoméditerranéen thermoméditerranéen méditerranéen subméditerranéen</td>
<td>Caractère accentué Caractère moyen Caractère atténué Caractère transitional</td>
<td>3 a 3 b 3 c 3 d</td>
<td>7 à 8 5 à 6 3 à 4 1 à 2</td>
</tr>
<tr>
<td>4</td>
<td>Thermoxérochimérique Mésoxérochimérique Thermoxérochimérique Mésoxérochimérique Thermoxérochimérique Mésoxérochimérique Subthermaxérique Submésaxérique</td>
<td>Température du mois le plus froid &gt; 15°C Température du mois le plus froid &lt; 15°C Température du mois le plus froid &gt; 15°C Température du mois le plus froid &lt; 15°C Température du mois le plus froid &gt; 15°C Température du mois le plus froid &lt; 15°C Température du mois le plus froid &gt; 15°C Température du mois le plus froid &lt; 15°C</td>
<td>4 a Th 4 a Mes 4 b Th 4 b Mes 4 c Th 4 c Mes 4 d Th 4 d Mes</td>
<td>7 à 8 5 à 6 3 à 4 1 à 2</td>
</tr>
</tbody>
</table>
ERRATUM :
— page 211, 7ème colonne, 11ème et 12ème lignes : à la place de "caractère accentué" lire "caractère atténué".

<table>
<thead>
<tr>
<th>MODALITÉ</th>
<th>SOUS-RÉGION</th>
<th>REGION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bixérique-équatorial (subdesertique)</td>
<td>5 a</td>
</tr>
<tr>
<td></td>
<td>Thermobixérique</td>
<td>5 b</td>
</tr>
<tr>
<td></td>
<td>Mesobixérique</td>
<td>5 c</td>
</tr>
<tr>
<td></td>
<td>Subthermobixérique</td>
<td>5 d</td>
</tr>
<tr>
<td></td>
<td>Bixérique</td>
<td>5 e</td>
</tr>
<tr>
<td></td>
<td>Thermobixérique</td>
<td>5 f</td>
</tr>
<tr>
<td></td>
<td>Mesobixérique</td>
<td>5 g</td>
</tr>
<tr>
<td></td>
<td>Subthermobixérique</td>
<td>5 h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DÉSIGNATION ABRÉGÉE</th>
<th>TEMPÉRATURE DU MOIS LE PLUS FROID &gt; 9°C</th>
<th>TEMPÉRATURE DU MOIS LE PLUS FROID COMPR. ENTRE 0 ET 10°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>NON</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 a</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 b</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 c</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 d</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 e</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 f</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 g</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 h</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

| 9 a                  | 0                                     | 0                                                      |
| 9 b                  | 0                                     | 0                                                      |
| 9 c                  | 0                                     | 0                                                      |
| 9 d                  | 0                                     | 0                                                      |
| 9 e                  | 0                                     | 0                                                      |
| 9 f                  | 0                                     | 0                                                      |
| 9 g                  | 0                                     | 0                                                      |
| 9 h                  | 0                                     | 0                                                      |

L'ensemble des 2 pêches séchées est supérieure à 8 mois.

Temperatura do mois le plus frioz (le) temperatura do mois le plus frioz compr. entre 0 e 10°C.
II. **Climats froids et tempérés froids**

La courbe thermique prend des valeurs négatives à certains moments de l'année.

<table>
<thead>
<tr>
<th>REGION</th>
<th>SOUS-REGIONS</th>
<th>MODALITÉ</th>
<th>DENOMINATION ABRÉGÉE</th>
<th>TOTAL MOISSECS + MOIS DE GEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Erémique</td>
<td>Il peut ne pas y avoir des précipitations tous les ans</td>
<td>8 a</td>
<td>11 ou 12</td>
</tr>
<tr>
<td>(Désert froid)</td>
<td>Vrai désert</td>
<td>Il n'y a pas de neige accumulée</td>
<td>8 b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Désert</td>
<td>Il y a un peu de neige accumulée</td>
<td>8 c</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Hémiréhumique</td>
<td>Une seule modalité</td>
<td>9</td>
<td>9 ou 10</td>
</tr>
<tr>
<td>(Subdésert froid)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Xérothermique froid</td>
<td>Caractère accentué</td>
<td>10 a</td>
<td>7 à 8</td>
</tr>
<tr>
<td>Jours longs secs</td>
<td>Oroxérophère</td>
<td>Caractère moyen</td>
<td>10 b</td>
<td>5 à 6</td>
</tr>
<tr>
<td></td>
<td>Subméditerranéen</td>
<td>Caractère atténué</td>
<td>10 c</td>
<td>3 à 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transition avec le xérothermique chaud</td>
<td>10 d</td>
<td>1 à 2</td>
</tr>
<tr>
<td>11</td>
<td>Très froid</td>
<td>Plus de 8 mois de gel</td>
<td>11 a</td>
<td></td>
</tr>
<tr>
<td>Axérique</td>
<td>Froid</td>
<td>De 7 à 8 mois de gel</td>
<td>11 b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moyennement froid</td>
<td>De 4 à 6 mois de gel</td>
<td>11 c</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tempéré froid</td>
<td>Moins de 4 mois de gel</td>
<td>11 d</td>
<td></td>
</tr>
</tbody>
</table>

III. **Climat glacial**

La courbe thermique est toujours négative

| 12 | Cryomérique | La période froide dure toute l'année | 12 | 12 mois de gel |
Enfin pour un travail à grande échelle, on peut diviser les sous-régions en secteurs climatiques. Ces secteurs dans une même région climatique sont déterminés par la quantité totale de pluie tombant pendant la période humide, la moyenne des minima et des maxima de la température, la période très sèche avec la relation $P < T$, ou la période "sub-sèche" ($2T < P < 3T$).

Le but du présent travail est d'établir une carte à petite échelle des bioclimats de l'Inde et des régions voisines. Pour chaque type de bioclimat un diagramme ombrothermique est établi (1). Les limites, les sub-divisions et la végétation de chaque bioclimat sont expliquées dans le texte.

Un coup d'œil sur la carte montre que la péninsule indienne possède pratiquement tous les types bioclimatiques.

Dans notre étude des différents climats nous commencerons par les types les plus secs pour passer aux plus humides. Ensuite nous verrons les climats froid et glacial.

I. — CLIMAT CHAUD ET TEMPERE CHAUD (courbe thermique toujours positive)

1. CLIMAT ÉRÉMIQUE ( désertique chaud ) : 12 mois secs.

On peut voir sur la carte que les régions désertiques occupent une place importante comprenant le Thar en Inde et le Sind au Pakistan. À côté de cette zone importante, on peut distinguer trois petites régions de climat désertique : une à l'angle nord-ouest, l'autre à l'angle ouest du Pakistan et une dans la vallée de Gilgit, près de Srinagar.

Une particularité de ce climat désertique est sa tendance tropicale (pluie en jours longs), modalité "c", sauf dans le coin nord-ouest du Pakistan où il est de type irrégulier (pluies sans rythme saisonnier défini), modalité "d". Les diagrammes ombrothermiques de Jacobabad (fig. 1) et de Panigur (fig. 2) illustrent respectivement ces modalités "c" et "d".

Cette partie nord-ouest de la Péninsule se trouve au delà de l'influence de la mousson, laquelle ayant accompli 1.000 miles ou plus au dessus du continent, y arrive complètement sèche.

L'aridité du climat s'ajoutant au sol sableux produit une maigre végétation de type désertique.

(1) Les diagrammes ombrothermiques sont publiés en appendice.

F. IV 8.
2. CLIMAT HÉMI-ÉRÉMİQUE (sub-désertique) : 9 à 11 mois secs.

Entourant la zone du désert central, une zone sub-désertique s'étend vers l'ouest jusqu'au pied des montagnes du Balouchistan et vers le nord jusqu'au pied de l'Himalaya.

Trois nuances dans ce climat :

"a" méditerranéen, "b" tropical, et "c" irrégulier, intermédiaire entre "a" et "b".

Le sous-type "a" méditerranéen à sécheresse de jours longs et pluies d'hiver se rencontre dans le nord-ouest du Pakistan. Le graphique de Dalbandin (fig. 3) en est le diagramme type.

Le sous-type "b" à tendance tropicale couvre la presque totalité du Kutch et du Rajasthan et plus au nord une partie du Punjab occidental. Jodhpur (fig. 4) est pris comme exemple. Il est intéressant de noter que ce sous-type se retrouve dans l'Inde du Sud près de Bellary. La cause probable de l'aridité de Bellary semble être sa situation géographique dans une vallée entre les Ghât occidentaux et orientaux.

Le sous-type "c" avec répartition saisonnière irrégulière des pluies, forme une ceinture de transition entre les deux précédents sous-types. Fort Sandeman (fig. 5) est la représentation graphique de ce climat.

En comparant les trois diagrammes de Dalbandin (fig. 3), Fort Sandeman (fig. 5) et Jodhpur (fig. 4), on peut avoir une idée de la transition entre les tendances à pluie d'hiver et à pluie d'été.

Fort Sandeman montre deux maxima de pluviosité, l'un de janvier à mars, l'autre en juillet-août. Cependant le premier seulement de ces maxima est situé au dessus de la courbe des températures.

Dans l'Inde du Sud on trouve le sous-type "c" à Coimbatore, il peut s'expliquer une fois encore par sa position topographique à l'abri des monts Nilgiri et Annamalai des Ghât occidentaux. En réalité, comme le montre la figure 9, Coimbatore est bixérique, c'est à dire avec deux périodes sèches. Cependant comme la somme des deux périodes sèches dépasse neuf mois, on classe cette station dans la division 2 "c", c'est-à-dire sub-désertique à pluies irrégulières.

La végétation qui pousse dans de telles conditions de sécheresse est toujours une forêt épisteme comme l'indique l'ouvrage de CHAMPION (Forest Types of India and Burma 1936).
3. CLIMAT XÉROTHERIQUE (méditerranéen): 1 à 8 mois secs, jours longs secs.

Dans la partie nord-ouest de la Péninsule le facteur décisif est la chute hivernale des pluies qui proviennent du sud-ouest; combinées avec la température basse elles créent un climat semblable au climat méditerranéen.

Les géographes considèrent que les caractères essentiels du climat méditerranéen sont: un hiver doux qui n’affecte pas la végétation, des pluies de printemps et d’automne, une période sèche en été qui arrête la croissance des plantes herbacées et ralentit la croissance des arbres et arbustes (Gaus sen 1955 a). Cependant les phytogéographes sont en désaccord au sujet de la présence du climat méditerranéen dans la Péninsule indienne.

Grisebach (1884) se basant sur la physionomie de la végétation considère le Balouchistan comme non méditerranéen.

Engler (1899-1919) conclue différemment en partant de considérations floristiques et inclue le Balouchistan dans les limites méditerranéennes.

D’après Eig (1931) la limite orientale de la région méditerranéenne est douteuse. Il se demande si elle s’étend jusqu’à la Perse, l’Afghanistan ou au delà. Il parle aussi d’une région irano-tourannienne aux caractères très voisins de ceux de la région méditerranéenne. Comme différence essentielle entre les deux il note l’absence de forêts climax dans la région irano-tourannienne. Mais là encore la limite orientale de cette nouvelle région est douteuse. “Attein-t-elle la limite ouest de la région sino-japonaise, ou bien la haute Asie à l’Est de l’Afghanistan doit elle être considérée comme une région séparée?”

Le présent travail nous permet, à l’aide de diagrammes ombro-thermiques d’établir la présence du climat méditerranéen sur le subcontinent avec les modalités suivantes: a, b et d. Cette région à climat méditerranéen s’étend sensiblement jusqu’à l’ouest de la vallée de l’Indus.

a) Caractère accentué: Xéothermo-méditerranéen: (7 à 8 mois secs.)

C’est le climat de la région montagneuse du Balouchistan avec Quetta (fig. 6) comme station type. Cependant ici la longue période de sécheresse (7 à 8 mois) explique le type de végétation xérophile. C’est à cause de la grande sécheresse du climat que l’aspect physionomique
du "maquis" méditerranéen n'y apparaît pas. Ainsi Erc ( Loc. Cit.)
distingue l'absence de forêts climax comme caractère différentiel entre
ces régions méditerranéennes et Irano-touraniennes.

D'un point de vue floristique Engler classe cette région comme
méditerranéenne. Parmi les auteurs récents nous pouvons mentionner
Chatterjee (1947) qui reconnaît une origine méditerranéenne orientale
to 10% de la flore indienne. En conséquence il est très probable que le
coin du Balouchistan servent de tremplin aux éléments méditerranéens et
favorise leur pénétration.

A l'appui de la thèse de la dominance du climat méditerranéen
dans cette région nous pouvons citer Hardy (1920), parlant des états
himalayens du nord-ouest: "Dans la région du district de l'Indus, le
climat est nettement sec et la végétation aux basses et moyennes altitudes,
prend un aspect méditerranéen avec des arbres trapus, à feuilles
persistantes et coriaces, à cimes arrondies. Beaucoup de pentes sont soit
complètement dénudées soit parsemées d'une formation buissonnante à
feuilles persistantes équivalent à la "garrigue" méditerranéenne. Le
district est extrêmement favorable à la culture du maïs et du blé". Il est
remarquable de constater que le diagramme ombrothermique de
Quetta est semblable à celui de Techachapi (Sierra Nevada, Californie).

b) **Caractère moyen : Thermo-méditerranéen :** (5 ou 6 mois
secs).

Une petite région de ce sous-climat se rencontrent dans la partie
est et dans l'ouest du Pakistan.

Drosh est caractéristique de ce type (fig. 7).

d) **Caractère de transition : Sud-méditerranéen :** (1 ou 2
mois secs).

La vallée de Srinagar est dans ce climat. En fait le diagramme
ombrothermique de Srinagar (fig. 8) montre trois périodes de sécheresse:
une en juin, l'autre en septembre et la troisième en novembre, par
conséquent ce type pourrait se classer dans un nouveau bio-climat
"trixérique". Mais comme les périodes sèches de septembre et novem-
bré sont de courte durée, de faible intensité et immédiatement suivies
de mois pluvieux, on peut ne pas les considérer comme sèches. Seule,
la période sèche de juin est de quelque importance et par conséquent
le sous-type est classé comme sub-méditerranéen.
4. CLIMAT XÉROCHIMÉNIQUE (tropical) : (1 à 8 mois secs, jours courts secs).

Th : termo-xérochiménique (température du mois le plus froid supérieur à 15°C).

a) Caractère accentué : (7-8 mois secs).

Ce climat couvre la plus grande partie de la péninsule indienne, depuis l'extrémité de Saurashtra jusqu'à Goa sur la côte ouest, s'étendant sur le plateau Malwa et une partie de la plaine du Gange dans le nord et dans l'est, et sur le plateau du Deccan (Mysore exclu) vers le sud. Le diagramme de Nagpur (fig. 10) est la représentation graphique de ce climat.

Une petite zone de ce climat réapparaît dans l'extrême sud-est de l'Inde où l'influence de la mousson est faible sous la protection des Monts Palni au nord et de Ceylan à l'est. Un climat semblable se rencontre dans la partie nord de Ceylan. Là la végétation est sèche. La forêt épineuse d'Acacia planifrons est confinée à ces régions de l'extrême sud-est de l'Inde et du nord de Ceylan (Hooker 1906).

En ce qui concerne la végétation de la plus grande partie de la péninsule indienne, on peut distinguer plusieurs secteurs d'après la quantité de pluies annuelles ou en considérant le facteur sol. Ainsi, la plaine littorale de l'ouest et les pentes au vent des Ghât occidentaux s'allongent depuis Goa jusqu'à Alibag, recevant environ 2500 mm de pluies, portent des forêts tropicales semi décidues. Le plateau du Deccan situé entre les deux chaines de montagnes, Ghât occidentaux et orientaux, ne reçoit qu'une faible partie des pluies 750 mm ou moins, et porte une forêt épineuse. Le reste de la région à pluies intermédiaires est recouvert de forêts tropicales à feuilles caduques. Parmi ces forêts on peut encore distinguer un faciès à Shorea robusta (Sâl) couvrant la partie Est de cette région. D'après Shimper (1903) la forêt de "Sâl" est supportée par des sols légers riches en silice et graviers, très perméables et elle disparaît lorsque le sol devient compact.

b) Caractère moyen : (5 à 6 mois secs)

Dans l'Inde du Sud ce climat couvre une région comprise entre Goa et Calicut.

Plus à l'est, cette région se continue le long de la côte orientale envoyant des digitations à l'intérieur de la région "a" précédente à caractère accentué. Ces digitations sont situées soit le long des régions montagneuses des Ghât occidentaux, soit le long des vallées du plateau entaillé par les rivières Godavéry et Mahanadi. Ainsi dans la région sèche, à caractère accentué (7-8 mois secs), la période sèche est atténuée à 5-6 mois, soit par les hautes montagnes, soit par les vallées des rivières de la côte orientale.
Encore plus à l’est ce climat s’étend en une large bande couvrant en partie l’Orissa, le Bihar, le Bengale et le Pakistan oriental. Elle occupe aussi les basses terres de Birmanie, la Thaïlande presque entièrement et une partie de l’Indochine.

Le diagramme de Calcutta (fig. 11) est un exemple typique de ce climat. D’autre part, le diagramme de Madras (fig. 12) représente un cas un peu différent valable pour la côte sud-est depuis Nellore jusqu’à Negapatam. Cette plaine côtière et sabloise de Coromandel est sous l’influence non seulement de la pleine mousson du sud-ouest de juillet à septembre mais aussi de la mousson décroissante du sud-ouest et de la mousson du nord-est d’octobre à décembre. Ce qui donne à Madras un diagramme d’un type particulier.

Les types de végétation de ce climat varient aussi suivant les secteurs. La côte occidentale à fortes pluies possède une forêt humide décidue, la côte de Coromandel au régime pluviométrique particulier, a une forêt de type plus sec. La région orientale commençant à l’embouchure de la Krishna et s’étendant vers le Bengale coïncide avec le type de forêt tropicale semi décidue de CHAMPION.

Les conditions édaphiques déterminent la “mangrove” de Sundariband près de Calcutta et de Masulipatam.

c) Caractère atténué: (3 à 4 mois secs).

Ce sous-type apparaît dans le sud-ouest de la péninsule avec Cochin (fig. 13) comme station type. On le rencontre aussi au pied de l’Himalaya oriental, à Ceylan, en Assam et surtout en Birmanie et Indochine. Il se trouve aussi dans les montagnes de la région “b” précédente à caractère moyen (5 à 6 mois secs).

La végétation est soit sempervirente ou semi décidue comme dans le sud ouest de l’Inde où la mousson est très marquée, soit d’un type plus clair de forêt tropicale humide, à feuilles caduques, à Shorea robusta (Sâl) comme aux pieds de l’Himalaya.

Un exemple intéressant de diagramme ombro-thermique apparemment de type méditerranéen, dû à l’irrégularité des pluies, est donné par Batticaloa (Ceylan) (fig. 14). Cependant dans ce cas, bien que les jours longs soient secs, la température du mois le plus froid est supérieure à 20° C. Par conséquent cette station ne peut pas être classée comme méditerranéenne, d’ailleurs sa végétation est du type tropical. Cette anomalie provient de l’irrégularité des pluies ainsi que nous allons le montrer.

Examinons les diagrammes de Diyatalawa (Ceylan) et Batticaloa (fig. 15 et 14). Dans le premier nous trouvons deux minima de pluies. L’un en février, l’autre en juin-juillet. Cependant (d’après la
convention d'échelle \( P = 2T \) la courbe de pluie reste au dessus de la courbe de température, et il n'y a pas de sécheresse. Mais si nous suivons la convention \( P = 3T \) en essayant d'introduire une période de sub-sécheresse nous faisons apparaître une période légèrement sèche en juin-juillet. La ligne en pointillé représente la courbe des précipitations à une échelle triple de celle des températures. On trouve alors que la période de sub-sécheresse se situe en jours longs. Si nous examinons maintenant le diagramme de Batticaloa, nous retrouvons une période sèche pendant les jours longs. Ici les conditions sont bien plus sèches qu'à Diyalatalawa les deux minima ont disparu et se sont combinés pour produire une seule période sèche en jours longs. Ces conditions ne doivent pas être confondues avec le type méditerranéen, car la température est toujours supérieure à 20° C et la végétation est véritablement tropicale.

d) Climat de transition: Sub-thermaxérique: (1 – 2 mois secs).

On peut aussi appeler ce climat sub-équatorial, car on le trouve au voisinage du climat équatorial. Il se rencontre à Ceylan dans la partie centrale, en Indochine le long de la côte orientale, à l'extrémité méridionale de la Birmanie et en Malaisie.

Dalat (Indochine) en est la station type (fig. 16). Comme la sécheresse ne dure que un à deux mois seulement, elle n'affecte pas la végétation. Cette végétation est donc une forêt dense tropicale humide.

Mes. Mésoxérochiménique: (Température du mois le plus froid inférieure à 15° C).

C'est le climat des montagnes de moyenne altitude.

a) Caractère accentué: (7 – 8 mois secs).

Ce sous-type se rencontre dans l'Inde centrale dans la haute plaine du Gange avec deux digitations dans le sub-désert le long des vallées de la rivière Jumna. Aligarh (fig. 17) représente graphiquement ce climat.

Des flots de ce sous-type apparaissent aussi dans les montagnes de moyenne altitude tels que le Mont Abu dans la chaîne des Aravallis et le Pachmarhi.

b) Caractère moyen: (5 – 6 mois secs).

C'est le climat de la région du Kwangtung (Chine) ou se trouve la forêt sub-tropicale.
C'est essentiellement un climat de montagne et par suite on le rencontre dans les Nilghiris, les Himalayas et la région montagneuse de Birmanie et de l'Indochine. La fig. 18 de Shillong est un exemple de ce type.

Tandis que dans les Nilghiris et en Birmanie la végétation est de type sub-tropical humide de CHAMPION (1936) le long de l'Himalaya jusqu'à environ 4000 m, limite de cette zone, nous pouvons distinguer avec Hooker (1906), Schimper (1903) et Hardy (1920) une bande de forêt feuillue décidue tempérée suivie par un étage de conifères et rhododendrons.

Il est intéressant de noter que dans un climat analogue des hautes montagnes de l'Afrique du Sud, Bagnouls (1958) a trouvé deux étages semblables : une de forêt dense et humide pris, en altitude, une forêt sèche de montagne.

5. CLIMAT BIXÉRIQUE

Th: Thermo-bixérique (température du mois le plus froid supérieure à 15° C).

a) Caractère accentué (7-8 mois secs).

b) Caractère moyen (5-6 mois secs)

Madura et Trichinopoly dans le sud de l'Inde (fig. 19-20) sont les représentations respectives de ces sous-types "a" et "b". Leurs diagrammes ombro-thermiques montrent deux périodes sèches et deux périodes humides. Mais l'une des saisons humides est si courte et immédiatement suivie d'une période sèche qu'elle apparaît sans signification. Le résultat est que la végétation de ces stations est semblable à celle des régions voisines, à savoir une forêt sèche à feuilles caduques.

Mes: Climat mésobixérique (température du mois le plus froid inférieure à 15°).

Avec des périodes humides distinctes et deux périodes sèches prononcées, ce sont les climats de la partie nord et de la partie nord-ouest de la péninsule. Ces régions sont affectées à la fois par les pluies d'hiver du nord-est et par la mousson du sud-ouest. On distingue trois modalités de ce type.

(1) L'étude détaillée d'un climat bixérique doit, évidemment, tenir compte de la durée et de l'intensité respectives des deux périodes sèches et du temps qui sépare ces deux périodes. Cela a une grande importance biologique.
a) Caractère accentué: (7 – 8 mois secs).

Ce caractère se rencontre en deux petites régions en bordure du semi-désert. Patiala (fig. 21) est une station typique. Du fait de la proximité de la région sub-désertique, la forêt épincée est le caractère dominant du paysage.

b) Caractère moyen: (5 – 6 mois secs).

Cette modalité est la plus étendue, dans la région de Patiala et les états du Punjab oriental, ainsi qu'à la base de l'Himalaya oriental.

Le diagramme d'Ambala (fig. 22) est typique. La forêt décidue domine dans la première de ces régions tandis qu'une formation sub-tropicale sempervirente humide couvre une zone s'étendant le long de l'Himalaya jusqu'à 2100 mètres d'altitude (HAREY 1920).

c) Caractère atténué: (3 – 4 mois secs).

Il se rencontre dans la partie supérieure de la plaine de l'Indus. Représenté par la station de Rawalpindi (fig. 23).

Les pluies d'hiver de décembre à février rendent possible la culture du blé et de l'orge dans la partie sud-ouest du Punjab (MILLER 1944).

6. CLIMAT THERMAXÉRIQUE (sans période sèche).

On peut aussi l'appeler climat équatorial. Nous y reconnaissions deux modalités.

Euthermaxérique (température du mois le plus froid supérieure à 20° C).

Hypothermaxérique (température du mois le plus froid comprise entre 15 et 20° C).

Dans le premier cas, il s'agit du climat de la forêt tropicale, dense, humide des plaines et des basses altitudes de Ceylan et de Malaisie. Le graphique de Colombo en est un exemple (fig. 24).

Le second cas est favorable à la forêt dense sempervirente des montagnes d'altitude modérée (en dessous de 2000 m près de l'équateur) comme le sont les montagnes de Ceylan. Un exemple en est Diyatalawa (fig. 15).
7. CLIMAT MÉSAXÉRIQUE (pas de saison sèche).

Eumésaxérique (la température du mois le plus froid se situe entre 10 et 15° C).

Dans l'Inde intertropicale, les sommets des Nilghiris et des Palni Hills ainsi qu'en Birmanie le Lai-Ling près de Mandalay portent une végétation humide et sont sous l'influence de ce climat. Kodaikanal (fig. 25) représente graphiquement ce type.

Il est possible que ce climat existe aussi dans la partie orientale de l'Himalaya, mais le manque d'informations météorologiques ne nous permet pas de le situer.

Hypomésaxérique (température du mois le plus froid comprise entre 0 et 10° C).

On trouve ce climat en Chine centrale et septentrionale. La végétation est un mélange de conifères et d'arbres décidus à période active estivale comme les types de Mongolie à chênes et hêtres.

Il est probable que ce climat se rencontre aussi en quelques endroits dans l'Himalaya.

II.—CLIMATS FROID ET TEMPERE FROID (la courbe de température est négative pendant une partie de l'année).

8. CLIMAT ÉRÉMIQUE (désertique froid, le total des mois froids et des mois secs est de onze ou douze).

Ce type est le plus courant dans l'Himalaya occidental et le plateau du Pamir qu'il borde. La sécheresse a deux origines ici : l'une due à la température en dessous de 0° C inhibant l'absorption de l'eau par les racines et l'autre est due aux mois secs.

Examinons le diagramme n° 26 de Leh. Nous y trouvons des températures négatives pendant cinq mois (novembre à mars) suivis par une période sèche de sept mois (avril à octobre) avec des températures positives. Dans un cas semblable il est nécessaire de considérer que les précipitations pendant l'hiver se font sous forme de neige. Si ces précipitations sont suffisantes, et si les vents sont modérés, la neige s'accumulera et fondra au début du printemps. Pendant cette période de fonte il y a une humidité abondante favorable à la végétation. Cet effet de la fonte de neige, qui est capable de réduire l'effet de la sécheresse au début de la saison sèche, est mis en évidence par la ligne en pointillé sur le diagramme. En conséquence nous ne considérerons pas le mois d'avril comme sec.
Dans le cas du climat désertique froid de l’Himalaya il y a des chances pour que la neige puisse s’accumuler, nous le classerons dans la modalité “c”.

9. CLIMAT HÉMI-ÉRÉMIQUE (sub-désertique froid) (le total des mois froids et des mois secs est de neuf ou dix).

Le climat des vallées de l’Himalaya occidental est de ce type.

Le graphique de Kargil (fig. 27) montre une période froide s’étendant de novembre à mars et une saison sèche de mai à octobre. Par la compensation dûe à la fonte des neiges, nous pouvons considérer mai et juin comme humides.

Dans cette région la végétation est de type tempéré sec.

10. CLIMAT XÉROTHÉRIQUE FROID


11. CLIMAT AXÉRIQUE FROID (pas de période sèche).

Ce climat se rencontre dans l’Himalaya entre 4000 et 5500 mètres. Comme il n’existe pas de stations météorologiques dans cette zone, nous avons extrapolé à partir des stations de plus basses altitudes comme par exemple Darjeeling (2266 m) à l’extrémité orientale, et Simla (2203 m) à l’extrémité occidentale, en utilisant un gradient conventionnel de température de 0°C par 200 mètres d’altitude. Ainsi la période sèche de un ou deux mois de Darjeeling et Simla disparaît quand on s’élève en altitude.

Cette zone correspond à une végétation alpine. En l’absence de documents météorologiques nous ne pouvons préciser les modalités de ce climat.

III. — CLIMAT GLACIAL (la courbe de température est négative toute l’année).

12. CLIMAT CROMÉRIQUE (la période froide s’étend sur 12 mois).

C’est le cas des sommets de l’Himalaya au dessus de 5500 mètres, porteurs de neiges éternelles.
CONCLUSION

Le but du présent travail est de démontrer que la méthode des diagrammes ombro-thermiques nous permet de caractériser très clairement chaque type de climat, et la classification nous permet de délimiter aisément les différents bio-climats, eux mêmes déterminant la végétation.

Le Laboratoire de Botanique de l'Université de Toulouse (France) a étudié par cette méthode une grande partie du monde et les résultats obtenus sont très satisfaisants.

C'est pour répondre au vœu du Professeur Gaussen que chaque pays établisse une carte bio-climatique précise de son territoire, que ce travail sur l'Inde a été entrepris.

Cette carte contient des erreurs inévitables dues au manque de renseignements météorologiques suffisants ainsi qu'il a été souligné plus haut. Quoiqu'il en soit la carte marque un premier pas vers la détermination des bio-climats de l'Inde. Ayant groupé les différentes régions de la péninsule dans le cadre d'une classification climatique facilement applicable au reste du monde, la recherche des climats analogues se trouve facilitée. L'un des objectifs essentiels de la climatologie appliquée est de mettre en évidence les climats analogues du monde. La connaissance des bio-climats d'un pays et de leurs types homologues à travers le monde est de première importance pour l'économie de ce pays pour effectuer des échanges d'espèces économiquement importantes. Un pays tel que l'Inde possédant une très large gamme de bio-climats, offre d'amples possibilités d'amélioration de sa flore par des échanges d'espèces indigènes de valeur économique entre ses différentes régions analogues ou par l'introduction d'exotiques dans les bio-climats qui leur conviennent.

Par exemple un problème important est celui de la fixation des dunes mobiles du desert indien. Les efforts jusqu'alors ont été peu couronnés du succès. Le type de phyto-amélioration qui a été poursuivi dans les déserts sableux de l'Asie centrale et du Kazakhstan (Petrov 1957) est très démonstratif. Connaissant les relations bio-climatiques existant entre ces déserts et les déserts indiens, on peut adopter un programme analogue et même employer les mêmes espèces de plantes pour l'amélioration du Thar.

Des recherches dans cette voie sont poursuivies à la Faculté des Sciences de Toulouse et une étude de la corrélation entre les types de végétation de l'Inde et leurs facteurs écologiques ainsi que l'établissement des formules écologiques fera l'objet d'un article dans une communication ultérieure.
REMERCIEMENTS

Nous remercions M. LeGris, Directeur de la Section Scientifique de l'Institut Français de Pondichéry, pour les conseils qu'il nous a prodigués et l'aide matérielle qu'il nous a donnée, notamment en nous donnant la documentation météorologique et écologique et en faisant la traduction de ce travail. Nous remercions aussi M. Rinaldo qui s'est chargé de dessiner la carte et les graphiques.

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BIOCLIMATIC TYPES OF SOUTH-EAST ASIA

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Faculté des Sciences, Toulouse

At the World Forestry Congress held at Dehra Dun in 1954, GAUSSEN in exposing his new method of bioclimatic classification had emphasized the idea that in climatology the distribution of the temperature and the precipitation during the course of a year had a far greater importance than the mean annuals. On a worldwide scale, the mean annuals have only a secondary influence and the climatic formulae and coefficients which make use of them are applicable only in one climatic region. In a region the formula gives importance to one principal factor, if in changing the region the principal factor is also changed, the formula is no longer valid. From this arose the necessity to define a "climatic region". With this point in view, GAUSSEN (1955b) evolved the classification of biological climates. In 1957, the method in its final form was applied to the study of the bioclimates (BAGNOULS and GAUSSEN 1957).

This classification is based on the rhythm of the temperature and the precipitation in the course of the year. It essentially takes into consideration the periods that are favourable and unfavourable to the vegetation i.e. the hot and the cold periods, the dry and the wet periods.

Below we shall describe certain terms.

CONVENTIONS AND DEFINITIONS

Hot month: A month whose mean temperature is above 20° C. There is no risk of frost during the hot month. The risk is feeble if the mean temperature lies between 15 and 20° C. It exists for temperature below 15° C.
Hot period: The period of the successive hot months.

Cold month: Month whose mean temperature is below 0° C. Below freezing, precipitation is of no direct use to the plant and as such its effect on vegetation is the same as that of a dry month.

Cold period: The period of the successive cold months.

Dry month: A dry month is that whose monthly total of precipitation expressed in millimeters is equal to or less than twice the mean monthly temperature expressed in degree centigrade: \( P < 2T \).

This relation is established by considering the ecological works of number of authors in different parts of the world, where a dry period manifests.

Dry period: Period constituted by the successive dry months.

Ombrothermic diagram: On a graph are marked:

— on abscissa the month of the year.

— on ordinates, to the right the scale of precipitation in millimeters, to the left the temperature in °C at a scale double than that of the precipitation. The curve of precipitation is shown in full line, that of the temperature in broken line. When the precipitation (ombro) curve passes under the temperature (thermic) curve one has \( P < 2T \). The surface of crossing then indicates the duration and upto certain extent the intensity of the dry period. Such a graph is called ombro-thermic diagram.

For rendering these diagrams comparable between themselves, we have marked on the graph the same length for representing one month, 10° C and 20 mm of precipitation.

Based on these conventions and definitions it is easy to define the twelve climatic regions.

**DATA EMPLOYED**

The meteorological data for the 246 stations of India Pakistan, Burma and Ceylon are taken from "Climatological Tables of Observatories in India".

For Indo-China and Thailand the data used are from "Annales des Services Meteorologiques de la France d'Outre-Mer" and "World weather records of Smithsonian Collections".
The part of Iran is shown after Bagheri and Bagnouls (1956).

If the meteorological stations are well distributed throughout the Indian sub-continent and the neighbouring countries, for the region of Himalaya and Burma we have only a few widely separated stations.

**THE CLASSIFICATION**

Below, we may point out a résumé of the Bioclimatic Classification, which is essentially based on the Ombrothermic diagram. Three main types are distinguished according to the curve of temperature. These are:

I. — Hot and Temperate Hot climate. The temperature curve is always positive (above 0° C.).

II. — Cold and Temperate cold climates. The temperature curve takes negative value (below 0° C.) during certain time of the year.

III. — Glacial climate. The temperature curve is always negative.

In this main division the regions and the sub-regions are further formed according to:

- the duration and the intensity of the dry period
- the duration and the intensity of the cold period
- the characteristic values of the temperature
- the regime of the temperature
- the regime of the precipitation
Table of climatic regions and sub-regions

I. *Hot and temperate hot climates.* Temperature curve is always positive.

<table>
<thead>
<tr>
<th>REGION</th>
<th>SUB-REGION</th>
<th>MODALITY</th>
<th>BRIEF DENOMINATION</th>
<th>NUMBER OF DRY MONTHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>True desert</td>
<td>The rain may not fall every year</td>
<td>1 a</td>
<td>12</td>
</tr>
<tr>
<td>Eremic</td>
<td>With Mediterranean tendency</td>
<td>Rain during short days</td>
<td>1 b</td>
<td></td>
</tr>
<tr>
<td>(Hot desert)</td>
<td>With Tropical tendency</td>
<td>Rain during long days</td>
<td>1 c</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Attenuated character</td>
<td>Rain without seasonal rhythm</td>
<td>1 d</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>With Mediterranean tendency</td>
<td>Long days dry</td>
<td>2 a</td>
<td>9 to 11</td>
</tr>
<tr>
<td>Hemieremic</td>
<td>With Tropical tendency</td>
<td>Short days dry</td>
<td>2 b</td>
<td></td>
</tr>
<tr>
<td>(Hot subdesertic)</td>
<td>Attenuated character</td>
<td>Without seasonal rhythm</td>
<td>2 c</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Xerothermomediterranean</td>
<td>Accentuated character</td>
<td>3 a</td>
<td>7 to 8</td>
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<tr>
<td>Xerotheric</td>
<td>Thermomediterranean</td>
<td>Moderate character</td>
<td>3 b</td>
<td>5 to 6</td>
</tr>
<tr>
<td>Long days dry</td>
<td>Mesomediterranean</td>
<td>Attenuated character</td>
<td>3 c</td>
<td>3 to 4</td>
</tr>
<tr>
<td>(Mediterranean)</td>
<td>Submediterranean</td>
<td>Transitional character</td>
<td>3 d</td>
<td>1 to 2</td>
</tr>
<tr>
<td>4</td>
<td>Thermoxerochimic</td>
<td>Temperature of the coldest month $&gt; 15^\circ$ C</td>
<td>4 a Th</td>
<td>7 to 8</td>
</tr>
<tr>
<td>Xerochimic</td>
<td>Mesoxerochimic</td>
<td>Temperature of the coldest month $&lt; 15^\circ$ C</td>
<td>4 a Mes</td>
<td></td>
</tr>
<tr>
<td>Short days dry</td>
<td>Thermoxerochimic</td>
<td>Temperature of the coldest month $&gt; 15^\circ$ C</td>
<td>4 b Th</td>
<td>5 to 6</td>
</tr>
<tr>
<td>(Tropical)</td>
<td>Mesoxerochimic</td>
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<td>4 b Mes</td>
<td></td>
</tr>
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<tr>
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<td></td>
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<tr>
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<td>Subtheraxeric</td>
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<td>4 d Th</td>
<td>1 to 2</td>
</tr>
<tr>
<td></td>
<td>Submesaxeric</td>
<td>Temperature of the coldest month $&lt; 15^\circ$ C</td>
<td>4 d Mes</td>
<td></td>
</tr>
</tbody>
</table>
### II. Cold and temperate cold climates.

The temperature curve is negative during certain time of the year.

<table>
<thead>
<tr>
<th>REGION</th>
<th>SUB-REGION</th>
<th>MODALITY</th>
<th>BRIEF DENOMINATION</th>
<th>NUMBER OF DRY MONTHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Bixeric</td>
<td></td>
<td>Total of both dry periods more than 8 months</td>
<td>2 c</td>
<td>9 to 11</td>
</tr>
<tr>
<td></td>
<td>Thermobixeric</td>
<td>Temperature of the coldest month &gt; 15°C</td>
<td>5 a Th</td>
<td>7 to 8</td>
</tr>
<tr>
<td></td>
<td>Mesobixeric</td>
<td>Temperature of the coldest month &gt; 15°C</td>
<td>5 a Mes</td>
<td>6 to 8</td>
</tr>
<tr>
<td></td>
<td>Thermobixeric</td>
<td>Temperature of the coldest month &gt; 15°C</td>
<td>5 b Th</td>
<td>6 to 8</td>
</tr>
<tr>
<td></td>
<td>Mesobixeric</td>
<td>Temperature of the coldest month &gt; 15°C</td>
<td>5 b Mes</td>
<td>4 to 8</td>
</tr>
<tr>
<td></td>
<td>Ther nobixeric</td>
<td>Temperature of the coldest month &gt; 15°C</td>
<td>5 c Th</td>
<td>6 to 8</td>
</tr>
<tr>
<td></td>
<td>Mesobixeric</td>
<td>Temperature of the coldest month &gt; 15°C</td>
<td>5 c Mes</td>
<td>4 to 8</td>
</tr>
<tr>
<td></td>
<td>Subthermazaxeric</td>
<td>Temperature of the coldest month &gt; 15°C</td>
<td>5 d Th</td>
<td>6 to 8</td>
</tr>
<tr>
<td></td>
<td>Submesazaxeric</td>
<td>Temperature of the coldest month &gt; 15°C</td>
<td>5 d Mes</td>
<td>4 to 8</td>
</tr>
<tr>
<td>6 Theraxemic</td>
<td>Euthermazaxeric (Equatorial)</td>
<td>Temperature of the coldest month &gt; 20°C</td>
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<td>0</td>
</tr>
<tr>
<td></td>
<td>Hypothermazaxeric</td>
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<td>6 b</td>
<td>0</td>
</tr>
<tr>
<td>7 Mesaxemic</td>
<td>Eumesaxeric (Temperate hot)</td>
<td>Temperature of the coldest month lies between 10°C and 15°C.</td>
<td>7 a</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Hypomesaxeric (Temperate)</td>
<td>Temperature of the coldest month lies between 0°C and 10°C.</td>
<td>7 b</td>
<td>0</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>REGION</th>
<th>SUB-REGION</th>
<th>MODALITY</th>
<th>BRIEF DENOMINATION</th>
<th>TOTAL OF DRY MONTHS + Mth. of FROST</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>True desert</td>
<td>The precipitation may not take place all the years.</td>
<td>8 a</td>
<td>11-12</td>
</tr>
<tr>
<td></td>
<td>Eremic</td>
<td>There is no snow accumulated</td>
<td>8 b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cold desert</td>
<td>There is little snow accumulated</td>
<td>8 c</td>
<td></td>
</tr>
<tr>
<td>REGION</td>
<td>SUB-REGION</td>
<td>MODALITY</td>
<td>BRIEF DENOMINATION</td>
<td>TOTAL OF DRY MONTHS + Mth. of FROST</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------------</td>
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<td>-------------------------------------</td>
</tr>
<tr>
<td>9 Hemispheric</td>
<td></td>
<td></td>
<td>9</td>
<td>9 to 10</td>
</tr>
<tr>
<td>Cold subsdesertic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Xerotheric</td>
<td>Oroxerothere (in the mountains)</td>
<td>Accentuated character</td>
<td>10 a</td>
<td>7 to 8</td>
</tr>
<tr>
<td>long days dry</td>
<td>Submediterranean</td>
<td>Average character</td>
<td>10 b</td>
<td>5 to 6</td>
</tr>
<tr>
<td>11 Very cold</td>
<td></td>
<td>Attenuated character</td>
<td>10 c</td>
<td>3 to 4</td>
</tr>
<tr>
<td>Cold Axeric</td>
<td></td>
<td>Transition with the hot xerotheric</td>
<td>10 d</td>
<td>1 to 2</td>
</tr>
<tr>
<td>No dry period</td>
<td></td>
<td>type 3d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 Cryomeric</td>
<td></td>
<td></td>
<td>12</td>
<td>12 months of frost</td>
</tr>
</tbody>
</table>

**III. Glacial climate**

The temperature curve is always negative.
Finally for the work on a big scale, one can introduce in a sub-region, "the climatic sectors". These sectors in the same regional climate are obtained by considering the total quantity of the rain falling during the wet period, the average of the minima and maxima of the temperature, the "very dry" period with the relation \( P < T \), or the "sub-dry" period \( 2T < P < 3T \).

**THE PLAN OF THE WORK**

The present work aims at establishing a map on a small scale of the bioclimatic types of India and its vicinity (1). For each type of bioclimate an ombrothermic diagram is drawn. The ombrothermic diagrams are given in the appendix. The limits, the sub-divisions and the vegetation of each of the bioclimate are explained in the text.

A glance at the map shows that the Indian subcontinent represents practically all the bioclimates.

To explain the different climates we shall begin with the driest type and pass on to the wettest. Next we shall deal with the cold and the glacial types.

**I. HOT AND TEMPERATE HOT CLIMATES.** (Temperature curve is always above 0°C).

**1. EREMIC CLIMATE** (Hot desertic): 12 dry months.

As may be seen on the map, the desert region occupies an important zone comprising the Thar in India and Sind in Pakistan. Besides this important zone, one may distinguish three small patches of desertic climate viz. one in the north-west corner, one in the western corner of Pakistan and one in the valley of Gilgit near Srinagar.

A peculiarity of this desert climate is that it is of tropical tendency (rain during long days), modality ‘’c’’ wherever it prevails, except in the north-west corner where it is of irregular type (i.e. rain without seasonal rhythm), modality ‘’d’’.

The ombrothermic diagrams for Jacobabad (Fig. 1) and Panigour (Fig. 2) illustrate these modalities ‘’c’’ and ‘’d’’ respectively.

This north-west part of the subcontinent is the area beyond the influence of the monsoon, for it having travelled 1,000 miles or more over the continent becomes completely dry here.

The aridity of the climate coupled with the sandy soil produces vegetation of a meagre desertic type.

(1) The map is joined to this booklet.
2. **HEMIEREMIC CLIMATE** (Sub-desertic): 9 to 11 dry months.

Surrounding the zone of central desert is a zone of sub-desert extending on the west to the foot of the Baluchistan highlands and on the north to the foot of the Himalayas.

This climate offers three tendencies:

(a) mediterranean  
(b) tropical and  
(c) the irregular, intermediate between “a” and “b”.

The mediterranean sub-type “a” with long days dry and winter rain is to be found in the north-west Pakistan. The graph of Dalbandin (Fig. 3) serves as its station type.

The sub-type “b” with tropical tendency occupies nearly the whole of Cutch and Rajasthan and further north a part of west Punjab. Jodhpour (Fig. 4) is selected as an example. It is worth mentioning that this sub-type occurs in South-India near Bellary. The probable cause of the aridity of Bellary may be explained by its geographical situation in a valley between the Western and the Eastern Ghats.

The sub-type “c” with its seasonally irregular rains, forms a transitional belt between the previous sub-types. Fort Sandeman (Fig. 5) is the graphical representative of this climate.

Looking at the three diagrams of Dalbandin (Fig. 3), Fort Sandeman (Fig. 5) and Jodhpour (Fig. 4) one may have an idea of the gradual transition from the winter rain to the summer rain tendency. In Ft. Sandeman, there are two maxima of rains, one during january-march, the other during july-august. However only the former mounts above the temperature curve.

In Southern India, one finds the sub-type “c” in Coimbatore which may be explained once again by its topographic position in the shadow of the Nilghiri and the Annamalai hills of the Western Ghat. In reality, as it is shown by Fig. 9, Coimbatore is xeric i.e. with two dry periods. However, as the sum of the two dry periods is more than 9 months, it is classed in the division 2 “c” i.e. sub-desertic with irregular rain.

The vegetation type permitted under such dry conditions is always a thorn forest, as may be made out from **Champion's** (1936) forest types of India and Burma.
3. **Xerothermic Climate** (Mediterranean): 1 to 8 dry months; long days dry.

In the North-West part of the subcontinent, winter rain from the North-West becomes a decisive factor and this feature along with the low temperature creates a climate similar to that of mediterranean countries.

The geographers consider as essential characters of the mediterranean climate a mild winter which does not affect the vegetation, the spring and autumn rains, a dry period in summer which stops the growth of non-woody plants and slows down the growth of the woody plants (GausseN, 1955 a).

However, from phytogeographic point of view there seems to be some discrepancies regarding the prevalence of the mediterranean climate in this subcontinent.

**Grisebach** (1884) who considered the aspect from physiognomy of vegetation, considered Baluchistan as non-mediterranean.

**Engler** (1889, 1919) on the other hand from floristic considerations reached a different conclusion and included Baluchistan within the mediterranean limit.

According to **Eic** (1931) the eastern limit of mediterranean region is doubtful. He questions, whether towards the Orient, does the mediterranean region extend up to Persia, Afghanistan and even beyond? He also speaks of an Irano-touranian region closely allied to the Mediterranean. As one of the essential points of differences between the two, he cites the absence of forest climax in the Iranotouranian region. But once again the eastern limit of the new region is doubtful to Eic. He questions, "Does it attain the western limit of Sino-Japanese region, or the High Asia to the East of Afghanistan forms a separate part in itself?"

Our present investigation with the help of ombrothermic diagrams enables us to establish the presence of a mediterranean climate in the subcontinent with the following modalities: a, b, and d. These regions with mediterranean climate extend up to the west of the Indus Valley.

### a) Xerothermomediterranean: (7 to 8 dry months).

This is the climate of the mountainous region of Baluchistan with Quetta (Fig. 6), as its station-type. However, here, the long period (7 - 8 months) of drought permits a very dry type of vegetation. It is because of this dry nature of the climate that
physiognomically a mediterranean “maquis” aspect does not come out. Engler (Loc. cit.) thus distinguishes the absence of forest climax as an important feature of difference between his mediterranean and Irano-touranian regions.

Considered from the floristic point of view, Engler classed the region as mediterranean. Among the recent authors, we may mention Chatterjee (1947) who assumes 10% of the Indian flora as of East mediterranean origin. Therefore, it is most likely that the corner of Baluchistan acts as a stepping stone for the mediterranean element and favours its penetration inwards.

As further support to the dominance of mediterranean climate in the present region, we may cite Hardy (1920) who speaking on the north-west Himalayas, states “In the Indus district region, the climate is decidedly dry and the vegetation assumes increasingly at the lower and middle elevation, a somewhat mediterranean aspect with stout, evergreen, round-headed, hard-leaved trees. Many of the slopes are either completely denuded or thinly dotted with a loose evergreen scrub equivalent to the mediterranean “garrigue”. The district is extremely suitable for cultivation of maize and wheat”. It is surprising to note that the vegetation of this region is classed by Champion as sub-tropical dry.

b) Average character. Thermomediterranean (5 or 6 dry month).

A small patch of this sub-climate occurs in the northern corner of west Pakistan.

Drosh is the representative of this type (Fig. 7).

c) Transitional character. Sud-mediterranean (1 or 2 dry months).

The valley of Srinagar is under this climate. As a matter of fact the ombrothermic diagram of Srinagar (Fig. 8), shows 3 periods of dryness: one in June, the other in September and the third in November and therefore this type may be classed into a new bio-climate “Trixeric”. However, the two dry months of September and November are so short in duration, so feeble in their intensity and followed immediately by wet months, that they may not be considered as dry. Only the dry period prevailing during June is of some importance and hence the sub-type is classed under sub-mediterranean.
4. XEROCHIMENIC CLIMATE (tropical): 1 to 8 months dry, short days dry.

Thermoxerochimenic (Temperature of the coldest month > 15° C).

a) Accentuated character (7—8 dry months).

It is the climate of a large zone in Peninsular India extending from the upper extremity of Saurashtra to Goa on the west coast, covering the Malwa Plateau and a part of the Gangetic Plain in the north and in the east and the Deccan Plateau with Mysore excluded in the south. Fig. 10 of Nagpour is a graphical representation of this climate.

A minor zone of this climate reappears in the extreme south-east corner of India where the influence of the monsoon is feeble being sheltered from the monsoon by the Palni hills in the north and Ceylon in the east. Similar climate occurs in the northern part of Ceylon. Here vegetation is dry. The thorn forest of Acacia planifrons is confined to these regions of extreme S. E. India and northern Ceylon (Hooker, 1906).

As for the vegetation of the larger zone of Peninsular India one may distinguish several sectors depending upon the amount of the annual rain or the soil factor. Thus, the west coast belt and the windward slopes of the western Ghats running from Goa to Alibag with about 2500 mm of annual rain bear some forests of semi-evergreen type. The Deccan Plateau situated between the two chains of mountains, the western and the eastern Ghats, robbed of a large portion of its rain and therefore with only 750 mm or less of annual precipitation bears thorn forest. The rest of the region with intermediate rains is clad with tropical deciduous forests. Among the deciduous forests, we may again distinguish a facies of Shorea robusta (Sal) forest, covering eastern part of the region. According to Schimper (1903), “Sal” forest occurs on a loose soil rich in silica and gravel that is very permeable to water and is absent wherever soil becomes firm.

b) Average character (5—6 dry months).

In South India, the region of this climate begins from Cape Comorin and broadens out gradually forming a triangle with Goa and the mouth of the river Krishna as the base, and Cape Comorin as the apex. Further eastwards, the region continues along the east coast sending projections into the previous region “a” of accentuated character. These projections occur either along the mountainous region of the Western Ghats on the west, or along the valleys of the plateaux cut
by the rivers Godavari and Mahanadi. Thus in the drier region of accentuated character (7 – 8 months dry), the dry period is made less pronounced, to 5 – 6 months, either by the high mountains or by the valleys of the rivers of the east coast.

Eastwards, the region of this climate forms again a broad belt in parts of Orissa, Bihar, Bengal and East Pakistan. It also occupies the lowlands of Burma, almost the whole of Thailand and a part of Indochina.

The diagram of Calcutta (Fig. 11) is a typical example of this climate. Madras (Fig. 12) on the other hand, presents a somewhat different case which is also true for the south-eastern coast extending from Nellore to Negapatam. This coastal sandy plain of Coromandel is under the influence of not only the advancing S. W. monsoon during July-September but is also influenced by the retreating S. W. or the N. E. monsoon during October-December. With the result, Madras presents a very peculiar type of diagram.

The vegetation types under this climate are also varied according to the sectors. The eastern region beginning from the mouth of Krishna extending towards Bengal coincides with the tropical semi-evergreen forest type of Champion.

The edaphic influences determine the tidal forests of Sundaribans near Calcutta and of Masulpamats.

c) Attenuated character (3 – 4 dry months).

This sub-type occurs in the South-West India with Cochin (Fig. 13) as Station-type. It is also found along the foot of the Eastern Himalayas, in Ceylon, Assam, most of Burma and Indochina. It also occurs on the mountains of the previous region “b” of average character (5 – 6 months dry).

The vegetation is either of evergreen and semi-evergreen type as in S. W. India where the influence of the monsoon is strongest, or is of loose forests of tropical moist deciduous “Sal” (Shorea robusta) as at the foot of the Himalayas.

An interesting example of irregularity in rain giving an apparently mediterranean type of ombrothermic diagram is afforded by Batticaloa (Ceylon) (Fig. 14). However, in this case in spite of the long days being dry, the temperature of the coldest month is above 20°C. Therefore, this station can not be classed as mediterranean which from vegetation point of view is also tropical. The apparent anomaly arises from the irregularity of rain as may be seen below.
Let us examine the diagrams of Diyatalawa (Ceylon) and Batticaloa (Figs. 15—14). In the former we find two minima of rain, one during February, the other during June-July. However, on the basis of $P < 2T$ rainfall remains above the curve of the temperature and there is no dryness. But if we follow the convention $P < 3T$ and try to introduce a period of sub-dryness, we find a sub-dry period during June-July. The dotted line represents the precipitation curve at a scale thrice that of the temperature. Therefore, here we find the sub-dry period during the long days. Now, if we examine the diagram of Batticaloa, we find the dry period during long days again. Here the conditions are far drier than Diyatalawa, the two minima have disappeared and have combined to produce single dry period during long days. This condition should not be confused with the Mediterranean type, because the temperature is always above 20° C. and the vegetation is of true tropical nature.

d) Submesaxeric. Climate of transition (1—2 dry months).

This climate may also be termed as sub-equatorial as it occurs on the margin of the equatorial climate. It is found in Ceylon in its Central part, in Indochina along the east coast, in the lower extremity of Burma and in Malaya.

Dalat (Indochina) is its station-type (Fig. 16). As the dry period lasts for 1 to 2 months only, the short dryness does not affect the vegetation. As consequences vegetation is dense tropical rain-forest.

Mesoxerochimenic (Temperature of the coldest month <15° C).

It is the climate of the mountains of average height.

a) Accentuated character (7—8 dry months).

A zone of this sub-type occurs in the central India in the Upper Gangetic Plain with two fingers projecting in the sub-desert along the valleys of the river Jumna. Aligarh in fig. 17 graphically presents the climate.

Islands of such climate also occur on the mountains of mean altitude such as Mount Abu on the Aravali range and Pachmarhi.

b) Average character (5—6 dry months).

This climate occurs in China in the region of Kwangtung which is covered with subtropical evergreen forests.
d) Submesaxeric. Climate of transition (1—2 dry months).

This is essentially a mountain climate and as such is found along the Nilghiris, the Himalayas and the hilly region of Burma and Indochina. Fig. 18 of Shillong is an example of the type.

Whereas in the Nilghiris and Burma, the vegetation is the subtropical wet type of Champion (1936), along the Himalayas up about 4000 m (12000 ft.) where this zone extends we may distinguish according to Hooker (1906), Schimper (1903) and Hardy (1920) a temperate belt of non-coniferous deciduous forest growth succeeded by a belt of Conifers and Rhododendrons.

It is interesting to note that in the high mountains of South Africa, Bagnouls (1958) in a similar climate recognises two analogous belts viz. a dense humid forest and further up a dry mountain forest.

5. BIXERIC CLIMATE (Two dry periods)

Thermobixeric (temperature of the coldest month is ≥15°C).

a) Accentuated character (7—8 dry months).

b) Average character (5—6 dry months).

Madura and Trichinopoly in South India (Figs. 19—20) are the respective representatives of these sub-types “a” and “b”. Their ombrothermic diagrams reveal two dry and two wet seasons. But of these, one wet season is of so short a duration followed immediately by a dry period and as such appears insignificant. As result, the vegetation of these stations is similar to that of their neighbouring regions, viz. a dry forest.

Mesobixeric climate (temperature of the coldest month <15°C).

With two distinct wet and two pronounced dry periods, are the climates in the northern and north-eastern parts of the sub-continent. These are the regions which are affected both by the N. E. winter rains and the S. W. monsoon. This type presents the following three characters.

a) Accentuated character (7—8 dry months).

This character is encountered in two small patches around the sub-desert. Patiala (Fig. 21) is a typical station. Being in the vicinity of sub-desert, thorn forest is a conspicuous feature of the landscape.
b) Average character (5—6 dry months).

The character is fairly extensive in around Patiala and East Punjab States as also in basal zone of Eastern Himalaya.

The diagram of Ambala (Fig. 22) serves as a station-type. Deciduous forest dominates the former region. In the latter i.e. along the Himalaya upto 2100 m a sub-tropical wet evergreen aspect prevails (Hardy, 1920).

c) Attenuated character (3—4 dry months).

It is the character met with in the upper plain of Indus, exemplified by the station of Rawalpindi (Fig. 23).

The winter rain during december to february makes the cultivation of wheat and barley possible in this south west part of the Punjab (Miller, 1944).

6. Thermaxedric Climate (There is no dry period).

This may also be termed as an equatorial climate. We shall recognize two modalities here.

a) Euthermaxedric (temperature of the coldest month > 20° C).

b) Hypothermaxereric (temperature of the coldest month < 20° C).

In the first case, it is the climate of the tropical dense rain forest of the plains and of the low altitudes of Ceylon and Malaya. Colombo is an example of the ombrothermic figure (Fig. 24).

The second condition is favourable to the dense evergreen forests of the mountains of moderate altitude (below 2000 m near the equator) as those of Ceylon. Diyatalawa is an example (Fig. 15).

7. Mesaxedric Climate (No dry period).

a) Eumesaxedric (temperature of the coldest month lies between 10 and 15° C).

In the inter-tropical India the summits of the Nilghiris and the Palni hills and Burma the Lai-Ling hill near Mandalay with wet vegetation are under the influence of this climate. Kodaikanal (Fig. 25) presents this type graphically.

It is possible that this climate prevails over part of Eastern Himalaya also but due to lack of meteorological data we can not locate it.
b) Hypomesaxeric (temperature of the coldest month lies between 0 and 10° C).

It is the climate of Central and northern China where broad-leaved summertime green trees like Mongolian types of Oaks and beeches with conifers prevail. It is again likely that this climate occurs in parts of Himalaya.

Il. COLD AND TEMPERATE COLD CLIMATES (temperature curve is negative during some time of the year).

8. EREMIG CLIMATE (Cold desertic) (The total of the cold months and the dry months is 11 to 12 months).

This type is prevalent in Western Himalaya and the plateau of the Pamir which it borders.

The dryness is of two kinds here: one caused by the temperature below 0° C inhibiting the absorption of water by the roots, and the other caused by the dry months.

Let us examine the diagram number 26 of Leh, the selected type. Here, we find negative temperature for five months, (November to March) followed by a dry period of seven months (April to October) with positive temperature. In such a case, it is necessary to consider that the precipitation during the winter is in the form of snow. If this precipitation is sufficient and if the winds are moderate, the snow would accumulate and melt at the time of the Spring thaw. During this melting period there is abundant humidity favourable to vegetation. This effect of the melting of the snow, which is capable of reducing the effect of dryness during the early dry period is shown by the dotted lines on the diagram. As result, we will not consider the month of April as dry.

As there is a chance for the snow to accumulate in the present case, we shall class the cold desertic climate of Himalaya in the modality “c” of the classification.

9. HEMIEREMIG CLIMATE (sub-desertic cold) (The total of the cold months and the dry months is 9 to 10 months).

The valleys of Western Himalaya are influenced by this climate.

The graph of Kargil (Fig. 27) shows the cold period extending from November to March and the dry period from May to October. By the compensation of the melting of the snow, we shall consider may end June as wet months.

Here, vegetation is of dry temperate type.
10. COLD XEROETHERIC CLIMATE

This climate does not exist in India but prevails on the high mountain ranges of Afghanistan and Iran. It is similar to the mediterranean climate except that the winters are cooler.

11 COLD AXERIC CLIMATE (There is no dry period).

It is the climate that one finds in the Himalayas from 4,000 to 5,500 meters. Although there does not exist any meteorological station for this type, we have derived it from the stations of lower altitude as for examples Darjeeling (2,266 m) on the eastern end and Simla (2,203 m) at the western extremity, with the convention that the temperature decreases by 1°C with approximately every 200 m. rise in altitude, whereas the dry period of 1 to 2 months of Darjeeling and Simla disappears with further rise in altitude.

This zone corresponds with the alpine vegetation. In the absence of meteorological data, we can not precise the modalities of this climate.

III. GLACIAL CLIMATE (the temperature curve is negative throughout the year).

12. CRYOMERIC CLIMATE (the cold period lasts for 12 months).

This high summits of Himalaya above 5,500 m with eternal snow are the bearers of this climate.

CONCLUSION

The aim of the present work is to show that the method of the ombrothermic diagrams permits us to characterise very clearly each type of climate and the classification enables us to delimit easily the different bio-climates which determine vegetation.

In the Botany Department of the University of Toulouse (France) a large part of the world is so classified and the results obtained are very satisfactory.

In response to Prof. Gaussen's wish that each country should establish a precise bio-climatic map of its territories, this work on India was undertaken (1).

In the absence of sufficient meteorological data, as pointed out earlier, it is likely that the map contains some errors. However, the

(1) A translation of the legend of the map of Bioclimatic types of South East Asia, joined to this paper, is given in appendix.
map marks a first step towards the determination of the bio-climates of India. Having grouped the different regions of the sub-continent in the framework of a climatic classification that can be easily applied to the rest of the world, light could be thrown on the problem of analogous climates. One of the essential objects of applied climatology is to indicate the analogous climates of the world. To know the bio-climates of one country and their analogous types around the world is of prime importance to the economy of that country for the exchange of economically important species. A country such as India with a very wide range of bio-climates offers ample possibilities for amelioration of its flora by exchange of economic indigenous species from one region to another analogous one or by introduction of exotics in the suitable bio-climate.

To give an example, the fixation of the mobile sand dunes of the Indian desert remains a problem. The type of phyto-amelioration work that is carried out in the sandy deserts of Middle Asia and Kazakhstan (Petrov, 1957) is very illustrative. Knowing the bio-climatic relations between these deserts and the Indian desert, one may adopt an identical plan and even employ the same plants for the amelioration of the Thar.

Further work on these lines is in progress at the Faculty of Sciences of Toulouse and a study on the corelation between the vegetation types of India and their ecological factors and ecological formulae will appear elsewhere.

ACKNOWLEDGEMENTS

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APPENDIX

Legend of the map of Bioclimatic types of South East Asia

1. Hot and temperate hot climates
   (temperature curve is always positive)

   Eremic
   (Hot desertic)
   \{ 1 - (1c) with tropical tendency
   \{ 2 - (1d) with irregular tendency
Hemieremic (Hot subdesertic)
\[
\begin{align*}
3 & - (2\ a) \text{ with mediterranean tendency} \\
4 & - (2\ b) \text{ with tropical tendency} \\
5 & - (2\ c) \text{ with irregular tendency}
\end{align*}
\]

Xerothetic (mediterranean)
\[
\begin{align*}
6 & - (3\ a) \text{ accentuated character (7-8 dry months)} \\
7 & - (3\ b) \text{ moderate character (5-6 dry months)} \\
8 & - (3\ d) \text{ transitional character (1-2 dry months)}
\end{align*}
\]

Xerochimicnic (tropical)
- temperature of the coldest month $> 15^\circ C$

Termo-xerochimicnic
\[
\begin{align*}
9 & - (4\ a\ th) \text{ accentuated character (7-8 dry months)} \\
10 & - (4\ b\ th) \text{ moderate character (5-6 dry months)} \\
11 & - (4\ c\ th) \text{ attenuated character (3-4 dry months)} \\
12 & - (4\ d\ th) \text{ subthermoxeric (1-2 dry months)}
\end{align*}
\]
- temperature of the coldest month $< 15^\circ C$

Meso-xerochimicnic
\[
\begin{align*}
13 & - (4\ a\ mes) \text{ accentuated character (7-8 dry months)} \\
14 & - (4\ b\ mes) \text{ moderate character (5-6 dry months)} \\
15 & - (4\ c\ mes) \text{ attenuated character (3-4 dry months)} \\
16 & - (4\ d\ mes) \text{ submesoxeric (1-2 dry months)}
\end{align*}
\]

Bixeric (two dry seasons)
- temperature of the coldest month $> 15^\circ C$

Thermo-bixeric
\[
\begin{align*}
17 & - (5\ a\ th) \text{ accentuated character (7-8 dry months)} \\
18 & - (5\ b\ th) \text{ moderate character (5-6 dry months)}
\end{align*}
\]
- temperature of the coldest month $< 15^\circ C$

Meso-bixeric
\[
\begin{align*}
19 & - (5\ a\ mes) \text{ accentuated character (7-8 dry months)} \\
20 & - (5\ b\ mes) \text{ moderate character (5-6 dry months)} \\
21 & - (5\ c\ mes) \text{ attenuated character (3-4 dry months)}
\end{align*}
\]
22 — (6 a) — euthermaxeric — temperature of the
coldest month > 20°C
(equatorial)

Thermaxeric

23 — (6 b) — hypothermaxeric — temperature of the
coldest month > 15°C,
< 20°C (subequatorial)

24 — (7a) — eumesaxeric — temperature of the coldest
month > 10°C,
< 15°C (hot temperate)

Mesaxeric

25 — (7 b) — hypomesaxeric — temperature of the
coldest month > 0°C,
< 10°C (temperate)

II Cold and temperate cold climates
(temperature curve negative during certain time of the year)

26 — eremic (cold desertic): total dry months and
freezing months / = 11 to 12

27 — hemieremic (cold subdesertic): total dry months
and freezing months = 9 to 10

28 — cold xerotheric: (oroxerother)

29 — cold axeric: cold temperate and less than
4 freezing months.

III Glacial climate
(temperature curve always negative)

30 — cryomeric: the cold period lasts throughout the
year
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CARTE DES INDICES XEROTHERMIQUES

LEGENDE

Nombre de jours biologiquement secs au cours de l'année

- ou dessus de 300 X₅
- de 250 à 300 X₅
- de 200 à 250 X₄/₅
- de 150 à 200 X₄
- de 100 à 180 X₃
- de 40 à 100 X₂
- ou dessous de 40 X₁

0 100 200 300 400 500 Kilomètres
TYPES BIOCLIMATIQUES DU SUD-EST ASIATIQUE

PAR

V. M. MEHER-HOMJI

LEGEND

Echelle

0
10
20
30
40
50
60
70
80
90
0° 10° 20° 30° 40° 50° 60° 70° 80° 90°