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TWENTYEIGHTH SIR ALBERT CHARLES SEWARD MEMORIAL LECTURE

PRESENT TRENDS IN ECOLOGY

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I AM very much honoured to be invited to deliver the 28th Sir Albert Charles Seward Memorial Lecture which coincides with the celebration of the anniversary of the founder of Birbal Sahni Institute of Palaeobotany.

I want to express my gratitude to Professor T. S. Mahabale, Chairman of the Governing Body, and to Dr M. N. Bose, the Director of this famous Institution. At the outset, I would like to say that I was surprised when I received their invitation and reminders — since I do not feel to deserve this honour, and also because I must confess, I have not been specialised in palaeobotany. But I have always found interest in this science and in the closely related branch palynology, which I have tried to develop in our Institute of Pondicherry.

I will not praise before your learned assembly the merits of palynology in various fields, and especially in taxonomy and evolution. I will only mention the common benefits of a good cooperation of palynologists and ecologists. The pollen analysis of borings may give proper information on the evolution of the floristic composition of the vegetation in the historical past. The historical background of the plant-cover, which palynology provides is important for understanding the present floristic composition of the vegetation from its variations in time. It also brings evidences on the evolution of crops and land-use in various regions and is very helpful to archeologists who want to rebuild the vegetational landscapes of ancient civilizations.

But to answer questions regarding the structure of vegetation or palaeoclimates, some knowledge is required of the temperament or ecological amplitude of species and plant communities. The structure of the past vegetation can be known by the floristic composition which is reflected by the pollen analysis. Ecological group of species are more useful in such interpretations of these analyses than the conventional groups of arboreal (AP) or non-arboreal pollens (NAP). Typical examples are given by the savannas in which the dominant grasses or herbs are also mixed with ligneous pioneer species.

This leads me to comment on the present trends in ecological studies.

Although the concept of ecology is now one century old it has come more and more in the limelight during the last decades, — so much so that it has deviated from its original definition which is the study of the relations of living organisms with their environment. For too many people, especially in the western countries, and thanks to mass media, ecology means merely pollution, and environment is equal to urbanism or town planning.

Considering the large variety or areas covered by ecological studies and their fields of application, I have restricted my subject to the scientific aspects and trends of modern ecology.

At the origin of modern ecology is the recognition that the living matter might be considered not only at the level of organisms, but also at the level of their populations, and mainly of their grouping in communities and biocoenoses in the ecosystems. In fact, to these higher levels of organization corresponds new specific properties resulting from the inter-actions of the various elements of the system. Therefore, it is important to consider all the living species of a *biocoenosis* in order to understand the structure, the functioning and the evolution of the complex system which they form.

This global, holistic conception of the problems is the originality of Ecology as compared to the more specialized or reductionist approaches of the other sectors of Biology. But before making a synthesis, analytic researches are necessary and the ecologist must also *be a specialist*, but a specialist able to communicate, to dialogue with others, in view of solving the whole problem. In practice, an ecological study will be essentially the work of a team of specialists of several disciplines. Experience shows the importance of the problems of communication between specialists in the multidisciplinary researches. This is particularly true in the case of environmental studies when biologists and socio-economists have to cooperate on the same problem. The concepts they are accustomed to, are sometimes so different that they have to make their vocabulary understandable to each other.

Another originality of this global approach of the problem is the necessary notion of system. Thus the *ecosystem* plays a central part in the ecological researches. It may be defined as the simplest level of organisation of the living world, being compatible with a certain degree of autonomy. It appears as the fundamental unit, of which essential properties have to be studied. It is an open system, in the thermo-dynamic sense of the term, which fits in the general theory of systems. But an ecosystem is so complicated that it has to be subdivided into sub-systems, the so-called " black boxes " in the models, each studied separately; the photosynthesis at the level of the leaves, or the soil compartment are examples of such sub-systems, linked by exchanges of matters and flows of energy. We will briefly review some of the main problems related to the *structure*, the *functioning* and the *equilibrium*, or transformations of ecosystems.

STRUCTURE OF ECOSYSTEMS

The various elements of the *biotope* and the *biocoenosis* have complex interrelations resulting from their localization in space, their variations in time, their role in the transfers of energy and matter which characterize the functioning of the ecosystem. It is difficult and arbitrary to dissociate structure and functioning, one conditioning the other. Any change in the structure like opening of the plant-cover by over-exploitation, overgrazing will obviously result in changes in the functioning of the system which in turn will gradually affect the floristic composition. Drought resistant species may replace shade species in the new community. But on the other hand, it is also possible and easier to consider separately the structure which will characterize a greater variety of ecosystems over larger areas. The mapping of ecosystems and of groups of ecosystems, i.e. landscapes, is based on the various aspects of the structure.

The first phase of any study of ecosystem is the qualitative and quantitative inventory of species. The first difficulty is taxonomy. Relatively advanced in botany, although rather incomplete for tropical regions, the taxonomy faces, in the animal kingdom, a great number of difficult problems linked to the large number of species, to the extreme diversity of animal sizes, and for the arthropods, to the existence of larval forms. Fortunately for ecology, all the species have not the same importance and a choice can be made of *dominant*, *characteristic* or *influential* species. The study of indicator species has theoretical and practical importance. Once their ecological range is known, they may reveal the influence of limiting factors of the biotope. Biological indicators, mostly aquatic plants or insects are widely used in the survey and monitoring of river water pollution. The ecological groups of species in the undergrowth of moist deciduous or degraded forests for example are good indicators of the dynamism of the phytocoenosis. These inventories are also basic for the studies of population dynamics, and biomass calculation especially for the zoocoenosis.

Another aspect is the *temporal structure*. Independent of the climatic or biotic disturbances, there are some variations or *phenological phases* of the ecosystems related to periodic, generally seasonal fluctuations of the environmental factors. The phenology of plant communities is a determining factor of the ecological niches and of the ethology of animal species, which in return play an important role in the dissemination of diaspores, in pollination and even in the destruction of plants. It has been shown in Africa that the ecological niche of monkeys varies with the fruiting of climber species on which they feed themselves resulting in wide dispersal of their seeds.

The third aspect is the *spatial structure*. This is the horizontal distribution, density, importance of plant-cover, and the vertical stratification of plant-and-animal communities, on which are based the measures of biovolumes and biomass. It may also vary seasonwise. The components of the biotope play obviously a great part in the structure of the biocoenosis. Climatic and edaphic studies are essential. Also regular measures of hydric and thermic profiles in the soil are necessary to locate the levels of global activity of the main groups of micro-organisms and their evolution. A global approach of this underground activity is estimated by the measure of carbon dioxide produced at various levels of the profile by the activity of the micro-organisms and partly also by the respiration of roots. This activity of the decomposers of the organic matter is greatly influenced by humidity and varies seasonwise. The importance of the biological activity of the soil in the turnover of organic matter and geochemical cycles is well known. In the tropical African savannas, it accounts for more than 60% of the energetic balance of the ecosystem.

FUNCTIONING OF ECOSYSTEMS

In this period of rapid changes in the world we need to set up a policy of optimal and rational utilisation of the renewable natural resources of the earth, and one of the objectives of ecology is precisely to help in forecasting the consequences of modifications of the environment.

The forecast of the evolution of the ecosystem supposes a better understanding of the mechanisms of the trophic or social relations between the various groups of the biocoenosis and also their interaction with their environment. This can be considered at various levels of organization.

— At the *level of the individuals* may be cited the studies of physiological adaptations (for instance halophytes), nitrogen fixation, water cycle in the plant. The knowledge of the ecological tolerance of species is at the base of silviculture and had also many agronomic applications for cultivated plants.

— At the *level of the populations* much has been done in the study of population dynamics of various animal species. The strict dependence between the ecological conditions and the demographic profile of populations has led to the concept of *demographic strategy*. Two main types of strategies are generally distinguished: (i) The strategy " r " corresponding to a high rate and a short cycle of reproduction. In the species of this group, the number of individuals expands rapidly to occupy the ecological niches as soon as the proper conditions become available. To this category belong the pioneer species. (ii) The strategy " k " with a lower rate and longer cycle of reproduction. The species in this group tend to tap a maximum of the total (k) amount of resources available in their niche. The area, or volume, of their " territory ", which they defend against intruders, depends upon k. It is also at this level that the modelling has till now given the best results. The demography of *plant populations* is far behind. But research should be promoted for the reforestation species, which could have direct applications in management programmes.

— At the *level of the communities*, some of the important problems are the modalities of sharing the resources of the environment, the trophic chains, the relations prey-predator and the *adaptive strategies*. Plant communities play obviously a fundamental part in the functioning of the ecosystems since they are the origin of all the trophic chains. They have been mostly studied by phytosociological methods. More quantitative approaches are now developed specially for the *Measures of biomass* and biovolumes and the estimate of the primary production. In this field, the International Biological Programme provided an important stimulus and exchange of information for the adjustment and standardization of methodologies.

— At the *level of the ecosystem*, we may consider two main groups of problems. The first group corresponds to the study of *trophic chains*, and *transfers of energy and matter*, in other words the distribution of energy flows the biogeochemical cycles. During the last few years such researches are carried out in India on some typical ecosystems. They mostly aim at the evaluation of the forest primary production and the turnover of organic matter. Some are located in the less disturbed forests along the Western Ghats like the Silent Valley, Bandipur area or *sholas* of the Palni Hills. The other problems deal with the *equilibrium* or the *evolution of biocoenosis*.

— The evolution of biocoenosis has till now been studied mostly for the phytocoenosis. In fact, the vegetation may be more easily accessible to study; it also directly reacts to the modifications of the environment and specially to human activities. The classical method to study the progressive or regressive transformations of the phytocoenosis is based on the notion of *series of vegetation*, generally accepted by ecologists and phytogeographers. Series of vegetation may be defined as the vegetation types related by dynamic links to a given climax in an area of homogeneous ecological conditions. It has proved very useful in the cartographic and biogeographic approach, in the study of groups of ecosystems.

CARTOGRAPHY OF ECOSYSTEMS

Taking account of the complexity of the problem and of the number of disciplines involved, the researches on functioning must be necessarily confined to a limited number of ecosystems. From these synoptic stations, the conclusions will be generalised for similar ecosystems. A cartographic inventory of the ecosystems is, therefore, needed. It will at the same time answer the question of the geographical location and inventory of renewable natural resources, which is one of the aims of the " Man and Biosphere " programme of UNESCO.

At this scale, the only practical criteria for the characterization of ecosystems are those of vegetation structure, more accessible to qualitative and quantitative studies over large areas. At the beginning, two main approaches were followed: one giving the preference to floristic structure (phytosociology), the other to the dynamism of vegetation (series). But with the research of correlations between the structure of the vegetation types and the components of the environment (climate, soil and biotic factors) these two tendencies have now practically merged together.

A good number of vegetation maps at various scales have been produced so far in several countries. Much more are needed. Researches are also developing in the direction of ecological maps integrating the zoocoenosis and their relations with other components of the ecosystems, and finally in close relation with these researches a new field of cartography is oriented towards the relations of man and his environment, and specially the evaluation of the consequences of the transformations of this environment.

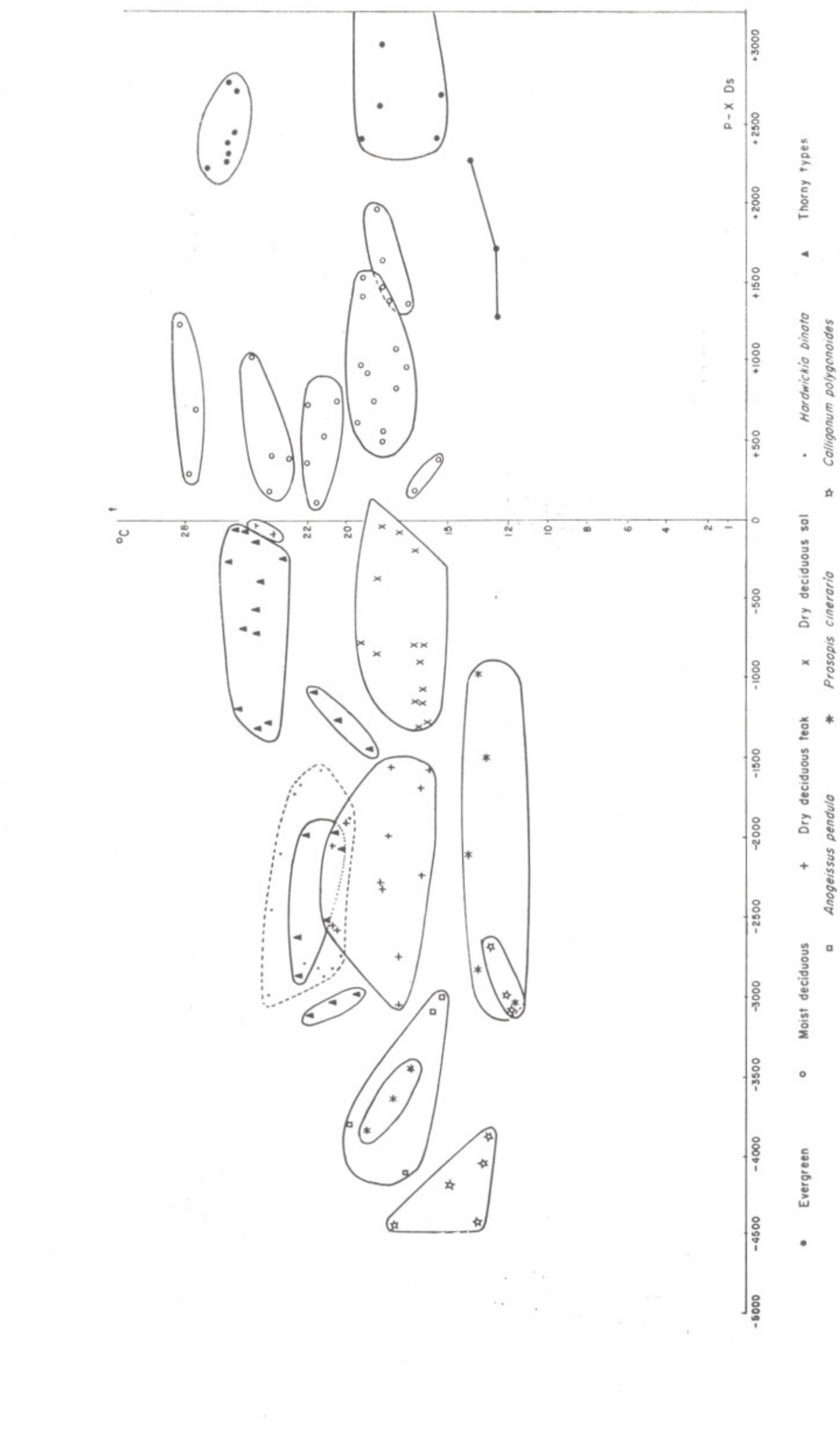
Since the last decade, the technological progress in remote sensing has been of fundamental help in cartography. The use of aerial photographs and its advantages in photogrammetry are well known. The satellite imageries and digital data offer new possibilities, among which two are specially interesting in our fields: the short periodicity of the collected data and their digital form which allow an automatic computer-assisted cartography. This is essential for the monitoring of natural resources, specially in sensitive zones, where the vegetation is disturbed either by over-exploitation, fire or erosion. These are the objectives of the UNEP/FAO programme on " global ecological monitoring ".

The important facilities offered by the technology in any case does not exempt the ecologist-biogeographer from collecting a necessary minimum of information from the field, to correlate the ground truth with the remote sensing data.

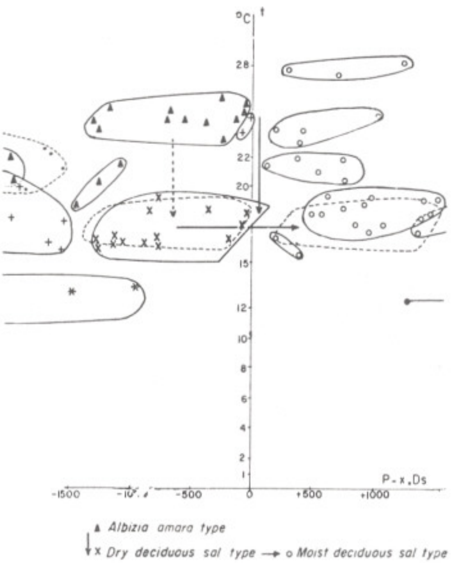
ECOLOGICAL CORRELATIONS

I have already mentioned the importance of ecological correlations in the cartography of ecosystems. I will now briefly give an example of the possible use of such maps in palaeobotany.

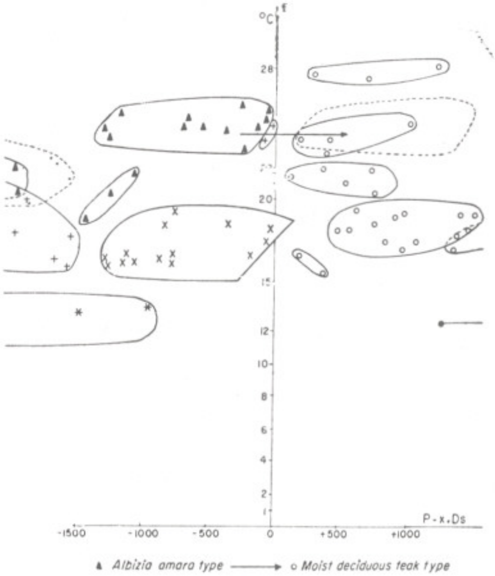
While studying the vegetation of India, I tried to correlate the distribution of the forest types and series of vegetation with the values of some bioclimatic indices proposed by various authors. I also formulated a " Hydric balance index ", P-x.DS relating the annual rainfall (P) to the evaporation (x.DS), i.e. saturation deficit into number of biologically dry days. Plotted on a graph with the hydric balance index on



TEXT-FIG. 1 — Graphic areas of the vegetation types in relation to the mean temperature of the coldest month (t) and hydric balance (P–X. Ds).



TEXT-FIG. 2 — Influence of decrease of the mean temperature of the coldest month on the migration of the flora.



TEXT-FIG. 3 — Influence of increase of the rainfall on the migration of the flora.

one axis and the temperature of the coldest month on the other axis, the series of vegetation separated out clearly in distinct graphic areas (Text-fig. 1). This correlation gives an expression of the ecological range of the series.

It was, therefore, possible to estimate the amplitude of bioclimatic variations that would result in the substitution of one vegetation type by another; in other terms the bioclimatic variation is sufficient to allow the migration of the flora from one region to another. Following are the two examples:

— In the hypothesis of a lowering of the temperature of the coldest month by 8°C, and the consequent decrease of evaporation, the conditions in the Madras-Madurai region would resemble those prevailing presently in Bengal (Text-fig. 2).

— In the hypothesis of an increase of annual rainfall by 500 to 1000 mm which is not excessive during a pluvial period, Madras region would experience the conditions of the moist deciduous forest of Kerala (Text-fig. 3).

The conclusion is that relatively slight variations of temperature and precipitation may result in bioclimatic changes permitting the migration of " humid " Indo-Malayan flora along the coastal region of Coromandel towards the Western Ghats and Sri Lanka, and the flora of Malabar towards Sri Lanka. Further, I believe that ecology may be of some help to fundamental sciences like Palynology and Palaeobotany.

But it also appears that the global, holistic character of modern ecology requires a real and *active cooperation of scientists* of various disciplines. This is not to the only benefit of ecology. It would be useful and beneficial to the whole community, to develop more *active exchanges* between the *world of ecology and that of Decision makers, Planning Officers, Engineers,* who have to solve technical problems. It is my sincere hope that this could be achieved before it is too late.