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THE CLIMATES OF INDIA AND ITS VICINITY ACCORDING TO A NEW METHOD OF CLASSIFICATION

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The purpose of a climatic classification is to characterize climatic regions in terms of those principle elements such as temperature and precipitations, which are the most decisive in the determination of the landscape of the earth's surface. It attempts to develop the similarities which the climatic elements bear to each other and their relation to their principle causes; the effect of latitude, of atmospheric and oceanic circulation, in opposition to geographic accidents.

Climatic classifications owe their origin to phytogeographic descriptions though in recent years there has been some controversy in defining this subject and its relation to meteorology, geography and statistics. The physiognomic descriptions of plant associations are related to the first descriptive maps of the distribution of temperature and rainfall, and in this connection we should cite valuable contributions of De Candolle (1885), Grisebach (1866), Drude (1887), and Schimper (1898), that include the analysis of the diverse plant types of the world in relation to the principle climatic elements which determine them.

Wladimir Koppen, a St. Petersberg-trained biologist, contemporary of the phytogeographers mentioned above, was the first to attempt a rational classification of the major climatic groups, taking as a basis the phytogeographical manifestations which they determined and adopting a terminology and symbolism similar to those used by De Candolle. His first classification appeared in 1900 and it has been repeatedly changed both by himself and his well or ill wishes and finally appeared in his masterpiece, Handbuch der Klimatologie published in 1936.

Koppen's system of classification has been widely accepted, e.g. by Van Royen (1927), Russel (1931, 1932, 1934), Scaetta (1933), McDougall (1936) and Ackerman (1941), as the best possible one then available, but each one admitted its obvious defects.

The American workers from among the above list viz. Van Royen, Russel and Ackerman found that the boundaries as defined by Koppen's classification do not correspond to the real natural limits of the major climatic zones as they are expressed by soil and vegetation and hence suggested moving a boundary one way or other by slightly changing its numerical value.

McDougall ignored Koppen's differentiation of summer, winter and well-distributed rainfall regimes and redivided them on an arbitrary basis, whereas Kendall criticized Koppen for not including seasonal concentration of rainfall. Scaetta on the other hand went out to "enlarge and define" his classification for equatorial Central Africa by introducing additional isotherms and isohyets which are not in fact well considered improvements. Gorcznski directed his modification of Koppen's classification to the cold climates alone.

Koppen, in his work had recognised the importance of evaporation to distinguish between humid and dry climates but being unable to measure it, he developed as his indices relations between precipitation and temperature weighing both in such a manner that the resulting indices would correspond to the boundaries between the actual vegetation types. Since then, many authors had directed their attention to solve this problem, with an idea to improve upon the primary concepts laid down by Koppen. Notable among them being Meyer (1926), who simplifying the earlier formula of Szymkiewicz (1925), proposed the simple ratio of total annual precipitation to mean saturation deficit; Vazquez (1933) and Rosenkranz (1936) who put forward a "phyto-climatic index" and an "index of oceanicity" respectively, and Transeau (1915), Livingston (1916), Livingston & Shreve (1921) and Davidson (1934, 1935, 1936, 1937) who advocated the use of evaporation data from a free-water surface or atmometers.

The precipitation—evaporation ratio though very attractive to use, could not be computed for all the regions due to the absence of necessary data and this had demanded some alternative, and that the formula put forward had usually been one in which only the precipitation and temperature appeared alone or in some of their functional forms. Among such formula mention may be made of Lang's (1915) "rain factor" which is simply the ratio of annual precipitation (mm) divided by the mean annual temperature (^{0}c); Stefanoff's (1930) "hygric continentality" obtained by dividing the annual precipitation (mm) by the altitude (metres); Albert's (1928) "reduced rain factor" derived from the rainfall and the mean temperature of the frost-free period only. The weakness of these three formula is that they don't take into consideration the seasonal distribution of the rainfall.

De Martonne's (1926, 1926a, 1927, 1928) "index of aridity" which could be computed for a single month or a group of months, is in effect a modification of Lang's rain factor, but as has been pointed out by several authors (1931), this index comes out to be higher, the higher the humidity of the climate.

There are two more formula which belong to this class one by Emberger (1930, 1932) and another by Thornthwaite (1931, 1934). Emberger's formula

being applicable to Mediterranean climates alone cannot be used for classifying other types of climates as has been pointed out by Dhir (1951).

Thornthwaite, in his first attempt rejected both Koppen's and De Martonne's classifications and offered a new one obtained by summing the individual months' "temperature efficiency" and "precipitation effectiveness". This precipitation effectiveness" is a function of rainfall and temperature evolved to fit the loses of water from open pans run by U.S. Weather Bureau at 21 stations in the western part of that country and is applicable to only those figures as had been proved by Bharucha and Shanbhag (1953), Forbes (1932), Jones and Bellaire (1937). His formula when solved for evaporation shows that the evaporation varies directly as the approximate temperature and has a small inverse dependence on precipitation. This relation is true to some extent (if we do not reach the limiting condition) where unlimited supply of water is available for evaporation, but in the case of soil surface in nature it would be absurd to say that evaporation increases when there is no water to evaporate.

There are many expressions with the aid of which evaporation from open water surfaces could be predicted, though all of them are to some extent empirical, but they make at least some attempt at physical realities. One such formula is by Rowher (1931) which has been thoroughly tested both in the laboratory and outside, the second is by Thornthwaite himself in collaboration with Holzman (1942) and the third is by Penman (1928). Evaporation data obtained by any one of these formula could be used in conjunction with precipitation to classify the climates instead of using the expression as laid down by Thornthwaite which gives results quite contrary to our experience.

It may however, be doubted whether evaporation from pans or large bodies of water is in any way representative of the evaporation from soils covered with vegetation. In nature there are two processes viz. (1) the evaporation from the soil and (2) the transpiration from the plants which are active in transporting the precipitated water back into the atmosphere.

It is well established that the process of evaporation requires :-

(1) A source of heat to maintain the water temperature which in turn will maintain the molecular motion.

(2) An excess in the number of molecules leaving water over those re-entering it or in other words, the saturated vapour pressure at the surface temperature of water must exceed the actual vapour pressure in the space immediately above the water surface.

In nature these fundamental requirements are provided by the following meteorological factors :-

(a) The sun and sky radiation provides most of the energy needed to maintain the temperature of water and the molecular motion (1948) (1949) (1949) (1950).

(b) The atmosphere immediately above the water in which the actual vapour pressure is less than the saturation vapour pressure at the temperature of the water surface (1937).

(c) Wind movements which remove the excess of water vapour above the water surface and thus prevent the saturation point being reached (1937).

(*d*) The air temperature also plays an important role in at least two ways :-

(*i*) It controls the temperature of the water through thermal convection and thus acts as a source or sink for heat energy depending upon whether the air is warmer or colder than water.

(*ii*) Since it controls the temperature of water it partially determines the vapour pressure deficit.

Evaporation is also controlled by the nature of the container through its response or relation to meteorological factors. A body of clear water absorbs a large percentage of solar and sky radiation while muddy water will reflect much of it. In case of deep water, solar energy will be distributed throughout a large mass of water to a depth of several feet with the result that the diurnal variation of the surface temperature will be small. Black soil will absorb a large percentage of incident radiation as compared with any other soil in the same condition. Most of the sun and sky radiation falling on the soil is retained in a thin layer near the surface since soil is opaque to light. This causes a large rise in the soil surface temperature as opposed to that of water under similar conditions. With a saturated soil surface the solar energy will be available for evoporation instead of warming the soil. Hence evaporation from saturated soil will be greater than that from a large mass of water under similar meteorological conditions. This is true for a wet soil surface, but as soon as the surface becomes dry other factors come into operation. At this stage evaporation does not take place from the interface of soil and air, but a few millimeters below. Hence the water molecules have to diffuse through the dry soil which acts as a "potential barrier" before being caught and blown away by the pevailing wind. This potential barrier which increases the path of the molecular diffusion, reduces the rate of evaporation (1944) (1949). Secondly heat conduction from the surface into the deeper layer of the soil becomes smaller as the pores are filled with water whose thermal conductivity is smaller than that of water.

The rate of movement of water vapour molecules from the layers below to the surface of the soil is determined by the size and shape of the pores. The greater the number of large pores the more direct the routes by which vapour can escape. Hence sand and other soils with large pores or cracks are subjected to higher rate of evaporation than are fine textured soils.

The depth to which evaporation from bare soils extends depends on the soil porosity and the depth of the water table. On fine textured upland soils where the water table does not influence evaporation, water losses will be limited generally to the first foot of the soil. Coarse-textured soils and cracked soils possess more and larger avenue for escape of the vapour particles and here evaporation may remove water from depths as great as 5 to 6 feet (1952).

Where water table lies close to the surface so that capillary flow supplies water to the surface for evaporation, soil porosity again is the limiting factor, but this time the movement of water will be in the liquid state rather than in the vapour state. Since capillary conductivity depends inversely on the radius of the pores, fine textured soils will affect the water table to a greater depth than coarse textured ones. For a coarse sand the limiting depth is about 14 inches while that for clay or heavy loam it is 3 to 4 feet (1946) (1948). Thus in areas where evaporation opportunity is great because of

high water table, the depth to which evaporation is effective is greater in clay than in sand ; whereas in upland soils, where the water table is a factor, the reverse is true.

Evaporation is also affected by the vegetation covering the soil. Thus the trees which act as wind breaks increase the rate of evaporation due to higher temperature near the ground caused by poor wind circulation behind the wind breaks (1941) (1952) 1954). The plant residue which is added to the soil from time to time conserves heat which brings about a higher rate of evaporation (1954). It is also well established that evaporation rates vary considerably, according to the degree of protection afforded to the surface by the plant (1948).

In case of agricultural lands the evaporation rates during part of the year will be similar to that from bare lands carrying stubbles, while during the growing season the rates will change from time to time due to varying height, colour of the crops and the degree of protection offered to the soil.

Transpiration which is more powerful than evaporation in reducing the available water from the soil depends upon three factors :- (1) meteorological ; (2) physical and (3) biological.

Meteorological factors : The same factors namely, the absorbed sun and sky radiation, air temperature, air humidity and air movements which are responsible in bringing about and fixing the rate of evaporation, are the only external agents that determine the rate of transpiration. But these factors are altered considerably by the location, colour and orientation of trees and their leaves. Thus the shaded leaves will transpire less than the unshaded ones because of the difference in the available sun and sky radiation. It is a known fact that wind increases with height (1950) in the layers nearest to the ground with the result transpiration from short grasses will be less than that from isolated trees, other things being equal. The colour decides the amount of energy absorbed by the leaf which in turn governs the rate of transpiration. Dark green leaves will absorb more energy than light green ones, and thus will transpire more when other conditions are kept constant. Orientation of the leaves with respect to the incident beam of light determines the amount of energy absorbed which in turn affects the rate of transpiration. A leaf turned with its surface normal to the beam of incident radiation absorbs more energy than the one turned edgewise to the beam resulting in a corresponding difference in the rate of transpiration (1926) (1950). The mechanical influence exerted by the wind such as bending and waving of the leaves to and fro and thus altering their exposure from time to time will have a profound influence on the rate of transpiration. Numerous other examples can be cited wherein the rate of transpiration will be affected by the modification of the meteorological factors through the transpiring agent, the plant.

Physical factors :- Physically transpiration from a plant is impossible soon after the soil moisture reaches the wilting point. The available moisture for transpiration is thus limited between the field capacity and wilting point because at the higher energy level (viz. the wilting point) the suction exerted by the roots is not sufficient to overcome the force with which moisture is being held by the soil particle. As the amount of moisture within these two limits is different for different soils the total transpiration from different plants growing on different soils will be different. Secondly the rate of transpiration within these two limits is not constant but continuously decreases as the force needed to withdraw water from the soil increases when the soil moisture falls below the field capacity (1905) (1941) (1943). The depth of the soil mantle, the formation of the claypan and fragipans which restrict the depth of the root zone will in turn alter the amount and rate of transpiration.

Biological factors :- Biologists (1938) have so far recognized two types of transpiration viz. (i) Cuticular, (ii) Stomatal. In the cuticular transpiration vapourization of water and its escape into the air as it is formed takes place just at the periphery of the leaf while in the stomatal transpiration, this conversion occurs at the periphery of the substomatal chambers within the internal atmosphere of the leaf. The vapour then has to pass through the open stomata before escaping into the atmosphere. The stomatal transpiration is thus governed by the opening and closing of the stomata and also by the internal atmosphere of the leaf. Out of the two, the cuticular transpiration is usually smaller than the stomatal, when open stomata are frequent, but it is more important when stomata are sparse or predominantly closed.

Physiologists (1919) (1938) working in this field have found that the rate of transpiration is governed by the following four internal factors of the leaf: (a) the water vapour pressure of the cuticle, (b) the frequency of the stomata and the average size of their opening, (c) the vapour tension in the substomatal chambers, and (d) the area of the leaf surface. These factors are altered considerably by the influences of external factors such as radiant energy, humidity, temperature, movements of the air, the texture, the moisture content and fertility of the soil, while the last one viz. the area of the leaf surface depends to a considerable extent on the plânt species.

Little is known about the vapour pressure of the cuticule and that of the cell walls about the substomatal chambers. It depends on the nature of the surfaces, their temperature as well as on their relative degree of wetness and also upon the current rate at which heat from the absorbed radiant energy is being received at the vapourizing surface without a corresponding rise in temperature.

Opinions of the scientists regarding the closing and opening of the stomata and thus controlling the rate of transpiration are very diverse. In a study (1946) carried out in South Africa it was found that the stomata of all tree foliage closed as soon as there was a strong wind and thus restricted the transpiration almost immediately, while on grass the effect was quite different, an increase in the transpiration rate was noted at first but soon afterwards this had also decreased. These findings are in opposition to the view that the sweeping wind always accelerates transpiration ((1946) (1946). Controversies also exist regarding the effect of sunshine on the rate of transpiration. Some are of the opinion that after 9 to 10 a.m. no further increase in transpiration is possible due to stronger light (1946) while others (1905) (1948) hold that when water supply is available the transpiration will be greater, the greater the intensity of sunshine. This latter view is quite contrary to the findings that (i) plants which had all along received a meagre supply of water are nevertheless in a position to transpire rapidly when full supply of water is given to them, (1905) and (2) that the rate of transpiration from trees with fully open stomata is very small at about 5 p.m. even on very bright days (1946). Thus even though the external factors and the opening of the stomata are made responsible for the rate of transpiration there must be still some internal factors of the plant which regulate it because of the factors stated above and also the closing of the stomata even in good sunshine when the water reserves in the soil are sinking.

Most of the water required by the plants is extracted by the roots from the soil particles in contact with them. Even though there is some movement of water from the adjoining soil column, moisture held by the soil particles several inches from the roots does not become readily available for the plants (1951). Hence the rate of extraction of water which in turn determines the rate of transpiration is governed by the biological factor " the root system of the plant ". Obviously the greater the volume of the soil occupied by the roots, the greater will be the water removed. There are considerable differences among the species in respect to the depth of the root system, Dogwood being notably a shallow rooted species, while Pine often sends its roots to a depth of several feet (1952). This genetic character of the plant with respect to its root growth is altered considerably by the physical factors as pointed above.

The rate at which elongation of the roots takes place in search of moisture is different for different species and also different in different seasons. Weaver (1935) states that young actively growing roots in a permeable soil may grow at rates of half an inch to two inches in a day, while in an experiment (1952) with the tomato plant it was found that the root zone which was at 4 feet on June 15, reached 6 feet on July 20, 8 feet by about the 15th of August and 12 feet on September 3rd. using all the available water throughout the depths. This shows that in the case of annual plants the rate of extension of the root system during the growing season is not constant which results in different rates of extraction and transpiration of water. In case of perennial vegetation also the same result must hold good but data on the root size and its growth is still lacking. The rate of root growth and its extent is controlled considerably by the pore space, aeration, fertility, moisture content and temperature of the soil. All these factors change in the soil profile at the same place and from place to place.

A short description of the processes of evaporation and transpiration given above makes it clear that both these phenomena are governed by several complicated agents and they cannot be equal or in any way comparable to the water loss from the evaporating pans or atmometers. Furthermore, in the case of evaporating pans or atmometers, the substance to be evaporated viz. water is unlimited and the rate of evaporation is solely governed by the evaporating agents as modified by the nature of the container. In nature however, such conditions of unlimied supply of water occur only during the wet season and even during this season the supply of water depends upon the intensity and distribution of the storm as well as on the soil, vegetation and landscape. The evaporation off an open water surface is sometimes regarded as being a measure of the evaporating power even if this proposition is accepted ; however, it can be regarded as sound only for unit area of an infinite water surface. The evaporation from small limited surfaces like that of the evaporating pans used by the American Weather Bureau is affected by many special boundary conditions and also by the turbulence set up across the rims of the pans. Under such conditions it is rather difficult to tell as to what is being measured by these evaporation pans. For these reasons the results or relations derived from such studies of evaporation cannot be used to define the aridity or humidity of a place.

Realizing that his precipitation-evaporation ratio and the temperature efficiency indices can give little hint of the complexity of soil moisture relationship and that they cannot be regarded as adequate measures of precipitation efficiency, Thornthwaite proposed his second classification (1948) based on the humidity and aridity indices which is the difference between the precipitation and the "consumptive use." The term "consumptive use" (1933) which was in vogue in irrigation practices was introduced into climatology by Thornthwaite, changing its name into what is called "potential evapotranspiration". It is defined as the amount of water which would be lost from a surface completely covered with vegetation and supplied with ample water. This quantity according to Thornthwaite but not in the opinion of Blaney (1933) who founded the term "consumptive use", depends only on the amount of solar energy received by the surface and the resulting temperature than on the kind of plant. Two objections were already raised regarding this assumption in the preceding paragraphs and the experimental results of Henrici (1946) and Blaney and Criddle (1945) are quite contrary to this view.

Thornthwaite's concept of potential evapotranspiration though useful in irrigation practices, becomes highly hypothetical for the classification of climates since the required condition of land completely covered with vegetation and supplied with adequate water through out the year occurs only in a limited part of the world. Secondly the empirical relation between evaporation and temperature obtained by Thornthwaite is based on the data of water requirements of the crops at 12 irrigated areas in U.S.A. in latitudes ranging from 29°N to 43°N and is subjected to the same criticism as was directed to his first classification. Thirdly, though he says that the potential evapotranspiration depends only on the amount of solar energy, his formula for obtaining the monthly potential evapotranspiration is based on a correlation with the monthly temperature, but the mean monthly temperature is, in itself, not a measure of the available energy for evaporation and transpiration. Any formula which is based on temperature and empirically corrected for latitudes gives erroneous values of potential evapotranspiration if the temperature of a locality is largely influenced by high altitude, presence of warm and cold ocean currents and advective air. His formula, as it stands, gives higher values of potential evapotranspiration during the winter months than what could be explained on the energy consideration. Besides these short comings of his formula his system of classification assumes :—(*a*) that the water which could be held in the soil and is made available to the plant (i.e. the amount of water in the soil between the field capacity and wilting coefficient) is 4 inches for all soils, (*b*) that the energy needed to withdraw this amount of water is the same at all moisture content till the wilting point is reached, (*c*) that the amount of water which is available for runoff is 50% of the water surplus for all landscape and soils ; which are not at all acceptable.

In nature transpiration and not evaporation from the soil, which stops as soon as an insulating dry cap is formed on its surface, is powerful in removing water in unit time by acting simultaneously on the whole depth of the soil column occupied by the root zone and it also removes more water in the long run since it reaches to a greater depth than what evaporation can do. Hence evaporation in nature which takes place primarily through transpiration is not really a loss to be deducted from rainfall, as is done by Thornthwaite in his second classification, for finding the availability of water for plant growth. In fact the opposite is more nearly true ; the natural evaporation from plant covered soils represents almost entirely the water that has been used in growth with the result that places where there is high evaporation must have a luxuriant growth of vegetation which fact is not brought about by Thornthwaite in any one of his classifications.

It has been already remarked that the precipitation-evaporation ratio is very attractive in the classification of the climates of the continents but the

determination of the natural evaporation is very difficult. The only sound method for its determination based on turbulence theory had been put forward by Thornthwaite and Holzman (1942) and achieved its perfection in the hands of Pasquill (1949). Determination of this quantity based on this method under different climatic conditions has not yet been undertaken by any one so far. In the absence of such data we have to confine our attention to other more reasonable methods for classification rather than use some hypothetical quantity which has no real physical existence.

TEMPERATURE AND PLANT GROWTH

Temperature influences in one way or other every chemical and physical process connected with plants. Solubility of minerals, absorption of water, gases and mineral nutrients, diffusion, synthesis as well as vital processes such as growth and reproduction are all controlled by temperature. Since these processes are necessary for plants to become established and to survive, temperature controls to a considerable extent the distirbution of plants on the earth and largely determines the flora of the different regions. Moreover temperature delimits the areas of successful production of most agricultural crops.

Plants in their evolution have become adapted to a large range of temperatures. For example certain blue-green algae could thrive in hot springs where the water is always near the boiling point. On the other hand there are examples of plants in the arctic regions which could stand the winter temperature upto, —90°F. These cases are only exceptional ones, interesting from the point of view of enormous adaptability of plant protoplasm to temperature. Barring these exceptions almost all plants (the higher as well as the lower ones) are capable of carrying on growth only within a narrow range.

Several investigators have tried to find the relation between temperature and growth. All of them came to the conclusion that there is a temperature below which growth is not possible. This temperature is called the minimum temperature and is in the vicinity of 0°C (32°F). There is likewise a maximum temperature above which growth ceases. This higher temperature is somewhere near 50°C (122°F). Between these two limits there is an optimum temperature at which growth proceeds with the greatest rapidity. These three points are called the cardinal growth temperatures.

All experimenters have found that the optimum temperature when the growth rate is maximum is in the vicinity of 30°C (86°F) though it is found to vary slightly with the species and the length of their exposure. Lehenbauer (1914) from his investigation on the growth of maize seedlings in relation to temperature found that the greatest rate of growth occurs within the temperaure range 29° to 32°C. Wadley (1936) from his study of green bugs in relation to temperature found that the rate of their development was most rapid at 30°C. The relation between growth and temperature is shown in Fig. I. From this figure we find that the optimum and maximum points are closer together than are the optimum and minimum.

In the year 1884 Van't Hoff propounded his famous principle that the velocity of a chemical reaction doubles or trebles with each rise in temperature of 10°C. His relation could be expressed in the form :—

$$V = CK^t$$

where K assumes the value of 1.072 or 1.116 when the velocity of the reaction doubles or trebles with a 10°C rise in temperature.

This law has been applied by Physicists, Chemists and Botanists to their respective problems. Physicists found that the various physical relations vary somewhat but do not exactly double with an increase of temperature of 10°C. Chemical reactions however, seem to double with a 10°C increase in temperature while reactions in physical chemistry increase at a rate less

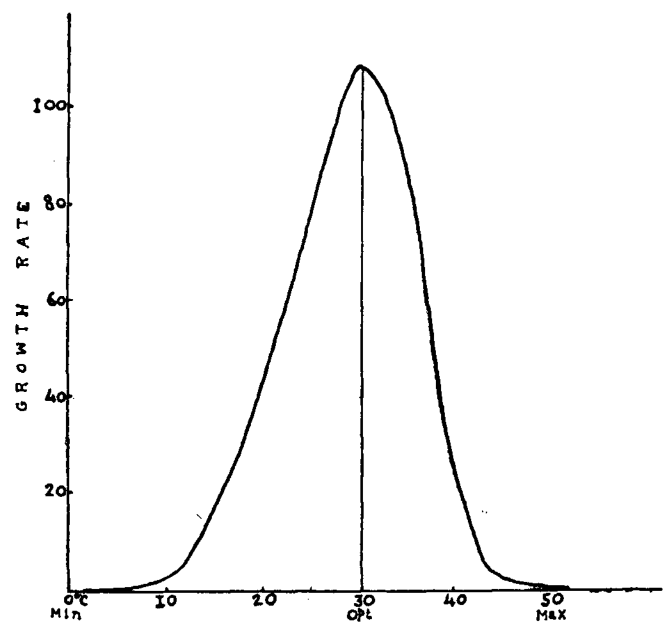


FIG. I

than two for each increase of 10°C. In physiological processes it is customary to determine the temperature coefficients from the actual growth measurements. By temperature coefficient we mean the quotient of two growth rates that are separated from each other by 10°C. This temperature coefficient according to Van't Hoff's law should assume a value of either 2 or 3. But experimental determination shows that the temperature coefficients vary much more than what could be explained on the basis of Van't Hoff's law. Table I gives the temperature coefficients of the growth rates of maize seedlings for various 10°C ranges of temperatures as obtained from the experiments of Lehenbauer. It is clear from this table that the temperature coefficients decrease continuously as the temperature increases from the minimum to the maximum value and that the Van't Hoff's law is applicable only in the limited range of 20°C to 31°C and no where else.

A short account of the relation between temperature and growth given above makes it clear that upto 30°C, temperature acts as a stimulant for growth while beyond that, temperature and growth are inversely related. These relations between growth and temperature cannot be explained by the simple Van't Hoff's equation which goes on increasing as the temperature increases when a constant value of either 1.072 or 1.116 is assigned to K. The equation would, however, represent the experimental facts if the value of K goes on decreasing as the temperature goes on increasing with the result K would have different values for different temperatures.

Any expression that correlates temperature with growth must necessarily contain two terms. One of them must represent the stimulating action of temperature on growth upto 30°C while the second must represent the growth

TABLE I

Temperature in C	12–22;	13–23;	15–25;	18–28;	20–30;	21–31;	22–32;	25–35;	32–42;	33–43;
Growth rate 0.01 mm.	6–59;	10–64;	20–75;	28–98;	45–108;	53–109;	59–111;	75–86;	111–11;	101–6;
Temperature Coefficient	9 83;	6.49;	3.75;	3.50;	2.40;	2.06;	1.88;	1.55;	0.09;	0.06;

retarding action beyond 30°C and that the two terms must be so adjusted that at the optimum temperature the effect of the first term must just be equal to that of the second.

The satisfactory formula for the growth index in terms of the percentage of the optimum growth would be in the form :—

$$V = [\,pqr\ (e^{rt})\,]\ (e^{rt} + q)^{-2} \quad \ldots\ldots\ldots(2)$$

where p, q, r, are constants and e is the base of the Napierian system of logarithms. The constants could always be so adjusted as to take care of other factors besides temperature on which growth depends.

The above equation when solved using the data published by Lehenbauer (1914) (in the absence of any other data) was found to give the following values for the constants.

p=1681.0 ; q=1118.8 ; r=0.24 ; and the final equation for growth comes out to be :—

$$V = (1681{\cdot}0)\,(1118{\cdot}8)\,(0{\cdot}24)\ e^{(0\cdot24)\,t}\ [\,e^{(0\cdot24)\,t} + (1118{\cdot}8)\,]^{-2} \quad \ldots\ldots\ldots(3)$$

The agreement between the values of growth index as obtained from equation (3) and those of experimental determination was quite good which is clear from Fig. 2 in which the computed as well as the observed values are plotted.

This growth index which integrates all the factors that affect growth should be made the yard stick to measure the climate of a place instead of temperature alone or some functions of temperature as has been done by all investigators so far.

In order that vegetation may thrive at a place, besides soil, temperature and sunshine, there must be another equally important climatic element, the precipitation. If there is no precipitation there cannot be any vegetation. Hence the ratio of monthly precipitation (in inches) to the growth index corresponding to the mean monthly temperature in degree centigrade and multiplied by 100 gives what is called "the monthly effective growth ratio".

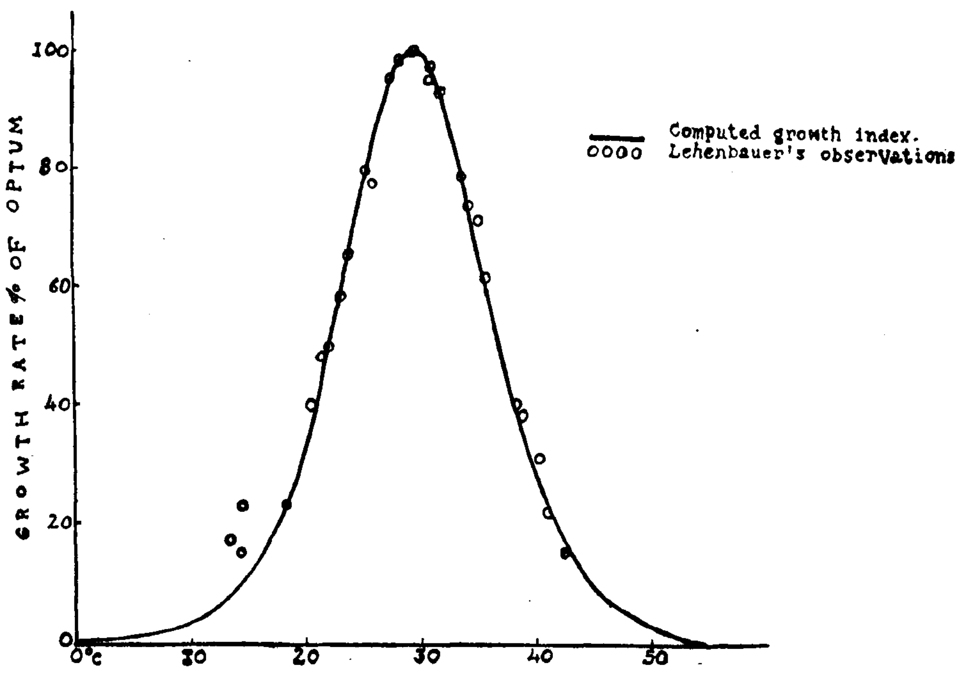


FIG. 2

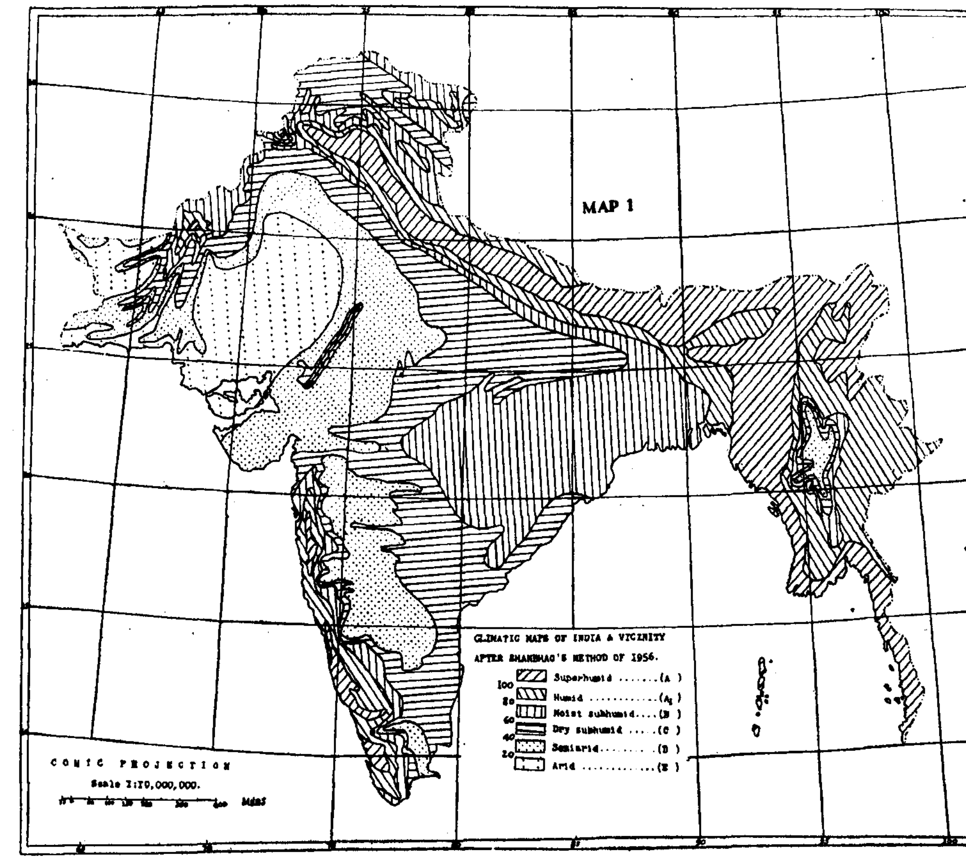
The sum of the twelve monthly effective growth ratios of a station gives what is termed the "Effective Growth Index" and is represented symbolically as E.G. Thus the effective growth index is :—

$$\text{E. G.} = \sum_{n=1}^{n=12}\left[\frac{100\,(P)\,[\,e^{(0.24)t}+1118\cdot8\,]^2}{(1681\cdot0)\,(1118\cdot8)\,(0.24)\,e^{(0.24)t}}\right]_n \quad \ldots\ldots\ldots\ldots(4)$$

The above formula enables one to compute the monthly effective growth ratio and the E.G. of a station where monthly observations of precipitation and temperature are available. The computation of the growth index by means of the formula (3) is very laborious hence a table is constructed which gives the growth index of a month corresponding to the temperatures from 1°C to 50°C, these being the limits of temperatures which we normally experience in the tropical and extra-tropical parts of our country as well as the temperatures between which vegetation can grow.

The method outlined above was first applied to India and its vicinity. The E.G. was found out for every station where temperature and precipitation records extended through a period of 30 years or more. Nearly 300 of these indices were plotted on a map of scale 1 : 5,000,000 and the E.G. index isopleths were drawn. Through the study of vegetation, soil and landscape six major climatic regions were recognised and defined (See Map 1, a reduced map of the original). The various climatic types together with their limits are as follows :—

Climatic types.	*E.G. Index.*
A Super humid	100 and above.
A_1 Humid	80 to 100.
B Moist sub-humid	60 to 80.
C Dry sub-humid	40 to 60.
D Semi-arid	20 to 40.
E Arid	0 to 20.



Super-humid climates are not very extensive in India and its vicinity. They occur in some parts in the south-west of the sub-continent especially along the windward side of the Cardamom and Nilgiri hills and the Sahyadri mountains. There is also a small island in the high mountains of the Western Ghats near Mahabaleshwar. All the coastal regions of Burma from the extreme south to Mukai mountains, the Arakan Yoma, Khasi hills, Barail Range, Patkai hills to Namkin mountains in the extreme north-east, Bhutan, some parts of Nepal, Siwalik hills to Murree and Rawalpindi in the north-west, together with a small island near Quetta form the only super-humid climates in the sub-continent. Humid climatic regions which occur adjacent to the super-humid climiates, run as a narrow strip all along the Western Ghats from the 8th parallel in the south to the 20th parallel in the north. A second strip of humid region which starts from the coast near Noakhali in East Pakistan runs along the foot of the Himalaya and practically surrounds the super-humid climatic region of this area. Small islands, one in the vicinity of Karakoram Range, another in the Greater Himalayan Range in the north, a third in the Toba and Kakar range in the north-west together with the whole of Burma except the valley in the lee of the Pegu Yoma all belong to humid climates. Sub-humid climates are most extensive in India. The great belt of sub-humid (moist) climatic region starts from the mouth of Brahmaputra and Mahanadi and runs along the western side of the Northern Circars and covers practically the whole of Madhya Pradesh, Western Bengal, parts of Eastern Pakistan and then goes further as a thin strip encircling the humid region of the Himalayan range. Smaller areas belonging to this class occur in the extreme north-east and north-west of India, the Aravali hills, the eastern slopes of the Western Ghats and in central Burma. The major sub-humid (dry) climatic region which commences from the mouth of the Mahanadi runs along the coast of Madras down to the 10th parallel, and occupies practically the whole of the Carnatic region of Madras, south-east parts of Mysore, eastern parts of Hyderabad, northern parts of Deccan, central parts of the Gangetic valley, north-eastern parts of the Punjab, and the Sulaiman Range down to Central Baluchistan. Semi-arid climatic region in the south of the sub-continent consists of a small beak shaped area that runs from the south-east coast of Madras to the Palghat gap. The Deccan plateau of Bombay, the lower slopes of Sahyadri Parvat, upper valley of Godavari, central valley of Krishna as well as that of Tungabhadra, Chitaldurg district of Mysore are all characterised by semi-arid climate. From the Kathiawar Peninsula to the Aravali Range, then north ward and north-west ward to the Punjab, the middle slopes of the Sulaiman mountains and the contiguous regions in Baluchistan form the extensive areas of semi-arid climate. Semi-arid climate is also prevalent in the central Irrawaddy valley in Burma. The arid region starting from the extreme north-west of Kathiawar comprises practically the whole of Cutch, Rajputana, the central and lower courses of the Indus and the Makran coast. The north-west portion of Baluchistan is also characterised by this type of climate.

Seasonal Concentration of the Effective Growth Index.—The effective growth index (E.G.) represents the total for the year but it cannot tell us anything as to how it is distributed throughout the year. It is absolutely necessary to know from the point of planning whether this index is spread uniformly throughout the year or whether it is concentrated in any season.

It is necessary at this stage to give a brief idea about our seasons since the seasons of other countries like those of America and Europe are not at all experienced here.

The Indo-Pakistan sub-continent is termed as a "land of monsoons" since the monsoon constitutes the most important rain yielding winds in the major part of our country. The year in this continent is divided into four seasons in relation to the monsoon. They are as follows :—

(1) The winter or the north-east monsoon season (December to February).

(2) The summer or the pre-monsoon season (March to May).

(3) The rainy season or the monsoon season (June to September).

(4) The autumn or the post monsoon season (October to November).

Thus each one of our seasons is not of equal duration viz. of three months. The monsoon season has 4 months while the post monsoon is of only two months. This unequal duration of these two seasons introduces more difficulties in defining the seasonal concentration of the effective growth index. However, taking into consideration all these factors the following seven sub-types are recognised.

(*a*) The effective growth index present in sufficient amount throughout the year.

(*b*) The effective growth index deficit in winter and summer.

(*c*) The effective growth index deficit in post monsoon & summer.

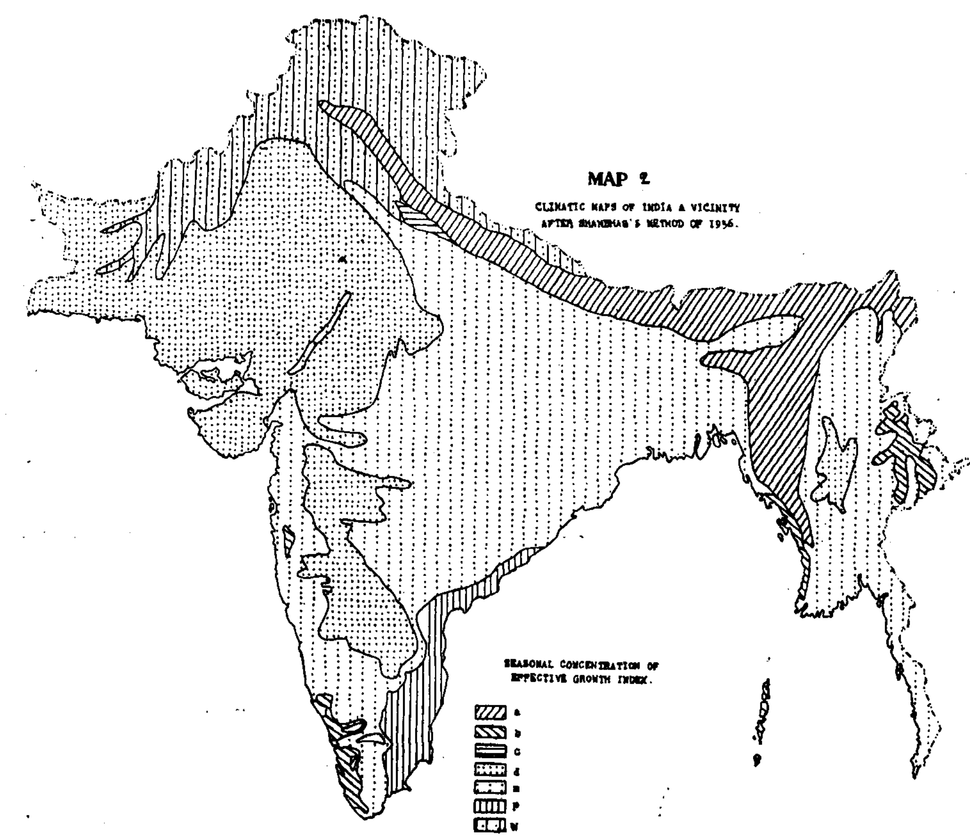
(*d*) The effective growth index deficit at all seasons.

(*m*) The effective growth index deficit at all seasons except in monsoon.

(*p*) The effective growth index deficit at all seasons except in post monsoon.

(*w*) The effective growth index deficit at all seasons except in winter.

To be classed as *a* the total index must be more than 70 and no season should have a value less than 21 except the monsoon and post monsoon seasons when the indices should be more than 28 and 14 respectively. When



the total index is more than 70 and the monsoon and post monsoon indices are more than 28 and 14 respectively, the subtype is *b*. If the monsoon and winter indices are more than 28 and 21 respectively and if the total exceeds 70, the subtype is c. In *d* the E.G. index must be less than 70 and the monsoon and post monsoon indices must be less than 28 and 14 respectively while during the other seasons it must be less than 21. When the monsoon index is more than 28 and post monsoon, winter and summer indices are less than 14, 21 and 21 respectively the subtype is *m*, while in *p* the post monsoon index must be more than 14 and the monsoon, winter and summer indices must be less than 28, 21 and 21 respectively. In the case of the subtype *w* the total index must be more than 70 and its concentration during winter must be more than 21 and the other seasons monsoon, summer and post monsoon should have indices less than 28, 21 and 14 respectively.

The distribution of climatic subtypes based on the seasonal concentration of the effective growth index is shown in Map 2.

It is clear from this map that types *m* and *d* representing the monsoon concentration and deficit at all seasons respectively of the effective growth index are most extensive. Type *p* prevails on the south-east coast of the sub-continent where the retreating south-west monsoon, getting moisture laden while passing over the Bay of Bengal gives sufficient rain during the month of October and November for the vegetation to grow. During the monsoon period the rainfall in this part is not sufficient to bring the cumulative sum of the monthly effective growth indices to 28. Type *b* is found in isolated patches in the whole of the sub-continent. Two of them occur in the south-west, one along the southern end of the Sahyadri and the second in Travancore along the Cardamom hills. The third island is found in the northern peak of the Western Ghats near Mahabaleshwar while the fourth one occurs along the west coast of Burma near Arakan Yoma. Except in Nilgiri and Cardamom hills type *a* is found only in the super-humid climatic regions of the Himalaya and the Arakan Yoma. The north-west part of the country is the only portion where the monsoon becomes less effective for, having travelled 1,000 miles or more across the continent, it becomes completely dry. In this part, winter rain from the north-west creates a climate much similar to that of Mediterranean and it is here where we find the type *w*. Type *c* is found as a single island in the Siwalik hills near Dehra Dun which receives sufficient rain in monsoon as well as in winter.

An Index of Thermal Efficiency

The growth index which has the property of showing that low as well as high temperatures act as a limiting factor for plant growth can be used to define climatic regions based on temperature efficiency. The regions thus defined will be of great help from the point of view of irrigation planning since it gives us an idea of the regions which can grow most when water is made available.

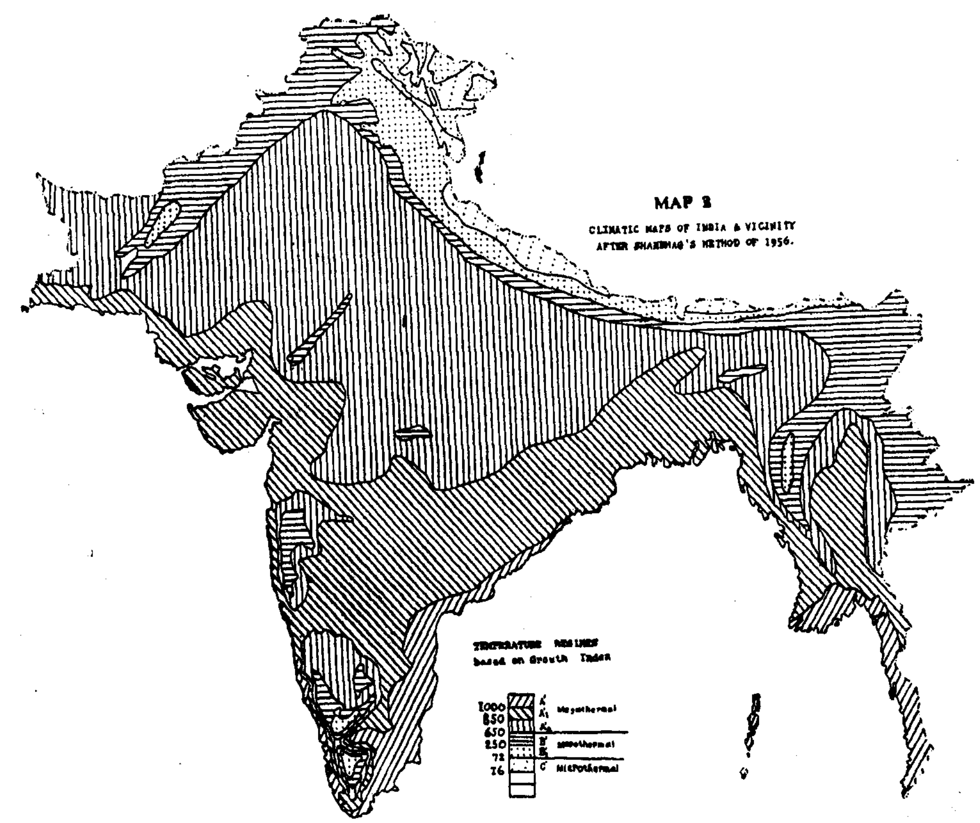
Just as the effective growth index (E. G.) has been expressed as an accumulated sum of the individual monthly effective growth ratios, a similar method is adopted to express the thermal efficiency in terms of the growth index. The sum of the twelve monthly growth indices is called the "Net Growth Index" and is represented symbolically as N.G. The least favourable thermal conditions for plant growth are in the polar regions. The thermal efficiency and hence the plant growth is clearly zero at the polar limit of the tundra. Under most favourable growth conditions the N.G. would be 1,200 but such conditions though they prevail for some time of the year in certain parts of the tropics do not last throughout the year because of the seasonal variations in temperatures. Even in the equatorial regions, where the mean monthly temperatures do not differ appreciably through the year, the optimum temperature is hardly reached. Thus there is no place in the world where the upper limit for N.G. (1200) is ever reached. Hence the upper and lower points of the temperature efficiency in relation to growth are 1,200 and 0

respectively and other limits for separating the megathermal, mesothermal, microthermal taiga, tundra and frost are defined after plotting on a map of the same scale mentioned above, the N.G. of the same stations for which the E.G. had already been determined. They are as follows :—

Climatic Type		*N.G. Index*
A′	Megathermal	1000 and above.
A′1	,,	850 to 1000.
A′2	,,	650 to 850.
B′	Mesothermal	250 to 650.
B′1	,,	72 to 250.
C′	Microthermal	16 to 72.
D′	Taiga	8 to 16.
E′	Tundra	1 to 8.
F′	Frost	0 to 1.

The isopleths bounding the provinces defined above are drawn and shown in Map 3.

The Megathermal (A′, A′1, A′2,) climates occupy practically the whole of the country except the mountains where the temperature decreases with



height and the consequent lowering of the growth index. Secondly the seasonal variation of temperature also becomes large with the increase in altitude. Winter growth indices fall off slowly with the increase of latitude. Mangalore, Cochin, Pamban and Trichinopoly lying in the south have growth indices 73.1, 69.5, 76.8 and 65.9 per cent of the optimum respectively in the month of January which is the coldest month of the year, while during the same month Agra, Cawnpur, Allahabad and Peshawar in the north have only 6.09, 5.30, 15.8 and 4.50 values for the indices. During May, the hottest month of the year the difference between the growth indices of the above mentioned southern and northern stations is very small because of the temperatures of these stations lie in the vicinity of the optimum. In the month of May the maximum temperature is not experienced by the coastal regions in the southern part of the country owing to on shore winds that are induced due to the low pressure trough which stretches from Multan to Chota-Nagpur, but is felt in the interior of the continent. Thus the growth index of the interior and northern stations again decreases due to increased temperatures. All the coastal stations in the south, south-east and south-west of the sub-continent have the growth indices in the vicinity of the optimum for nearly 8 months of the year while the number of months for which the growth is maximum decreases as we move towards the north. This necessitates the division of the Megathermal climates into three sub-divisions.

Mesothermal (B′) climates are found in the north-west along the Sulaiman and the Hindu Kush mountains, in the north-east along the Himalayan and the Patkai Ranges while in the east they occur along the upper elevations of Arakan Yoma and Tanen Taung-gyi mountains. Small areas of this climate are also found in the central parts of the Western Ghats, the Aravalli and the Mahadeo hills, the Nilgiri and Northern parts of the Cardamom hills. In general they are at high elevation in the southern mountain regions whereas they are found at lower elevations in the north. The most extensive area of the colder type of the mesothermal (B'_1) climate is in the Great Himalayan Range though smaller areas are found on the peaks of the higher mountains in the south, north-west and east of the sub-continent. Except the high elevation of the Himalayas and the Karakoram Range, the microthermal climate (C′) is not experienced anywhere in India. The Taiga (D′), Tundra (E′) and Frost (F′) don't at all occur in this sub-continent.

Seasonal Concentration of the Growth Index

To complete the climatic classification, it is necessary to take into consideration the seasonal concetration of the growth index because of the differences in the annual march of the growth indices due to the differences in the annual march of temperature. It is possible that two places may have the same values for the N.G. In one the growth indices may be distributed uniformly throughout the year while in the second it may be concentrated during a few months of the year. The N.G. alone cannot differentiate between two such places. To express such a climatic difference the seasonal concentration of the growth indices should be taken into account.

At the equator the annual range in the temperature is small, much smaller than the diurnal variations, due to relatively small variation of the solar altitude. Hence for equatorial regions the sum of the growth indices for any three consecutive months will be approximately 1/4 or 25 per cent of the annual total. On the other hand, in the Polar regions during the summer months alone, when the temperature rises above freezing point, growth is possible. Under such conditions the sum of the growth indices of the three summer months will be equal to the growth for the whole year. Thus the sum of the growth indices for the three summer months will increase from 25 to 100 per cent of the annual growth, as we move from the equator outwards towards the poles provided other factors such as vicinity of sea or mountains does not alter the temperature of a locality and introduces abnormalities.

It has been already pointed out that the summer months of this land of monsoon are entirely different from those of the other countries. These summer months or the dry season acts as a rest period for vegetative life due to a pronounced seasonal concentration of precipitation. Thus in its action on vegetation this dry period coincides with the winter of the middle latitudes. The south-west monsoon which prevails from June to September i.e. during what would without it be the hottest months of the year, is of greatest importance not only in moderating the heat and dessication but also in promoting growth. Hence instead of the usual practice of finding the sum of the growth indices for the three summer months and then expressing it as the percentage of the total it was thought that for our climates the ratio of the sum of the growth indices during the four monsoon months to the total should be used to define the seasonal concentration of the growth index.

On the basis of the monsoon concentration of the growth index the following seven subtypes have been defined.

Subtypes	*Percentage Monsoon Concentration*
n′	17 to 24.
M′	25 to 33.
a′	34 to 42.
b′	43 to 58.
c′	59 to 75.
d′	75 to 99.
e′	100.

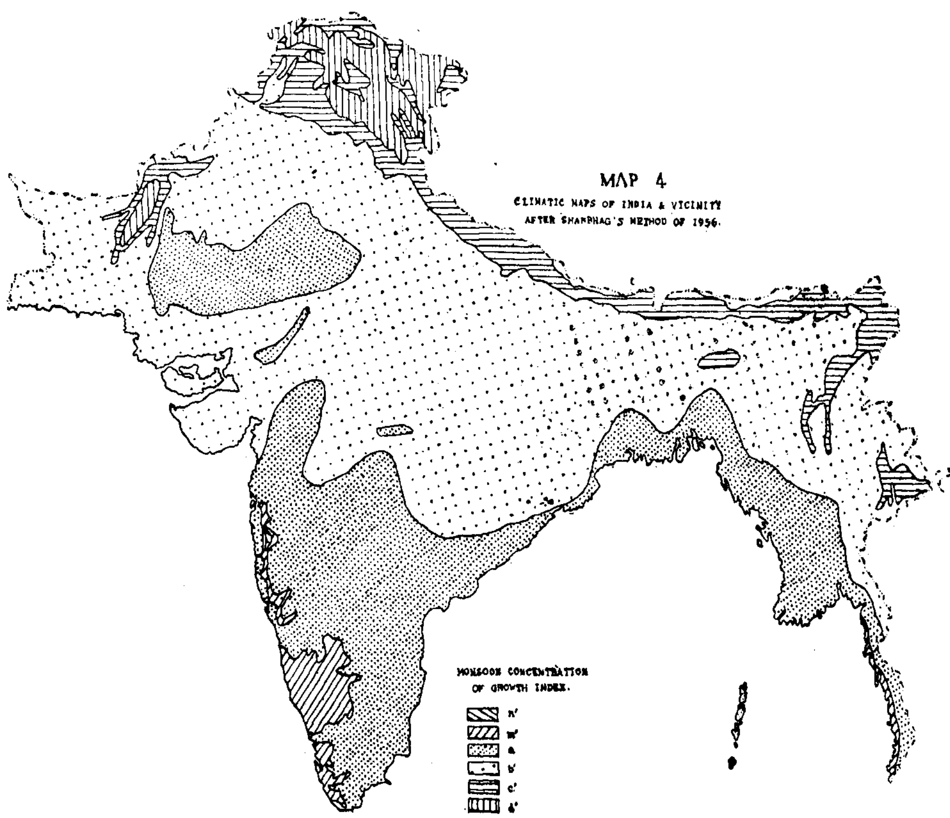
In India the first six out of the seven subtypes are found and mapped (See Map 4).

Effective Growth Index	Net Growth Index	Seasonal concentration of the effective growth index	Monsoon concentration of the growth index
A	A′	a	m′
A1	A'^1	b	n′
B	A'^2	c	a′
C	B′	d	b′
D	B'^1	m	c′
E	C′	p	d′
	D′	w	e′
	E′		
	F′		

Elements of Climatic Classification

The following four symbols used together give a complete picture of the climate of a place.

Table 2 gives the necessary data for the classification of some selected stations. The first five stations though belonging to the same principal group viz. the super-humid climates, illustrate the five different types of seasonal distribution of effective growth indices. Even though all the six a, b, c, m, p, w subtypes of the A and A_1 climates are possible, the p subtype rarely occurs while the d subtype is an impossibility. The subtype *a* cannot be found in the B, C, D, and E climates. The E climates are always of the d subtype. Thus there are several combinations which are theoretically impossible.



The effective growth index and the net growth index are the two most important climatic elements, for besides taking heat and water which are most important factors in dominating the organic and inorganic world the growth index integrates all other factors such as soil, evaporation, humidity radiation and wind. More experiments are to be performed under natural conditions to find the final expression for the growth index. These experiments will only alter the values of constants p, q and r but not the form of the equation. If these are once determined and standardised they will help a great deal in the future planning of the country and also in the agricultural evaluation of

climate for taxing purposes. Under such plans farmers would be taxed not on how much they have grown, but on how much the climate and soil permit them to grow.

The objections that may be raised against this system of classification will be those that were directed against Koppen's, for just like Koppen's system it takes vegeation as the basis for defining the climatic boundaries. In the opinion of the author no classification however rational it may be, can be independent of vegetation for if there is no vegetation there cannot be any classification. The plant which integrates all the various factors of the climate could alone be used as a " Climatometer " and no other single factor can serve such a purpose.

TABLE II

Climatic Classification of Selected Stations

Station	Effective growth index (E. G.)	Seasonal concentration of E.G.				Net growth index (N. G.)	Monsoon concentration of (N. G.)	Climatic type
		Winter	Summer	Monsoon	Post Monsoon			
Cherapunji	1404.0	44.6	385.2	881.1	93.1	263.3	51.2%	A B′ a b′
Derha Dun	158.6	64.3	6.4	83.7	4.2	664.4	52.7%	A A'_2 c b′
Ambala	142.2	109.4	2.6	26.0	4.2	644.5	59.8%	A B′ w c′
Calicut	136.0	1.6	13.6	103.9	16.9	1113.6	31.5%	A A′ b m′
Rangoon	107.9	0.9	14.4	82.5	10.1	1123.2	34.2%	A A′ m a′
Marmagoa	99.9	0.2	1.2	95.3	3.2	972.6	36.7%	A_1 A'_1 m a′
Ranchi	95.4	20.6	5.1	63.0	6.7	664.5	46.5%	A_1 A'_2 m b′
Bombay	74.9	0.1	1.7	71.0	2.1	915.4	41.0%	B A'_1 m a′
Calcutta	67.3	4.0	9.0	47.8	6.5	950.8	42.0%	B A'_1 m a′
Madras	47.1	8.1	2.9	15.7	30.4	1067.0	37.0%	C A′ p a′
Indore	42.3	3.1	0.8	35.3	3.1	724.6	42.0%	C A'_2 m b′
Chitaldurg	39.0	0.9	4.7	25.4	8.0	721.7	30.8%	D A'_2 d m′
Ajmer	36.6	12.8	1.7	19.8	2.3	657.4	54.8%	D A′ d b′
Jodhpur	18.3	3.1	0.8	13.4	1.0	756.8	50.7%	E A'_2 d b′
Bhuj	17.9	0.8	0.8	16.2	0.1	850.8	46.2%	E A'_1 d b′

TABLE III

Growth Index for various temperatures in degree condigrade

T.C.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	00.46	00.47	00.48	00.49	00.50	00.52	00.53	00.54	00.55	00.57
2	00.58	00.60	00.61	00.63	00.64	00.65	00.67	00.69	00.70	00.72
3	00.74	00.76	00.77	00.79	00.81	00.83	00.85	00.87	00.89	00.92
4	00.94	00.96	00.98	01.01	01.03	01.05	01.08	01.11	01.13	01.16
5	01.19	01.22	01.25	01.28	01.31	01.34	01.37	01.41	01.44	01.48
6	01.51	01.55	01.59	01.62	01.67	01.70	01.74	01.78	01.83	01.87
7	01.92	01.96	02.01	02.06	02.11	02.16	02.21	02.27	02.32	02.38
8	02.43	02.49	02.55	02.61	02.68	02.74	02.81	02.87	02.94	03.01
9	03.09	03.16	03.23	03.31	03.39	03.47	03.55	03.64	03.73	03.81
10	03.90	03.99	04.09	04.18	04.28	04.38	04.49	04.60	04.71	04.82
11	04.93	05.04	05.17	05.29	05.41	05.53	05.66	05.81	05.96	06.09
12	06.24	06.37	06.52	06.67	06.84	06.99	07.17	07.32	07.57	07.67
13	07.84	08.04	08.22	08.41	08.60	08.83	09.02	09.23	09.44	09.65
14	09.86	10.09	10.33	10.57	10.80	11.05	11.31	11.59	11.83	12.12
15	12.40	12.66	12.97	13.25	13.53	13.85	14.19	14.49	14.81	15.16
16	15.48	15.82	16.13	16.51	16.79	17.22	17.66	18.08	18.47	18.83
17	19.30	19.70	20.10	20.52	20.98	21.40	21.85	22.33	22.83	23.12
18	23.86	24.32	24.80	25.10	25.87	26.45	26.97	27.58	28.12	28.68
19	29.32	29.87	30.53	31.13	31.76	32.33	33.02	33.61	34.35	34.99
20	35.71	36.38	37.12	37.80	38.50	39.23	39.95	40.60	41.46	42.27
21	43.07	43.87	44.73	45.37	46.24	47.03	47.82	48.67	49.66	50.40
22	51.26	52.17	52.98	53.77	54.85	55.77	56.58	57.46	58.40	59.37
23	60.17	61.23	62.11	63.65	64.30	64.90	65.86	66.64	67.67	68.64
24	69.46	70.36	71.38	72.26	73.11	74.10	74.99	75.81	76.77	77.80
25	78.74	79.53	80.41	81.23	82.19	83.00	83.67	84.67	85.41	86.21
26	86.93	87.38	88.60	89.35	89.90	90.71	91.32	92.04	92.60	93.24
27	93.90	94.60	94.96	95.58	96.12	96.56	97.07	97.54	97.94	98.26
28	98.62	99.00	99.26	99.60	99.86	100.00	100.00	100.00	100.00	100.00
29	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
30	100.00	99.82	99.72	99.27	98.90	98.60	98.26	97.86	97.36	97.00
31	96.46	96.00	95.84	95.06	94.46	93.88	93.22	92.60	91.92	91.28
32	90.50	89.86	89.16	88.34	87.70	86.85	86.10	85.30	84.49	83.60
33	83.10	82.00	81.20	80.30	79.40	78.49	77.59	76.70	75.80	74.91
34	74.00	73.05	72.10	71.00	70.30	69.40	68.50	67.60	66.73	65.56
35	64.60	63.70	62.83	61.94	61.00	60.11	59.13	58.15	57.22	56.44
36	55.60	54.82	53.80	52.96	52.12	51.20	50.30	49.46	48.60	47.84
37	47.00	46.11	45.21	44.44	43.67	42.91	42.17	41.36	40.63	39.81
38	39.16	38.48	37.71	37.10	36.20	35.53	34.87	34.20	33.60	32.93
39	32.27	31.62	30.99	30.44	29.78	29.16	28.58	28.03	27.42	26.91
40	26.33	25.81	25.24	24.76	24.28	23.74	23.21	22.78	22.27	21.79
41	21.36	20.88	20.45	20.04	19.62	19.19	18.80	18.37	18.06	17.54
42	17.29	16.93	16.64	16.14	15.75	15.43	15.14	14.76	14.47	14.19
43	13.84	13.55	13.21	12.97	12.59	12.34	12.13	11.81	11.57	11.21
44	11.03	10.81	10.50	10.34	10.03	9.83	9.64	9.38	9.18	8.92
45	8.78	8.62	8.35	8.19	7.99	7.83	7.60	7.43	7.31	7.10
46	6.98	6.84	6.65	6.51	6.32	6.21	6.09	5.86	5.75	5.64
47	5.53	5.40	5.28	5.16	5.01	4.92	4.82	4.69	4.58	4.46
48	4.36	4.29	4.16	4.08	3.95	3.89	3.79	3.69	3.63	3.52
49	3.44	3.38	3.28	3.20	3.12	3.06	3.03	2.99	2.87	2.78
50	2.72	2.68	2.60	2.52	2.46	2.40	2.36	2.28	2.24	2.19

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AGRICULTURAL PLANNING IN INDIA

By

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Since India attained independence in August 1947, remarkable progress has been achieved in various fields of economic activities, particularly so in irrigation and agriculture. Before an attempt is made to appraise precisely the development that has taken place, it may be worthwhile to take stock of the exact position with regard to food supply, agricultural production and population immediately preceding partition. With the separation of Burma in 1937, and a consequent loss in the internal supplies of approximately 1.3 million tons of rice, the problem of food began to loom large. The over-running of Burma by the Japanese forces in 1942-43 created a severe famine in Bengal, and conditions had by no means got stabilised when the sub-continent was partitioned into India and Pakistan, which led to a further aggravation of the problem of food. It must be remembered that as a result of partition, India lost disproportionately both in the quantity and quality of her cultivated lands.[1] The pangs of birth of Independent India, free from British suzerainty were, indeed, acute. Partition, in its wake, brought in a series of problems, by far the most difficult and urgent was that of 7.5 million Hindu refugees who migrated from Pakistan. The Muslims who left India for Pakistan are estimated to be less than six millions, thereby creating a net increase of population of 1.5 millions. Most of these refugees coming into India had nothing other than the clothes they wore and the primary duty of the government was to rehabilitate them.[2] At the same time immediate attention had to be focussed on problems like the scarcity of industrial raw materials like cotton and jute, boundary disputes, defence requirements, etc., but behind all this was the problem of hunger created by a rapidly increasing population. Thus, the natural increase of population, the influx of refugees, and the disproportionate decrease in the cultivated area as a consequence of partition, these have all operated jointly to make the food problem, even more acute.

It is difficult to make any precise comparison between the *per capita* amount of food available at the beginning of the century and today, especially because of the recent introduction of cash crops like jute, cotton and sugarcane

[1] Population of Pakistan was 22% that of undivided India while the food production capacity of the region was estimated at 30%. Undivided India had 298 million acres of cultivated land of which 72 million acres were irrigated, i.e. 24%. As a result of partition, India got 48 million acres of irrigated area out of a cultivated area of 251 million acres, i.e., the irrigated area constituted only 19% of the total cultivated area. In pre-partitioned India there were 24 million acres irrigated by State controlled canals—the better irrigated lands—and of this a little more than half was ceded to Pakistan.

[2] Whatever abuses have been, or are being showered upon the Ministry of Rehabilitation of the Government of India, it is only a few who recognise the magnitude of this problem. That it has achieved so much in so short a time under such difficult odds, goes to its great credit. Today a stage has been reached when the displaced persons, have by and large, adjusted themselves to their new environments and with the economic development of the country, they will undoubtedly find their rightful place. It may be that we have not repaired all the tears in the economic fabric, but commendable progress has been achieved.

in the agricultural cycle. But, even if proper weight is given to these and the entire production converted to a uniform food crop basis, there is no doubt that there has been a substantial decrease in the quantity available per person ; the estimated figure being 600 lbs. in 1901 and 400 lbs. in 1951.[3] In respect of food grains alone, the deficit in 1950, at the then existing levels of population and consumption[4] was estimated at about 3 million tons, mostly rice. The first task that the National Government took upon itself, next to the rehabilitation of the refugees, was to find food in adequate quantities. Towards this end, various steps were taken, firstly to augment the area under cultivation by reclaiming lands left untilled, secondly by increasing the facilities for irrigation, thirdly by improving agricultural yields, not only by better seeds and better manures, but also by modern methods of animal husbandry, fishing, etc., and lastly to create an incentive for better living among the villagers. At the same time efforts were also made to develop the industries, both large scale and cottage.

Expanding the area under cultivation apparently seems easy. Statistical returns, certainly of doubtful accuracy, might show that 80—90 million acres of land lie as cultivable waste, but inspite of the long agricultural heritage and the food famine in the country, except in the newly irrigated tracts of Central India and the freshly deforested regions like Assam, elsewhere the extent of cultivated area during the last fifty years has either been constant or has shown a steady decline, particularly so in some parts of Bihar. Reclamation measures have been promoted both by the State Government and by the Central Tractor Organisation of the Government of India since 1947. By 1951, the State Governments reclaimed 1.5 million acres and the Central Tractor Organization 0.5 million acres, altogether 2 million acres ; but it must be confessed that a good part of this has really gone back into disuse by now. Further-more, comparative figures since 1946 have shown that the area under fallows has increased by 10 million acres ! ! Is this not proof conclusive that agriculture has been pushed to sub-marginal limits and that expanding the area under cultivation is not as easy as it is made out to be ?

IRRIGATION

It must not be forgotton that agriculture still depends largely on a precarious and fickle monsoon. The rainfall is highly seasonal, all the rain being concentrated in the four summer months, the remaining eight months being generally dry, necessitating the need for storage reservoirs. Further-more, the average figures of rainfall give the false impression that most parts enjoy an adequate amount, but the variations from year to year are so great that agriculture is reduced to a mere gamble, unless it is fortified by irrigation.

Recent estimates show that the aggregate surface flow of the rivers of the Union of India is about 1,356 million acre feet and in 1947, only 76 million acre feet, i.e., 5.6% of the surface flow was used for irrigation. Although the entire surface flow can never be diverted for garnering the crops, engineers suggest that about 450 million acre feet, about a third, could be so harnessed. Substantial water supplies exist underground and with the development of tube well irrigation, it will be possible to considerably augment water supplies, particularly so, in the Gangetic basin.

[3] *Cf.* U.S.A. where in the same period the *per capita* food production has increased by 15% although the population has more than doubled itself.

[4] The daily adult ration was either 8 ozs. of wheat, or 8 ozs. of rice and 2 ozs. of wheat or millet.

Immediately on the formation of the National Government, various multipurpose projects (some of them modelled on the T.V.A.) linking irrigation, power development, flood control, etc., were taken on hand. Of these, the larger are the Bhakra-Nangal (8 million acre feet on the Sutlej to irrigate 1.4 million acres), the Damodar Valley (2.7 million acre feet on the Damodar, a tributary of the Ganges, to irrigate 0.6 million acres), the Hirakud (11 million acre feet on the Mahanadi to irrigate 0.3 million acres), the Tungabhadra (6 million acre feet on the Tungabhadra, a tributary of the Krishna, to irrigate 0.5 million acres), etc. By planned development, the Government hopes to double the area under irrigation and to generate 7 million k.w. of hydro-electric energy in 15 to 20 years, i.e., by 1966-71. In the first five-year plan of 1951-56, it is hoped that 8.5 million acres of fresh land will be brought under irrigation, besides generating 1.1 million k.w. of energy. The actual achievements up to March 1955,—5 million acres under irrigation and 0.7 million k.w.[5] of electric energy, give room for optimism. To cite some examples: The Nangal dam, the Nangal hydel channels and the Bhakra canals have all been completed. The work on the distribution channels and extension of transmission lines in Rajasthan and Pepsu have made substantial progress, and it is expected that about 100,000 acres of land will be given to *Kharif* (summer) irrigation by the beginning of 1956. In the Damodar Valley Project, the Bokaro thermal station generating 50,000 k.w. out of an ultimate capacity of 200,000 k.w. and the Tilaya dam power station generating 4,000 k.w., have been in commission since 1953, and the Konar dam completed by 1954. Nearly 2/3rds of the earth work of the Maithon dam has been executed and the progress in the construction of the Durgapur barrage and the Panchet hill dam is satisfactory. Likewise, in the Hirakud dam, nearly half the work of the dam construction is finished; the left and right dykes are nearing completion; the power-house machinery is under installation which it is hoped will be ready by 1957. The Tungabhadra dam has almost been completed and 33,000 acres have been brought under irrigation. In addition to these large schemes, several smaller projects, tube well schemes, tanks, etc., have been executed, all of which have substantially enhanced the facilities for irrigation.

The Hirakud project is expected to generate 125,000 k.w. by 1957 and the Tungabhadra power supply is expected to start in 1957, the Machkand in a few months and various thermal schemes as at Chola, S. Guzerat, Madras, Cuttack, etc., have made good progress. Actually about 0.5 million k.w. of new power have been added by the end of 1954, of which nearly 200,000 have been in the power-hungry areas of Andhra, Assam, Madras, Mysore and T.-C. State. In India, more than half the power generated is used in the three cities of Calcutta, Bombay and Madras, and even today a substantial amount of the total energy produced is consumed in the urban areas. Except in Madras, Mysore, T.-C. State and U.P., elsewhere,[6] rural electrification has made no progress and the prospects for development are, indeed, rosy.

Electrical energy produced in India and Pakistan in 1938 was 2,530 million k.w.h.; in 1947—it was 4,164 million k.w.h.; in 1948 the Union of India alone produced 4,584 million k.w.h.; in 1949—4,920 million k.w.h.; in 1953—6,624 million k.w.h.; and in 1954—7,448 million k.w.h.[7] Do not these figures speak for themselves?

[5] Government of India, Planning Commission, First Five-Year Plan, Progress Report April-September 1954, April 1955, p. 40.

[6] Madras—2,500 villages; Mysore—700 villages; T.-C. State—500 villages.

[7] Mid annual report ECAFE Oct. 1954-March 1955.

AGRICULTURE

It can be stated with a certain amount of confidence that the agricultural situation in the country has improved distinctly and the disequilibrium in the economy caused by war and partition has been largely set right. In respect of food grain production, a major problem which presented formidable difficulties in 1950-51, the target set for 1956 has already been exceeded by 1954. About one half of this increased production is certainly due to a succession of favourable monsoons; the other half alone could, therefore, be credited to increased area and improved methods.

In the first Five-Year Plan of 1951-56, the anticipated increase in the production of food grains was 7.6 million tons, cotton 1.26 million bales, jute 2.09 million tons, etc. Except for sugarcane and jute, in all other cases, the target set for 1956 has either been actually achieved, or nearly achieved by 1954. Actual figures show that the production of food grains has increased by 22% from 54 million tons in 1949-50 to 66 million tons in 1953-54; of this increase of 12 million tons, rice accounts for 4.2 million tons, wheat 0.7 million tons, millets 5.3 million tons, and grams and pulses 1.5 million tons. Experience in the past has shown that production in the best year sometimes varies from the median by as much as 20%, or even more, and when it is remembered that the monsoons during the period 1951-54 have been unusually good, a good deal of this increase must actually be credited to favourable climatic factors. A careful analysis of regional increase shows that tracts like Rajasthan, Madhya Pradesh, Hyderabad, etc., that is, regions where there has been no improvement in facilities for irrigation have all shown spectacular spurts in production, all of them put together by as much as 5 to 6 million tons. Surely this increase has to be credited to the natural elements. All the same, even on a conservative estimate, having made the allowance necessary for such unusually favourable climatic elements, still it can be stated that out of the increased production of 12 million tons, at least six million tons, say 50% of the total, is due to improvements in irrigation and agricultural methods. This is more or less, a permanent gain.

The greatest achievement on which the Government of India can take legitimate pride is, that it has, during the last seven years, not merely got over the deficit of three million tons in food grains, but, despite the increased population, added substantially more *per capitā*, and removed all the irksome restrictions consequent on controls and rationing.

295 million Indians, forming 83% of the total population live in rural areas and more than 70% of the people derive their livelihood from the land by agriculture, including the exploitation of animals and vegetation. 50% of the National Income is contributed solely by agriculture. But, all the same, it is not in a very healthy state and the average yield of crops is very poor as seen from the following:—

Crop	Average Indian Yield	Average World Yield	Example of country with good Yield
Wheat	10·3 bushels/acre	17 bushels/acre	Canada 22 bushels/acre
			Denmark 51 ,, ,,
Barley	12·0 ,, ,,	20 ,, ,,	Canada 27 ,, ,,
Maize	8·4 ,, ,,	24 ,, ,,	U. S. A. 34 ,, ,,
Rice	12·9 ,, ,,	18 ,, ,,	Italy 53 ,, ,,
			Japan 42 ,, ,,
Sugarcane	10 tons/acre	14 tons/acre	Java 53 tons/acre

Agriculture in India is faced with a host of problems like fragmentation and dispersal of holdings, inadequacy of farm-yard manure and artificial fertilisers, lack of perennial sources of water-supplies, improper seeds, etc., as a consequence, the type of agriculture that is practised is subsistence farming. Unless there is a change over to economic farming, there can be no substantial progress ; but this requires as a *sine qua non* economic holdings. Agriculture cannot become an effective industry until the unit of management is much larger than what it is at present. Attempts have been made to check fragmentation and sub-division of holdings, but it must be confessed that in spite of legislation, the work of consolidation has only been partly successful.[8] Co-operative farming methods have been tried but it has met with limited success only in Bombay and U.P.[9] ; elsewhere it has failed. The difficulties of co-operation are well known, the attachment of the peasant to his lands—in many cases the only earthly possession which he has—which he considers to be much more safe and permanent than any other form of investment, and consequently the suspicion with which he looks upon suggestions to surrender his land for joint ownership—the disputes and dissensions amongst the villagers and his scepticism for new innovations in the field of agriculture, these are all important. But even then, it must be admitted that the State Governments have not gone the whole hog in popularising co-operation.

If agriculture is to improve substantially, the holdings in each village must be consolidated through co-operative societies which must treat the whole village as a single unit, the individual owner being assigned his share of the crop in proportion to the extent of his holdings. To make co-operation attractive, the Co-operative Society, with the backing of the Government, should guarantee the proprietors of land an annual yield as much as the average they have now been getting for the last five years, plus a fifty or even seventy percent share in the net increased output. Co-operative joint farming must secure for the small farmer the economies and advantages of large scale agriculture.

Furthermore, the actual tilling of the fields must only be entrusted to farmers who have an aptitude for agriculture, as evidenced by the high yields in their plots, of course, with the added provision that they must continue to employ the labour in the village as farm-hands to prevent rural unemployment. Like any other profession, agriculture must attract the best men and not the failures in life. It is hoped that if these suggestions are followed, there would be a better climate for co-operation.

Another great problem of agriculture is the very high percentage of population dependent on it. In 1901, 71% of the whole population of 235.5 millions, i.e., 146 millions were directly dependent on it ; in 1951, the corresponding percentage was 69, slightly less than in 1901. This has given room for some economists to argue that India is on a healthy road to progress. Nothing can be farther from the truth. Is it realised that the population dependent on agriculture in 1951 was 249 millions, i.e., 100 millions more

[8] The achievements in consolidation have been as follows :—

In Bombay 732 villages covering an area of one million acres, in Madhya Pradesh 3,000 villages covering an area of 2.777 million acres, and in the Punjab 2,400 villages covering an area of 3.877 million acres. Both in U.P. and Madras, consolidation has made very little progress.

[9] In 1954, the co-operative farms in Bombay had a membership of 8,714 and covered an area of 77,000 acres; the corresponding figures for U.P. were 2,089 and 32,400.

than in 1901 ? And during this period of fifty years there has been no substantial expansion of cultivated area, with the result that the *per capita* area of cultivated land has diminished steadily from about 1.0 acre in 1901 to 0.7 of an acre in 1951. The trend in production has been downward and agriculture has at best been stagnant.

The increasing pressure of population on the soil and the growing indebtedness of the agriculturists have resulted in the emergence of a class of landless labourers. In 1901 their total number was about 20 millions, but the latest figures of 1951 seem to suggest that they are about 76 millions, more than a fifth of the entire population ! ! It is these people to whom any political philosophy other than the existing one appears to be a bed of roses, and no wonder they become pawns in the hands of propagandists.

To meet this land hunger, one of the remedies suggested has been to fix a ceiling on land holdings through legislation, an idea which has received favour with most State Governments and Statutes are on the anvil. Mention must also be made of the efforts of Shri Vinobha Bhave, one of the foremost disciples of Mahatma Gandhi, in obtaining gifts of land (Bhoo-dan ; Bhoo= land, dan=gift) from the rich for distribution to the landless. It has met with some success in the various States he has visited, but it must be remembered that the problem is not entirely one of mal-distribution, and therefore could not be solved by re-distribution. It is a case in which 360 million people are hungering for cultivated land, and so long as it is not much more than 300 million acres, whatever the method of distribution is, the *per capita* holding will be less than an acre.

In some States like Travancore-Cochin, politicians have been and are shouting from housetops that land is a divine heritage and has to be divided equally amongst the people. On the present population of that State it is found that the *per capita* share would be 0.30 acres of cultivated land, or 0.11 acres of rice land. There has been a clamour for effecting such a division. Is it realised by the people and the politicians themselves that if this were done, even the present low production would be reduced still more ? And, furthermore, where is the guarantee that population will remain constant ? In a few years when there is a further increase in population will it not lead to another claim for re-distribution based on the then existing numbers ? And when will this end ? The Government in power will probably have nothing else to do than re-distribute property. This is certainly not the method to improve agriculture, or the lot of the agriculturists.

A direct method of augmenting the yield of crops would be by a greater application of manure. As a rule, natural organic manures are cheaper and more efficacious than the inorganic fertilisers. The annual potential supply of animal manure has been estimated at 600 million tons, of which less than 40% alone is at present converted into manure and put back into the fields. Plans have been laid to collect the dung, the urine mixed with soil, litter and other vegetable refuse for improved storage in trenches. Treated in this way, it is expected that at least 300 million tons of animal manure which would provide about 1.2 million tons of extra nitrogen, together with large quantities of phosphoric acid and potash would be available. The production of compost from urban and rural waste materials and its application on a large scale plays a very important role in the development of intensive cultivation. During the period 1948-51, production has increased in the rural areas from 1.3 million tons to 8.4 million tons and in the urban areas from 0.5 million tons to 1.4 million tons. Later figures, though incomplete, seem to suggest that the same trend has been kept up. Projects are on hand to convert municipal waste into compost, as much as 11 million tons by 1955, but there is still some prejudice against the use of the sewage of towns in truck farming, for which it is eminently suited. In the past, the Indian farmer has made little use of these forms of manure, and in the absence of any cheap fuel, more than 50% of the cattle dung was used in the kitchen. Greater application of these is likely to revolutionise yields.[10]

Considerable attention has also been devoted for the production of artificial fertilisers and the Government themselves have erected a plant actually the largst of its kind in Asia, at Sindri, 15 miles from Dhanbad, very near the Damodar Valley coal fields. The production at Sindri has increased from 35,000 tons in 1951 to 249,000 tons in 1953-54. Production has also started at other centres like Mysore and Travancore.

A normal estimate of India's annual needs of chemical fertilisers will be about 2 to 3 million tons. The soils of India are particularly deficient in nitrogen and the production of nitrogenous manures is far below requirements. Attempts are being made to popularise the use of these artificial fertilisers and they are being advanced to the farmers on the basis of loans. The consumption of Ammonium Sulphate during 1954 is estimated at 550,000 tons as against 420,000 tons in 1953, and it looks as though the target of 610,000 tons set for 1956 will be realised.

Additional use of manure, improved seeds, a more dependable supply of water, soil conservation, all these put together have actually resulted in substantial improvements in yield in various parts of India. Rice yields have risen up significantly by transplanting Japanese methods of cultivation.[11]

Cotton, the most important industrial fibre, has also reacted very favourably. The area under cultivation has increased from 14.6 million acres in 1950 to 17 million acres in 1954 and production has risen from 2.97 million bales to 3.93 million bales i.e., nearly 33-1/3%, an achievement in excess of 80% of the target set for the first Five-Year Plan. Half the increased production is due to increased acreage and the other half to better methods of production. But what is more significant is the steady increase in the long-stapled varieties which are in great demand in the mills of India. From 3.4 million acres in 1950, the acreage has shot up to 6.0 millions in 1954. To some extent, this is reflected in the increased mill consumption of Indian cotton from 2.7 million bales in 1951 to 3.7 million bales in 1954, and the diminution of imports from 1.2 million bales to 0.62 million bales.

This, however is not the case with the next important fibre, jute. The economy of the industry was crippled by partition ; the industry located at Calcutta had to get the bulk of the raw material from East Pakistan. The first Five-Year Plan provided for the production of the minimum quantity of raw jute within the country, about 5.4 million bales by 1956, and various means like subsidised distribution of fertilisers, construction of retting tanks, establishment of seed multiple farms, demonstration farms, double cropping, etc., were all adopted. Still, neither the area nor the yield has increased ; actually in 1954, the yield was about 1.3 million bales less than in 1950. Geographic and economic factors seem to control production much more than the fillip which the Government and the industry could give. And very recently, Pakistan has devalued its currency, thereby making raw jute of Pakistan origin still cheaper and time will show what its effects are.

[10] It is estimated that by the application of compost for wheat, the increase in yield will be worth Rs. 25/- for every Rs. 10/- so invested.

[11] A study based on 3,500 demonstration plots for Japanese paddy in the State of Bombay, indicates an increase in yield from 2,205 lbs. per acre by the local methods to 3,477 lbs. per acre by the Japanese methods. Likewise, in the Bhatat Development Block of Uttar Pradesh, the yields of improved varieties of wheat show an increase from 20 to 40% over the local varieties, and about 75% of the wheat area of U.P. is saturated with improved varieties.

The Government appointed a Soil Conservation Board in 1953 and soil conservation work has been started in some of the river valley projects and it is hoped that a green belt will soon be created in the western margin of Rajasthan desert. But unfortunately no records are available about the actual developments that have been put into effect. Land Use Survey Boards were also set up in 17 States but no progress report is available to show what work has been completed and personal enquiries are left unanswered. One wonders whether this is due to the hostility of the Revenue and Land Survey Departments of these States to permit strangers, particularly students of Geography to enter such sanctified and forbidden territory.

Many people seem to think that mechanisation of agriculture would be the panacea for the ills of India. Nothing could be farther from the truth. Mechanisation results in producing a higher yield per man employed, not a higher yield per acre cultivated. Mechanisation is essential in countries like the U.S. where labour is relatively scarce and expensive, but not in countries like India and China where there is a plethora of labour and a lack of employment and which therefore require labour intensive methods. Application of even the simplest mechanical methods would throw out of agricultural employment at least half the present population now dependent on it, as many as 125 million people and it would, indeed, be a hopelessly difficult problem for any government to find alternative work for such a mass of people. There is a surplus population in relation to existing resources which shows itself not in the form of unemployment as in the case of industrialised countries, but as chronic under-employment affecting a large section of the agricultural community. It has been estimated that in Madras, agricultural employment for a single rice crop lasts for about ten weeks, for a double crop for about sixteen weeks, and for a dry crop about four weeks—say in all 20 to 22 weeks in a year ; in the Punjab agricultural labourers work for 200 days, in the canal irrigated tracts of the U.P., it is about 180-200 days while in the unirrigated tracts it is as low as 120.

The rural unemployment is partly due to the seasonal nature of the rainfall and perennial irrigation should improve conditions very much. Furthermore, attempts are being made to promote cottage industries, animal husbandry, fisheries, etc., to keep the farmers more usefully occupied. To augment the agricultural output and improve the standards of living by every possible means, a multifaced attack has also been envisaged by creating Community Development Projects and National Extension Service Blocks. In an agricultural economy which has remained stagnant for years, a large number of people remain attached to agriculture without really contributing anything to production. Since gainful occupation outside agriculture is not available to a sufficient degree, the protective instinct of society gives every one some stake in economic activity, even though his services are redundant. It would, indeed, be a desideratum if some people are taken away from agriculture and found employment in industries, trade and transport ; this would certainly affect agricultural output beneficially.

ANIMAL HUSBANDRY

India has the largest bovine population in the world, approximately 150 million cattle, 43 million buffaloes, 40 million sheep, 47 million goats, 1.5 million horses, etc. There is little or no demand for beef owing to religious inhibitions. As a matter of fact, bovine cattle are protected from indiscriminate slaughter by State legislation and cattle protection is one of the directive principles of the Constitution of India. The annual yield of milk of a cow varies very considerably from 65 lbs. in Madhya Pradesh to 1,445 lbs. in East Punjab ;[12] the yield of a buffalo varies from 315 lbs. in Assam to 2,500 lbs. in Sourashtra. India with more than 15 times the number of cattle of Canada, has an yield of milk only twice as great !! From early times, a large proportion of the milk has been utilised for making *ghee* (clarified butter) and therefore greater attention has been devoted to richness rather than yield.

It cannot be denied that there exists a tremendous surplus of useless and inefficient cattle which press upon the inadequate supplies of fodder. The probable cause why cattle deteriorate in staturé, stamina and in productive capacity is mal-nutrition and it may be induced, at least partly by the poor food value of the paddy straw which forms either their exclusive diet, or a very large part of it. A significantly large proportion of milch cattle get little or no succulent fodder except for the natural grazing during the monsoon months. The various reserves for grazing are not properly managed to yield the fullest benefit. Silage is unknown and the annual production of concentrates other than rice, gram and *gowra* is about 2½ million tons, giving a *per capita* quota of 25 lbs. per annum !

With approximately a fifth of the world's cattle, India is not in a position to afford the luxury of maintaining separate types for milch and draught. On the other hand, it must maintain a dual purpose animal, the male for transport and agricultural operations, and the female for milch. By constructing *Gosalas*, (home for the cows), the Five-Year Plan proposed segregating the old and inferior cattle, but the achievement up to the end of 1954 showed that only 3% of the money set apart for this has been spent, showing thereby that it has not received the popular support that was expected. Several key village centres and artificial insemination centres have been established, but only in South India and Bihar are the latter popular. Very much more work will have to be done in the field to popularise these methods and to segregate the old and infirm cattle.

FISHING

For a diet which is mostly comprising of cereals like rice and vegetables, as in India, fish would form an excellent supplement, providing the necessary proteins,[13] and its consumption has consequently both a qualitative and quantitative value. The potentialities for the development of the fishing industry, are, indeed, very great. Not even a minute fraction of the wealth which lies off the 2,900 miles of the coastline of India is being exploited, mainly because of the limited range of the fishing vessels and the inadequate freezing facilities for storage and distribution. The target for 1956 for equipping 140 boats with marine engines has already been exceeded and several of them are being used in Bombay and in Madras. Off the coast of Travancore, deep sea fishing is being experimentally conducted by the Mother-Craft method under the guidance of Norwegian experts. Besides these, eleven insulated vans have been received and they are being operated by the Government and through co-operative societies in Bombay, Madras and Travancore-Cochin. Furthermore, cold storage plants have also been established at Mangalore, Calicut and Satpati (Bombay).

12 The average consumption of milk per head per day in India is one of the lowest on record, about 6 ozs., but it varies from 19 ozs., in Sourashtra to 1.2 ozs. in Assam. Cf. Canada 57 ozs., Australia 44 ozs., U.K. 40 ozs., and U.S.A. 36 ozs.

13 The annual *per capita* consumption of fish in 1950 in India was estimated to be as low as 3 lbs. and this figure stands as a remarkable contrast to the neighbouring countries like Ceylon and Burma where it is 16 and 70 lbs. respectively.

COMMUNITY DEVELOPMENT AND NATIONAL EXTENSION SERVICE

In the hope of improving the lot of the agriculturists in the villages, Government of India have started a new venture of opening up Community Development Project areas (C.D.P.) and National Extension Service Blocks (N.E.S.).

The Community Development Project was first inaugurated in October, 1952 in 55 centres, each covering a population of 290,000 and comprising 3 blocks. By October 1953, another 53 Community Project areas were established. Besides these, 607 National Extension Service Blocks have also been set up and of these, 132 have been recently converted into Community Projects.

In the Community Development Project areas, there is a multi-purpose programme which aims at simultaneous development in a variety of fields, such as agriculture, animal husbandry, health, social education, cottage industries and the like. In the National Extension Service Blocks, on the other hand, the effort is mainly concentrated on agriculture and animal husbandry. The aim in both cases, is not merely to provide for ample food, clothing, shelter, health, and recreational facilities in the villages, all these are there, but more important than all these material improvements is the attempt to create a change in the mental outlook of the people, instilling in them an ambition for higher standards of life and the will and determination to work for such standards. This is a human problem—how to change in the twinkle of an eye, the mental outlook of 70 million families living in the country and arouse enthusiasm in them for new knowledge and new ways of life and inspire them with the ambition and will to live a richer life.

The progress in the field of agriculture of the C.D.P. and N.E.S. has been substantial and special mention may be made of (1) the digging of 528,170 compost pits, (2) the distribution of 150,000 tons of fertilisers, 50,000 tons of improved seeds, 69,325 improved implements, etc., (3) the construction of a large number of minor irrigation works which have brought under cultivation an additional area of 613, 220 acres, (4) the reclamation of 270, 897 acres of land and (5) the introduction of such crops like fruits and vegetables in about 125,000 acres in rotation. As regards animal husbandry 871 centres were started (including key village and artificial insemination centres) and 3,040 breeding bulls were supplied. 5,471,856 cattle were given preventive inoculation and another 2,426,796 given medical treatment. The construction of village roads was a prominent feature ; 1,014 miles of *pucca* (good, all seasonal) roads and 11,665 miles of *kacha* (poor, only useful in dry season) roads, were completed. 10,373 new village houses were constructed and 96,362 old ones reconditioned. Substantial progress has also been made in the fields of education, health and rural sanitation, although it must be confessed that only the very fringes of the problem have been touched.

The idea of mobilising peoples' co-operation for large projects is one of the basic principles of the five-year plans. The river valley projects have offered unique opportunities for associating the public actively with State ventures and have created a climate in which the public felt that they had a hand in working out their own material progress. It has been demonstrated in the Kosi Project that large scale public works like the excavation of earthern embankments to house the river can be successfully undertaken by organised manual labour without wholesale dependence on machinery, the spirit of self-help and joint endeavour, in most cases overcoming the handicaps of local apathy and party factions. The Bharat Sevak Samaj which was entrusted with this work has enlisted public co-operation along three main lines: (1) Voluntary gifts of land for the construction of protective embankments; (2) *Shramdan* or gift of labour; and (3) paid labour through the agency of *Gram-Panchayats* (Village Councils) and labour co-operatives.

Hundreds of acres of land have been voluntarily surrendered and placec at the disposal of the project authorities, and, indeed, such gifts were mad(not only by those who stood to benefit, but also by those who had to leave fo ever—their own cherished lands—for the protection of the lands of their fellow citizens.

The *Shramdanees* (voluntary unpaid workers) are mostly from the middle class peasants, students and social workers. The secondary schools and colleges in the Kosi area have each sent 90 to 100 students at a time and the students of the basic schools are continuously camping at the site of the works. Boys of the auxiliary cadet corps, numbering about 11,000 have shown remarkable enthusiasm in constructing a portion of the eastern bank, while 300 students of the Bihar University have put up a camp of their own and are busy erecting the western embankment. People who had never before handled a spade and who had always looked down with contempt on manual labour are today working shoulder to shoulder with the rank and file of regular labourers with great zeal and enthusiasm. This spirit, which appreciates the dignity of labour, is much more important than anything else and in this, one sees a ray of hope for the future.

Under a Gram Panchayat or Labour Co-operative, 200 labourers have to be enrolled to form a co-operative with a unit leader in charge of the work. Each unit leader gives a pledge to the Bharat Sevak Samaj and binds himself to construct according to specifications, at least 1,000 feet of the embankment with 200 labourers within 120 days. For all practical purposes he is a contractor except that he makes no personal profit, the money he receives being distributed as follows: 90% to the workers, 7½% to the Gram Panchayat (to which is added an equal contribution from the Government, the total amount being earmarked for schemes of Community Development) and the balance of 2½% being left over to meet the costs of establishment and supervision of the unit leader. The individual contractors are eliminated and their personal profits diverted to community savings. The example at Kosi has found immediate response in other places as at Burhi Gandak in N. Bihar, in Goalpara and Dibrugarh in Assam, at Dhumrighat in Etah (U.P.), etc. Enthusiasm has been generated in the local people and they have been inspired to work together for the realisation of a common purpose. Besides all these, it has also provided employment for thousands of men. Here is a scheme eminently suited to conditions in India, where there is chronic unemployment and under-employment, where instead of machines, men dominate the scene.

It is hoped that by 1956, a fourth of the population of the country will benefit by the C.D.P. about 75 million people living in 100,000 villages and that the entire rural population will be brought within the ambit of the C.D.P. by 1961. The actual achievements up to the end of 1954 are 220 Community Development Project areas and 498 National Extension Service Blocks in operation, covering a total of 73,450 villages with a population of 54.39 millions. A precise yardstick to measure the success of the C.D.P. and N.E.S. is the extent of voluntary contributions of the people under the various schemes. The estimated total voluntary contribution of the people in cash, labour, materials, etc., up to 30th September, 1954, amounted to 38.2 million rupees (8 million dollars) which was a little less than half the Government expenditure incurred during the same period. The results achieved and the experience gained have both been extremely encouraging, and we are led to conclude that if the sacrifices are justly and evenly distributed throughout the community and the leadership is disinterested, there appears to be no limits to which people will not willingly and devoutedly stretch themselves for a common cause.

OTHER DEVELOPMENTS

Besides all these, spectacular progress has taken place in the development of industries both cottage and large scale, as well as in associated fields like transport. Education, health, family planning, these have all received considerable attention, and on the whole, one is led to an optimistic outlook. If the same progress continues to be maintained for the next fifteen or twenty years, the future appears to be not merely rosy, but perhaps even glorious. Full employment for the masses is probably the crux of the matter and it looks as though there is cause for optimism.

Such achievements, however, should not blind us to the various social problems which still exist—to take a concrete example, the submergence of occupied lands when large dams and river valley projects are constructed. The normal procedure would be payment of cash compensation to the owners of property whose lands have been acquired. But the Government of India felt that a river valley project was something more than a business concern; it was a welfare organisation and it was decided (especially so in Damodar Valley Corporation) to create new, well planned villages, where the "displaced persons would exchange his hovel for a decent cottage, darkness for electric light, and fanaticism for faith." For the rehabilitation of the persons affected in the construction of the Tilaya dam (one of the dams of the Damodar Valley Corporation) a tremendous amount of good work was done by a competent technical staff. Well ventilated houses, proper roads with avenue trees, children's parks, these were all constructed and the corporation spent at least 8 million rupees (nearly 1,650,000 dollars) more than what it would have paid as cash compensation. Yet, it has failed to enlist the co-operation of the villagers. Till January 1954, out of 343 houses built, 182 remained unoccupied, and out of 4,500 acres of land carefully reclaimed on a scientific basis, with its fertility being built up by adequate use of artificial and green manures, nearly 1,730 acres remained unclaimed. Furthermore, the very people for whom they were built are agitating for cash compensation. Rival political parties are at work inciting people to demand impossible compensations. This scheme of giving land for land and house for house is basically sound, especially because the illiterate villager is likely to squander away overnight all that he might get as cash compensation, but it looks as though this is far too enlightened for the present conditions in India.

On a careful appraisal, we can justly conclude, that the country has made a spectacular advance in various fields during the last eight years, although there yet remains much more to be done. But given good will and peace, it looks as though prosperity is just round the corner.

Hydrobiological Investigations of the Hope Reservoir and of the Thambaraparani River at Papanasam, Tirunelveli District, Madras State. *

By

S. V. GANAPATI, B.A., M.Sc., A.R.I.C.

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1. *Introduction.*

The majority of the rivers of the Madras State are in spate during the monsoon seasons and a large volume of water is lost to the Bay of Bengal. So they have during recent years been dammed at suitable places and the stored water is used for irrigating paddy fields, for fish culture and/or for generating hydel power. One of such rivers in the State is the Thambaraparani flowing in the extreme south of the Deccan Peninsula; it is dammed at two places at Papanasam in Thirunelveli District where the stored water is mainly used for generating electricity; the overflow water of the river and the water in the two reservoirs are also used for irrigating paddy fields and for fish culture. The hydrobiological conditions of the two reservoirs and of the river were investigated for initiating a programme of intensive pisciculture, on three occasions—twice in 1948 and once in 1951—and the results of the investigations made on these occasions form the basis of this paper.

2. *Material and Methods.*

The Thambaraparani river takes its rise in the hills of Papanasam from several small rapids and from the large fall at Kalyanathirtham (Fig. I). It is dammed in two places constituting two reservoirs—Hope Reservoir (A) and the Diversion Weir Reservoir (B), the latter serving as a constant head tank for the pipes carrying water to the Power House situated lower. The Hope Reservoir and the Tambaraparani river system upto the foot of the Great Falls may be roughly divided into three sections for the purpose of this investigation: (a) the Feeder streams and the Hope Reservoir; (b) the river from the upper Dam to the Diversion Weir; and (c) from the bottom outlet in the Diversion Weir till the foot of the Great Falls at Kalyanathirtham.

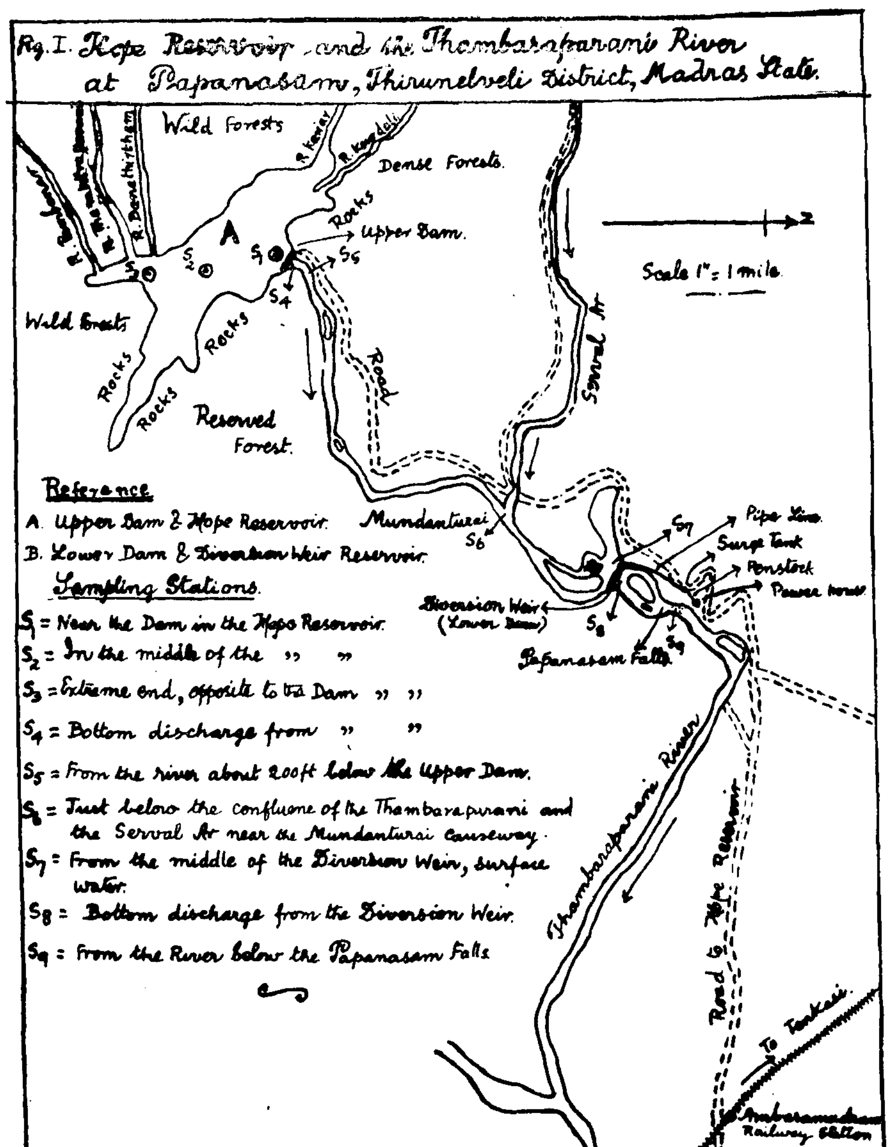
The important physico-chemical and biological conditions in the Hope Reservoir and the river below were examined and the results are tabulated

* Part of a Thesis approved for the D.Sc. Degree of the Madras University.

in Tables I to IV. The methods of analysis and the proceedure adopted have been described in my previous paper (Ganapati 1943). Samples from different depths were taken in the Hope Reservoir by means of a Friedinger's water bottle of bore metal cylinder from a boat.

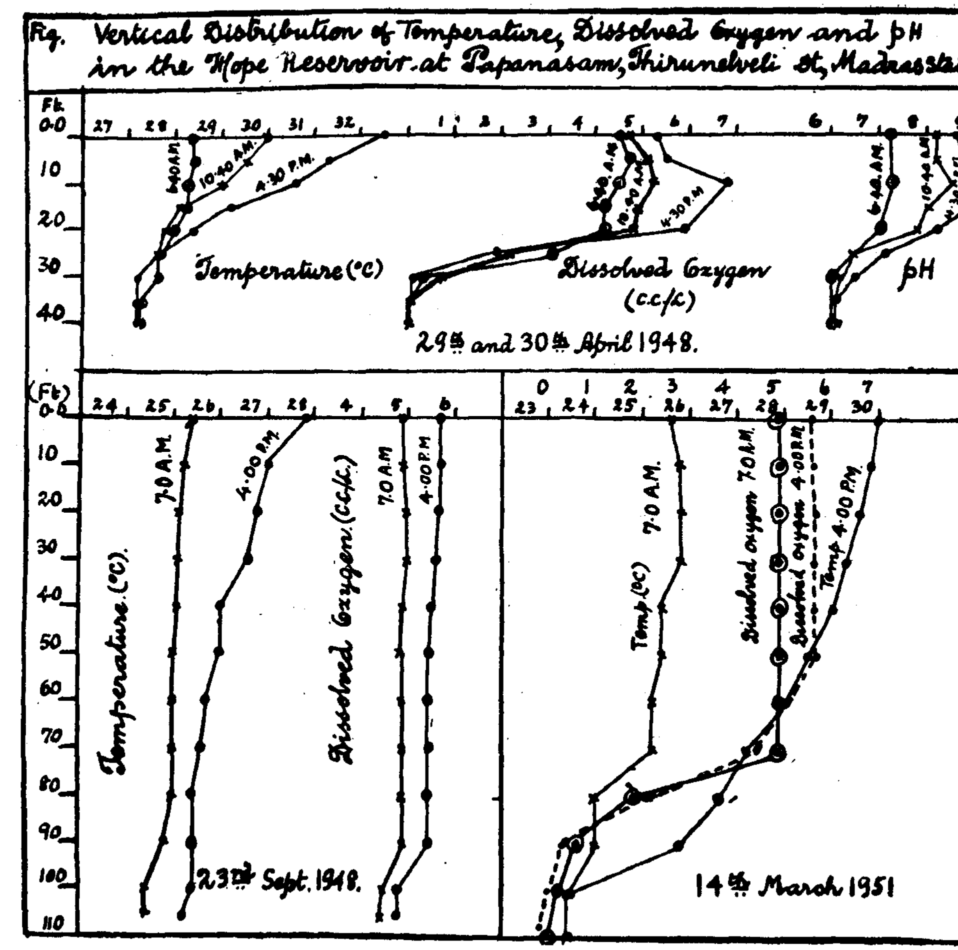
3. *Location and Morphology*

The Thambaraparani river drops from a height of 300 feet over the picturesque Papanasam Falls (Fig. I) and the power development is through



regulating the river flow at two places above the Falls and harnessing the energy previously wasted over the Falls. Regulation is effected by the con-

struction of the Thambaraparani Dam and the Hope Reservoir about 6 miles above the Falls on the thickly wooded Papanasam Hills. They rise steeply several thousand feet to the watershed ridge on the Madras-Travancore



border. These hills consist of a central uplift from which radiate ridges on three sides forming a triangle of gradually decreasing height. The main valley between these ridges constitutes the Hope Reservoir. The masonry dam across the river is 200 feet above the river bed and is 800 feet long forming a reservoir with a storage capacity of 5,500 m. c. ft. Two discharge pipes each of 81′ 6″ diameter are located at the base of the dam. It is proposed to utilise eventually the energy of the varying discharges from these discharge pipes also.

The water stored in the Hope Reservoir is let out through one or two discharge pipes at a time into the river to Mundanthorai (about two miles above the Papanasam Falls) ; where it is joined by the natural flow of "Serval Ar", the two rivers draining approximately equal areas of the catchment (Fig. I). The combined flow is then diverted from the river, course about a mile lower down at the left flank into a low pressure pipe by means of the intake and a diversion weir designed to discharge a maximum of

120,000 cusecs of water. This structure consists of an overflow weir or dam 1,350 feet long across the full breadth of the river giving a pondage of 28 m. c.ft. with an intake chamber discharging into the pipes at the left flank. This pondage constitutes the second reservoir for regulating the resulting flow which is converted into electrical energy by diverting it from the main river course about ¾ mile above the Falls through a steel low pressure pipe 9 feet in diameter ; four 66″ penstock pipes 520 feet long carry the water from these down to the hill slope from the surge tower to the Power House, which is located at the foot of the Papanasam Falls near the Agasthyar Temple. The works were started in the latter half of 1938 and completed in 1943. So the age of the reservoirs was only 5 years in 1948. Large areas of forest in the catchment have been felled to meet the heavy war time demands for firewood during the Second World War and these areas have been cultivated. So considerable quantity of silt is being carried into the reservoir.

The sill level of the reservoir which is elongated and sinuous is 720 feet above mean sea-level. Its capacity at various depths is given below :—

Mean Sea Level.	Actual depth in feet.	Water spread in Million Sq. Ft.	Capacity in M.C. Ft.	Remarks.
720	20	1.36	13	
730	30	3.98	40	
740	40	8.39	102	
750	50	16.25	225	
760	60	24.08	427	Lowest draw level.
770	70	30.64	700	
780	80	36.24	1,035	
790	90	40.46	1,418	
800	100	44.27	1,842	
810	110	47.64	2,301	
820	120	50.44	2,792	
830	130	53.06	3,309	
840	140	55.45	3,852	
850	150	57.85	4,418	
860	160	60.47	5,010	
870	170	63.00	5,627	
880	180	65.77	6,271	
890	190	68.24	6,941	
900	200	70.22	7,634	

So, the maximum depth near the dam is 200 feet at full reservoir level when its water spread is 70.22 million square feet and capacity 7,634 m. c. ft.

4. METEOROLOGICAL DATA

(Table I)

The rainfall is about 60 inches per annum at the Papanasam Falls and rises progressively to about 200″ at the higher reaches. The catchment is affected by both the monsoons, the North-East generally predominating. It will be seen from the Table I that 95.42″ in 1948, 58.09″ in 1949, 65.61″ in 1950 and 84.47″ in 1951 were recorded at the Dam site. But in 1947 the two monsoons having failed the level was considerably low in April 1948. The maximum rainfall is usually recorded in the North-East monsoon season and the highest temperature and lowest rainfall are in the hot weather months—March to May.

5. SECTION A

(Tables II & III)

(*a*) *Feeder Streams* : The river Thambaraparani has four feeder streams viz. (*a*) the Pambanar, (*b*) the Banathirtham, (*c*) the Kariár, and (*d*) the Kowdali. Of these four, the latter two were dry owing to drought during the preceding monsoons of 1947. A trickle was therefore seen in the two former streams ; only. from this samples were taken on 1st May 1948. The results of analysis are given below :

Description	*The Pambanar*	*The Banathirtham*
(1) *Physical Conditions* :		
1. Time	11-35 A.M.	11-50 A.M.
2. Colour	Yellowish Brown	Yellowish
3. Transparency	> 30.0 cm.	> 30.0 cm.
4. Depth (inches) ..	6.0	8.0
5. Temperature (°C) ..	24.8	22.7

Description	*The Pambanar*	*The Banathirtham*
Chemical Conditions :		
6. Free/Co_2 (Parts per 100,000)	0.184	0.143
7. CO_3 ,,	Nil.	Nil.
8. HCO_3 ,,	0.915	0.915
9. pH	6.7	6.7
10. Dissolved Oxygen (CC/L).	3.718	4.682
11. % Saturation	61.3	75.8
12. Chlorides ,,	0.1	0.1
13. Nitrates (NO_3-N) ,,	0.02	0.03
14. Phosphates (P_2O_5) ,,	0.04	0.05
15. Silicates (SiO_2) ,,	0.14	0.15
16. Iron (Fe) ,,	0.02	0.01

The waters of the two streams are clear but yellowish in colour, very soft, poor in lime, acidic and contains phosphates, silicates, and nitrates in appreciable amounts. They add to the aquatic fertility of the reservoir.

(*b*) *Hope Reservoir* : Samples were taken from three places S_1 to S_3 within the reservoir and the results are shown in Tables II-A to II-D.

Physical Conditions : (i) *Water Level* : Water is always let out through one or both of the bottom discharge pipes, each of 8.5 feet diameter, and it comes out with such terrific force from the slightly up-turned mouths that water is sprayed into a thick, white cloud to a height of about 50 feet. There is always a gradual decrease in water level from January to May and an increase thereafter until the full reservoir level is reached in December. (Vide Table I). On the three occasions visited, the level was decreasing on 29th April (40 feet) and was increasing in September 1948 and March 1951 due to incessant rainfall in the catchment area. So the period January to May when there was least rainfall, more hours of bright sunshine and increased temperature was the best period for biological productivity.

On 29th April 1948, the level was very low (760 feet or actually 40 feet deep) due to drought during the previous year. Water was still being let out from the reservoir for generating electricity. Again during the examination on 29th September, 1948 the level had gone up to 107.7 feet, an increase of nearly 68 feet within 5 months due to heavy south-west monsoon rains. At the final examination on 14th March, 1951 after a lapse of nearly 2½ years, the level was 113.7 feet indicating that the reservoir had greatly benefited by both the monsoons in 1951.

(ii) *Colour*: The surface water was coloured greenish on all the three occasions showing vigorous plankton productivity. But the water discharging from the bottom was brownish due to the presence of iron dissolved in it.

(iii) *Depth of Visibility or Transparency* : of the water was measured by means of a Secci's disc. On 29th April it was 2'4" ; on 23rd September 6'0" and on 14th March, 1951 5'6".

(iv) *Temperature of Water* : (Vide Tables II-A, II-B, II-C & II-D). The temperatures at different depths were measured on the three occasions near the dam and once at 3 different places in the reservoir. A summary of the results is given below :

Table No.	Date	Time	Depth	Surface (°C)	Bottom (°C)	Difference (°C)
II-A	29-4-1948	10-40 A.M.	40 Ft.	30.0	27.2	2.8
	,,	4-30 P.M.	,,	32.5	27.2	5.3
	30-4-1948	6-40 A.M.	,,	28.3	27.2	1.1
II-B	1-5-1948	11-00 A.M.	,,	31.0	27.1	3.9
	,,	12-00 Noon	,,	31.6	27.2	4.4
	,,	2-00 P.M.	,,	31.8	27.0	4.8
II-C	23-9-1948	7-00 A.M.	107.7 Ft.	25.4	24.4	1.0
	,,	4-00 P.M.	,,	27.8	25.2	2.6
II-D	14-3-1951	6-45 A.M.	113.7 Ft.	25.6	23.4	2.2
	,,	2-30 P.M.	,,	30.0	23.4	6.6

It will be seen that (i) the highest temperature recorded for the surface water was 32.5°C at 4-30 p.m. on 29-4-1948 in summer, and the lowest was 25.4°C at 7-00 a.m. on 23-9-1948 during the north-east monsoon season ; (ii) the highest temperature recorded for the deepest layer was 27.2°C at 10-40 a.m., 4-30 p.m. on 29-4-1948, 6-40 a.m. on 30-4-1948 and 12 noon on 1-5-1948 The lowest temperature of 23.4°C was reached at 6-45 a.m. and 2-30 p.m. on 14-3-1951 ; (iii) a maximum difference of 6.6°C between the surface and bottom layers was seen at 2-30 p.m. on 14-3-1951 and a minimum difference of 1.0°C at 7-00 a.m. on 23-9-1948 ; (iv) the bottom temperature was found to be the same at 10-40 a.m. and 4-30 p.m. on 29th April and also 6-40 a.m. on 30th April, 1948 (on the next day) indicating that the circulation did not get deep enough at nights in summer. This is confirmed by the records for 6-45 a.m. on 14-3-1951. During the south-west monsoon season also the temperature was not homogeneous, for even at 7 a.m. on 23-9-1948 a difference of 1.0°C is noticed. This shows that the cicrulation does not reach deep enough to touch bottom, but only an imperfect partial circulation is taking place in the upper layers. (v) The inference to be drawn would be that even during the two monsoon seasons (north-east and south-west) when the lake gets filled up with water, there is no deep reaching circulation unless there is a strong gale. Thermal stratification occurs which is markedly noticed during the summer season resulting in the production of H_2S in the bottom-most layers throughout the day and night. It is not unlikely that the water in the reservoir assumes a homogeneous character without stratification during the rainy months when fresh supplies from the cold feeder hill streams augment the reservoir.

CHEMICAL CONDITIONS

(TABLE II)

I. *Dissolved Oxygen* : The following figures represent the figures for dissolved oxygen summarised from Tables II-A, II-B, II-C & II-D.

Table No.	Date	Time	Depth	Surface CC/L	% Sat.	Bottom CC/L%	Difference	Highest amount: Depth	Amt.	% Sat.
II-A.	29-4-1948	10-40 a.m.	40.0	4.677	94.0	Nil	4.677	10	5.226	92.3
	,,	4-30 p.m.	,,	5.286	..	,,	5.286	10	6.845	124.1
	30-4-1948	6-40 a m.	,,	4.568	79.8	,,	4.568	5	4.682	81.9
II-B.	1-5-1949	11-00 a.m.	,,	5.236	..	,,	5.236	0	5.236	..
	,,	12 Noon	,,	4.886	..	,,	4.886	20	5.842	101.3
	,,	2-00 p.m.	,,	5.212	..	,,	5.212	20	5.942	99.2
II-C.	23-9-1948	7-00 a.m.	107.7	4.862	81.0	4.602	0.260	20	4.966	82.8
	,,	4-00 p m.	,,	5.684	98.6	4.800	0.884	20	5.721	97.6
II-D.	14-3-1951	6-45 a.m.	113.7	4.884	81.9	Nil	4.884	0	4.884	81.9
	,,	2-30 p.m.	,,	5.580	100.1	,,	5.580	20	5.680	101.3

A reference to the above summary and the original tables shows that—

(1) the highest amount of oxygen recorded for the surface was 5.684 CC/L at 4-00 p.m. on 23-9-1948 and the lowest was 4.568 at 6-40 a.m. on 30-4-1948 ;

(2) the maximum recorded for the bottom layer was 4.800 CC/L at 4-00 p.m. on 23-9-1948 and the lowest amount recorded was 'Nil' on 29-4-1948 ; 30-4-1948 ; 1-5-1948 ; 14-3-1951—all during summer months.

(3) the maximum difference between the surface and bottom layers was noticed during summer months i.e. on 29th and 30th April, 1948, 1st May, 1948 and 14th March 1951 and the lowest difference is seen on 23-9-1948 ;

(4) at the bottom, oxygen was absent during the summer months (on 29th and 30th April, 1948, 1st May, 1948 and 14th March, 1951) and H_2S was present. The oxygenless region was about 10 feet in April and May, 1948 and in March 1951 ;

(5) the vertical distribution of oxygen at 6-40 a.m. on 30th April, 1948 and at 6-45 a.m. on 14th March, 1951 shows that there was no deeply reaching "turnover" in the night so that the distribution of oxygen was not uniform from the surface to the bottom. So, there was O_2 stratification. The presence of H_2S in the discharge pipes at all hours of the day and night confirmed the above observation.

Again, during the south-west monsoon when the reservoir was filled with water oxygen circulation is not thorough and does not go right to the bottom, for there is a gradual reduction from the surface to the bottom, the differences amounting to 0.260 to 0.880 CC/L during 9 hours of the day.

Supersaturation was seen in the upper 10 to 20 feet layer on 29-4-1948 and at 20 feet depth at 12 noon on 1st June, 1948.

II. *Sulphuretted Hydrogen* : Emanated from the outlet discharge pipes located at the bottom during March 1951 and April and May 1948. The amount of H_2S varied from a trace to 2.10 mg/L.

III. *Hydrogen ion concentration (pH)* : The following table summarises at a glance the results reported in Tables II-A, II-B, II-C and II-D regarding pH.

Table No.	Date	Time	Depth	Surface	Bottom	Difference
II-A	29-4-1948	10-40 A.M.	44	8.2	6.1	2.1
	„	4-30 P.M.	44	8.6	6.1	2.5
	30-5-1948	6-40 A.M.	44	7.2	6.0	1.2
II-C	23-9-1948	7-00 A.M.	107.7	7.8	7.6	0.2
	„	4-00 P.M.	„	8.1	7.9	0.2
II-D	14-3-1951	6.45 A.M.	113.7	7.6	6.3	1.3
	„	2-30 P.M.	„	8.0	6.3	1.7

1. The maximum figure recorded for the surface was 8.6 at 4-30 p.m. on 29-4-1948 and the lowest 7.2 at 6-40 a.m. on 30-5-1948.

2. The maximum figure recorded for the bottom was 7.9 at 4-00 p.m. on 23-9-1948 and the minimum 6.0 at 6-40 a.m. on 30-5-1948.

3. A maximum difference of 2.5 units between the surface and bottom layers was noted at 4-30 p.m. on 29th April, 1948 and the minimum of 0.2 unit at 7-00 a.m. on 23-9-1948.

4. The vertical distributions of pH at 6-40 a.m. on 30-5-1948 and 6-45 a.m. on 14-3-1951 showed that the pH of the water was not the same in all the layers from surface to bottom. In other words there was stratification in pH both during day and night in summer months ; but in September (South-West monsoon) there was a gradual reduction from the surface to the bottom, the difference amounting to 0.2 units only.

IV. *Phosphates* (P_2O_5) :—

Table No.	Date	Time	Depth ft.	Surface (pp. 100,000)	Bottom	Difference
II-A	29-4-1948	10-40 A.M.	44	0.001	0.010	0.009
	„	4-30 P.M.	44	Trace	0.010	0.010
	30-4-1948	6-40 A.M.	44	0.002	0.010	0.008
II-C	23-9-1948	7-00 A.M.	107.7	Trace	0.014	0.014
	„	4-00 P.M.	„	Trace	—	—
II-D	14-3-1951	6-45 A.M.	113.7	0.002	0.006	0.004
	„	2-30 P.M.	„	Trace	0.010	0.010

The quantity of phosphates present at the surface varied from a trace to 0.002 and from 0.006 to 0.010 parts per 100,000 at the bottom. They increased with the depth being greater at the bottom.

V. *Silicates* (SiO_2) :—

Table No.	Date	Time	Depth	Surface	Bottom	Difference
II-A	20-4-1948	10-40 A.M.	44	0.18	0.20	0.02
	„	4-30 P.M.	44	0.18	0.20	0.02
	30-4-1948	6-40 A.M.	44	0.18	0.20	0.02
II-C	29-9-1948	7-00 A.M.	107.7	0.14	0.18	0.04
	„	4-00 P.M.	„	0.14	0.19	0.05
II-D	14-3-1951	6-45 A.M.	113.7	0.16	0.20	0.04
	„	2-30 P.M.	„	0.16	0.20	0.04

Silicates varied from a minimum of 0.14 in September 1948 to a maximum of 0.18 parts per 100,000 in April 1948 at the surface and from 0.18 in September 1948 to 0.20 parts per 100,000 in April 1948 and March 1951. They were also found to be greater at the bottom than at the surface.

VI. *Iron* (Fe) :—

Table No.	Date	Time	Depth	Surface	Bottom	Difference
II-A	29-4-1948	10-40 A.M.	44	.002	.050	.048
	„	4-30 P.M.	44	Trace	.100	.100
	30-4-1948	6-40 A.M.	44	.003	.078	.075
II-C	23-9-1948	7-00 A.M.	107.7	.010	.020	.010
	„	4-00 P.M.	„	.010	.020	.010
II-D	14-3-1951	6-45 A.M.	113.7	.020	.100	.080
	„	2-30 P.M.	„	Trace	.080	.080

The quantity of iron varied from a minimum of traces at 4-30 p.m. on 29-4-1948 and at 2-30 p.m. on 14-3-1951 at the surface to a maximum of 0.02 parts at 6-45 a.m. on 14-3-1951 and from a minimum of 0.020 parts on 23rd September, 1948 to a maximum of 0.100 parts per 100 at 4-40 p.m. on 29-4-1948 and at 6-45 a.m. on 14-3-1951. More iron was found in the bottom than at the surface.

BIOLOGICAL CONDITIONS

(i) *Phytoplankton* : As the reservoir is surrounded by hills covered with thick forests, the riparian and aquatic fauna are rich. As nutrients are regularly washed into the reservoir from the catchment area, the phytoplankton is also very rich. The greenish colour of the surface water was due to vigorous algal growth. The qualitative and quantitative distribution of the several groups of plankton collected at the surface by means of a net No. 20 silk bolting cloth on the three occasions is shown in Table IV.

The total number of phytoplankton species was 40 and the percentage composition of the genera are given below :

Serial No.	Name of algal groups	No. of species	% of the total
1.	Chlorophyceae	13	32.5
2.	Desmids	9	22.5
3.	Dinophyceae	1	2.5
4.	Bacillariophyceae	4	10.0
5.	Xanthophyceae	1	2.5
6.	Euglenineae	1	2.5
7.	Cyanophyceae	11	27.5
	Total	40	100.0

It will be seen that Chlorophyceae and Desmids constitute together the largest group, while Cyanophyceae, Bacillariophyceae and other groups come next in order.

The organisms which were common at one time or other were (1) *Oocystis sp.*, (2) *Staurastrum pentacerum*, (3) *Botryococcus Braunii*, (4) *Melosira granulata*, (5) *Navicula sp.*, (6) *Surirella robusta var Splendida*, (7) *Microcystis aeruginosa*, (8) *Microcystis elebens*, (9) *Microcystis marginata*, (10) *Oscillatoria spp.* and (11) *Anabaenopsis sp.*

During the hot weather when the water level was very low as on 29-4-1948 (1) *Botryococcus Braunii*, (2) *Navicula sp.*, (3) *Surirella robusta var splendida*, (4) *Microcystis aeruginosa*, (5) *M.elebens*, (6) *M.marginata*, (7) *Oscillatoria spp.* and (8) *Anabaenopsis sp.* were the common forms. But when the reservoir was almost full as on 14-3-1951 (1) *Oocystic sp.*, (2) *Staurastrum gracile*, (3) *Staurastrum pentacerum*, (4) *Botryococcus Braunii* (5) *Melosira granulata* occurred in fair quantities.

During the south-west monsoon the common forms were : (1) *Oocystis sp.*, (2) *Botryococcus Braunii*, (3) *Surirella robusta var Splendida* and (4) *Microcystis aeroginosa*.

(2) *Zoo-Plankton* :—The zoo-plankton was represented by four groups (1) *Copepoda* (2) *Cladocera* (3) *Rotatoria* and (4) *Protozoa*.

6. SECTION B.

This section deals with the stretch of the river from the upper Dam down to the Diversion weir below—a length of about 5 miles passing through plain country containing dense forests. Samples were drawn from four accessible places in this Section (S_4 to S_7 of Table III). S_4 represents a mixture of the leakage and the outflow through the bottom outlet of the reservoir, S_5 is taken from the river about 200 feet below the dam, S_6 near the Mundanthurai causeway and S_7 from the middle of the Diversion weir (surface water) (Fig. I). The physico-chemical characteristics of each of the four samples are given in Table III.

S_4 represents the bottommost layer of water from the reservoir and it was always brownish in colour and smelt strongly of sulphuretted hydrogen in the hot weather in the locality near the Dam. The walls, pipes and stones etc., in the river, in short, everything up to S_3 was covered with a thin coating of brownish oxide of iron. H_2S and ferrous iron contained in the water emanating from the bottom discharge pipes were oxidised. The flowing water contained more oxygen, nitrates, phosphates and iron than the surface water in the reservoir.

S_5 resembled S_4 in all respects except as regards its content of iron which was slightly greater. Further all along the shore yellowish coloured tadpoles were seen in hundreds. But S_6 was inky coloured or greenish and contained much less of chlorides, but more of silicates and iron than S_4 or S_5. S_7 was inky coloured and contained very much less of chlorides, nitrates, phosphates, silicates, and iron than S_6.

7. SECTION C (Table III)

Samples were taken from two places (S_8 and S_9)—Table III—in the one mile stretch of the river which is very rugged. S_8 represents water flowing out of the bottom discharge pipe in the Diversion weir from a depth of about 25 feet in the second reservoir serving as a constant head tank for the pipes carrying water to the Power House below. It resembled S_7 in its content of chlorides only but had more nitrates, phosphates, and iron. S_9 also resembled S_8 in all respects except for its content of iron which was very much lower.

Fish Fauna : The indigenous fish fauna of the Hope reservoir and the Thambraparani river consisted of : (1) *Barbus sarana*, (2) *Anguilla bengalensis*, (3) *Discognathus armatus*, (4) *Barbus auribus*, (5) *B.pulchellus*, (6) *B.dirsalis*, (7) *Etroplus maculatus*, (8) *Danio aequipinnatus*, (9) *Rasbora daniconius*, (10) *Aplocheluis melastigma*.

Barbus sarana and *Anguilla bengalensis* were the only two economic food fishes, the others being larvicidal.

8. DISCUSSION.

From the foregoing it will be seen that the Hope reservoir formed at an altitude of 720 feet by damming the river Thambaraparani receives silt laden water from a catchment area composed largely of agricultural and forest land. The feeder streams carry appreciable amounts of nutrients in the form of phosphates, silicates, nitrates and iron. The water level in the reservoir is very high (about 200 feet) during the beginning of the year and gradually decreases during January to May, when conditions are quite favourable for productivity. A definite thermal stratification then occurs which continues more or less till the onset of the monsoons between June and December. This is to be inferred from the fact that the bottom discharge water in April 1948 and in March 1951 (hot weather conditions) contained H_2S while that in September 1948 did not. Occasional cases of fish mortality reported in summer months might be due to a sudden " turnover " caused by the summer showers and the consequent depletion of oxygen to critical limits in the entire reservoir resulting in a large scale mortality of fish. Ordinarily stagnation and circulation seem to succeed each other seasonally as in temperate lakes but it is naturally erratic where there is a sudden downpour of summer showers. The bottom temperatures varied from 23 to 28°C pointing to higher stability and rate of decomposition of bottom deposits resulting in a complete absence of dissolved oxygen and the production of H_2S in the bottom layers during summer and in the reduction of the oxygen content during the monsoon seasons. The water is soft and therefore, contains smaller amounts of carbonates and calcium.

The greenish colour of the water and the pH values indicated fairly high plankton productivity in the surface layers at all seasons. Estimation of the composition of the phyto-plankton in the summer of 1948 after a severe drought in the previous year showed the presence in large numbers of *Microcystis spp.* and the red coloured *Botryococcus Braunii.* Gams (1923, cited by Fritsch 1931) connects the occurrence of the red form of the ubiquitous plankton alga Botryococcus Braunii with rich nutriment in certain waters. The occurrence of the red form in the Hope reservoir, is probably due to the same cause.

But when the reservoir was full, the composition slightly varied as on 29th September 1948 and 14th March 1951. On the first occasion the number of species of green algae was greater and *Oocystis sp., Botryococcus Braunii* and *Surirella robusta var splendida* and *Microcystis aeruginosa* were the dominant forms. On the last occasion *Staurastrum spp., Oocystis sp., Botryococcus Braunii* and *Microcystis aeruginosa* were the dominant organisms. So, it would appear that the occurrence of the dominant forms of algae is in some way related to the level of water, which in turn is inversely correlated with the variations in the chemical constituents dissolved in the water. Organic matter is ordinarily high when the level is low and vice versa. *Microcystis aeruginosa* appears to be an ubiquitous inhabitant of this reservoir.

The Hope reservoir conforms to the "evolved" type of Pearsall and to the "eutrophic" type of Naumann (1929) on account of its fairly high level of biological productivity.

The Thambaraparani river in the other two sections carries much nutrient substances in the shape of phosphates, nitrates and silicates which are useful for increasing the fertility of paddy fields, irrigated with that water.

Pisciculture : The Hope reservoir and the Thambaraparani river system are best suited for the conservation and development of fisheries. The indigenous food fishes of this locality are : *Barbus sarana* and *Anguilla bengalensis.* So the reservoir was stocked initially on 6th October 1945 when 250 *Etroplus suratensis* and 1,000 *Macropoadus cupfres* were introduced. These two species have since bred, multiplied and established themselves and have also got well distributed in the entire river system down below. On 14th October 1956, 200 fingerlings of *Catla Catla* from the Cauvery have been stocked. Fingerlings of the other carps like *Labeo fimbriatus, Cirrhina cirrhosa, C.reba, Barbus carnaticus, B.hexogonolopis* from the Cauvery river and *Labeo rohita* from Bengal, *Cyprinus carpio,* from Ootacamund and *Chanos-chanos* from Pamban have also been introduced.

9. SUMMARY.

1. The Hope reservoir located at an elevation of 700 feet and the Thambaraparani river system were examined on three occasions, twice during summer and once during the south-west monsoon season.
2. A very marked and definite thermal stratification occurs in summer and circulation takes place in the south-west and north-east monsoon seasons.

3. The temperature of the water at the bottom is high resulting in a higher stability and increased rate of decomposition of bottom deposits, the consequent depletion of oxygen and production of H_2S in the bottom layers particularly during the summer months (March to May).
4. The biological productivity in the upper layers of water is fairly high and the reservoir comes under the "evolved" type according to Pearsall's classification though of very recent origin.
5. The river water contains appreciable amounts of phosphates and nitrates which raise the fertility of the rice fields irrigated with the water.
6. The indigenous fishery is poor. Carps from the Cauvery and exotic fishes have been recently introduced into the reservoir which is found to be best suited for the growth and development of these fishes.

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TABLE I. Showing the Rainfall and Water Level, Month-War in the Hope Reservoir, Madras State for the years 1948-51.

Month	1948 Total Rain-fall (inches)	1948 Average water level (feet)	1949 Total Rain-fall (inches)	1949 Average water level (feet)	1950 Total Rain-fall (inches)	1950 Average water level (feet)	1951 Total Rain-fall (inches)	1951 Average water level (feet)
January	9.43	82.09	3.82	145.75	1.23	113.96	6.46	144.86
February	1.80	85.56	0.02	134.25	2.35	98.39	0.46	135.63
March	1.83	75.06	0.85	109.90	3.21	79.90	1.84	112.58
April	1.31	61.40	2.85	82.40	1.34	59.51	6.72	94.63
May	2.05	50.33	5.67	62.12	3.75	34.44	6.53	63.67
June	21.35	69.25	3.30	74.77	3.47	62.71	11.15	84.47
July	6.18	116.30	6.16	75.91	3.77	76.55	6.54	109.43
August	3.41	113.33	2.19	78.81	1.96	83.92	0.32	111.82
September	0.17	108.20	2.42	78.41	3.68	100.96	11.49	92.73
October	16.42	105.70	7.30	79.62	5.26	110.64	9.23	121.02
November	23.08	128.81	19.65	94.80	13.58	113.29	21.21	131.49
December	8.39	147.40	3.86	116.80	15.51	130.98	2.52	137.50
Total	95.42		58.09		65.61		84.47	

TABLE II-A: Showing the vertical distribution of temperature, dissolved gases and certain important substances of biological significance in the Hope Reservoir, Madras State.

	29-4-1948; Depth of Visibility 2′ 4″ 10-40 A.M. B.S.S., C.B.S., N.W.* Greenish. Parts per 100,000								29-4-1948; Depth of Visibility 6′ 0″ 4-30 P.M. B.S.S., C.B.S., N.W.—Greenish.								30-4-1948 at 6-40 A.M. C.S., N.W.—Greenish							
		D. O.		H_2S						D. O.		H_2S						D. O.		H_2S				
Depth in Feet	Temp. (°C)	CC/L	% Sat.	Mg/L	pH	P_2O_5	SiO_3	Fe.	Temp. (°C)	CC/L	% Sat.	Mg/L	pH	P_2O_5	SiO_2	Fe.	Temp. (°C)	CC/L	% Sat.	Mg/L	pH	P_2O_5	SiO_2	Fe.
0.0	30.0	4.677	84.0	..	8.2	.001	0.18	.002	32.5	5.286	..	Nil	8.6	Trace	0.18	Trace	28.3	4.568	79.8	Nil	7.2	.002	0.18	.003
5.0	29.5	5.134	91.4	..	8.2	..	..	..	31.3	5.481	..	„	8.8	„	..	„	28.4	4.682	81.9	„	..	..	..	..
10.0	29.0	5.226	92.3	..	8.5	Trace	0.18	.002	30.6	6.845	124.1	„	8.8	„	0.18	„	28.2	4.484	78.2	„	7.3	.003	0.18	.003
15.0	28.1	4.951	86.2	..	8.0	..	..	..	29.2	6.345	112.4	„	8.8	„	..	„	28.2	4.236	73.9	„	..	..	..	..
20.0	27.8	4.803	83.3	..	7.8	.001	0.18	.005	28.4	5.882	102.9	„	8.2	„	0.18	„	28.0	4.186	72.8	„	7.0	.003	0.18	.003
25.0	27.6	2.148	37.1	..	6.4	..	..	..	27.6	1.884	32.7	„	7.1	.002	..	„	27.6	3.041	52.7	„	..	..	..	..
30.0	27.6	0.753	13.5	0.05	6.2	.006	0.18	.045	27.6	0.242	4.2	0.1	6.5	.004	0.18	0.04	27.6	0.043	0.87	0.4	6.0	.006	0.18	.005
35.0	27.2	Nil	Nil	1.20	6.1	..	..	..	27.2	Nil	Nil	1.5	6.1	.008	..	0.08	27.2	Nil	Nil	1.6	..	..	..	.066
40.0	27.2	„	„	2.10	6.1	.010	0.20	.050	27.2	„	„	1.8	6.1	.010	0.20	0.10	27.2	„	„	1.6	6.0	.010	0.20	.078

TABLE II-B: Thermal and Oxygen distribution at three different places in the Hope Reservoir on 1st June 1948.

Depth in feet	S_1 Near the Dam 11-00 A.M. B.S.S., N.W.				S_2 Middle of the Reservoir 12 Noon B.S.S., C.B.S., N.W.				S_3 Extreme end & Opposite to the Dam B.S.S., C.B.S., N.W. 2 P.M.			
0.0	31.0	5.236	..	..	31.6	4.886	..	..	31.8	5.212	..	..
20.0	27.6	4.804	84.1	..	27.8	5.842	101.3	..	27.6	5.742	99.2	..
40.0	27.1	Nil	Nil	0.40	27.2	Nil	Nil	0.5	27.0	Nil	Nil	0.6

* B.S.S.=Bright Sunshine. C.B.S.=Clear Blue Sky. C.S.=Cloudy Sky N.W.=No wind.

TABLE II-C: Vertical distribution of temperature, dissolved gases, and some important substances of biological significance in the Hope Reservoir on 23rd September 1948 at S_1 near the Dam.

Depth 107·7 Ft. Greenish Colour. Depth of visibility 6′0″.

	(a) 7-00 A.M. *C.S., N.W.—Parts per 100,000								(b) 4-00 P.M. I.B.S.S., N.W.							
	Temp.	D. O.		H_2S					Temp.	D. O.		H_2S				
Depth in Feet	(°C)	CC/L	% Sat.	Mg/L	pH	P_2O_5	SiO_2	Fe.	(°C)	CC/L	% Sat.	Mg/L	pH	P_2O_5	SiO_2	Fe.
0.0	25.4	4.862	81.0	Nil	7.8	Trace	.14	.010	27.8	5.684	98.6	Nil	8.1	Trace	0.14	.02
10.0	25.2	4.886	81.1	„	..	..	..	..	27.0	5.680	97.3	„	..	..	..	..
20.0	25.1	4.966	82.8	„	7.8	.004	.14	.012	26.8	5.721	97.6	„	8.1	Trace	0.14	.01
30.0	25.1	4.960	82.3	„	..	..	..	..	26.6	5.564	94.6	„	..	..	..	..
40.0	25.1	4.928	81.7	„	7.8	.006	.14	.014	26.0	5.541	93.3	„	8.1	.001	0.14	.01
50.0	25.0	4.904	81.2	„	..	..	..	..	26.0	5.526	93.0	„	..	..	..	..
60.0	25.0	4.908	81.2	„	7.8	.010	.14	.010	25.7	5.486	91.9	„	8.1	.008	0.14	.02
70.0	25.0	4.880	80.8	„	..	..	..	..	25.6	5.468	91.4	„	..	..	..	..
80.0	25.0	4.880	80.6	„	7.8	.006	.14	.018	25.4	5.500	91.7	„	8.0	.010	0.14	.02
90.0	24.8	4.900	80.9	„	..	..	..	..	25.4	5.489	91.5	„	..	..	..	..
100.0	24.4	4.688	77.0	„	7.8	.012	.14	..	25.4	4.822	80.4	„	8.0	.010	0.14	.02
105.0	24.4	4.602	75.4	„	7.6	.014	.18	.020	25.2	4.800	79.7	„	7.9	.014	0.19	.02

* C.S.=Cloudy sky. N.W.=No wind. I.B.S.S.=Intermittent bright sunshine.

TABLE II-D : Showing the vertical distribution of temperature, dissolved gases and certain important substances of biological significance in the Hope Reservoir, Madras State.

14-3-1951. Depth : 113.7 Ft. Depth of visibility : 5′6″.

Depth in Feet	S_1 Near the Dam at 6-45 A.M. on 14-3-51 cloudy sky. No wind.					Parts per 100,000			S_1 Near the Dam at 2-30 P.M. on 14-3-1951 B.S.S., C.B.S.. No wind.					Parts per 100,000		
	Temp. (°C)	D. O. CC/L	D. O. % Sat.	H_2S Mg/L	pH	P_2O_5	SiO_2	Fe.	Temp. (°C)	D. O. CC/L	D. O. % Sat.	H_2S Mg/L	pH	P_2O_5	SiO_2	Fe.
0.0	25.6	4.884	81.9	Nil	7.6	.002	.16	.02	30.0	5.580	100.1	Nil	8.0	Trace	.14	Trace
10.0	25.8	4.880	81.9	„	7.6	„	„	„	29.8	5.562	101.7	„	8.1	„	„	„
20.0	25.8	4.864	81.6	„	7.6	„	„	„	29.6	5.680	101.3	„	8.0	„	„	„
30.0	25.8	4.866	81.6	„	7.6	„	„	„	29.3	5.621	99.8	„	8.0	„	„	„
40.0	25.4	4.862	81.0	„	7.6	„	„	„	29.0	5.600	99.0	„	7.9	„	„	„
50.0	25.4	4.860	81.0	„	7.6	„	„	„	28.5	5.618	98.5	„	7.7	.001	„	„
60.0	25.2	4.860	80.7	„	7.6	„	„	„	23.0	5.081	88.4	„	7.5	.001	„	„
70.0	25.2	4.860	80.7	„	7.4	„	„	„	27.2	4.368	75.0	„	7.3	.001	„	„
80.0	24.0	1.840	29.9	„	7.2	„	„	.04	26.6	2.042	34.7	„	6.7	.006	„	.02
90.0	24.0	0.648	10.6	„	7.2	„	„	.04	25.8	0.361	6.1	0.1	6.4	.006	„	.06
100.0	23.4	0.360	5.8	0.10	6.3	„	.18	.08	23.4	Nil	Nil	1.0	6.3	.008	„	.06
110.0	23.4	Nil	Nil	0.15	6.3	.008	.20	.10	23.4	„	„	1.6	6.3	.010	.20	.08

TABLE III : Showing the results of the Physical and Chemical Examination of the Hope Reservoir and the Thambaraparani River System, Madras State.

Places of Sample collection	PHYSICAL CONDITIONS Date	Time A.M	Depth	Smell	Colour	Temp. (°C)	CHEMICAL CONDITIONS Carbon dioxide Free	CO_3	HCO_3	pH	D. O. CC/L	D. O. % Sat.	Cl.	NO_3N	P_2O_5	SiO_2	Fe.
SECTION 'A'																	
(i) FEEDER HILL STREAMS TO THE RIVER THAMBARAPARANI.																	
Pambanar Stream	1-5-48	11-35	6″	Nil	Y.B.	24.8	0.20	Nil	0.91	6.7	3.580	59.1	0.9	0.001	0.008	.25	0.03
Banathirtham Stream	„	11-50	4″	Nil	Y.	22.7	0.16	„	0.91	6.7	4.508	71.9	0.9	0.002	0.001	.26	0.04
(ii) HOPE RESERVOIR AND THE THAMBARAPARANI RIVER SYSTEM.																	
Hope Reservoir, Surface water	29-4-48	10-40	0	Nil	Gr.	30.0	0.15	Nil	2.13	7.5	4.680	84.0	1.0	0.001	0.001	0.18	0.002
„ „	23-9-48	9-40	0	„	„	26.8	Nil	0.30	1.37	8.4	5.171	88.2	0.8	Nil	0.001	0.14	0.009
„ „	14-3-51	3-25 P.M.	0	„	„	31.6	„	0.42	1.89	8.6	6.484	..	0.6	0.001	Trace	0.14	Trace
SECTION 'B'																	
Hope Reservoir Bottom discharge water	29-4-48	12-15	40	H_2S	Br.	27.2	0.27	Nil	2.74	6.3	3.86	66.3	1.0	0.008	0.010	0.20	0.050
„ „	23-9-48	10-00	107.7	Nil	„	24.2	0.15	„	1.95	7.1	5.437	88.8	0.8	0.004	0.010	0.18	0.020
„ „	14-3-51	3-30 P.M.	113.7	H_2S	„	23.4	0.38	„	3.84	6.5	4.826	77.8	0.6	0.004	0.015	0.16	0.080
From the Thambaraparani river about 200 feet below the Dam	29.4.48	12-20	0	Nil	Br.	26.8	0.49	Nil	2.13	6.3	5.100	87.0	1.0	0.004	0.008	0.21	0.14
„ „	23-9-48	10-30	0	„	„	24.2	0.13	„	1.80	7.5	5.437	88.8	0.8	0.002	0.010	0.21	0.30
„ „	14-3-51	3-40 P.M.	0	„	„	23.4	0.32	„	3.80	6.6	5.682	91.6	0.6	0.006	0.012	0.31	0.34
Just below the confluence of the river Thambaraparani and the Serval Ar. near the Mundanthurai causeway	29-4-48	12-50	0	Nil	Br.	30.2	0.15	Nil	1.83	6.9	5.100	91.8	0.6	0.006	0.010	0.36	0.22
„ „	23-9-48	1-00	0	„	Gr.	23.2	0.12	„	1.52	7.5	5.569	89.7	0.5	0.004	0.008	0.32	0.34
„ „	14-3-51	4-35	0	„	„	30.4	0.14	„	1.76	6.7	5.224	94.4	0.6	0.006	0.012	0.38	0.30

TABLE III : (*Contd.*) Showing the results of the Physical and Chemical Examination of the Hope Reservoir and the Thambaraparani River System, Madras State.

Places of Sample collection	Date	Time A.M.	Depth	Smell	Colour	Temp. (°C)	Carbon dioxide Free	Carbon dioxide CO_3	Carbon dioxide HCO_3	pH	D. O. CC/L	D. O. % Sat.	Cl.	NO_3N	P_2O_5	SiO_2	Fe.
	PHYSICAL CONDITIONS						CHEMICAL CONDITIONS						Parts per 100,000				
From the middle of the Diversion Weir surface	29-4-48	1-10 P.M.	0	Nil	Inky	29.8	0.18	Nil	1.83	7.0	4.410	79.1	0.3	0.001	0.004	0.19	0.04
„ „	30-4-48	9-40 A.M.	0	„	„	29.0	0.44	„	2.44	6.9	4.774	84.3	0.3	0.002	0.005	0.20	0.08
„ „	23-9-48	1-20 P.M.	0	„	„	25.4	0.13	„	1.37	7.5	5.304	88.3	0.2	Trace	0.001	0.18	0.05
„ „	14-3-51	5-00	0	„	Gr.	28.6	0.21	„	1.92	7.6	5.841	97.5	0.1	..	0.001	0.20	0.07
					SECTION 'C'												
From the middle of the Diversion Weir, Bottom discharge water	29-4-48	1-20 P.M.	25.0	Nil	Y.Br.	27.8	0.20	Nil	2.13	6.9	3.990	69.2	0.4	0.010	0.008	0.16	0.18
„ „	30-4-48	10-00 A.M.	25.0	„	„	28.2	0.25	„	1.52	6.9	4.906	85.5	0.3	0.012	0.008	0.16	0.20
„ „	23-9-48	1-10 P.M.	35.0	„	„	24.4	0.13	„	1.37	7.5	5.304	87.0	0.2	0.020	0.009	0.18	0.08
„ „	14-3-51	5-15	34.8	„	„	27.1	0.16	„	1.42	7.7	5.686	97.5	0.2	0.027	0.010	0.20	0.16
From the River below the Papanasam Falls	29-4-48	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
„ „	30-4-48	11-10	..	Nil	Br.	30.4	0.20	Nil	1.83	7.1	5.967	107.8	0.3	0.014	0.005	0.18	0.01
„ „	23-9-48	2-10	..	„	„	26.8	0.10	„	1.46	7.2	5.800	98.9	0.2	0.010	0.008	0.15	0.01
„ „	14-3-51	5-35 P.M.	..	„	„	25.6	0.12	„	1.62	7.3	5.581	93.9	0.2	0.010	0.004	0.12	0.01

TABLE IV : Showing the Plankton Content in the Hope Reservoir, Papanasam, Madras State

S. No.	Description of Organisms.	29-4-48	23-9-48	14-3-51
	1. PHYTOPLANKTON.			
	(A) VOLVOCALES :			
1.	Eudorina elegans	..	rr	..
	(B) CHLOROCOCCALES :			
2.	Coelastrum reticulatum	rrr	r	rr
3.	Dictyosphaerium pulchellum	..	rr	rrr
4.	Ankistrodesmus spiralis	rrr	r	rr
5.	Pediastrum Boryanum var nov	..	r	rr
6.	Pediastrum Clathratum	..	r	c
7.	Pediastrum duplex	rrr	rr	r
8.	Pediastrum simplex	rrr	r	rr
9.	Oocystis sp.	rr	ccc	c
10.	Kirchneriella lunaris	..	r	rr
11.	Scenedesmus quadricauda			
	(C) OEDOGONIALES :			
12.	Oedogonium sp.	..	r	..
	(D) CONJUGALES :			
13.	Mougeotia sp.	..	r	r
	(E) DESMIDS :			
14.	Closterium acerosum	rr	r	rr
15.	Closterium venus	rr	rr	rrr
16.	Euastrum spinulosum	rrr	rr	rr
17.	Cosmarium Lundelli	rr	r	r
18.	Cosmarium reniforme	rr	..	rr
19.	Cosmarium staurochondrum	rrr	r	rrr
20.	Spondylosium compactum	..	r	r
21.	Staurastrum gracile	..	r	cc
22.	Staurastrum pentacerum	..	r	ccc
	(F) XANTHOPHYCEAE :			
23.	Botryococcus Braunii	cc (Red)	cc (Red)	ccc (Red)
	(G) BACILLARIOPHYCEAE :			
24.	Melosira granulata	r	rr	c
25.	Syndedra ulna	r	r	r
26.	Navicula sp.	c	r	r
27.	Surirella robusta var splendida	c	cc	r
	(H) DINOPHYCEAE :			
28.	Peridinium gatunense	rr	r	r

TABLE IV: Showing the Plankton Content in the Hope Reservoir, Papanasam, Madras State.—*(Contd.)*

S. No.	Description of Organisms.	29-4-48	23-9-48	14-3-51
	(I) EUGIENINEAE :			
29.	Euglena acus	r	r	rr
	(J) CYANOPHYCEAE :			
30.	Microcystis aeruginosa	ccc	c	c
31.	Microcystis elebans	cc	r	r
32.	Microcystis marginata	cc	rr	r
33.	Aphanothece nidulans	r	rrr	rr
34.	Gleothece distans	r	rrr	rr
35.	Chroococcus tenax	r	..	rr
36.	Gomphosphaeria aponina	r	rr	rrr
37.	Anabaena spherica	r	rrr	rr
38	Oscillatoria Spp.	cc	rr	r
39.	Merismopedia punctata	rr	rr	rr
40.	Anabaenobsis sp.	c	rr	r
	(2) ZOO PLANKTON			
	(A) COPEPODA :			
1.	Nauplii	..	c	rr
2.	Cyclops spp.	c	r	cc
3.	Diaptomus	r	rr	c
	(B) CLADOCERA :			
4.	Alona	rrr	r	r
5.	Bosminopsis	rr	r	r
6.	Ceriodaphnia	..	rr	rr
7.	Diaphanosoma	rr	r	r
	(C) ROTATORIA :			
8.	Anuraea valga	..	r	rr
9.	Brachionus	..	r	rrr
10.	Asplanchna	rr	r	rr
11.	Polyarthra	..	r	rr
	(D) PROTOZOA :			
12.	Difflugia	rr	r	r

A STUDY OF THE HYDRO-ELECTRIC DEVOLOPMENT IN MYSORE

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INTRODUCTION

The State of Mysore lies between 11° 38′ N and 15° 58′ N and 74° 42′ E and 78° 36′ E and occupies an important position in South India. The State is handicapped by the absence of coal or oil as sources for its industrial development. The huge transportation cost of coal from north-eastern India—a distance of more than 1,000 miles—necessarily hindered the progress of industrial development. Taking advantage of her physiography the people of Mysore thought of harnessing its rivers at their falls ; which were otherwise useless for navigation and uneconomical, and which proved to be a treasure house of huge Hydro Electric Power resources.

Mysore was the pioneer State in the east for harnessing its rivers for the development of Hydro Electricity. The plan was thought off as early as 1898 on the river Cauvery at the famous Sivasamudrum falls ; (to the south-east of Bangalore in Mandya District).

I. SIVASAMUDRUM HYDRO ELECTRIC PROJECT

The first hydro electric undertaking called the Sivasamudrum Hydro Electric Project came into operation in the year 1902. This scheme was started with only six units having a total capacity of 4,320 kw. It was then primarily meant to supply power to the Kolar Gold Fields, 92 miles away. The high tension transmission for this purpose at that time was the longest commercial, high voltage transmission line in the world.

With the people of Mysore becoming more electricity minded, additional generating units were made from time to time and eventually in the year 1919 a reaction turbine driven generator of 3000 kw. was installed, as pellon wheel turbines were not very efficient for the head available at Sivasamudrum Station. Since 1902 the supply of electrical energy from Sivasamudrum has been provided for Bangalore and for Mysore cities and 226 other towns and villages in the State.

With the completion of the Krishnaraja Sagar Dam (12 miles north-west of Mysore) in the year 1920-21 it was found that sufficient quantity of water could be secured from the reservoir to generate more power and by that time the need for more electricity for Industrial expansion became inevitable. In order to meet the additional demand and to utilise the extra quantity of water made available for power generation, all the old generating units were removed and new and efficient units of 6,000 kw. were installed ; increasing the generating capacity stage by stage, starting from the year 1922, the installed capacity at Sivasamudrum finally stood at 60,000 K.P. in 1937.

The demand for power grew ever more. Town after town, and village after village were linked through an ever growing net-work of transmission and distribution lines to what may rightly be called the Industrial hub of the Mysore State.

II. SHIMSHA POWER PROJECT

The State Government in continuing its policies for industrial development thought it necessary to harness sources of power other than Sivasamudrum —if at all the pace of progress had to be maintained. Further as irrigation under Krishnaraja Sagar Dam developed, the need to conserve the stored water at considerable costs for the purpose of irrigation was keenly felt. Therefore the 900 cusecs of water that were to be let down in the river for the Government of Madras under the terms of the contract had to be utilised most efficiently to derive maximum benefit. Surveys revealed that if water is conducted about 6 to 7 miles to the neighbouring valley of the Shimsha river, each cusec of water could be made to develop 50 per cent more power than it would produce at Sivasamudrum. Thus the Shimsha Power Project came into existence in June 1940, with an installed capacity of 23,000 K.P., and at a greater head of 630 ft.

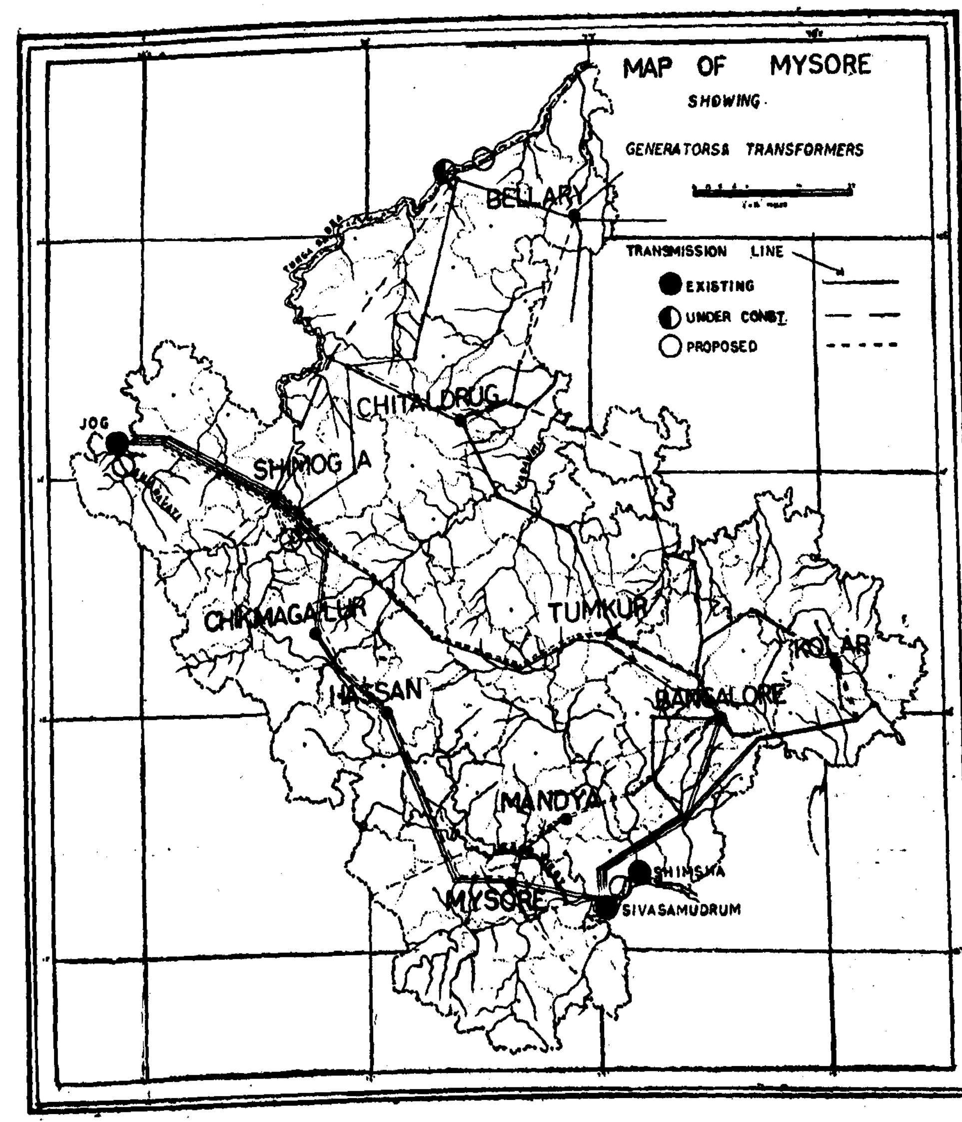
III. THE JOG OR MAHATMA GANDHI HYDRO ELECTRIC PROJECT

With the above two generating stations namely Siva and Shimsha spreading their tentacles farther and farther, brightening the roads and the interiors of homes and rotating the wheels of cottage, small scale and large scale industries, the power demand grew even more.

This was the main reason for the immediate starting of the " Mahatma Gandhi Hydro Electric Project " without in any way interfering with the natural beauty of the famous Jog falls on the Sharavati river in Shimoga District. The first stage of the project with an installed capacity of 48,000 k.w. was cut into service with four units of 12,000 k.w. each on the 21st February, 1948. With the completion of the work on the second stage consisting of 4 units of 18,000 k.w. each, the total installed capacity of 120,000 k.w. was put into commission in 1952. It is interesting to note that power at Jog is generated, transmitted and distributed at a frequency of 50 cycles whereas the other two stations generate and transmit at 25 cys. The Government has approved the conversion of the existing 25 cycles, to 50 cycles thus standardising the frequency of supply to 50 cycles throughout the State including the Kolar Gold Field area. The work is under progress and several northern places like Shimoga, Bhadravati, Davangere, Harihar and Chitaldrug have already been converted.

The transmission system consists of over 900 miles of 78,000 volts and 37,500 volts lines with a total of 1,350 miles of circuits. The power is supplied through transmission line to every corner of the State. A net work of high transmission system is under construction consisting of long distances of 110 k.v., 66 k.v., 33 k.v., 13.2 k.v. transmission lines.

Thus the Mysore electrical system has 179,200 kw, for its credit as the installed capacity ; but out of this 142,000 k.w. is carried as firm, owing to the limited flow of the Cauvery during the summer months and reckoning one unit of 18,000 k.w. at Jog as spare ; against this a coincidental peak demand of 111,000 k.w. on the system has already been reached.



PROGRESS

By the use of Hydro Electricity the State has made remarkable progress. The striking instances of this can be noticed in small towns and villages, which have been the centres of domestic handloom industry. With the advent of electricity most of the handlooms have been converted into a motor driven unit. The installation of modern electrically driven pumping sets is rapidly going on.

Key industries such as Iron and Steel, cement and paper mills, etc., have sprung up at Bhadravati and have been expanded in large proportion. An electrical pig iron furnace was recently installed at Iron & Steel Works, Bhadravati.

The availability of cheap power in the vicinity of Bangalore along with its salubrious climate has attracted national industries such as (a) The

Hindustan Aircraft Ltd., (b) The Indian Telephone Industries, (c) The Hindustan Machine Tools, (d) The Bharat Electronics Ltd. Besides these there are so many other big and small industries employing nearly a lakh of labourers.

A comparison could be drawn between the installation in existence at the end of the official year 1946-47 and as on 1951-52 indicating the rapid growth of the use of electricity in various directions.

Sl. No.	Particulars	1946-47	1951-52
1.	No. of units generated per month ..	27,898,700	46,156,400
2.	No. of units generated during the year	332,205,500	534,620,000
3.	Annual Gross revenue	1,18,32,559	1,86,00,000
4.	No. of towns and villages electrified ..	228	494
5.	No. of (a) Lighting installations ..	61,308	100,369
	(b) Heating installations } ..		5,757
	(c) Power installations } ..	6,350	6,677
	(d) Iron Pumps	1,021	2,825
	(e) Street lights	20,175	26,392
6.	Length of transmission lines in miles ..	1,366	1,801
7.	Consumption of energy per capita ..	34.8	40.4
8.	Capital outlay at the end	11,06,67,291	19,82,00,000

It may be seen that the programme after independence has been indicated as one of intense activity involving heavy capital expenditure.

Step-down Stations: It was planned to install step-down stations of adequate capacity at important points on these transmission systems, so that practically the entire State may be covered with the distribution system, the distance from each step-down station not exceeding in length by about 30 miles. Eight sub-stations with automatic protective equipment, etc., were purchased having a capacity ranging from 3,000 to 1,500 KVA and all these were installed and serviced at Sagar, Shimoga, Davangere, Tumkur, Mandya, Tiptur, Chitaldrug, and Chickmagalur. A similar unit is also installed in Goribidnur to feed the irrigation pump set loads and two more unit sub-stations, one at Chikhallapur and another at Doldahallapur. These installations feed to the extent of 1,500 to 300 KVA. which was formerly limited to 150 to 300 KVA. The capacity of Bangalore receiving station is increased from 15,000 KVA to 45,000 KVA. and of Mysore from 10,500 KVA. to 30,000 KVA.

Under the "Grow More Food Campaign" sponsored by the present Government, top priority is given to the supply of power to irrigation pumps in various parts of the State. The Dept. on an average are serving 1,000 pumps one year and the total irrigation pumps installed exceed 6,000.

Rural Electrification: A plan for the electrification of towns and villages was started in the year 1905. Considerable progress is achieved particularly since 1950. It has been the declared policy of the Government to provide all possible amenities to the rural parts of the State, with a view to raise

the general standard of living. The intention of the State Government is to electrify each and every village with a population of 1,000 or more. Till now more than 800 villages have been electrified. Schemes after necessary load survey of the places to be electrified have been prepared for nearly 600 villages and some of them have been sanctioned and works are under progress.

The table below gives some idea of the villages electrified:

No.		1951-52	1952-53	1953-54	1954-55	District Total till now
1.	Kolar	3	19	5	13	137
2.	Tumkur	3	4	3	5	30
3.	Bangalore	12	8	8	11	257
4.	Mysore	4	14	7	15	74
5.	Mandya	4	11	1	2	61
6.	Chitaldeva	1	7	13	11	45
7.	Hassan	1	3	6	9	28
8.	Chikkamagalore	8	1	6	3	44
9.	Shimoga	3	8	7	13	68
10.	Bellary				2	13
	Total ..	39	75	56	84	757

Progress under First Five-Year Plan: The first Five-Year Plan of Mysore as accepted by the Planning Commission has included a sum of Rs. 1,269 lakhs for 9 schemes taken up for development and distribution of electrical power in the State and an amount of Rs. 41 lakhs for three schemes in Bellary District since its merger in Mysore State in October, 1953. The plan as now revised stands at Rs. 1376.19 lakhs inclusive of Bellary District plan. The expenditure of Rs. 735.85 lakhs has been incurred for the last three years of the plan period and a provision of Rs. 226.08 lakhs is expected to be made for 1954-55. An allotment of Rs. 417.66 lakhs is required for 1955-56. The Mahatma Gandhi Hydro Electric Scheme which was started prior to 1951-52 has been completed at a total cost of Rs. 763.59 lakhs and this scheme will generate 120,000 K.W. power. The other important scheme is that of the Shimsha expansion project estimated to cost Rs. 320 lakhs for which a provision of Rs. 310 lakhs was made in the present plans, but the work has not been taken up for implementation till now for want of funds.

The remaining scheme for frequency conversion, extension of transmission lines and distribution lines, installation of step-down stations and power supply to irrigation pumping sets are all being implemented. For the last three years 284½ miles of transmission lines have been laid; 176 villages have been electrified, 36,151 lighting installations, 4,669 power installations, 9,190 street lights have been provided and 3,163 irrigation pumps have been serviced.

PROGRAMME UNDER SECOND FIVE-YEAR PLAN

In view of the non-availability of coal in the State and the depletion of our forests for fuel purposes, the demand for power is growing rapidly. If future plan is to be implemented and if power is to be provided for industrial enterprise, it is necessary to harness Hydro Electric power to the maximum extent possible. Also the further development of Mysore Iron and Steel Works is dependent on the availability of power. The Sharavati Valley Project popularly known as "Honnemavadu Project" if fully implemented will supply power at a low cost of about Rs. 700 per K.W. and the total quantity of power available will be nearly 710,000 K.W. at a cost of 57 crores on its completion. The immediate implementation of the Sharavati Valley Project is of the magnitude whose estimated cost is Rs. 2,287 lakhs. As this State is also supplying power to Bombay, Andhra and Madras in spite of the power shortage within its own boundary, this scheme is included in the plan with a nominal cost of Rs. 1,30,000 lakhs for the present, subject to enhancement on progress of work within the planned period. The consequent development like extension of transmission lines, installing step-down stations, rural electrification, etc., is estimated to cost about Rs. 1,773 lakhs including Bhadra Power under P.W.D. During the plan period electricity will be given to about 300 towns and villages.

PHYSICAL TARGETS

1.	Generation : Sharavathi Valley	..	71,000 K.W.
	Bhadra Project	..	41,040 K.W.
2.	Electrification of towns and villages	..	300
3.	Power Supply to Industries	..	5,000
4.	Lighting installations	..	50,000
5.	Extension of transmission lines above 22 KV		200 miles
6.	Sub-stations	..	10 miles

The load demand in the State by the end of 1961 is of the order of 352,670 K.W. as against the present firm capacity of 142,000 K.W. only. The first stage of Sharavati Valley Project is 71,000 K.W. costing Rs. 1,300 lakhs.

(a) The Tungabhadra Project Scheme with its present 2 units of 9,000 K.W. under construction and 2 units of the same size at Hampi Station will be carried out at an estimated total cost of Rs. 169 lakhs.

(b) The work on the Bhadra Reservoir Project is progressing. Its estimated cost is Rs. 82 lakhs.

FUTURE PROJECTS

(1) *Mekadatu Hydro Electric Works :*

The river Cauvery during its course on the border of the State provides another site for generation of power with a head of 210 ft. utilising the waters of the Siva and Shimsha Project. It will generate 24,000 K.W. power and is expected to cost Rs. 4 crores.

(2) *Shimsha Project Extension :*

If extended the new project will generate from 17,200 KVA to 92,000 K.V.A. by diverting all the water available in the river Cauvery. The Project will cost Rs. 3.2 Crores.

(3) *Honemaradu Power Project Extension Scheme :*

It will ultimately generate 7,10,000 K.W. and is expected to cost Rs. 57 crores.

CONCLUSION

With the completion of these Power Projects Mysore will be in a position to materialise her ambitious scheme for full development, which will ultimately provide employment to a large number and also considerably raise the standard of living to one and all.

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NOTES

A DRAFT SYLLABUS FOR A REFRESHERS' COURSE IN GEOGRAPHY *

By

SITANSHU MOOKERJEE

In the following paragraphs is given an outline-syllabus for a Refreshers' Course in Geography meant for geography teachers of recognised high schools in India. The duration of the course will be six weeks, classes meeting three times a week for lectures and once a week for practical work. Each lecture period should have a duration of one hour and each meeting for practical work of two hours. It has been assumed that the candidates joining the course would be graduates with geography as one of their subjects and the purpose of instituting this course is to impart to them a current orientation in the subject. The course would, presumably, make them up-to-date, confident and post them with information regarding the latest lines of research. While the method of teaching school geography may be left to the teachers concerned, this syllabus has been specially designed with a view to giving them the proper approach and background without which appropriate teaching methods cannot be devised. Topics for lectures have only been indicated; further details may be worked out by the Lecturers. Lectures should be carefully prepared and preferably written out before delivery, as the time available for the entire course is rather limited.

A. THEORY

FIRST WEEK : THREE LECTURES.

Course I : The Impact of Geography.

The Science of Geography : Its nature and content. Its place among the Social Sciences. Its inter-relationships. The status of Geography in a University curriculum. Geography and Geographers. Geography in the Twentieth Century : Geography in America and Europe : Different Schools of Geography. The Human bias. The shift of emphasis from exploration work to social studies. Geography a great essential in modern life. The major branches of the geographical stem. The message of Geography : In nature there are no boundary lines ; one element passes almost imperceptibly into another. The meaning of this message in our social and cultural life.

SECOND WEEK : THREE LECTURES.

Course II : Geomorphology.

Its subject-matter and relationship with other earth-sciences. Historical development and the latest lines of research. Principles and problems. The cycle concept—a fundamental idea. The great importance of fluvial erosion : other forms of erosion. The scientific study of topography. Landscape as a geomorphic unit.

* The above syllabus was submitted to the Dean of the Faculty of Arts, Nagpur University, Nagpur, India, by the author, Dr. Sitanshu Mookerjee, Head of the Department of Geography, Nagpur University.

THIRD WEEK : THREE LECTURES.

Course III : Oceanography and Climatology.

Their subject-matter and recent growth as independent sciences. A new and vast field of work. Climatology in problems of settlements and agriculture in pioneer areas. Climographs and homoclimes. Oceanography in problems of deep-sea fishing. The Wealth of the Oceans—a new assurance to meet man's ever increasing requirements of food and raw materials.

FOURTH WEEK : THREE LECTURES.

Course IV : Human, Economic and Political Geography.

(a) History of our civilisation : Evolution of the society from simple, primitive forms to the modern, complex types. Role of geography at every stage of this glorious record. Juxtaposition of different cultures. All geography is Human Geography. Human geography in France and Germany.

(b) Man's material needs and resultant activities. The economic sphere. Economic resources—their classification, distribution and utilisation. The principal occupations of mankind. Realms of high and low productivity. Influence of geographic factors. The problem of location of industries.

(c) Geography and the State. Problems of frontiers, resources, languages and nationalities. Geographical factors in the rise and fall of political states. Decline of empires and colonies. Problems of large States and small States. Generals and geographers—the problems of terrain and strategy. Ambitions of State and their groupings.

FIFTH WEEK : THREE LECTURES.

Course V : A Geography of India.

The structure and physiography of India : The three fundamental divisions. Climatic peculiarities—the mechanism and vagaries of the Monsoon. Problems of agriculture, irrigation. Forests, pastures and fisheries. Problems of power resources—the development of river valleys. Position with regard to minerals. Manufacturing industries and raw materials. The great problems of food supply, population and rehabilitation. Planning and salvation. India's regional patterns.

SIXTH WEEK : THREE LECTURES.

Course VI : The Application of Geography.

The development of Border Sciences—a recent trend in the West. Geography—a practical science. Its future lies in the applied field. Throughout the world the fundamental problem facing mankind is a disparity between land and livelihood, between resources and population and between utilisation and conservation. Here comes the training of Geography which alone can strike a balance between several conflicting needs. Geography is a Science of synthesis, co-ordination and harmony. Example of the Land utilisation Survey of Britain. Contributions of American, British, French and Canadian Geographers to their countries. Geographical personnel in the Services—the Army, the Navy and the Air Force. Cartographical assistance in topographical and geological mapping. Preparation of National Atlases. Geographers' role in explorations, snow surveys, river valleys projects, boundary commissions, national planning and soil conservation service. Geography and Government.

Science is international and of all sciences geography is the most international. The basis of culture is a broad outlook. Geography gives the perspective which is so essential in appreciating life and its problems. Geography in the problems of peace : the concept of regionalism. SEAC—an example of war-time regionalism and ECAFE, an example of peacetime geography.

B. PRACTICAL

First Two Weeks : Course I : Map-Work.

Topo-sheets and the Weather Map ; Acquaintance with maps of the International Series and Maps of the Land Utilisation Survey. Use of relief models and aerial photographs.

Third and Fourth Weeks : Course II : Map Projection.

The conception of map projection may be made perfectly clear. Construction of a few important projections. Properties of projections and choice of a projection.

Fifth and Sixth Weeks : Course III : Surveying and other Instruments.

Renewal of acquaitance with the chain, Plane table, Prismatic compass and Level. Principles of Survey Work. Working of other simple instruments, cartographical and meteorological. The purpose of work and the practice of operation may be made clear in the case of every instrument.

C. FIELD-WORK

After completion of the above series of lectures and practical work lasting six weeks, the candidates should be taken out on a field excursion. A first-hand experience of field-work and observation is very necessary for a good training in Geography.

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